Anton Paar

Measure
what is measurable
and make measurable
that which is not.

Galileo Galilei (1564-1642)

Software Manual

Indentation

Indentation Software Version 7

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Copyright information

Table of contents

1 ABBREVIATIONS & SYMBOLS

Physical quantity symbols are according to the ISO 14577 standard.

Abbreviations Symbols	Designations	Units
ADO	adjust depth offset	
AFM	Atomic Force Microscope	
A_p	projected contact area	m^2
C_{HM}	creep Martens hardness	%
C_{IT}	indentation creep	%
COS	Conscan confocal (observation head)	
e.g.	for example	
E*	plane strain modulus	Pa
E_{IT}	indentation modulus	Pa
ε (Epsilon)	geometric constant	
E_r	reduced modulus	Pa
F	test force	N
F_{max}	maximum test force	N
h	indentation depth under applied test force	m
h_c	contact depth of the indenter with the sample at F_{max}	m
H_{IT}	indentation hardness	Pa
HM	Martens hardness	Pa
h_{max}	maximum indentation depth	m
h_p	permanent indentation depth	m
h_r	tangent indentation depth	m
HV	Vickers hardness	Vickers
HV_{IT}	Vickers hardness calculated from H_{IT}	Vickers
.INI/.ini file	initialization file	
m	power law exponent	
MCT	Micro Combi Tester (measurement head) (applicable for MCT 1st generation **or** MCT^3 new generation)	
MHT	Microindentation Tester (measurement head) (applicable for MHT 1st generation **or** MHT^3 new generation)	
min	minutes	
min.	minimum	
NHT	Nanoindentation Tester (measurement head) (applicable for NHT^2 2nd generation **or** NHT^3 new generation)	
ν (Nu)	Poisson's ratio	
RIT	indentation relaxation	%
O&P	Oliver & Pharr	
S	contact stiffness	N/m

sec.	seconds	
STeP 4	Surface Testing Platform dedicated for 4 units	
STeP 5 HV	High Vacuum Surface Testing Platform dedicated for 5 units (primary & secondary vacuum pumps)	
STeP 5 V	Vacuum Surface Testing Platform dedicated for 5 units (primary vacuum pump only)	
STeP 6	Surface Testing Platform dedicated for 6 units	
TTX	Table Top	
UNHT	Ultra Nanoindentation Tester (measurement head) (applicable for UNHT 1st generation **or** UNHT^3 new generation **or** UNHT^3 HTV High Temperature new generation)	
UNHT Bio	Anton Paar BioindenterTM (applicable for UNHT^3 new generation) (measurement head)	
VID	optical Video microscope (observation head)	
Welast	elastic reverse deformation work of indentation	N.m
Wplast	plastic deformation work of indentation	N.m
Wtotal	total mechanical work of indentation	N.m
ηIT	elastic part of indentation work	%

	1 N/mm^2 = 1 MPa	1 J = 1 N.m	1 Vickers = 1 kgf/mm^2

2 INTRODUCTION

2.1 About Indentation Software

By choosing an Indentation Tester from the complete range offered by Anton Paar, the user benefits from all advantages of our powerful software: an easy to use window interface including numerous indentation measurement types, analysis methods, image management and advanced reporting functions.

The user interface of the *Indentation Software* (for **Windows® 7 and 10**) provided by Anton Paar is described in this manual.

This manual concerns the following indentation instruments of Anton Paar:

STeP -
- **MHT**
- **NHT**
- **UNHT** or **UNHT HTV** if ☑ High Temperature is checked in ***chap. 3.1.2.1, p. 14***
- **UNHT Bio**

TTX-
- **NHT**
- **UNHT**
- **UNHT Bio**

ℹ Some instructions can be specific to one instrument/measurement head; in that case it will be specified.

2.2 Enclosed content

This manual explains how to optimize the *Indentation Software* from Anton Paar. For information concerning the instrument, refer to its separate user manual.

2.3 How to use this manual?

- Software is preinstalled, refer to the ***Common Scratch & Indentation software manual - chap. Starting of software***, which explains how to use the *Indentation Software*.

- Software is not installed, refer to the ***Common Scratch & Indentation software manual - chapters About installation*** and ***Hardware configuration***, which guides the user through the installation and configuration processes.

Some *Indentation Software* features are common with *Scratch Software*.

Therefore if the information is not described in this manual, refer to the ***Common Scratch & Indentation software manual***.

For information concerning the instruments, refer to each corresponding ****measurement head* user manual***.

For information concerning the *Video Software*, refer to the ***Video software manual***.

In this manual:

- The images may differ from the actual product.
- "acquisition system" means dedicated computer with acquisition card and software.
- "STeP" means STeP 4, STeP 5 HV, STeP 5 V and STeP 6.
- "STeP 5" means STeP 5 HV and STeP 5 V.
- If not specified, generally "measurement(s)" means indentation measurement**(s)** → for single measurement **or** for matrix of measurement**s**.

For ***Troubleshooting*** see ***chap. 6, p. 173***.

3 MANAGING THE INSTRUMENT

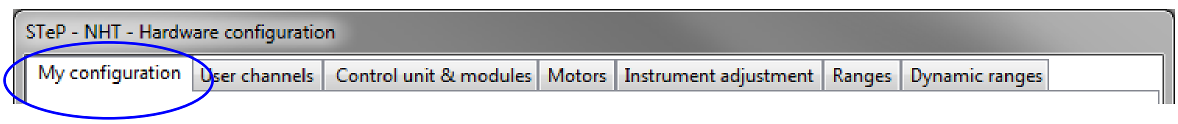
3.1 HARDWARE CONFIGURATION

Refer to the ***Common Scratch & Indentation software manual - chap. Hardware configuration***.

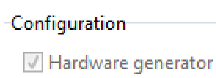
3.1.1 INSTRUMENTS TABS

Common tabs/functions for the Scratch and Indentation instruments are described in the ***Common Scratch & Indentation software manual - Hardware configuration -*** under each chapter about ***tab***.

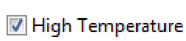
3.1.2 MY CONFIGURATION TAB



3.1.2.1 UNHT

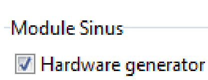


This inactive (grayed out) box is automatically checked to activate the (standard) Sinus hardware present on the UNHT.



This box should be checked if the instrument is a STeP 5 HV - UNHT HTV.

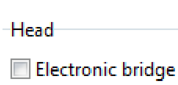
3.1.2.2 NHT



This box should be checked to activate the **optional** Sinus hardware present on the NHT; the corresponding software features become active (no longer grayed out).

If this option is not present, this box should be unchecked.

3.1.2.3 MHT



This box should be always unchecked with MHT.

3.1.3 'RANGES' TAB(S)

Refer to the ***Common Scratch & Indentation software manual*** and **carefully read** ***- chap. 'Ranges' tab(s)***.

3.1.3.1 UNHT range tabs

UNHT has 3 ***'Ranges'*** tabs.

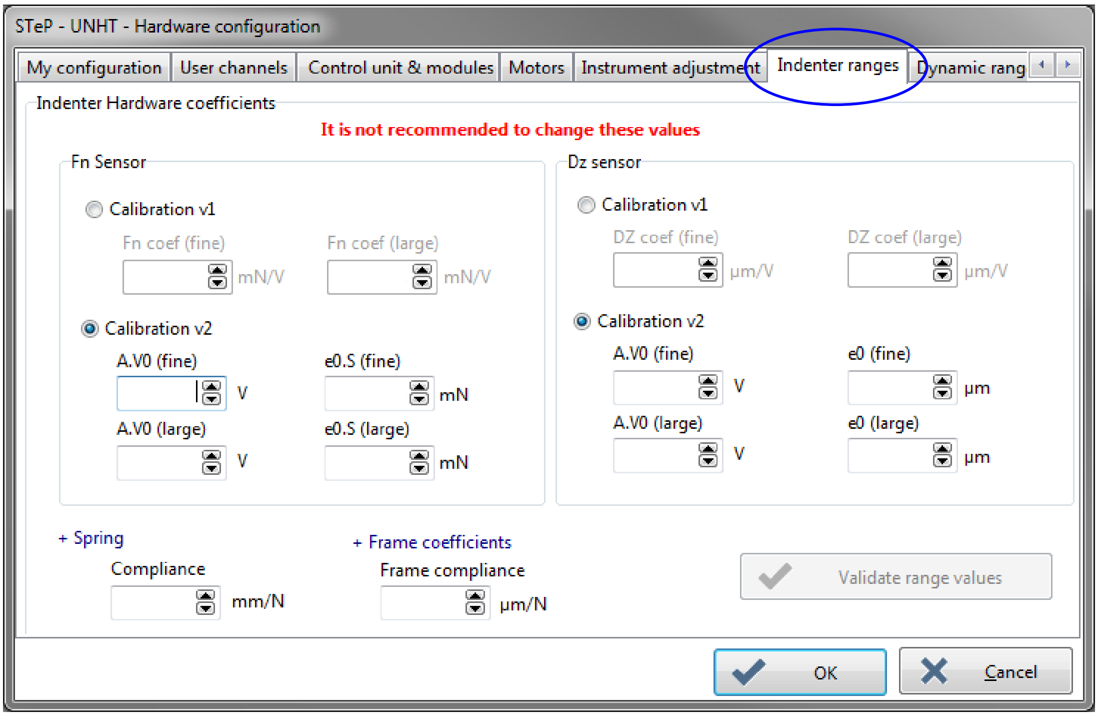


Fig.1 UNHT <u>Indenter ranges</u> tab

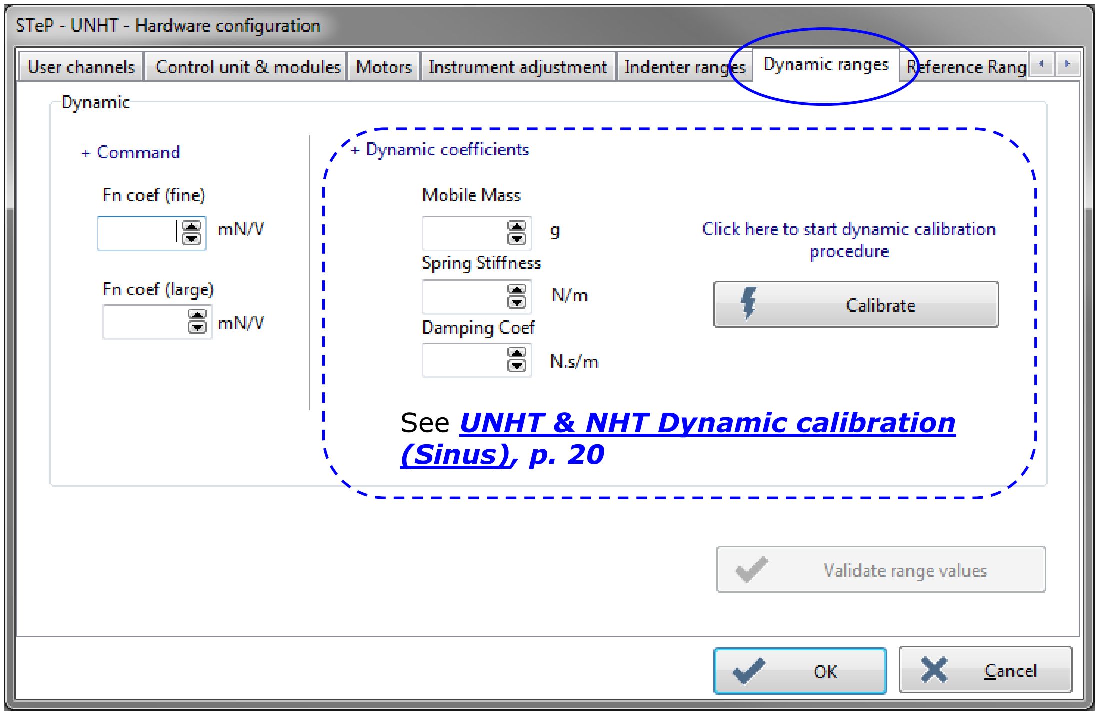


Fig.2 UNHT <u>Dynamic ranges</u> tab

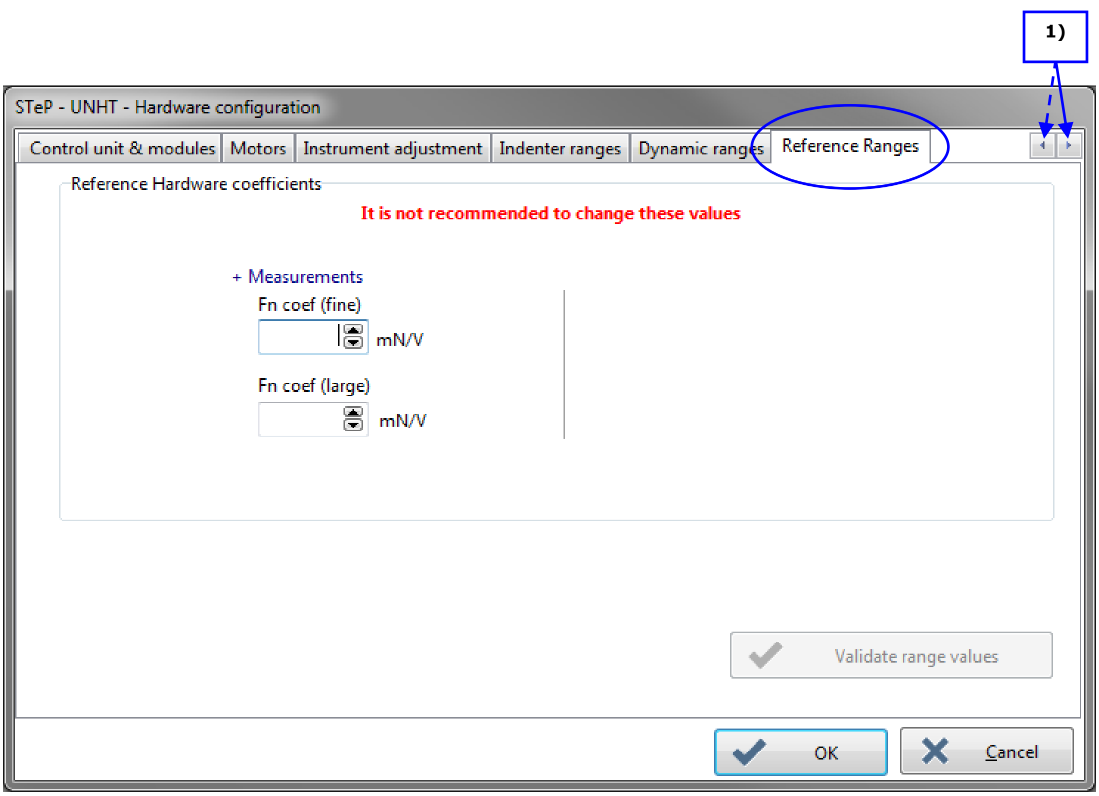


Fig.3 UNHT <u>Reference Ranges</u> tab

[1)] select (2 times max) the right cursor to display (fully) the 2 last tabs or select the left cursor to display (again) the 2 first tabs

3.1.3.2 NHT range tabs

NHT has 2 **'*Ranges*'** tabs.

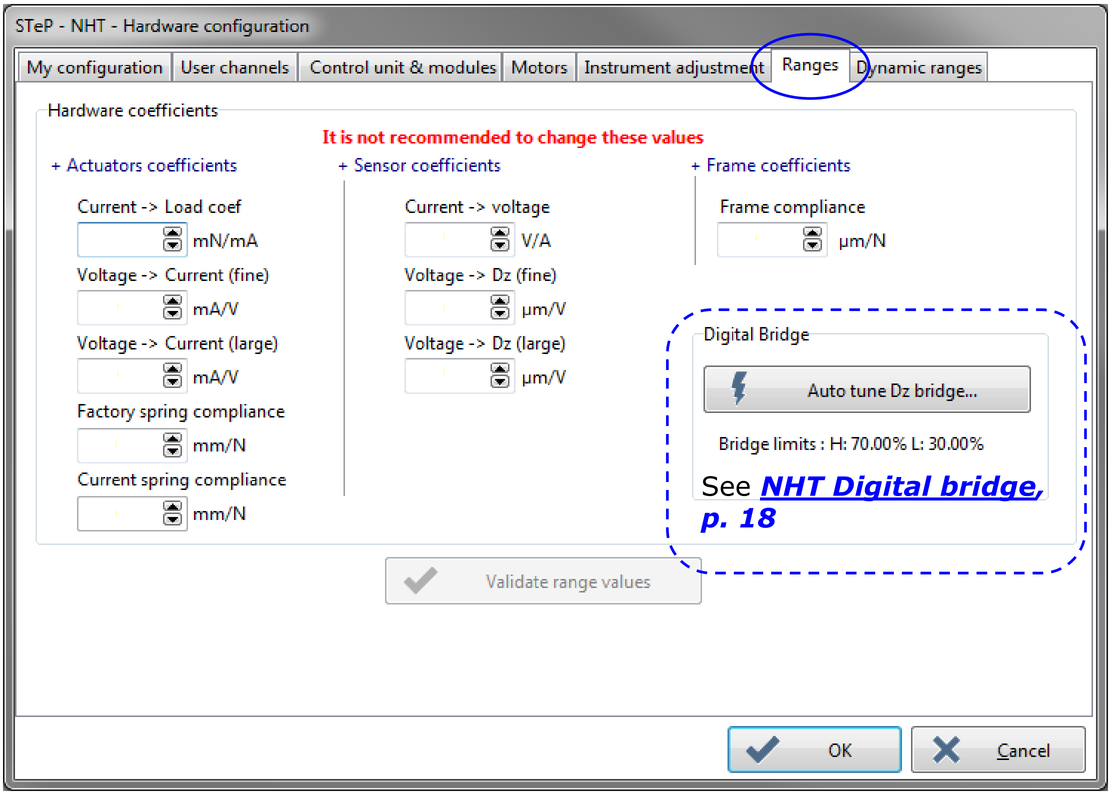


Fig.4 NHT <u>Ranges</u> tab

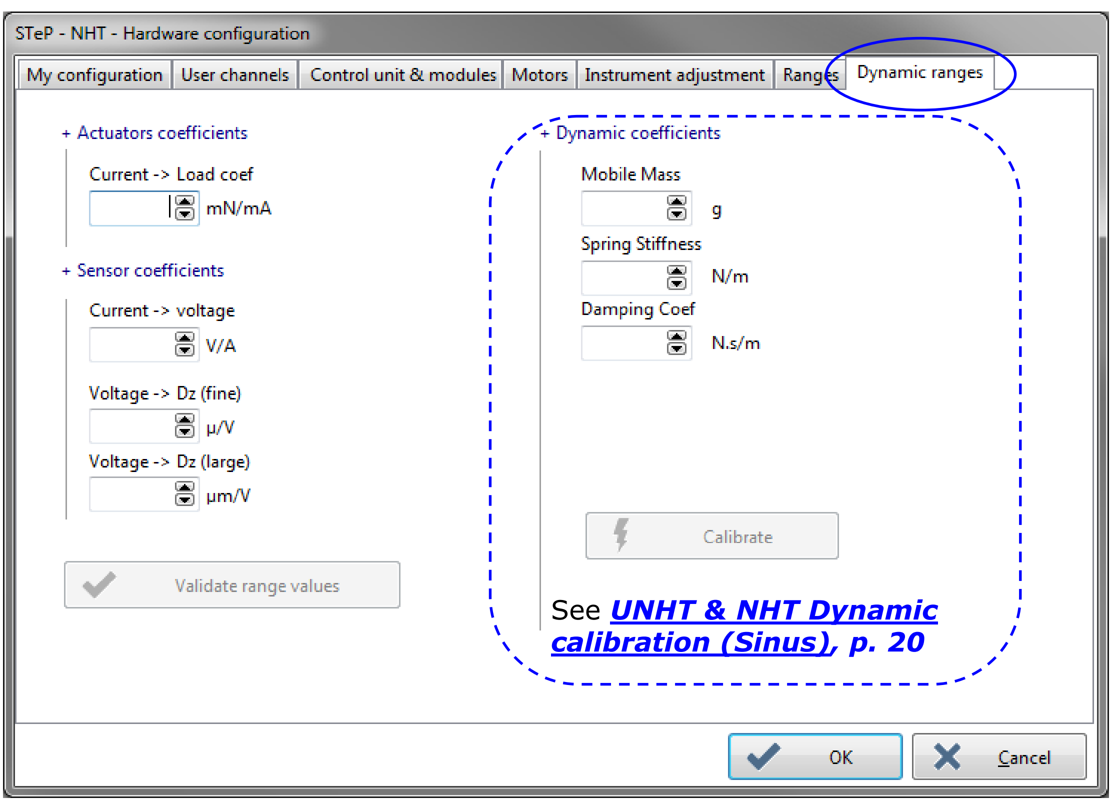
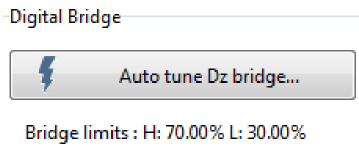


Fig.5 NHT <u>Dynamic ranges</u> tab

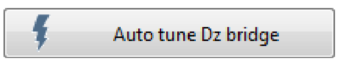
NHT Digital bridge

To properly use the instrument, the auto tuning of the Dz sensor bridge should be performed once during the instrument (control unit) installation. However this tuning can be performed again if needed. The procedure is an automatic tuning of the Dz bridge (electronic adjustment process).

In ***"Ranges"*** tab *Fig.4, p. 17*, click 

The *Dz Bridge tuning* window appears *Fig.6 below*.

a special area used for factory setting (not dedicated for the user) is available but an access code is needed to use it.

Click 

to start the automatic tuning process.

The tuning is processing: the software scans (progression bar % increases) the entire Dz sensor bridge and adjusts the limits for a quicker detection.

The *previous limits* saved in the software are displayed.

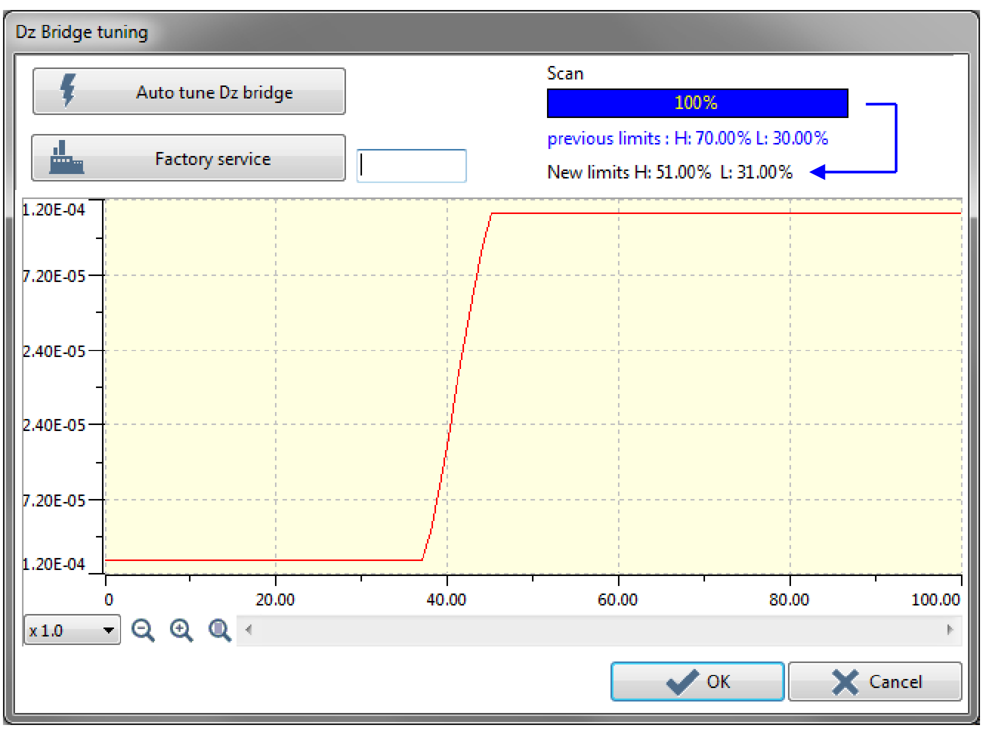
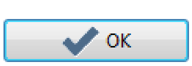


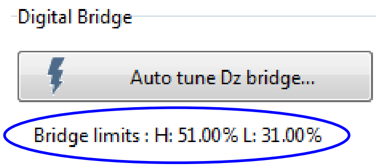
Fig.6 Scanning completed

End of the tuning: the scanning is completed (100 %) and the *New limits* calculated by the software are displayed.

Click 

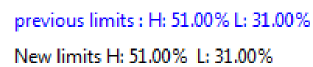
to validate the *New limits* (overwrite the previous ones) in the software.

In the **"*Ranges*"** tab *Fig.4, p. 17,*



the new Dz bridge limits appear.

If the tuning is performed again (after the first time), the *New limits* should be the same or almost the same as the *previous limits* - only a few % of difference should be displayed.



in *Fig.6, p. 18*

UNHT & NHT Dynamic calibration (Sinus)

The *Dynamic coefficients* fields and ***"Calibrate"*** button are located in the ***"Dynamic ranges"*** tab of the UNHT *Fig.2, p. 16* and NHT *Fig.5, p. 17*.

The dynamic calibration is only available with the **optional** Sinus mode.

With NHT

If [Calibrate] is inactive (grayed out), it means the **optional** Sinus hardware is not present (see ***chap. 3.1.2.2 NHT, p. 14***) and this calibration cannot be performed.

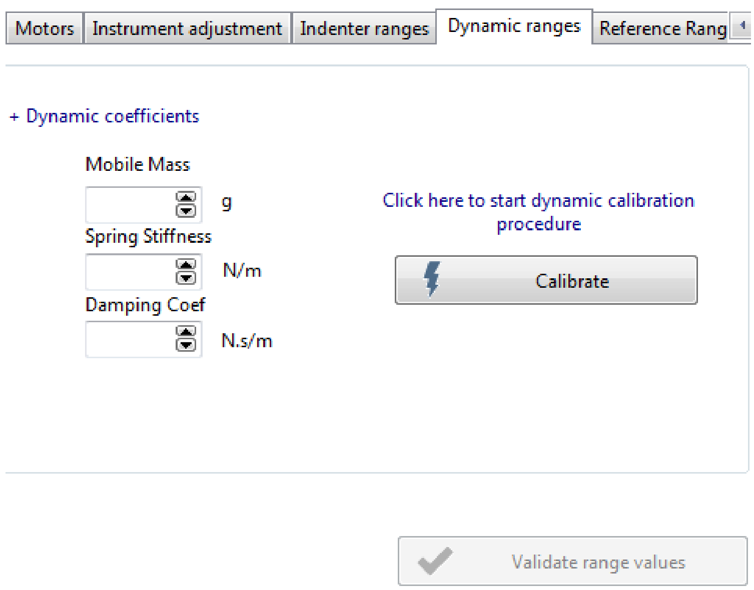


Fig.7 Dynamic coefficients (e.g. UNHT)

Before running any Sinus measurements, including the indenter Sinus calibration, this dynamic calibration should be performed:

- At the instrument installation.
- Each time a new indenter is used.

First it is recommended that an ADO has been **successfully** (ADO) performed; see ***chap. 4.4 Adjusting the depth offset (ADO), p. 56.***

Then click [Calibrate] to open the following *UNHT* **or** *NHT Head Dynamic Calibration* window *Fig.8, p. 21*.

If the procedure was already performed once before, the window contains the curves and values of the previous calibration.

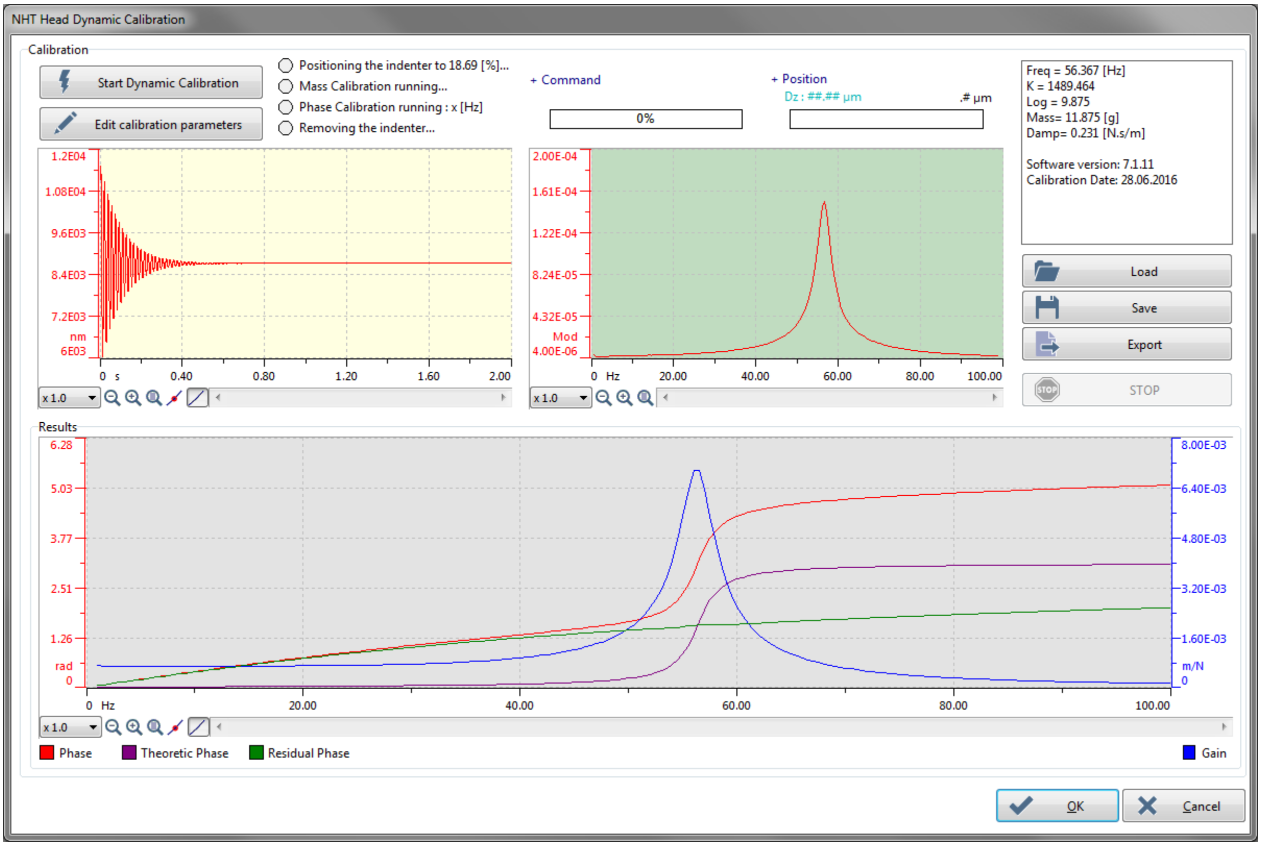
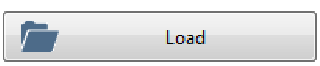
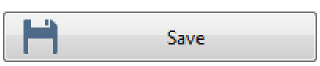


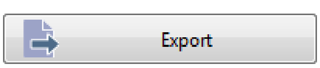
Fig.8 Head Dynamic Calibration window (e.g. NHT)



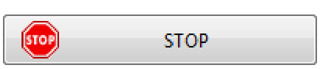
To load a dynamic calibration from a .DCF file format.



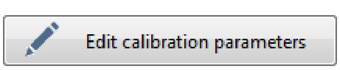
To save the current dynamic calibration into a .DCF file format.



To export the current dynamic calibration into a .TXT file format.

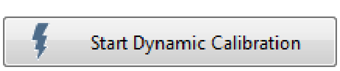


To stop the dynamic calibration when it is proceeding.

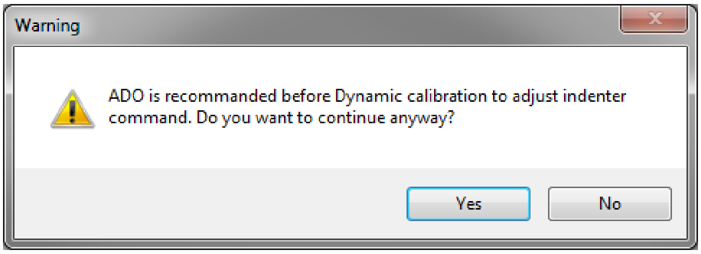


Only for NHT

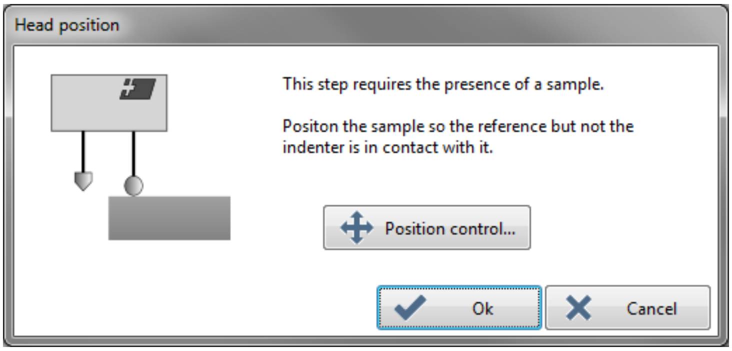
To set another indenter position for the calibration; for advanced user only.

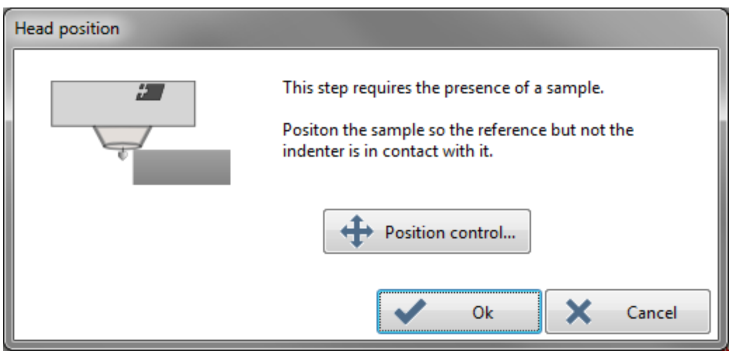


To start the semi-automatic dynamic calibration procedure which is described below.



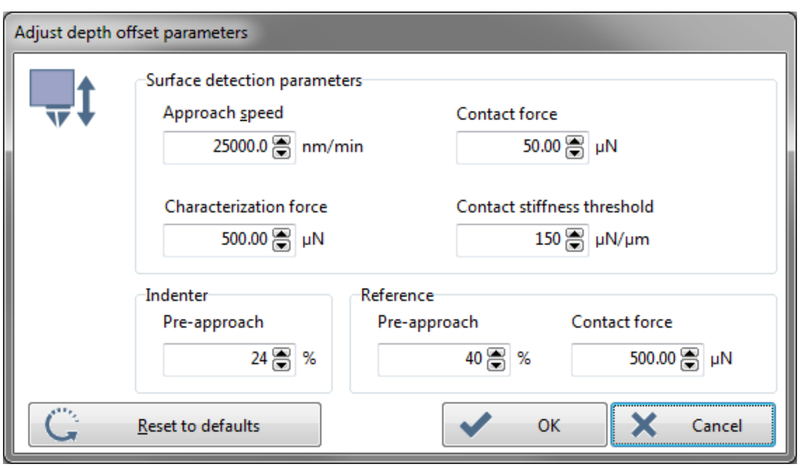
If no ADO or non-successful ADO has been performed, click Yes ; read *chap. 4.4 Adjusting the depth offset (ADO), p. 56* and then come back below.





Click Position control... to move the **edge** of the sample under the reference and so that the indenter **cannot** touch the sample (UNHT reference, NHT reference ring), as shown on the corresponding image.

Then click Ok.



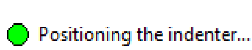
__For UNHT__

This additional *ADO parameters* window with the same previous successful ADO parameters appears and is used to approach the UNHT reference to the sample surface and also to pre-approach the indenter.

Click OK.

Then in the *Head Dynamic Calibration* window *Fig.8, p. 21*:

The 4 following circle status (on window top left side) blinks green one after the other (from top to bottom); wait.



(The reference approaches for UNHT and) the indenter pre-approaches.

Mass Calibration running...

Free oscillation analysis to determine the mobile mass and the damping coefficient: the curves in the 2 upper graph areas are displayed/updated.

phase calibration running : 11.0 [hz]

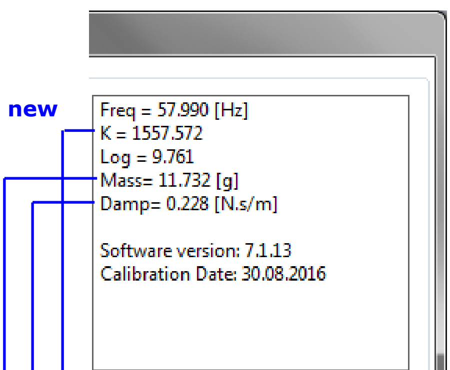
Forced oscillation analysis on a broad frequency range. It will compute the dynamic head response (phase and gain): the frequency value increases and the measurement curves are displayed in real time in the *Results* bottom graph area.

Removing the indenter...

When the phase calibration measurement is completed, the indenter (and reference for UNHT) are retracted.

Start Dynamic Calibration

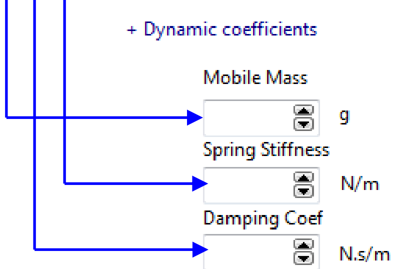
When this button becomes again active (no longer grayed out) the calibration is completed as follows:



The new calibration values are updated on the top right corner of the window and all new curves are displayed accordingly in all graph areas.

Click OK (approve).

In the ***"Dynamic ranges"*** tab *Fig.7, p. 20*:



All *Dynamic coefficients* field values are automatically updated with the 3 new values (approved) of the previous dynamic calibration.

Click Validate range values (validation of these new values).

3.1.3.3 MHT range tab

MHT has only one ***"Ranges"*** tab.

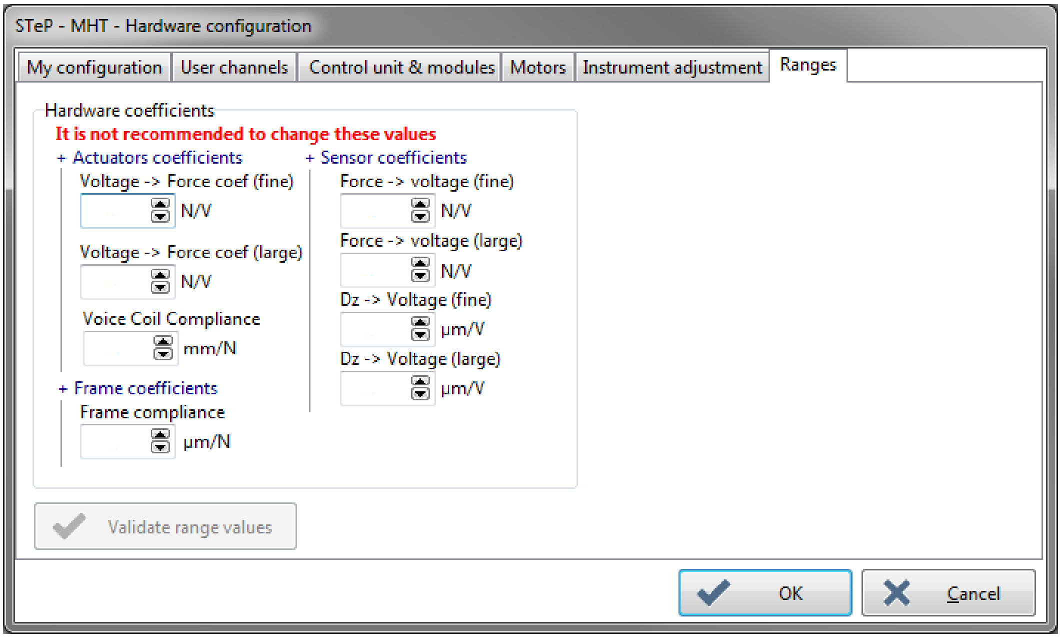
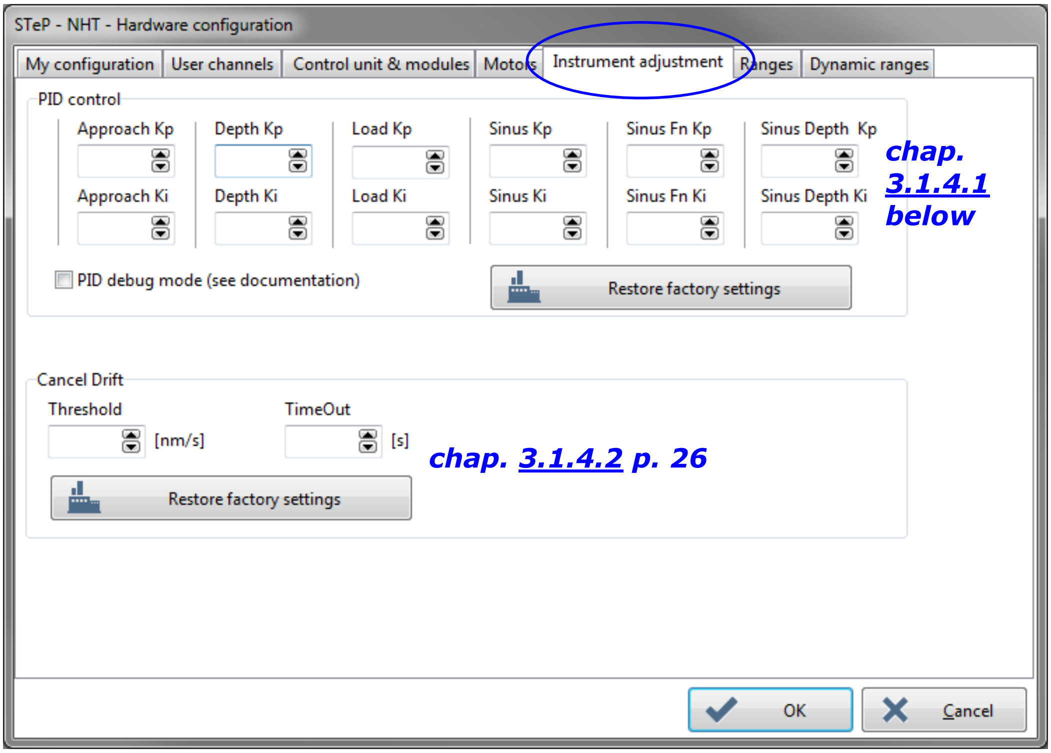


Fig.9 MHT <u>Ranges</u> tab

3.1.4 Instrument adjustment tab

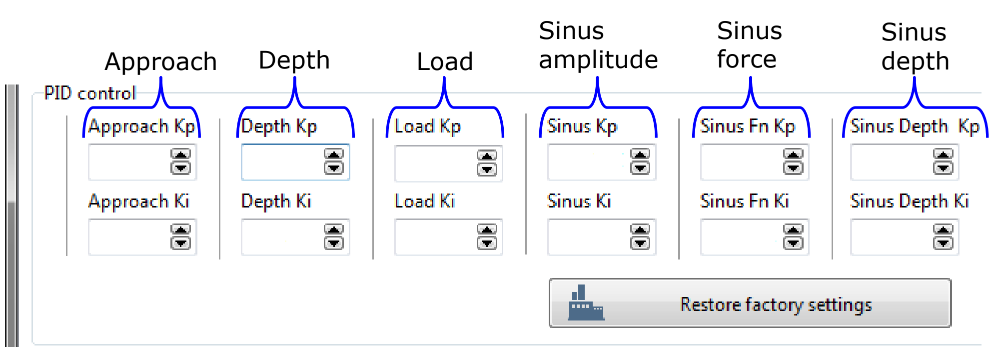


All *PID control Sinus* parameters are inactive (grayed out) with:

- MHT
- NHT, if Hardware generator is unchecked; *chap. 3.1.2.2 NHT, p. 14*

3.1.4.1 PID control parameters

It is not recommended to modify the factory parameter field values, which guarantee a good depth or load control during the indentation measurement on the majority of materials. If necessary, click Restore factory settings to restore these factory parameter values.



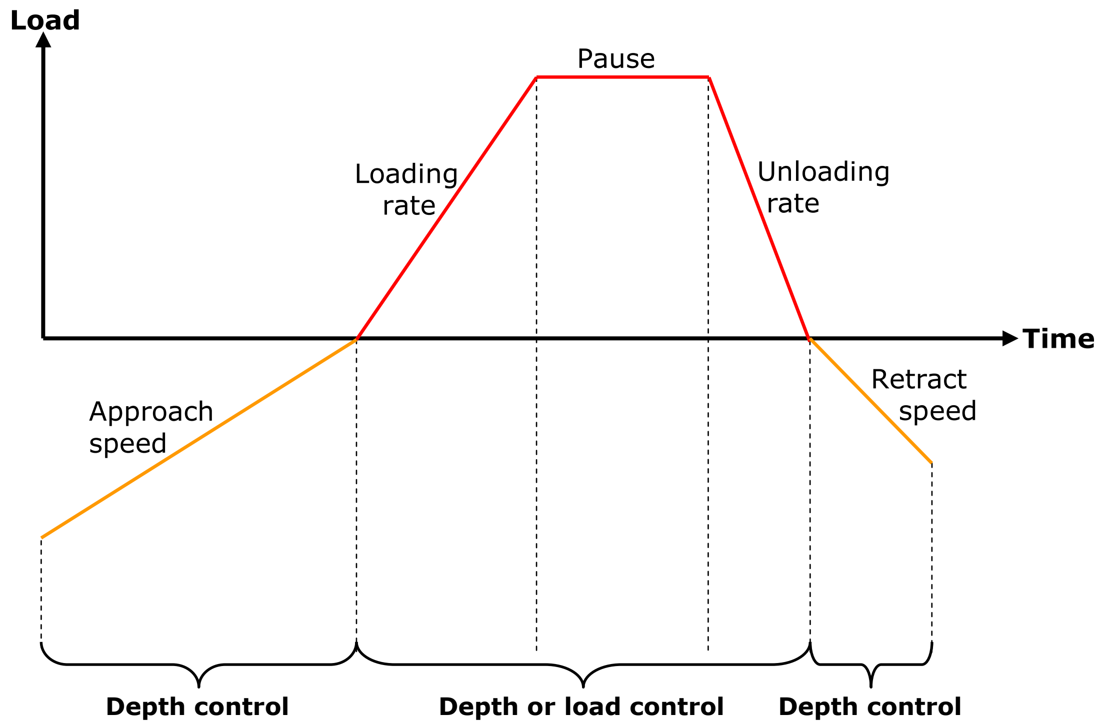
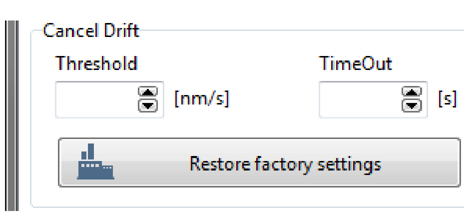


Fig.10 Control loop schematic description

In measurement cycle the approach phase and retract phase are depth controlled.

3.1.4.2 Stabilization (cancel drift)

During the automatic ADO process; from ***chap. 4.4.1, p. 57*** to ***4.4.3, p. 70*** and during the indentation measurement process; ***chap. 4.7, p. 122***, a *Stabilization* step Stabilization 30 [s] (in *Status* area) is performed to wait for an acceptable thermal drift before performing an indentation.



The stabilization ends:

When the thermal drift is under the set ***Threshold*** parameter field value,

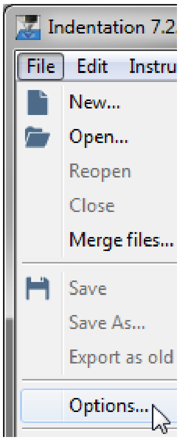
OR

after the elapsed set ***TimeOut*** parameter field value.

Click Restore factory settings to restore the factory settings.

3.2 OPTIONS/PREFERENCES (ISO NOMENCLATURE)

To display ISO 14577 nomenclature



Select ***File/Options...*** from the menu bar.

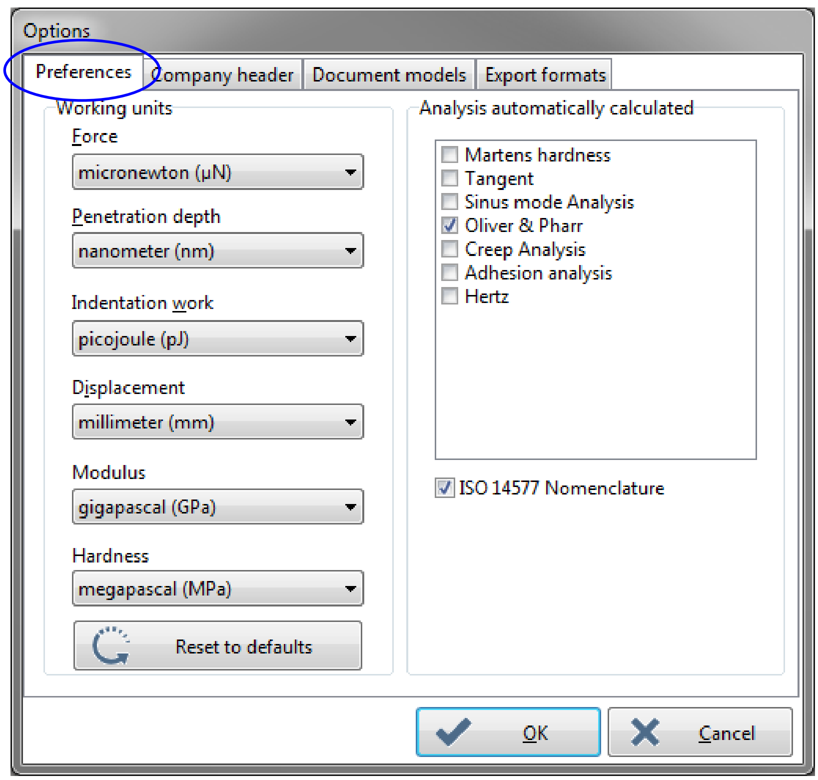
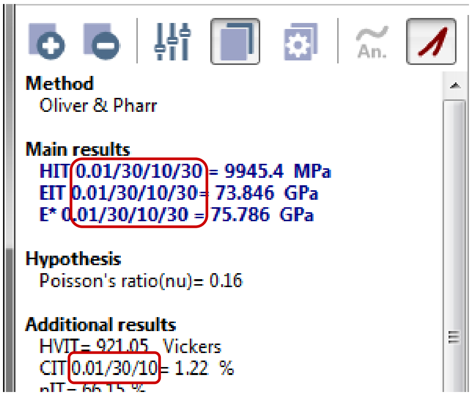


Fig.11 Preferences tab in Options window

The feature below is applicable with *Marten hardness*, *Tangent* and e.g. *Oliver & Pharr* analysis methods; see ***chap. 5.4, p. 144***.

Check ☑ ISO 14577 Nomenclature to display the analysis results in ISO 14577 format *Fig.12, p. 28*.



In the analysis result area (see *Fig.62, p. 130*) the ***Main*** and ***Additional*** results are displayed in ISO 14577 format.

E.g. HIT 0.01/30/10/30 ;

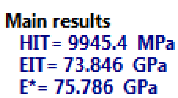
see the details of the nomenclature in accordance with the **ISO 14577-1:2002** standard.

Fig.12 ISO 14577 nomenclature

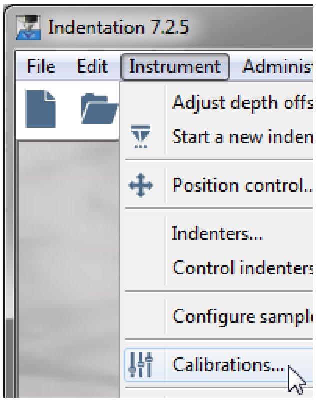
See also:

- ***chap. 1 Abbreviations & symbols, p. 10***
- ***chap. 7 Software formulas, p. 176***

unchecked in *Fig.11, p. 27* is the default format



3.3 Calibration window & tabs



Select ***Instrument/Calibrations...*** from the menu bar.

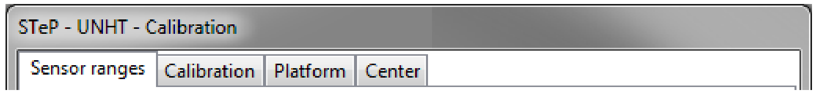


Fig.13 Calibration window (e.g. STeP - UNHT)

This window contains several tabs (depending on instrument) which allow configuring several calibration features:

Tab	for	chap.
"Sensor ranges"	UNHT/UNHT Bio	***3.3.1 below***
"Calibration"	All instruments	***3.3.2, p. 30***
"Platform"	All, except TTX-NHT	***3.3.3, p. 31***
"Center"	All instruments	***3.3.4, p. 33***

3.3.1 Sensor ranges tab (UNHT/UNHT Bio)

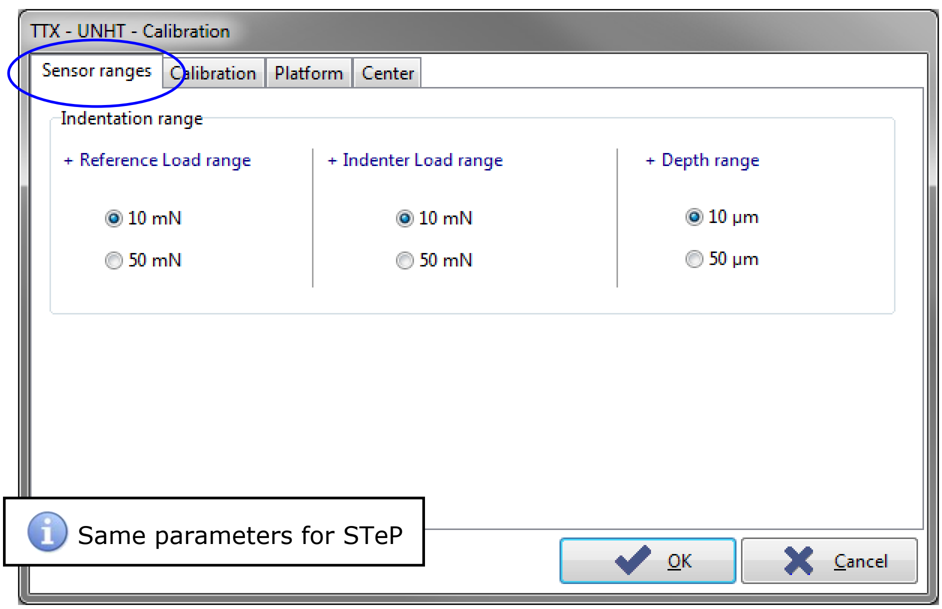
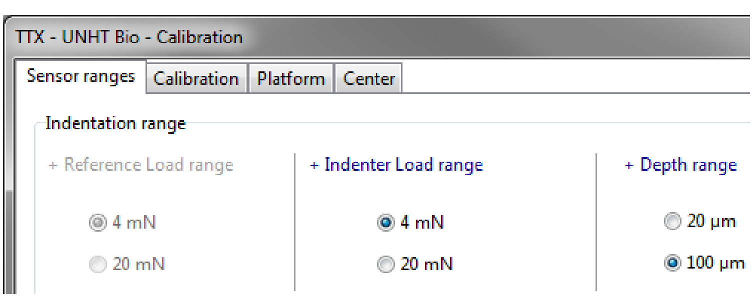


Fig.14 Sensor ranges tab (e.g. TTX-UNHT with fine ranges)



For UNHT Bio there is no reference load range (grayed out) and the range values are different than UNHT.

This tab is also available in the UNHT and UNHT Bio *Preferences* windows; for the detailed description see respectively ***chap. 4.6.5.3, p. 115*** and ***chap. 4.6.5.4, p. 115***

3.3.2 CALIBRATION TAB (DISTANCE)

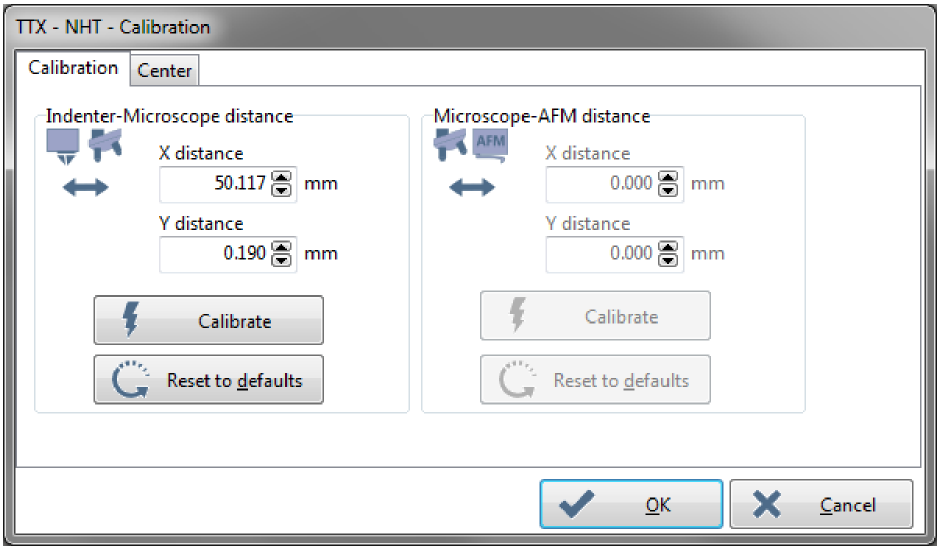
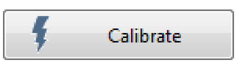


Fig.15 Distance calibration tab (e.g. TTX-NHT)

The distances[1] between,

- the indenter and microscope (VID)
- the indenter and AFM[2]

should be calibrated:

Click  to (re-)start the corresponding calibration procedure and refer to the ***Common Scratch and Indentation software manual - chap. Distance calibration*** for the detailed procedures.

Each active calibration should be re-performed whenever the user changes the indenter, in order to accurately localize the region of the indentation in the *Video* window/AFM[2] area.

1) in case of manual Y table, the *Y distance* fields are inactive (grayed out)

2) calibration with AFM is active (no longer grayed out) if the **optional** AFM is mounted only on the STeP instrument

3.3.3 Platform tab (not for TTX-NHT)

This tab is not available with TTX-NHT (as it does not have a motorized Z table).

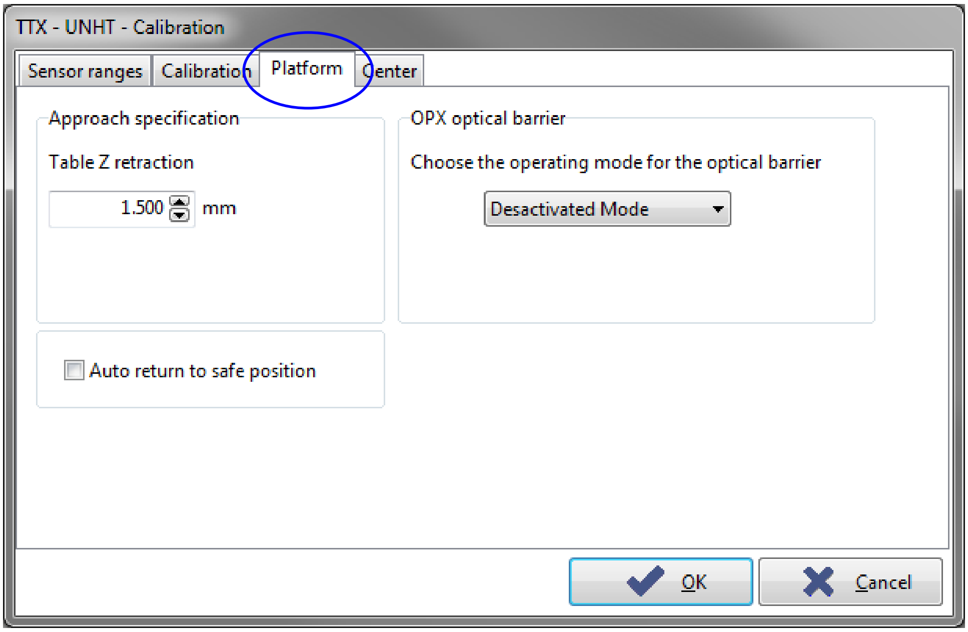
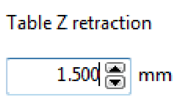


Fig.16 Platform tab (e.g. TTX-UNHT)

Table Z retraction



initial value

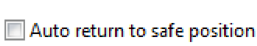
0.5 mm is the min. retraction possible value.

After each time that the motorized Z table is moved up (raised): e.g. for the focus adjustment and then the position control is closed, or after a measurement…, the table automatically moves back down (lowers) to the retraction value set in this field = rest position.

Beware of any collision.

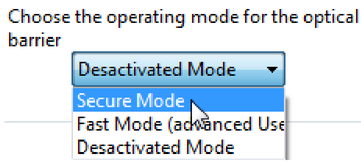
This parameter can be adjusted according to the height of sample used. If the sample is not flat and/or tilted, set enough margins in order that the sample does **not** enter in collision with the indenter during lateral displacements, e.g. between each indentation in a matrix.

Safe position



Check this box to automatically return to the safe position at the end of each measurement: the motorized tables/sample move to the extreme right front position; same position as clicking on the main toolbar.

Optical barrier



Choose one of the 3 following security modes for the optical barrier.

Secure Mode: if the optical barrier is interrupted, the current measurement, optical analysis or positioning is stopped. To perform a matrix of measurements with this mode, ***Table Z retraction, p. 31*** should be set at least to 7 mm, in order to not interrupt the optical barrier.

When the user is sure that there is no risk of a collision during all indentation matrix of measurements and additionally to save time, the following other operating modes can be selected. In these cases a lower value can be set in ***Table Z retraction, p. 31*** but **beware** of any collision:

> ***Fast Mode (advanced User)***: is similar to *Secure Mode* above, **except** the barrier is deactivated during measurements and optical analyses.
>
> ***Deactivated Mode***: the optical barrier is deactivated all the time.

3.3.4 CENTER TAB

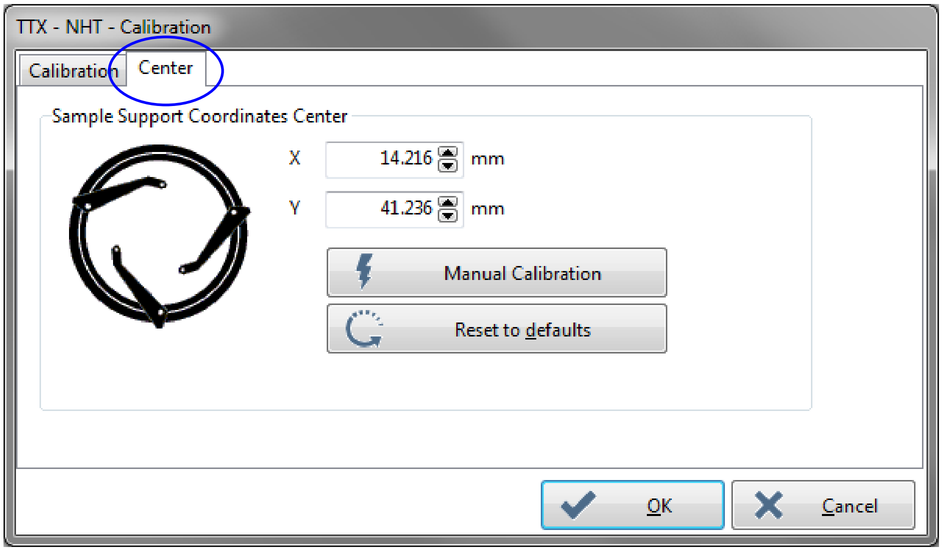


Fig.17 Center tab (e.g. TTX-NHT)

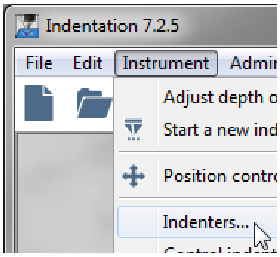
For the description details, refer to the ***Common Scratch & Indentation software manual - chap. Managing the instrument - Distance calibration - center calibration***.

In case of a manual Y table, the *Y* field is inactive (grayed out); the Y table should be manually moved.

X and Y field values shown in *Fig.17 above* are only an example; a calibration should have been performed for each available instrument (different field values).

3.4 MANAGING INDENTERS

The indenter which is mounted on the measurement head should be created and/or selected.



Select ***Instrument/Indenters...*** from the menu bar.

Edit indenters

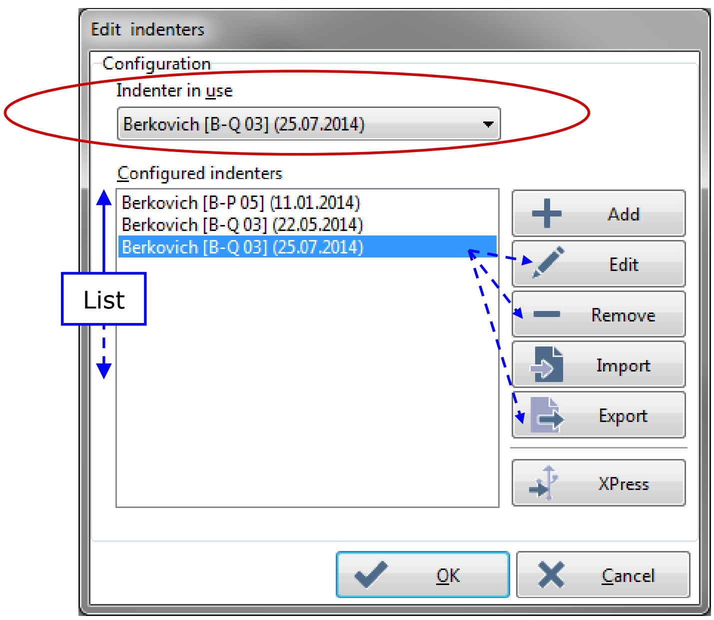
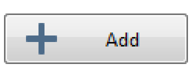
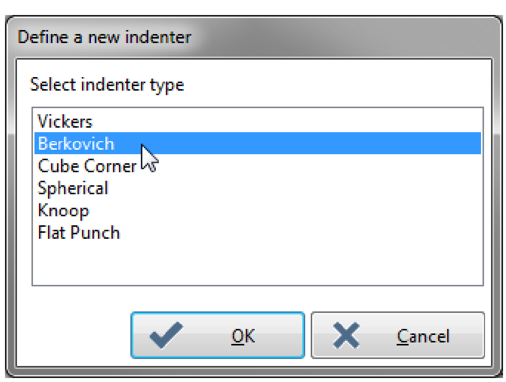


Fig.18 Edit indenter windows

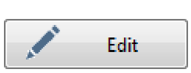


To create a new indenter in the *Configured indenters* list.



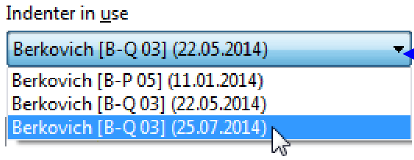
Select (double click) the type of the indenter which is used; see ***chap. 3.4.1 Indenter properties window, p. 37***.

Fig.19 Define a new indenter window



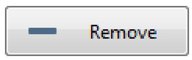
To modify the selected (highlighted) indenter in the *Configured indenters* list; see ***chap. 3.4.1 Indenter properties window, p. 37***.

Before running a measurement

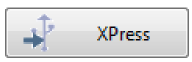


If there are several *Configured indenters* in the list, do **not** forget to select the *Indenter in use* with the last calibration date if available (the ***Calibration date chap. 3.4.3, p. 47*** is displayed next to the indenter serial number).

- To keep the old indenter calibration, create a new indenter – recommended.
- To overwrite an indenter calibration, edit the existing indenter; see ***chap. 3.4.2 Indenter calibration , p. 38***.

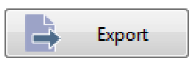


To remove the selected (highlighted) indenter from the *Configured indenters* list.



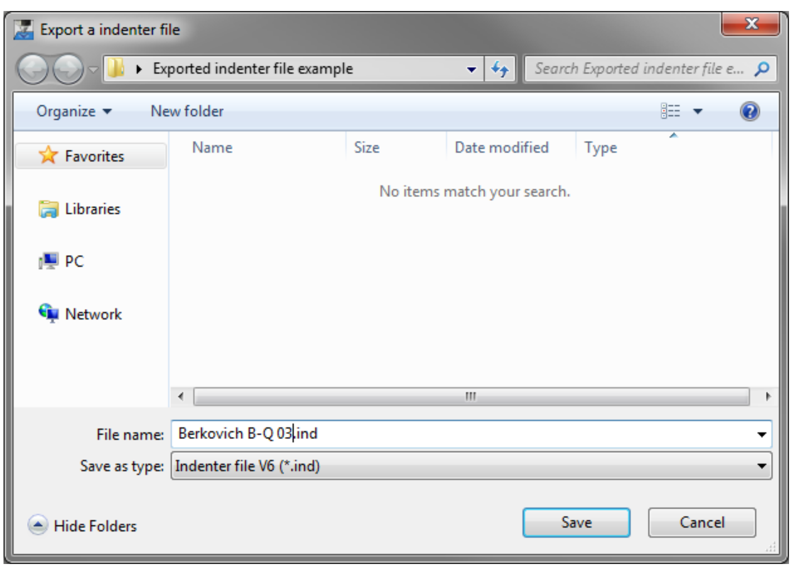
Not applicable.

Import/export

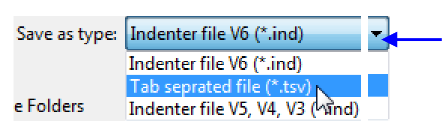


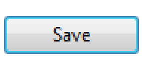
To export the selected (highlighted) indenter in the *Configured indenters* list (saved as an indenter file).

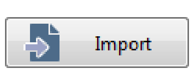
This window allows:



- Choosing a location where to save the indenter file.
- Modifying the default ***File name***: corresponding to the selected indenter.
- Changing of the default V6 .IND file format.

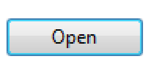


Then click 



To import an indenter (which was exported) in the *Configured indenters* list.

A similar as for the export above, a window allows choosing a location where to open an indenter file with .IND format.

Then select the file and click  or double click on the file to open it.

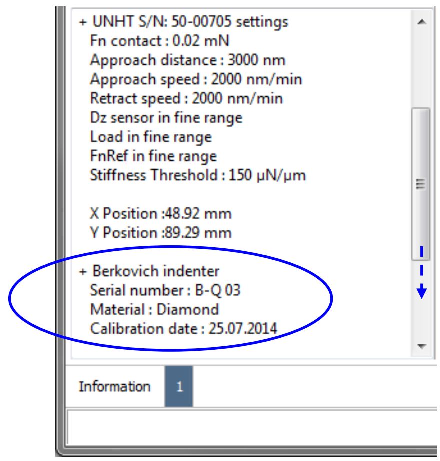
Indenter file (.IND) info

The exported/imported indenter .IND file format includes only the result of the calibration: only the **average point** (of the 5 indents kept or excluded from the .MIT file) **for each load**. Therefore it should not be confuse with the indenter calibration .MIT file format which includes all indentation measurements.

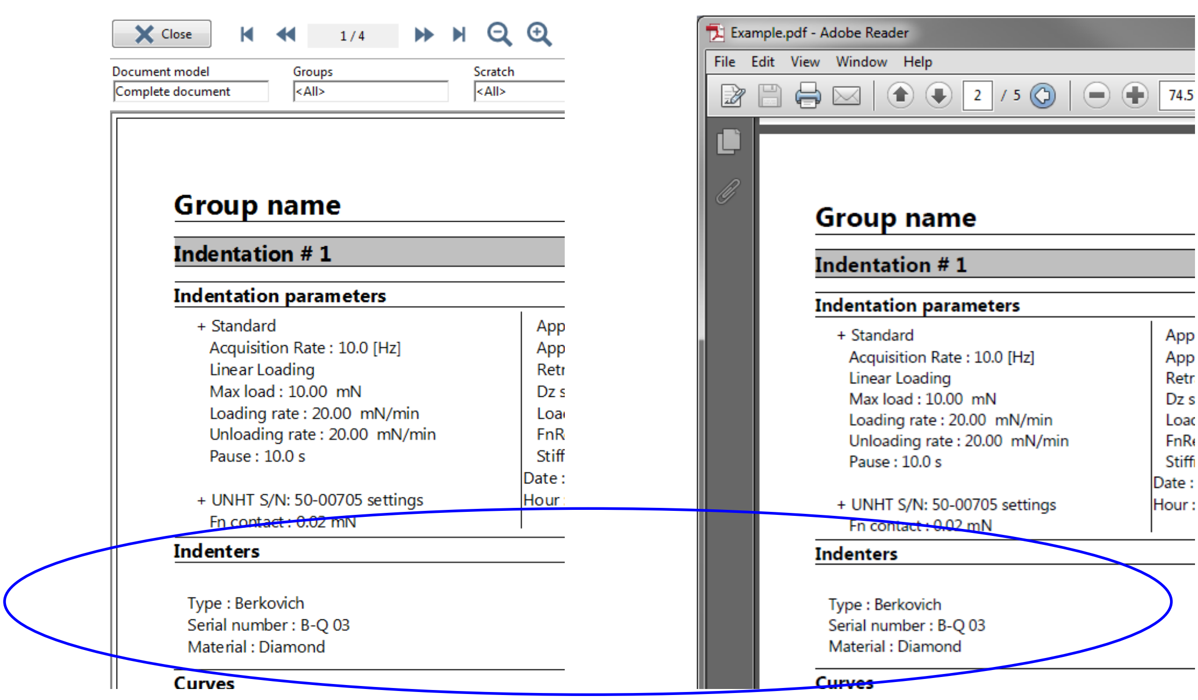
Indenter in results

Later, after each measurement, the indenter in use appears:

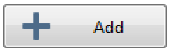
- on the bottom left side of the analysis results window; see from ***chap. 5.11 Managing the indenter in the result analysis, p. 164***.

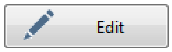


- in the printed/PDF report (from page 2 and depending on the report option configuration); refer to the ***Common Scratch & Indentation software manual - chapters***:
  - ***Customizing options (Document model tabs)***
  - ***Printing/PDF Documents***



3.4.1 Indenter properties window



or


is clicked in the *Edit indenter* windows *Fig.18, p. 34*.

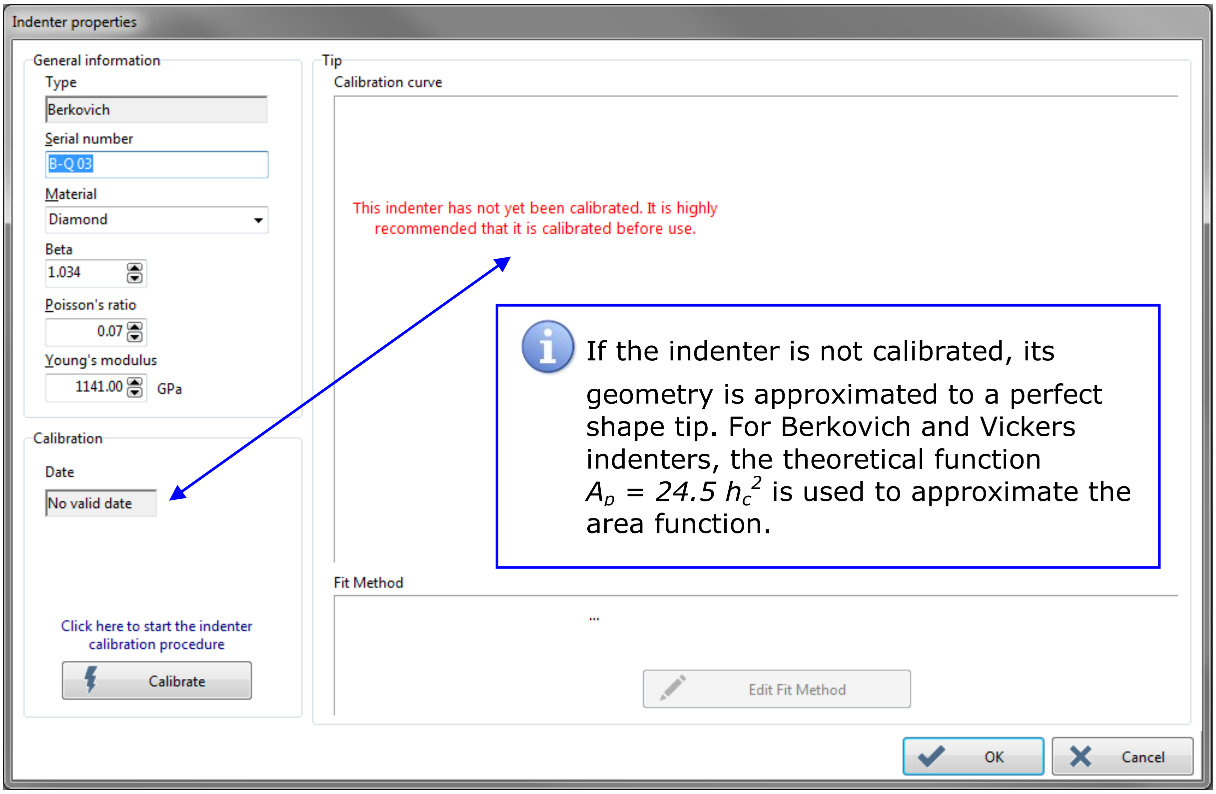
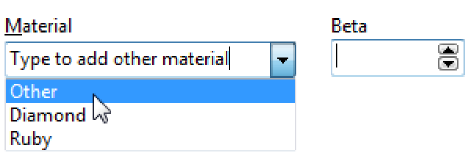


Fig.20 Indenter properties window with no calibration/date

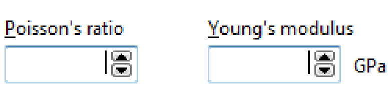
*


This field **should** be filled in.

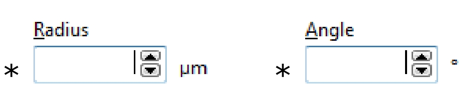
*


Adapt (set) the material and values of **all** other fields which will be used for the measurement analysis results.

The initial ***Beta*** value corresponds to the indenter type selected in *Define a new indenter* window *Fig.19, p. 34*.

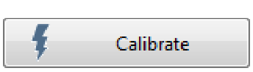


The initial ***Poisson's ratio*** + ***Young's modulus*** values correspond to the diamond material.



If Spherical or Flat Punch indenter type is selected in *Define a new indenter* window *Fig.19, p. 34* these 2 additional fields appear.

* indicated on the indenter provided certificate



To (re)calibrate the indenter; see the following ***chap. 3.4.2 Indenter calibration , p. 38***.

3.4.2 INDENTER CALIBRATION (QUASISTATIC/SINUS)

Calibrate is clicked in the *Indenter properties* window *Fig.20, p. 37*.
The calibration procedure starts.

3.4.2.1 Measuring a matrix of indentations

Use a certified Fused silica sample with UNHT and NHT, or a certified BK7 sample with MHT.

Sinus calibration is not available (Measuring a new matrix of sinus indentation inactive/grayed out) for MHT and UNHT Bio, and NHT without the **optional** sinus mode; see ***chap. 3.1.2.2 NHT, p. 14***.

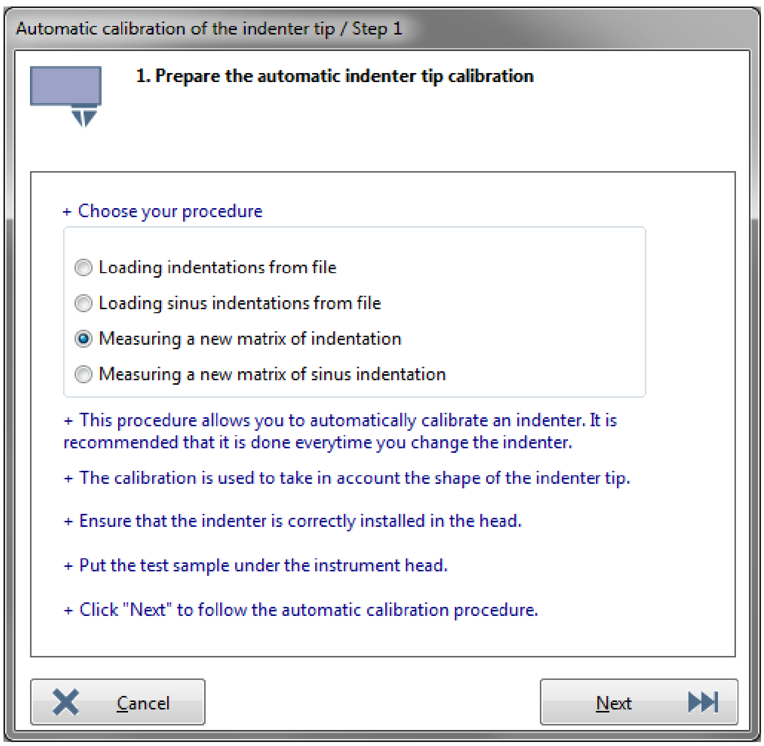
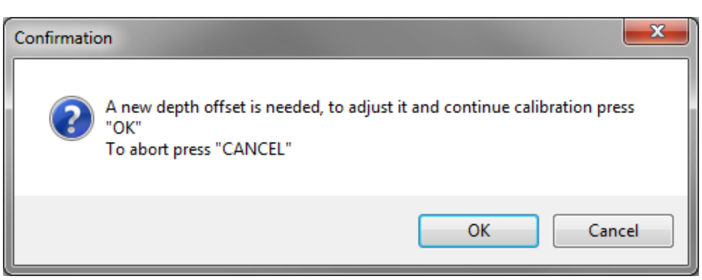


Fig.21 Choose a calibration procedure

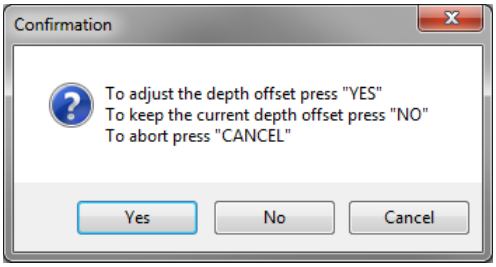
Select Measuring a new matrix of indentation for a quasistatic calibration **OR** Measuring a new matrix of sinus indentation for a Sinus calibration and click Next.

If the ADO is **not** yet successfully (ADO) performed:



Click OK to start a new ADO - for MHT in **fine** Dz range; see ***chap. 4.4 Adjusting the depth offset (ADO), p. 56***.

Otherwise if an ADO has already been **successfully** ( ) performed:



Click No to keep the current ADO (the sample has already been moved with a minimum displacement from the ADO indent → similar sample topography).

OR

Click Yes to start a new ADO (sample has not been moved or has been moved too much from the current ADO indent → the sample topography may vary); see ***chap. 4.4 Adjusting the depth offset (ADO), p. 56***.

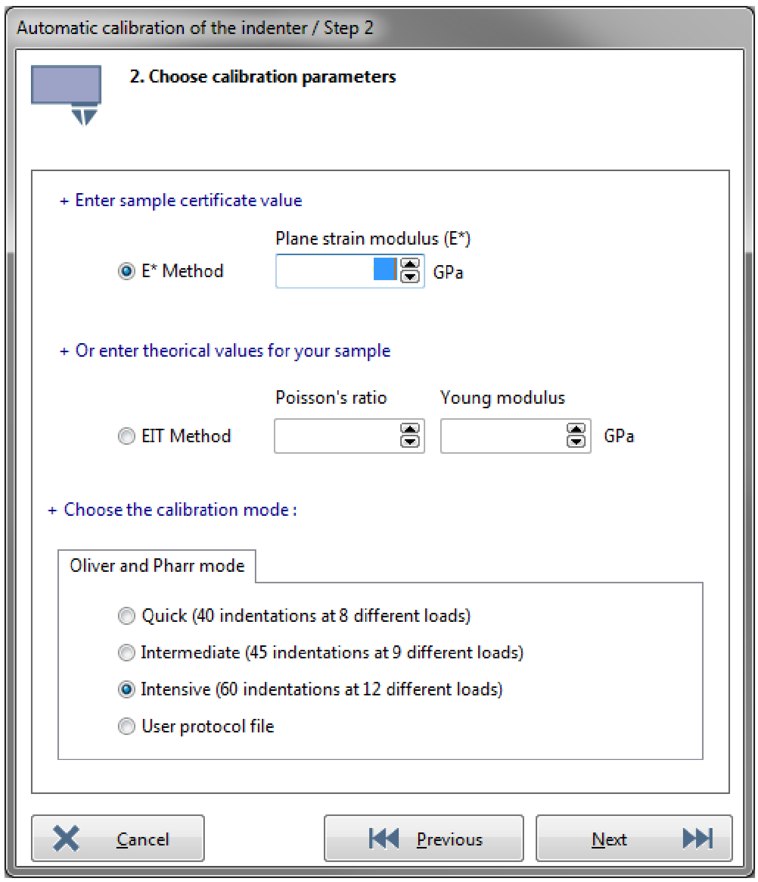
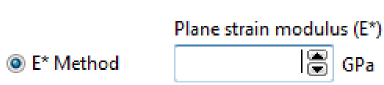
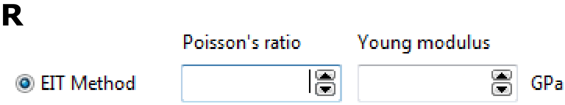


Fig.22 Calibration parameters (e.g. quasistatic UNHT)

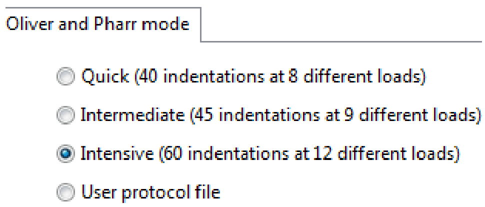


Select E* Method and set the *Plane strain modulus **E**** value noted on the certificate provided with the certified used sample. Then press ***"Enter"***.

OR



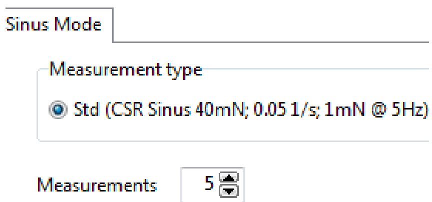
Select EIT Method and set the corresponding (theoretical) values in both fields.



Select a quasistatic calibration mode.

The number of the *indentations* and *loads* for the matrix of measurements are different for each measurement head.

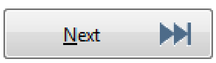
OR



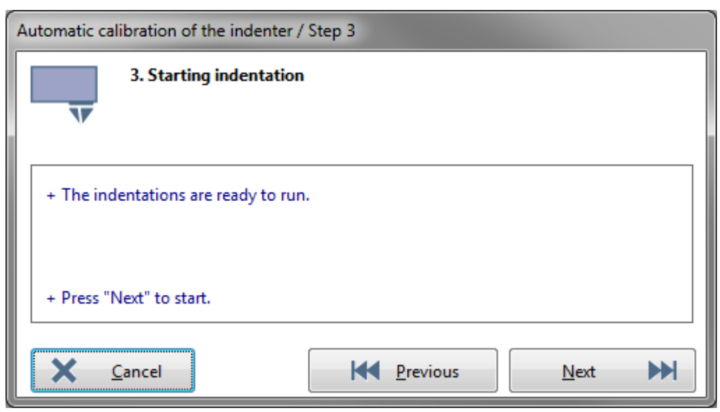
E.g. Sinus for UNHT

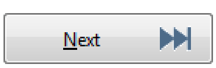
The Sinus mode is selected, set Measurements which is the number of indentations for the matrix single row advised value is 5.

Automatic Constant Strain Rate (CSR Sinus mN), load (mN) and frequency (Hz) values (to perform later each calibration measurement) are different for NHT.

Click 

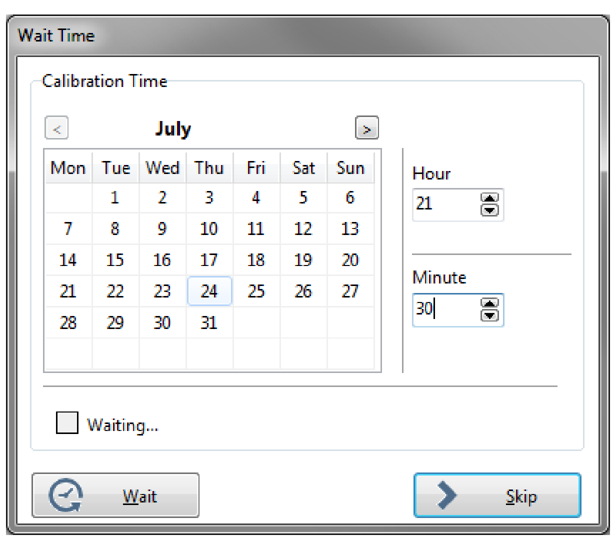
.



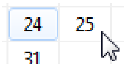
Click 

.

Wait time

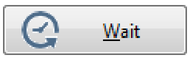


Set a delayed starting

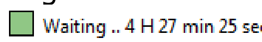


If necessary, to select another measurement date (than today) in the calendar. If necessary, click  to go to the next month (and then click  to come back).

To set the hour and minutes of the selected date when the matrix of measurements should start if the below button is clicked.

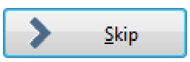


To wait for the date and time previously set (above), before starting the automatic matrix of measurements:

The remaining waiting time until the first measurement starts is displayed 

OR

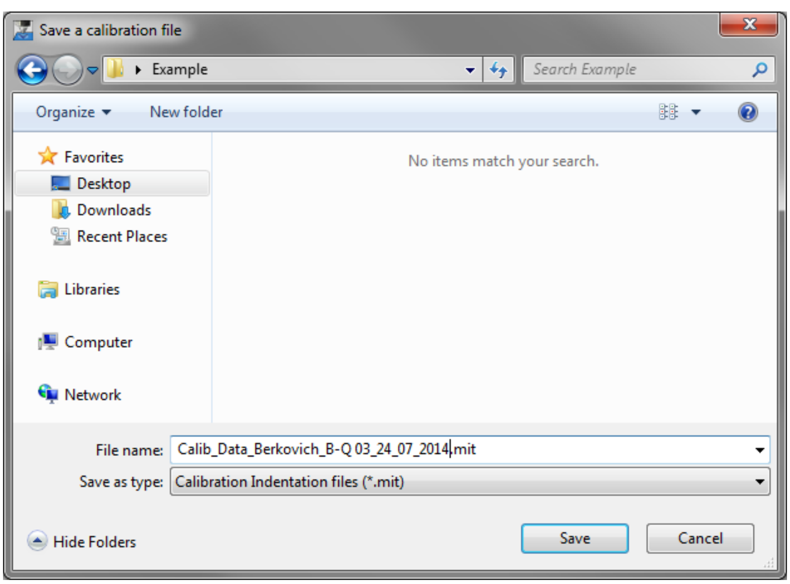
Direct starting



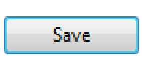
To start the first measurement of the matrix (even if 

has been clicked).

Then the *Indentation running…* window (same as *Fig.58, p. 122*) appears; wait for all automatic matrix of measurements are performed. Once the last measurement is completed, the following window appears and allows:



- Choosing a location where to save the calibration file.
- Modification of the default ***File name***: calibrated indenter with the date when the 1st calibration measurement has been **started**.
  The default file format is .MIT

Then click 

.

Then, the following window appears.

Contact area determination

E.g. with **quasistatic**, they are batches of 5 indent curves measured at different indentation loads: each 5 indents are performed at the same load. For all these indents/curves, e.g. 12 loads x 5 indents = 60 indents/curves, first the contact points should be refined if necessary and then only the relevant indents should be kept → the bad indents should be excluded from the calibration results.

With **Sinus** it is similar, **exception**: the number of indents measured depends on the previous setting (e.g. 5 indents advised) and there are no loads to select e.g. = totally 5 indents/curves.

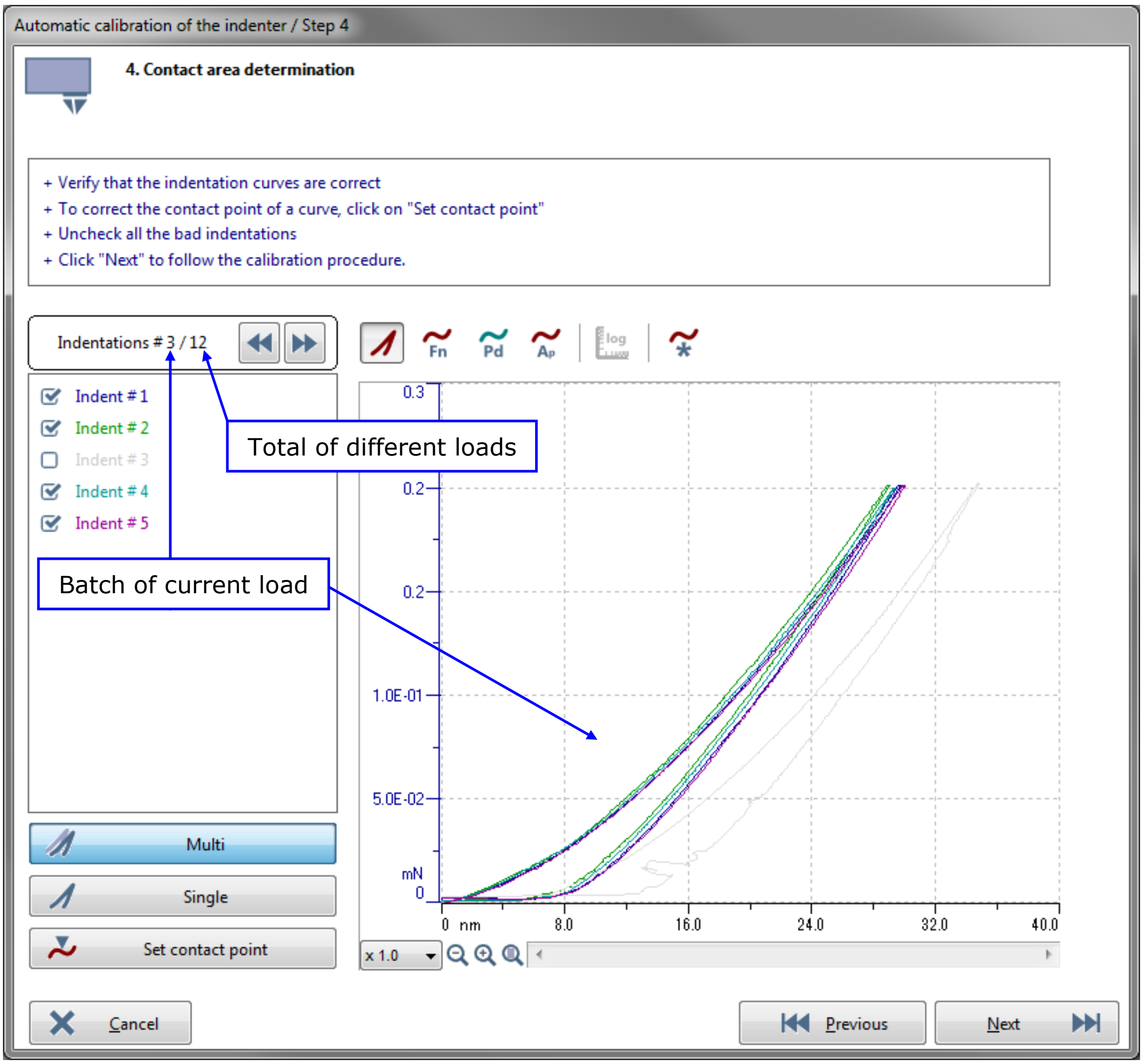
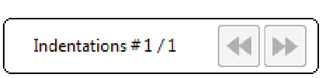


Fig.23 E.g. Indent #3/12 is excluded (non-relevant)

 (next)  (previous)

To select next or previous load batch.



inactive (grayed out)

For **Sinus**, no load to select.

Multi
(initial)

To show **all** curves of the selected load batch.

Place the mouse cursor on one indent of the batch to highlight the corresponding curve.

Single

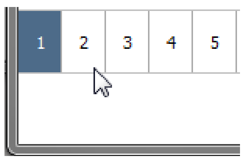
To show **one** curve of the selected load batch.

Place the mouse cursor on one indent of the batch to display it.

Procedure

Set contact point

To verify and refine if necessary the contact point for



all indent curves of the current load batch; see ***chapters 5.1.1.1 Contact point features, p. 133*** and ***5.1.1.2 Verifying/refining the contact point, p. 135***.

Then,
Keep only the relevant indents

Indent # 3 → Indent # 3

e.g. see *Fig.23, p. 42*

Uncheck to exclude (from the calibration results; see ***Validation of the results, p. 45***.) each non-relevant indent/bad curve, which becomes gray.

If necessary, check it again to re-include it (relevant).

With **quasistatic** mode, repeat the ***Procedure above*** for **each** load (e.g. 12 loads , so totally 60 (5x 12) contact points and curves should be verified).

To display the indent **curves** of the **current** load (/) on the graph

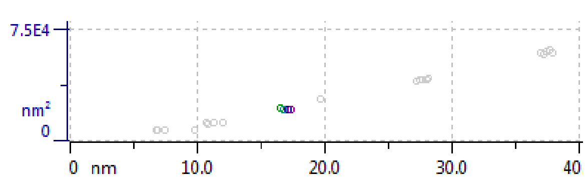
(initial) **F** vs. **h** (combined curves), **OR**

F vs. **time** (force curves), **OR**

h vs. **time** (depth curves)

OR

To display the projected area vs. contact depth:



Only with **quasistatic**, the indents of **all** loads are represented with circles on the graph. Only the relevant indents are displayed in color.

To display graph logarithm scales (selected).

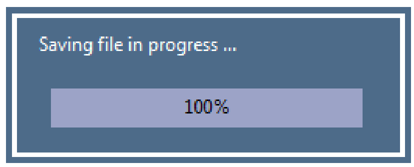
To display only the relevant indents of the **current** load; see ***Keep only the relevant indents, p. 43***:

The non-relevant (☐ Indent # 3 unchecked) indents in gray are hidden from the graph.

To zoom the indent curves on the graph; for the descriptions, refer to the ***Common Scratch & Indentation software manual chap. Features on graph areas - Zoom***.

When all contact points and curves are verified, click Next:

⚠ Any modifications (contact points and exclusion of non-relevant indents/bad curves) are automatically **saved** on the current calibration measurement file .MIT (which were saved after the matrix of measurements or loaded).



The following window appears.

Validation of the results

According to the previous ***Contact area determination***, from ***p. 42***, the red curve fits on the crosses displayed on the graph of the window *Fig.24 below*:

E.g. with a quasistatic calibration, each cross corresponds to the average of the relevant (kept) indents for each load (e.g. 12 loads = 12 crosses).

With a sinus calibration, each cross corresponds to the average of the relevant (kept) indents of the sinus analysis at the corresponding contact depth (more crosses).

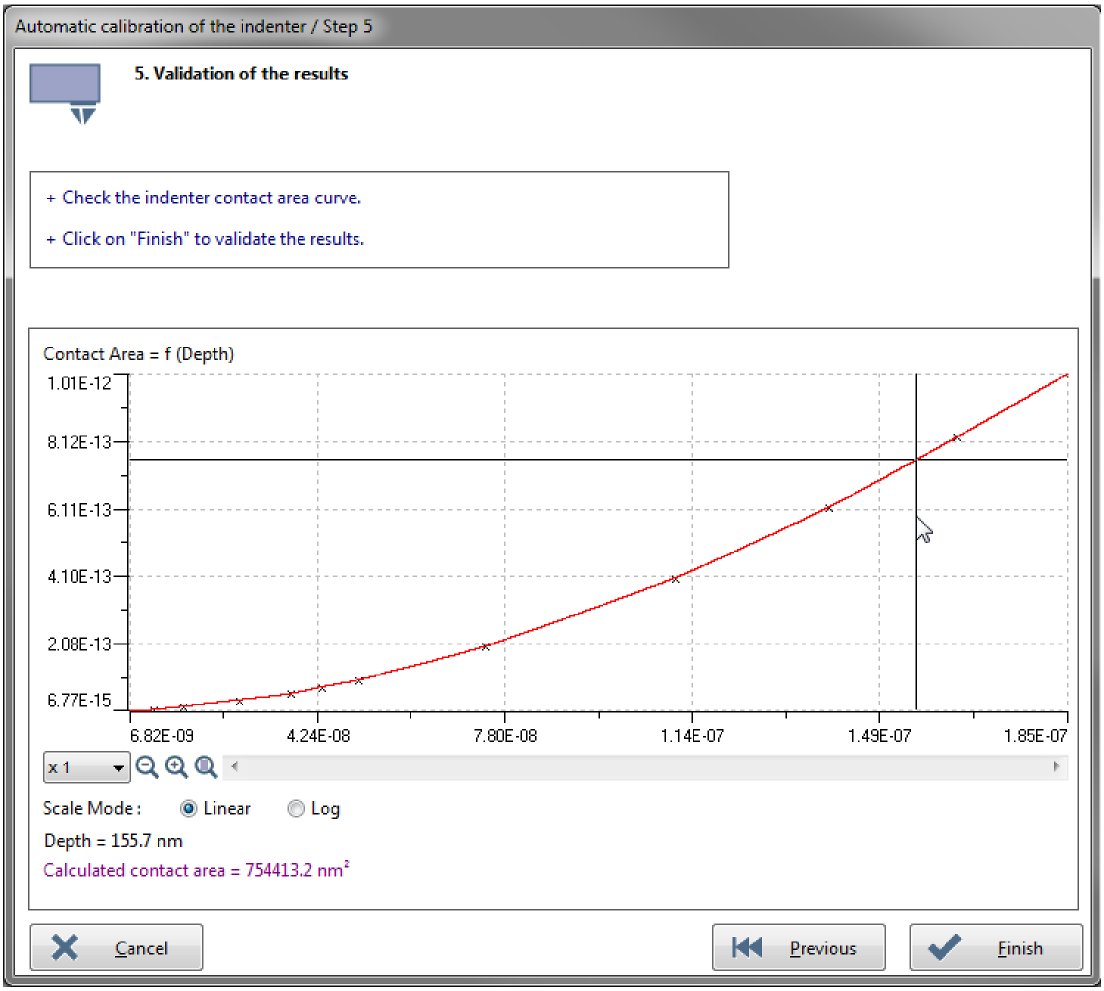


Fig.24 Curve results of indenter contact area (Ap) vs. contact depth (hc)

Select Log to display graph logarithm scales **OR** select (initial) Linear to display graph linear scales.

Verify the curve and if necessary click Previous and modify the ***Contact area determination, p. 42***.

When the curve is suitable, click Finish and see:

- ***chap. 3.4.3 Calibration date, p. 47***.
- ***chap.3.4.4 Fit methods Ap(hc) of the calibration, p. 48***.

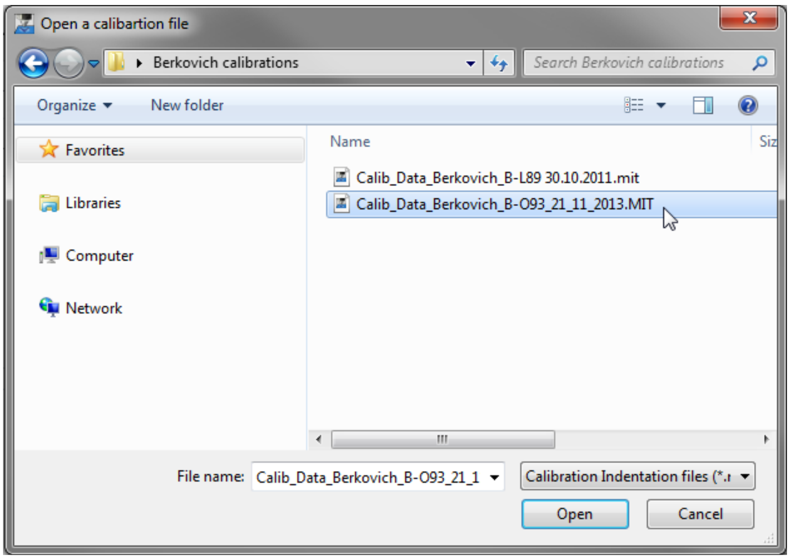
3.4.2.2 Loading indentations from file

This procedure is similar than for ***Measuring a matrix of indentations*** described in ***chap. 3.4.2.1, p. 38***, **exceptions**:

- There are no parts related to perform measurements.

- Select ◉ Loading indentations from file **OR** ◉ Loading sinus indentations from file in *Fig.21, p. 38* (chose a calibration procedure in the *Step 1* window).

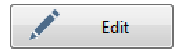
- The following window appears and allows:



- Choosing a location where to open a calibration file with .MIT format.

- Then select the file and click [Open] or double click on the file to open it.

3.4.3 CALIBRATION DATE

is clicked after a calibration in *Fig.24, p. 45* or 

is clicked in the *Edit indenter* windows *Fig.18, p. 34* for an indenter already calibrated.

The *Curve results of indenter contact area (Ap) vs. contact depth (hc) Fig.24, p. 45* is reported on the graph of the window below.

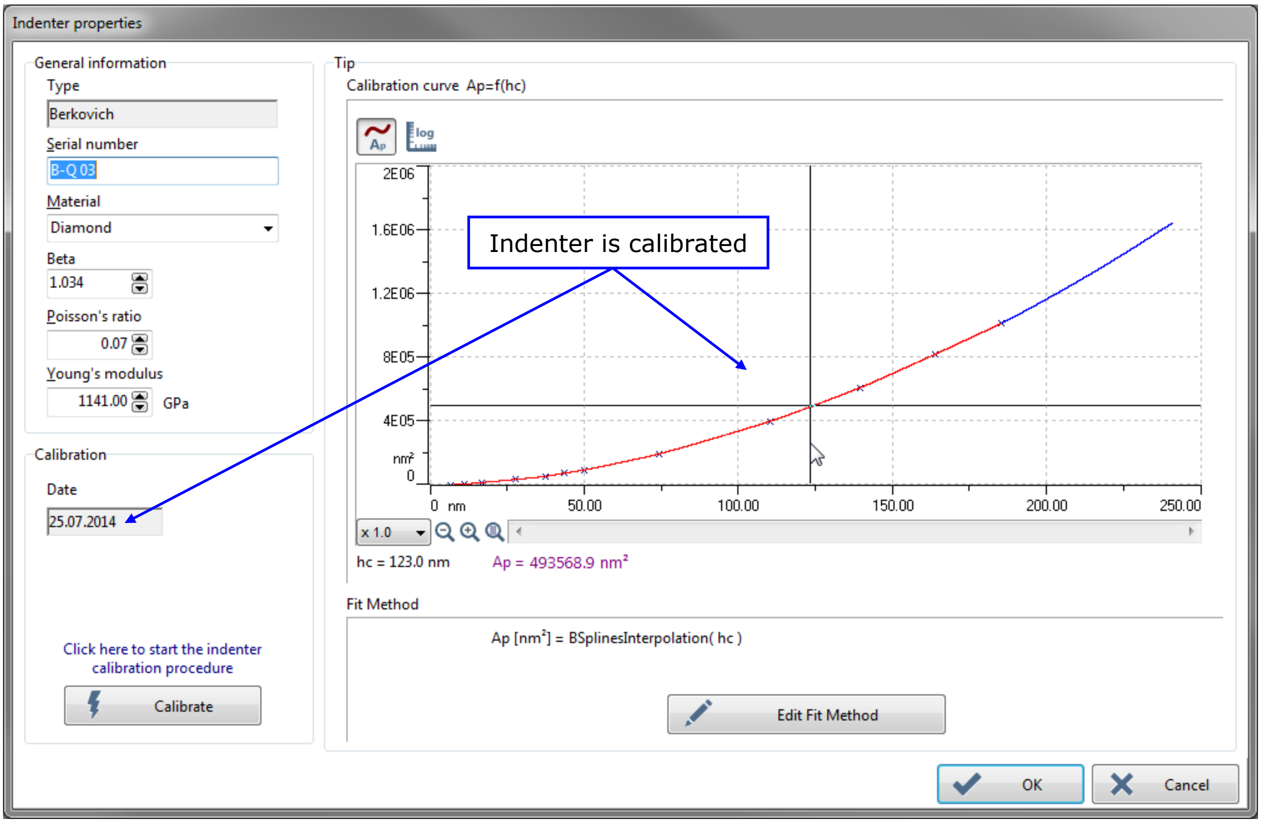
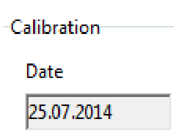


Fig.25 Indenter properties window (with calibration/date)



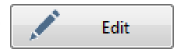
The displayed indenter calibration date **always** corresponds to the date when the last calibration measurement (weakest force) of the matrix was **ended**.

This date is also displayed next to the serial number of the indenter in the *Edit indenter* windows *Fig.18, p. 34*;

e.g. ***Berkovich [B-Q 03] (25.07.2014)***


The date format depends on the acquisition system setting; e.g. could be with this different format *25/07/2014*.

3.4.4 FIT METHODS $A_p(h_c)$ OF THE CALIBRATION

is clicked after a calibration in *Fig.24, p. 45* or 

is clicked in the *Edit indenter* windows *Fig.18, p. 34* for an indenter already calibrated.

The *Curve results of indenter contact area (Ap) vs.* contact depth from *Fig.24, p. 45* is reported on the graph of the window below.

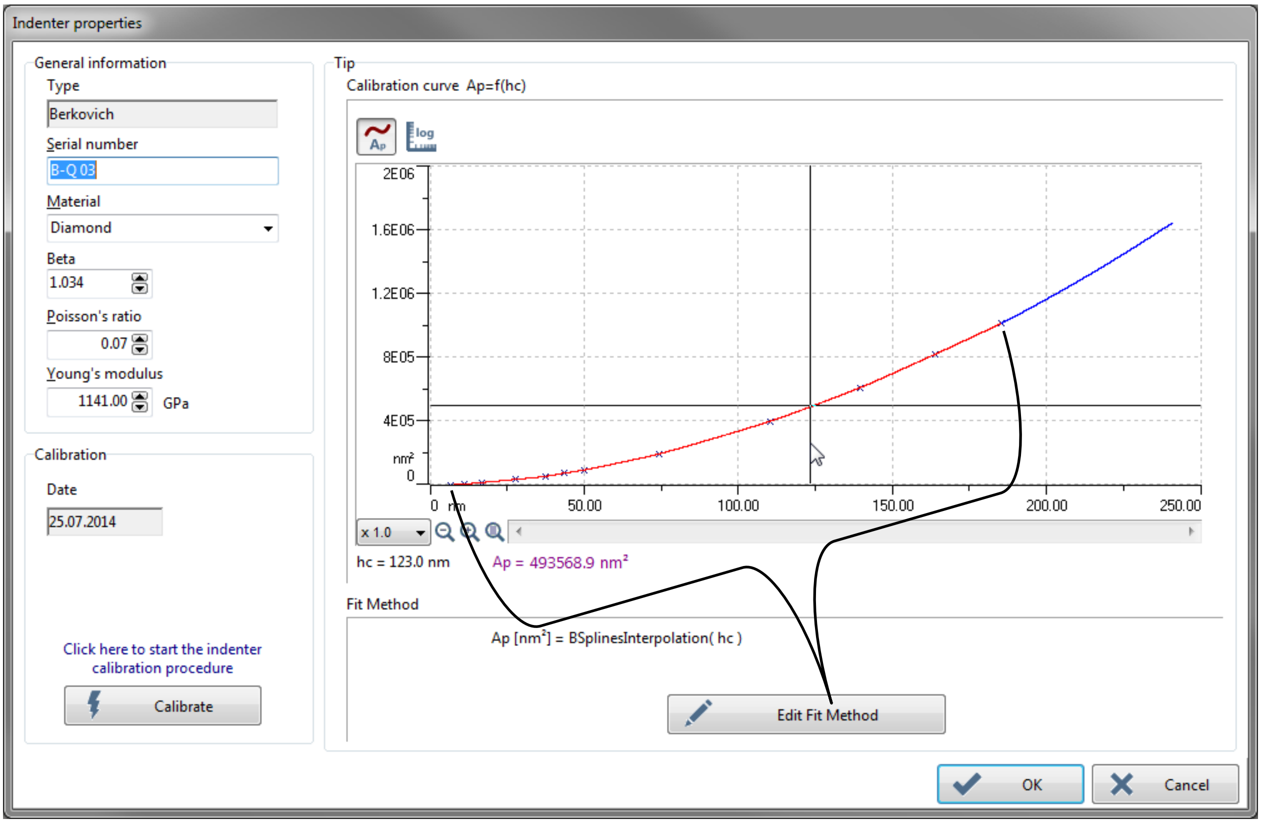


Fig.26 Indenter properties window Ap(hc) curve

<u>Graph scale display modes</u>

Also applicable in the following *Edit Fit Method* window *Fig.27, p. 49*.

To display graph linear scales, in order to focus on the highest indentation depths: **red** and **blue** part of the curve, e.g. in *Fig.26 above*.

OR

To display graph logarithm scales, in order to focus on the lowest indentation depths: **green** and **red** parts of the curve, e.g. in the *Fig.27, p. 49*.

Part of the curve in blue (*Fig.26 above*)

Theoretical function (A_p=24.5 h_c ^{2} for Berkovich and Vickers indenters, $A_p=\pi h_c(2R-h)$ for a sphere) with a shift in Y (ΔY) to ensure the continuity on the **last cross** (highest depth) of the calibration.

Part of the curve in green (*Fig.27 below*)

For Oliver & Pharr fit methods: sphere equation passing by the 1st cross (lowest depth) of the calibration.

For BSpline: spline equation passing by (0;0) and having the same tangent in (0;0) than the sphere equation passing by the 1st cross (lowest depth) of the calibration.

Part of the curve in red (*Fig.26, p. 48* and *Fig.27 below*)

Click [Edit Fit Method] to open the following *Edit Fit Method* window, which allows selection of a method to compute a best fit for the contact area function.

The default fit method is the ◉ BSpline Interpolation. If necessary select another fit method either a ◉ Linear Interpolation, ◉ Oliver & Pharr or a ◉ Polynome fit.

For Oliver and Pharr or Polynomial fit methods, the number of the computed coefficients should be adapted in the corresponding field, respectively Fractional terms : or Degree :

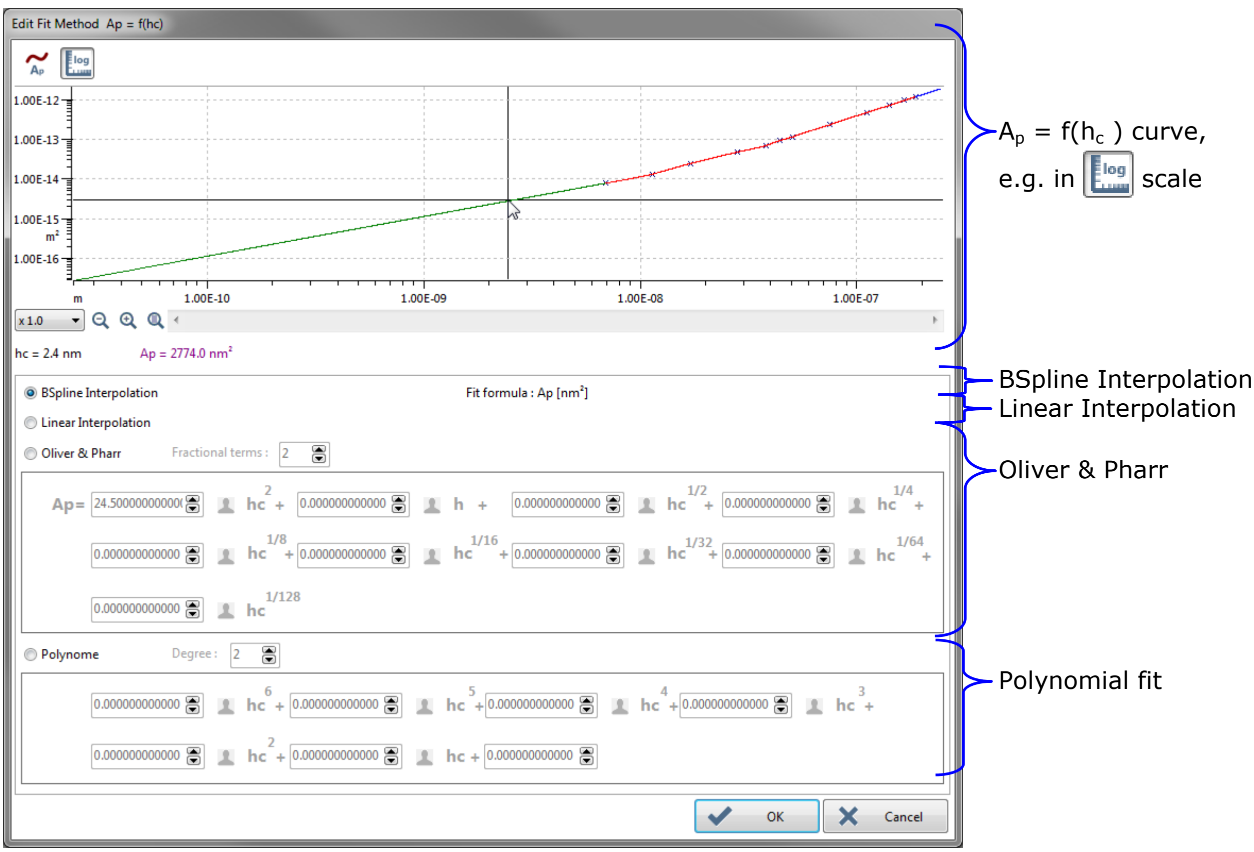
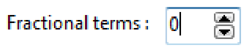
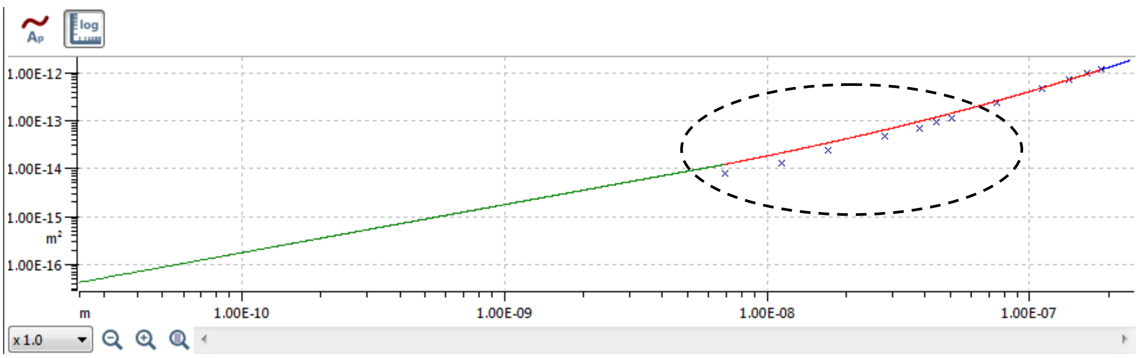


Fig.27 Edit Fit Method window

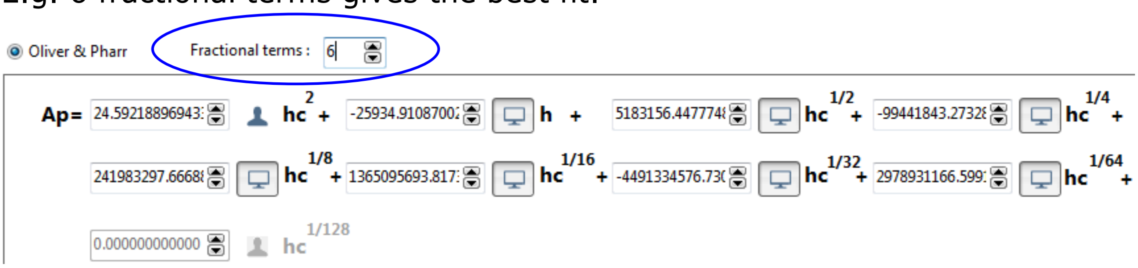
The following example describes the way to find the best fit with *Oliver & Pharr* fit method. In an ideal case the function should be a line passing by each cross (e.g. 12 crosses).

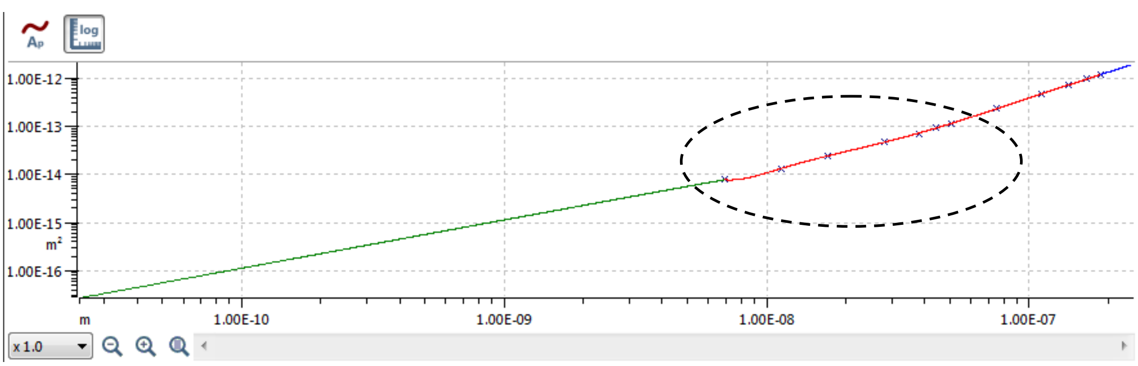
The first term $h_c{}^2$, the lead term, is by default to 24.5 (coefficient for a Berkovich or Vickers indenter).

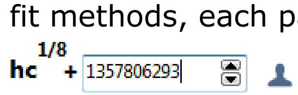
If a low  (e.g. 0) is used, the fit obtained is not good for some of the lowest indentation depths.



E.g. 6 fractional terms gives the best fit.





For *Oliver and Pharr* or *Polynomial* fit methods, each parameter for the A_p fit can be manually set by clicking  : e.g. 

(Re)click  for each filed which should be automatically (re)calculated by the software.

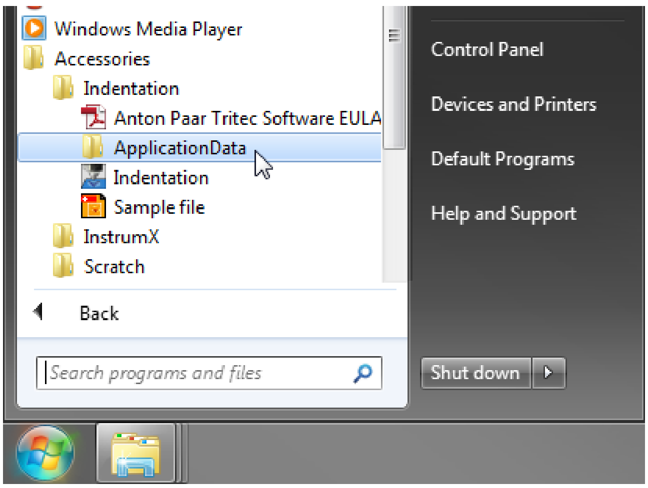
3.5 UNHT APPROACH MONITOR WINDOW (.INI FILE MANAGEMENT)

Be careful, bad modifications in the *UNHT.INI* file can have a direct influence on the UNHT behavior/measurements. Therefore in the file Notepad, edit only the `lines` (highlighted in gray) which are described below and exactly as they are typed (spelling is considered/case sensitive).

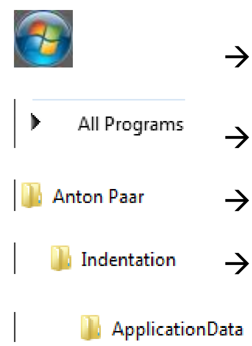
";" in front of each single line of the INI file allows comments.

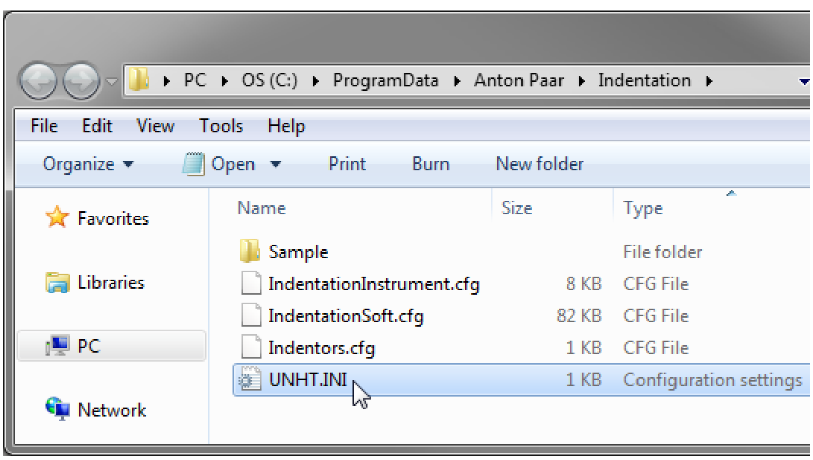
INI file activation

To activate the INI file management directly from the software.



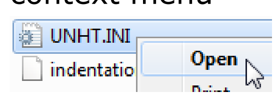
From the Windows® taskbar select:



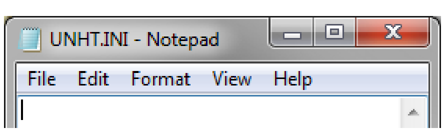


To open the *UNHT.INI* file in the Windows® Notepad:

- Right click on it and select open in the context menu



- Double click on it.



In the Notepad, at the section *[Extra]*, edit *ReloadIni* to ***= 1*** :

```
[Extra]
ReloadIni = 1
```

Save the file and close the Notepad.

Then restart the *Indentation Software* (this should be done only once):

Select ***File/Exit*** from the menu bar or click on the right top of the main window and start again the software by double clicking on the acquisition system desktop.

Now the ***.INI file*** appears in the ***Instrument*** menu bar.

UNHT Approach Monitor window

To hide or display later (during ADO process, measurements…) the *UNHT Approach Monitor* window, see the following descriptions.

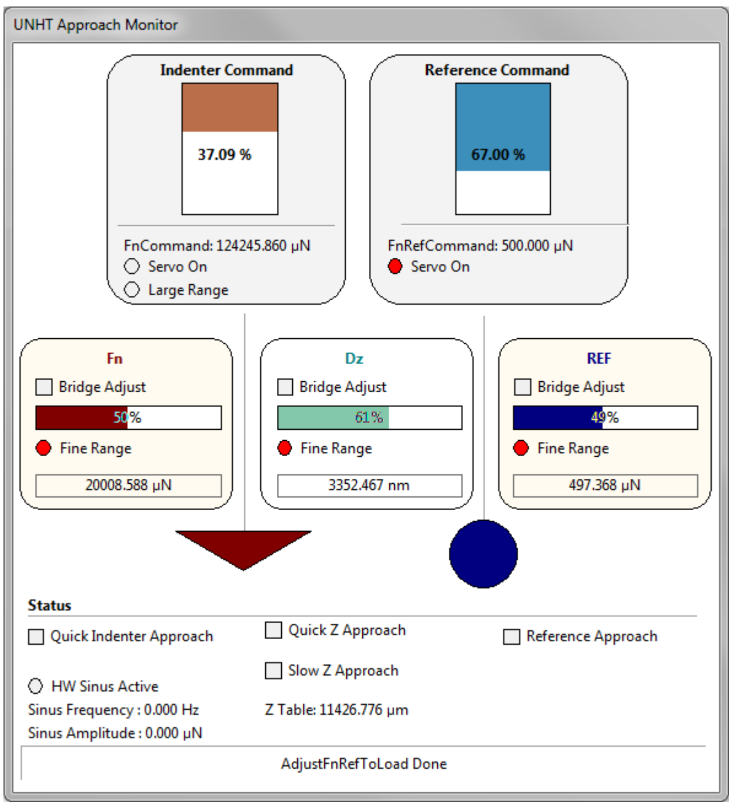
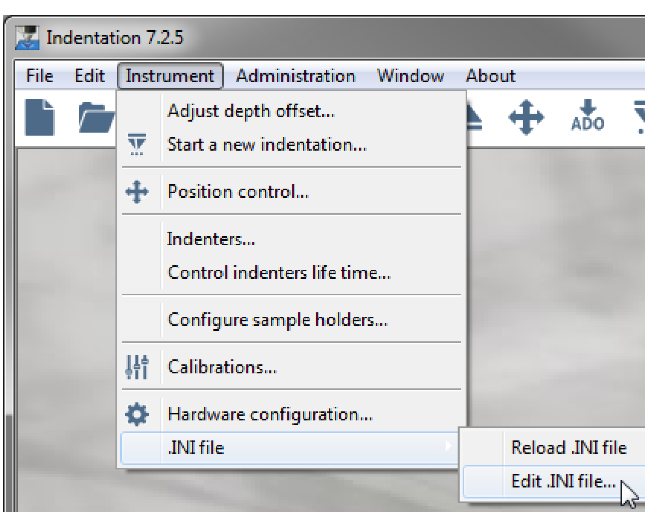
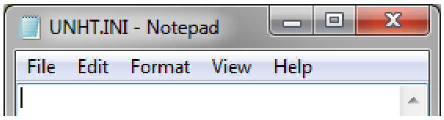


Fig.28 UNHT Approach Monitor window



Thanks to the ***INI file activation, p. 51***:

Select ***Instrument/ .INI file/Edit.INI file*** from the menu bar to open the Notepad .INI file.



The *UNHT Approach Monitor* window *Fig.28, p. 52* can be **deactivated** (will be hidden):

In the Notepad, at the section *[Monitoring]*, edit *Show* to ***= 0*** :

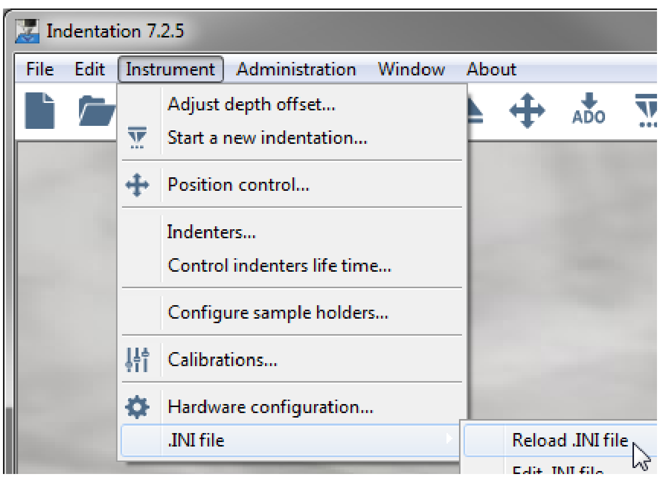
```
[Monitoring]
Show = 0
```

The *UNHT Approach Monitor* window *Fig.28, p. 52* can be **(re) activated** (will be displayed):

In the Notepad, at the section *[Monitoring]*, edit *Show* to ***= 1*** :

```
[Monitoring]
Show = 1
```

Save the file and close the Notepad.



Do not forget to then select ***Instrument/.INI file/ Reload .INI file***. to activate the last .INI file modifications.

(there is no need to restart the software)

4 TAKING A NEW MEASUREMENT

4.1 Introduction

For detailed manipulations and instructions, refer to each corresponding ***Measurement head* user manual**.

4.1.1 Warning

⚠ When installing the sample in a sample holder **AND** when moving the sample/(motorized) tables from the video microscope to the measurement head and vice versa, **avoid** any collision with:

- the measurement head, especially with the indenter/ reference (UNHT)/reference ring (NHT)/reference fork (MHT)
- the video microscope optical objectives

4.1.2 Notes for good measurements

For a maximum accuracy, the sample surface should be always perpendicular to the indenter axis (sample surface leveled). For some specific applications, a special sample holder is required to fulfill this condition.

Each sample should be firmly fixed (clamped, glued for UNHT Bio…) into the sample holder → the sample should not slide when it is indented and also when the (motorized) tables move.

Each sample and sample holder support surfaces should be clean and dust-free. Before performing a measurement (ADO included), the chosen sample surface area should be free of previous indents.

The indenter should be clean and not too much worn out.

The sample temperature should remain stable during measurement.

4.1.3 Generality

A new indentation measurement or measurements (matrix of indentations) involve a succession of logical steps, such as:

1. Installing the sample
2. Choosing the sample area for the measurement(s)
3. Adjusting the depth offset (ADO)
4. Setting up the configuration/parameters for the measurement(s)
5. Running the measurement(s)
6. Analysis of the measurement results

Each of these steps is described in the following chapters.

4.2 Installing the sample

1. To move the motorized tables to safe position (max. right front table position), click on the toolbar.

2. Install firmly the sample into the sample holder.

4.3 Choosing the indentation area

For all information about the *Position control* window features (management of the indenter/video microscope areas, different methods to move with different speed…), refer to the ***Common Scratch & Indentation software manual - chap. Managing the instrument - Control of the sample position***.

Do **not** change the focus once it has been adjusted. To **avoid** any collision, always verify the sample height before moving.

1. To choose the sample measurement area, click on the toolbar.
   In the *Position control* window which appears:

2. To move the sample/motorized tables under the video microscope click .

   The microscope zone should be activated (under microscope icon), otherwise click . The *Video* Software window is open, otherwise click Open video .

   For the video microscope module with STeP 4/6: to lower the module (if not already at the lowest position) click .

3. To adjust the focus of the sample surface on the *Video* screen, move the motorized Z table: click Up to raise / Down to lower.

   With a TTX-NHT, use the coarse and fine focusing thumbwheels.

4. To move the sample/motorized X-Y tables in order to choose the measurement area on the *Video* screen (under the middle of the crosshair), click / / / .

   With a TTX, the non-motorized table(s) should be manually move.

   When exiting the *Position control* window, the motorized table automatically retracts.

Then the sample will be automatically moved under the indenter, at the chosen measurement area, before starting the ADO procedure (ADO / ADO) and then before starting the measurement procedure ().

4.4 ADJUSTING THE DEPTH OFFSET (ADO)

The ADO procedure is carried out to correctly setup the depth sensor measurement range for the following indentation calibration/measurement(s):

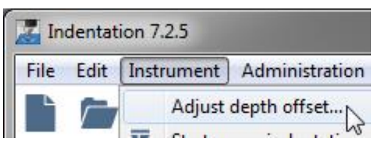
- Because of the unpredictable sample surface topography.
- To optimize the duration of the measurement(s).

This procedure should be performed:

- If the sample surface topography may vary between the indentation measurements.
- If the indentation measurements are performed on multi-sample where the surface topography varies.
- After changing the sample.
- After changing the indenter.
- Only for UNHT, after changing the reference.
- After restarting the software.

Before performing this procedure, the current position (measurement area) on the sample surface should be free of previous indents and clean.

Manual ADO procedure starting



Select ***Instrument/Adjust depth offset...*** from the menu bar or click / on the toolbar to start the following ADO step by step procedure windows:

1st *Adjust depth offset parameter*s window

2nd *Adjust depth offset in progress* window for the automatic (semi-automatic for MHT without electronic bridge) process (this window includes several sequence steps) - an indentation is performed.

3rd *Sample displacement after ADO* window

Automatic ADO procedure starting

The procedure can be automatically started from some calibration/measurement processes **if** the ADO has never been performed or if the last ADO is not successful ( ).

The **1st** and **2nd** windows described above are different depending on the type of the measurement head which is used. All of them are described in the 3 following chapters.

At the end of the procedure, if the ADO has been **successfully** performed, a green disk with a tick appears on the ado icon (main toolbar). If not, appears and the procedure should be performed again until it is successful.

4.4.1 UNHT/UNHT Bio ADO

The **1st** procedure window allows setting of the parameters which will be used to perform the ADO automatic process (**2nd** window).

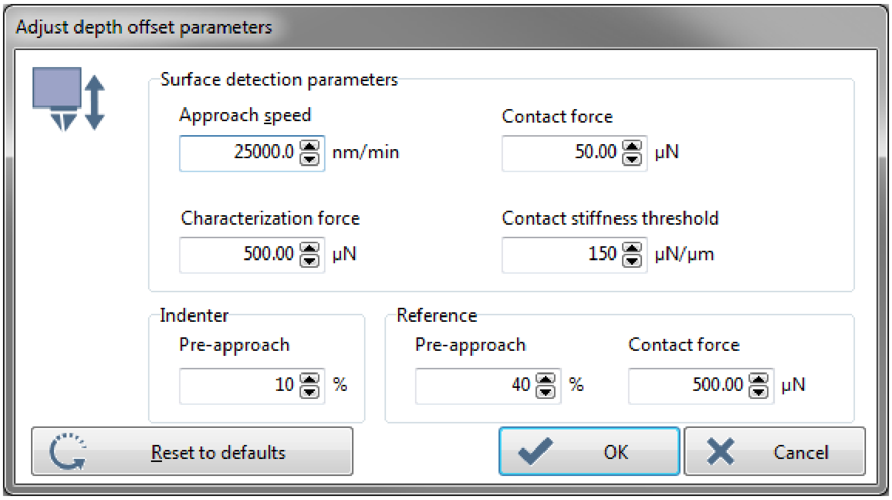


Fig.29 UNHT ADO parameters window

E.g. parameters shown on *Fig.29* are the defaults values which are normally suitable to perform a successful ADO with the UNHT.

Otherwise set other field values according to the application.

There is no reference with UNHT Bio, therefore the corresponding field are inactive (grayed out).

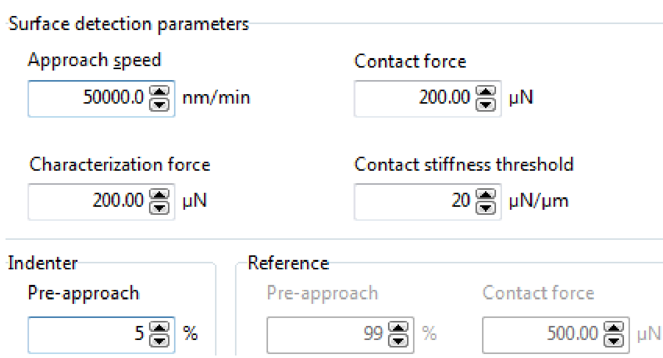


Fig.30 UNHT Bio ADO parameters window

E.g. parameter values shown on *Fig.30* are normally suitable to perform a successful ADO with the UNHT Bio.

Otherwise set other field values according to the application.

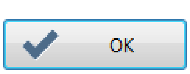
To reset all fields with the default values.

Indenter Pre-approach and ***Reference Pre-approach***

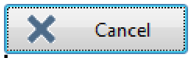
100 % is the rest position corresponding to the fully extended (lowest) position of each actuator displacement.

Rest position for the motorized Z table is the retracted (lowest) position; see ***Table Z retraction*, *p. 31***.

For ***Contact stiffness threshold*** details, see identical information as described in ***chap. 4.6.5.8*** (indentation measurement parameters)***, p. 119***.

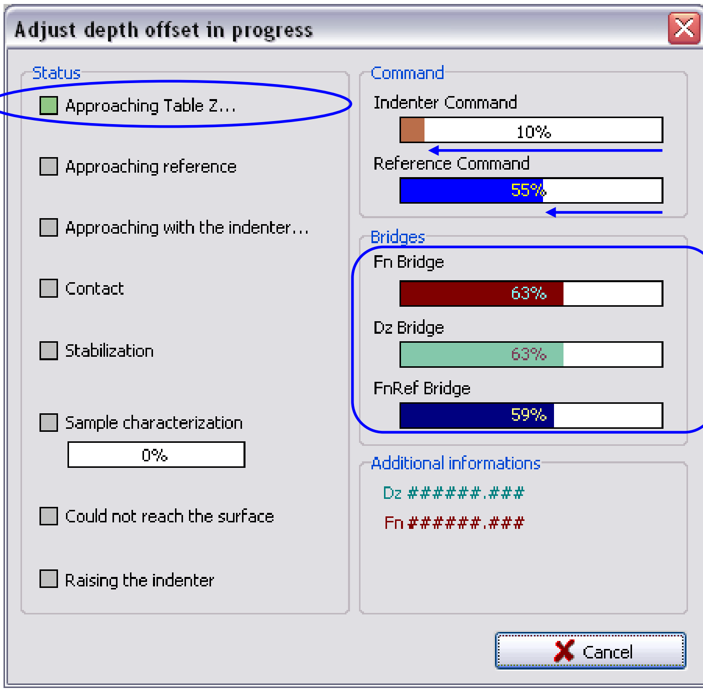
Click 

to start the following automatic ADO process.

The **2nd** procedure window is performing the automatic ADO process (steps). If necessary, click 

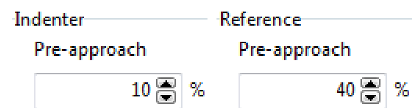
to stop the process and cancel the ADO. Otherwise wait until the **3rd** procedure window appears.

Steps concerning the reference are not applicable with UNHT Bio.



With **STeP 4/6**, the motorized head module approaches (moves down).

Then the indenter and reference retract (move up) to the previously set values:



except **+15 %** for the reference.

Then Fn, Ref and Dz sensor bridges are automatically adjusted.

And then the motorized Z table slowly approaches (moves up).

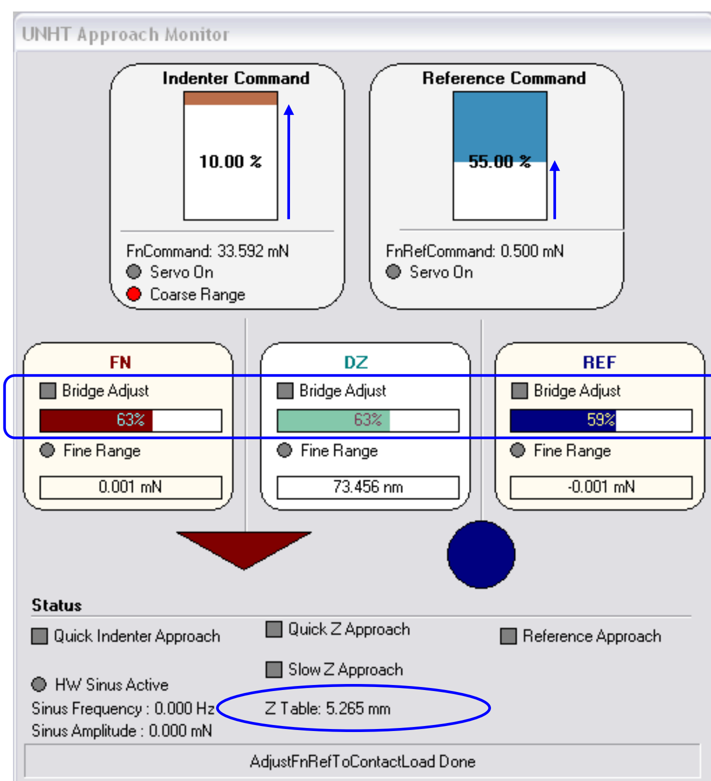
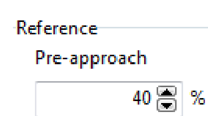
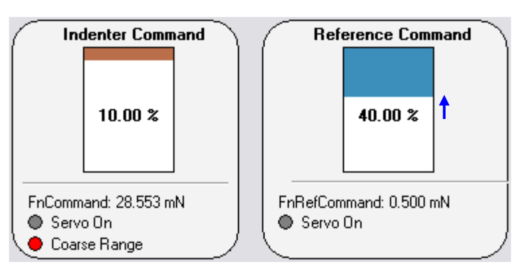


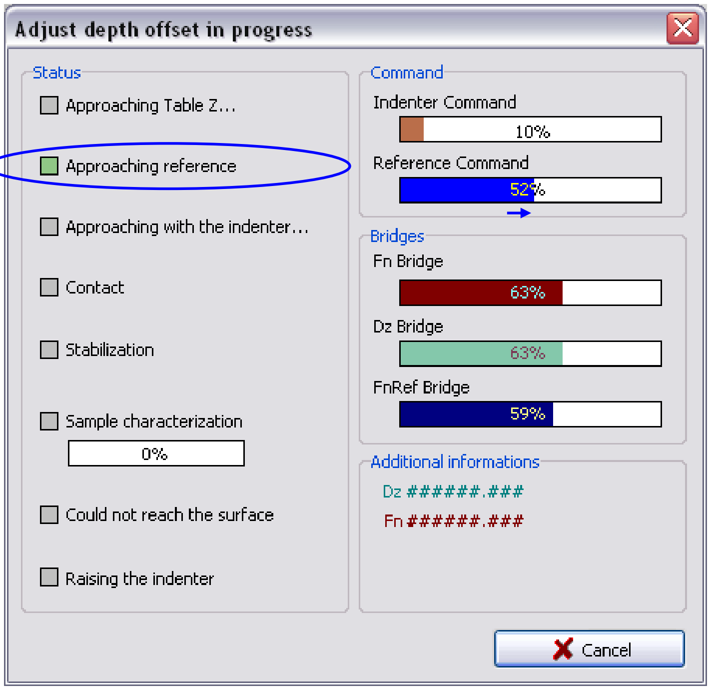
Fig.31 UNHT Approach Monitor extra window

The extra *UNHT Approach Monitor* window *Fig.31* can be hidden or displayed with the UNHT.INI file;
see ***chap. 3.5, p. 51***.

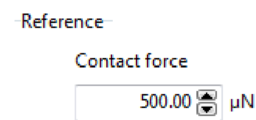
When the sample surface contacts the reference, the motorized Z table stops and the reference actuator is retracted (moves up) by **15 %** → return to the previously set value:

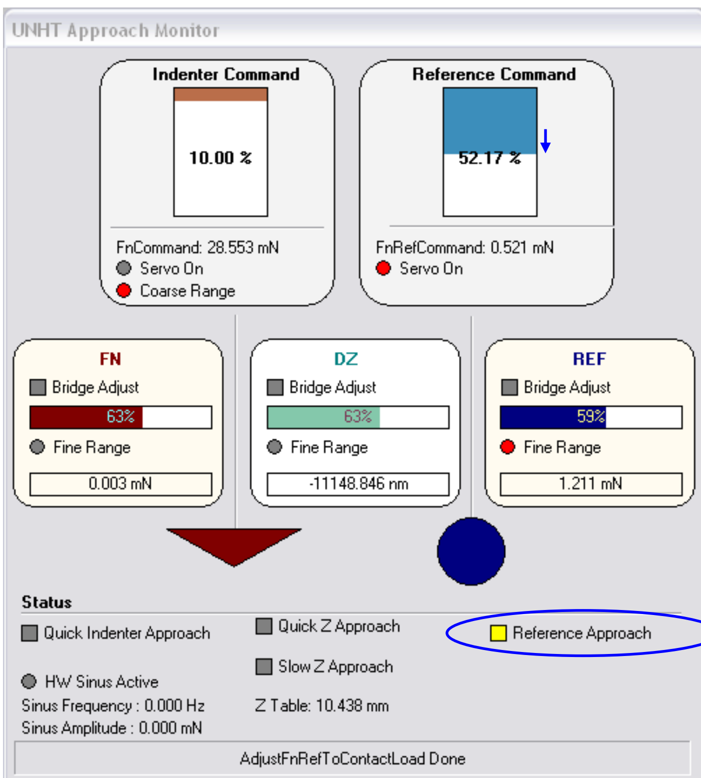




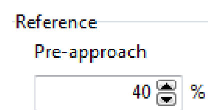


The reference approaches (moves down) until it reaches the previously set value:

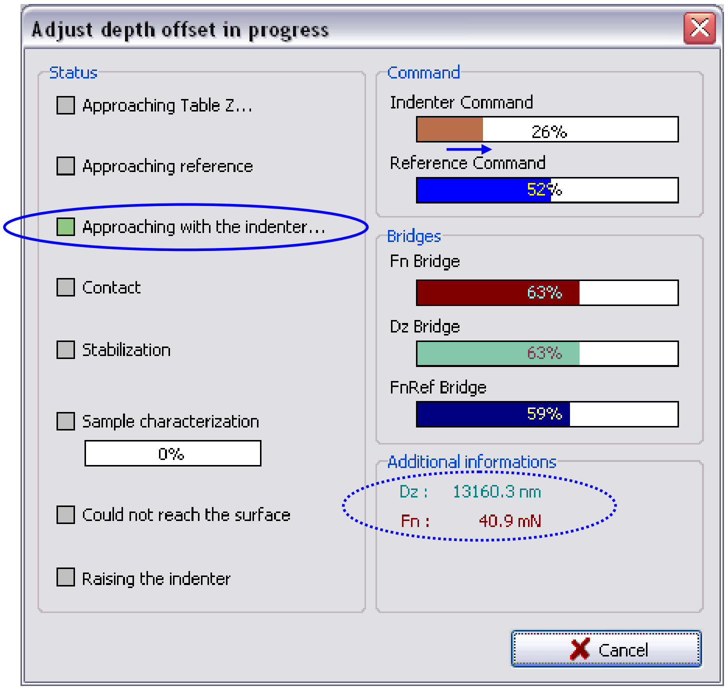


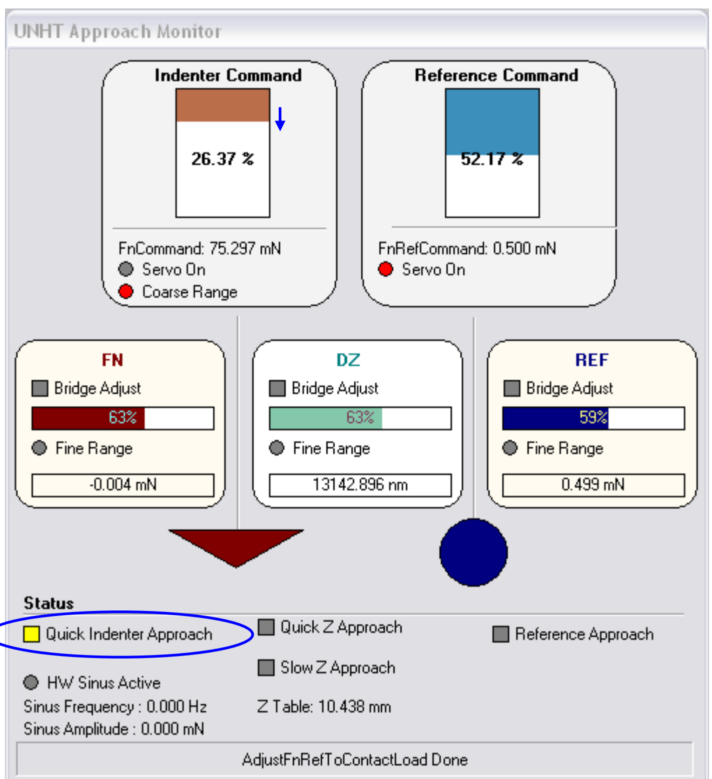


The reference touches ~10 % above the previously set position:

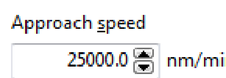


e.g. 40 % + ~10 % = ~50 % → 52.17 %

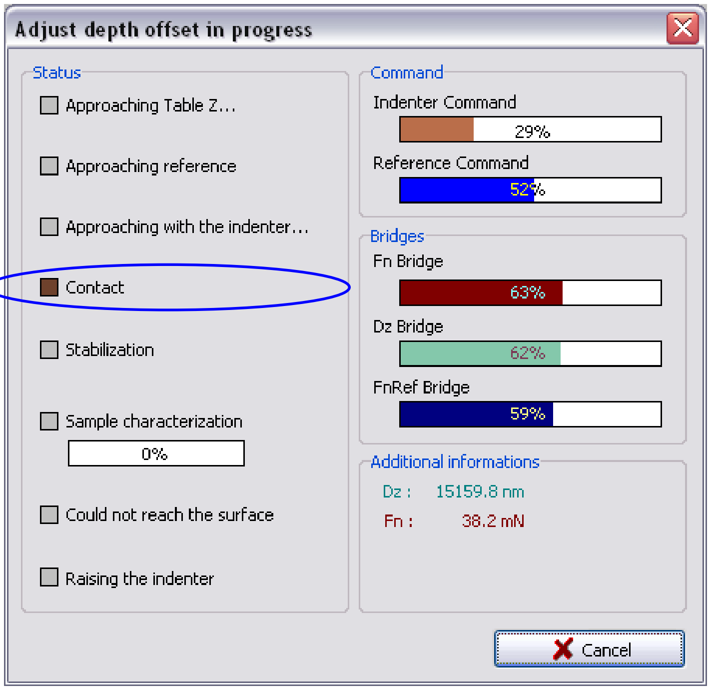


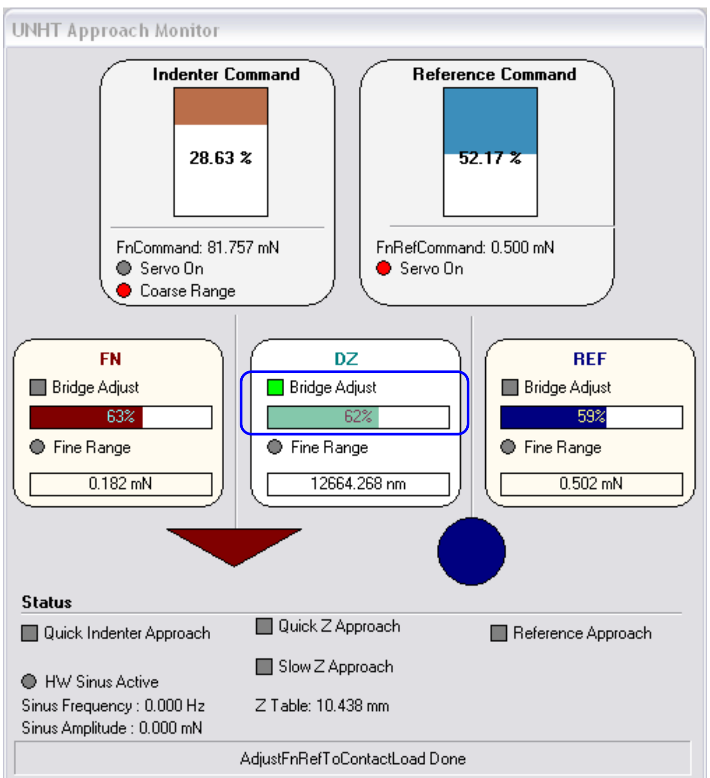


The indenter approaches (moves down) with the previously set:



until ...





... it contacts the sample surface:

The indenter has either reached the previously set:

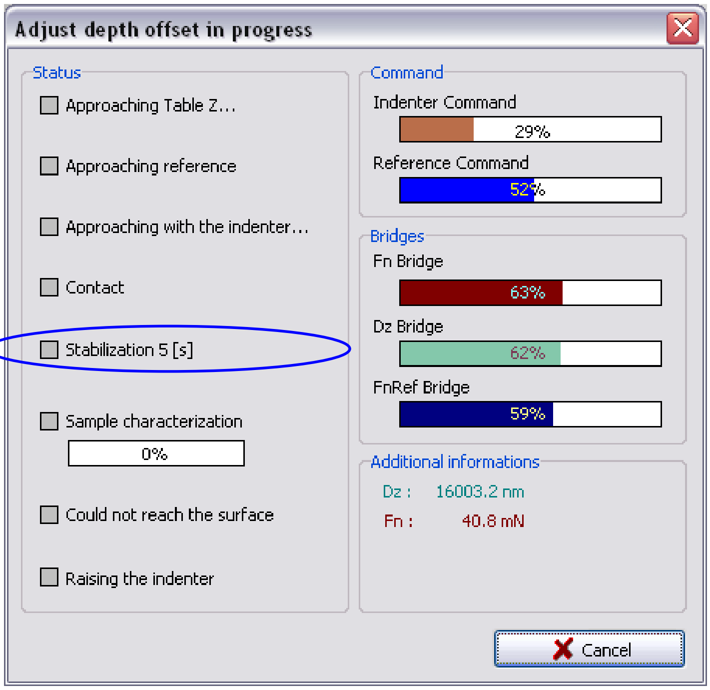
Contact stiffness threshold
150 µN/µm

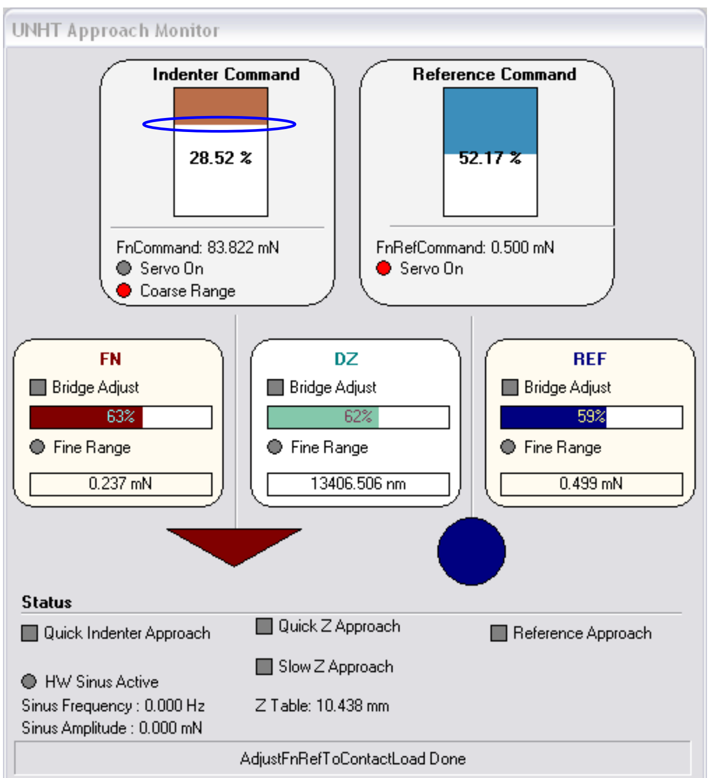
OR

Contact force
50.00 µN

(Surface detection parameters)

Then the Dz sensor bridge is adjusted.

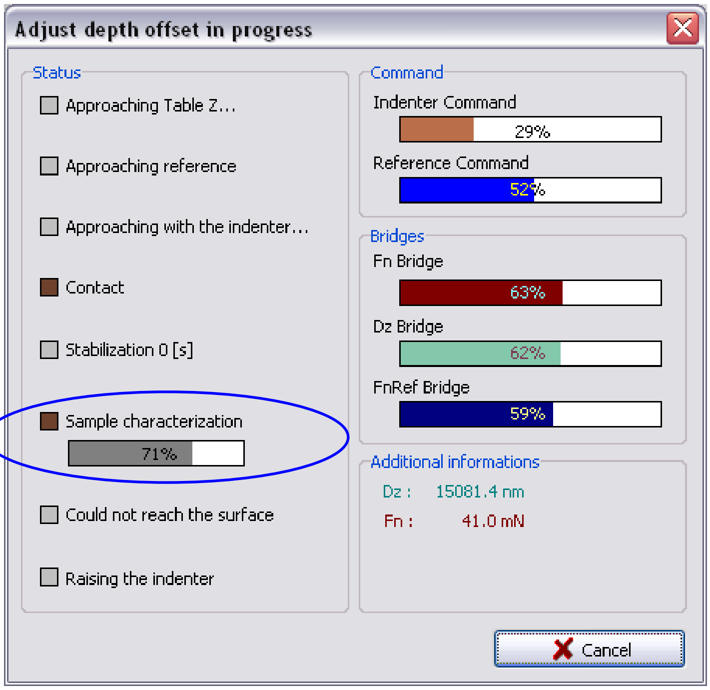


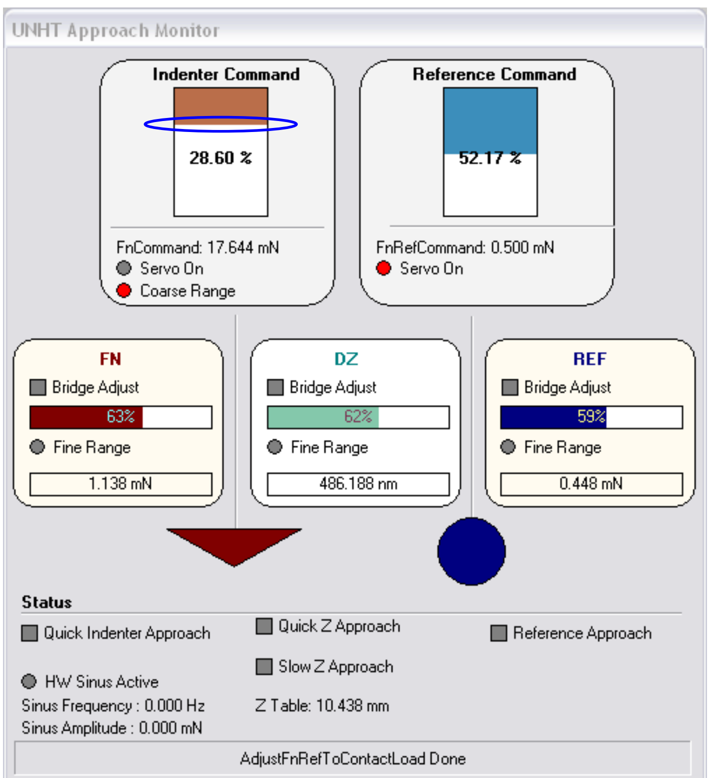


(indenter is still in contact)

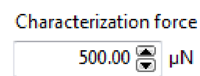
Wait for the stabilization; see ***chap. 3.1.4.2 Stabilization (cancel drift), p. 26***.

The indenter position slightly varies.

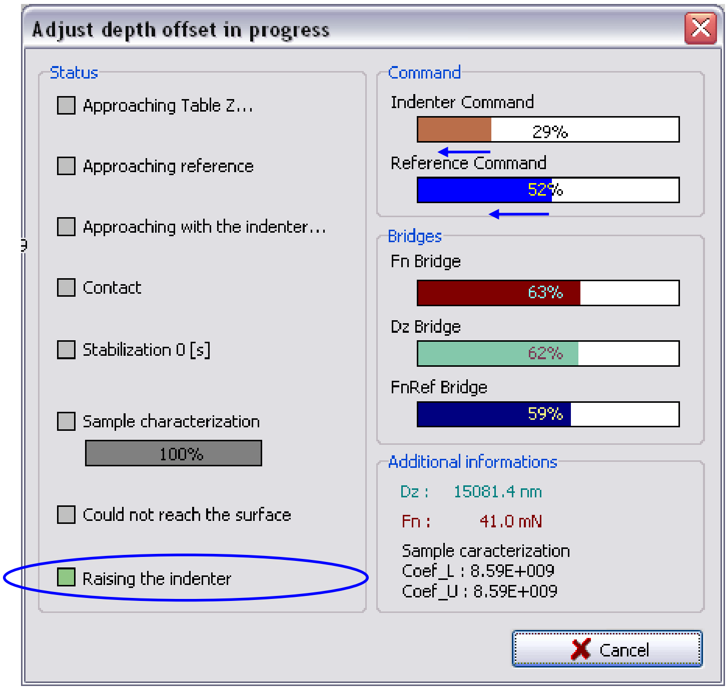




An indentation with the previously set:

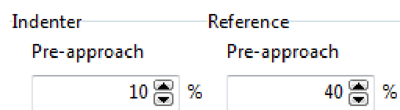


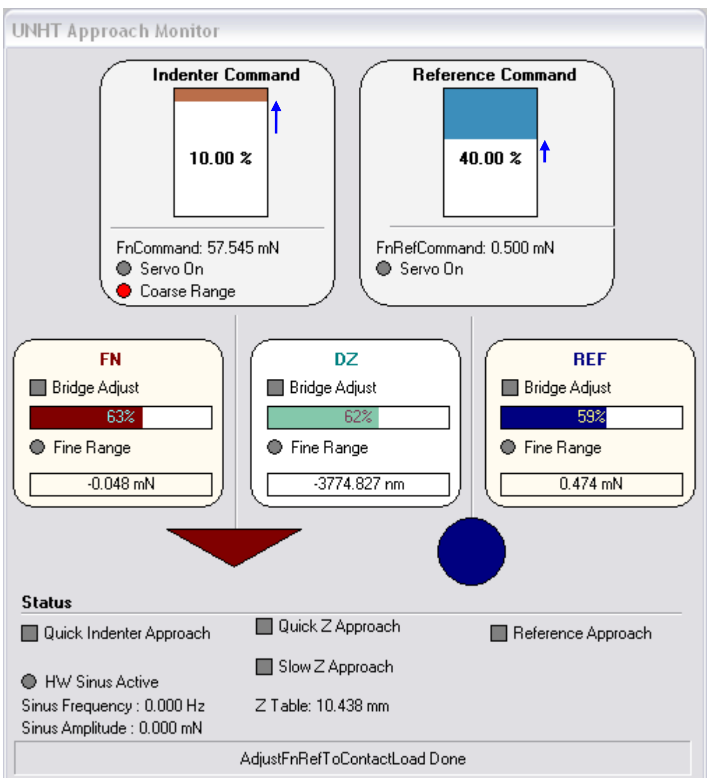
is performed to evaluate the sample mechanical properties; the indenter position slightly varies.



The ADO process is completed.

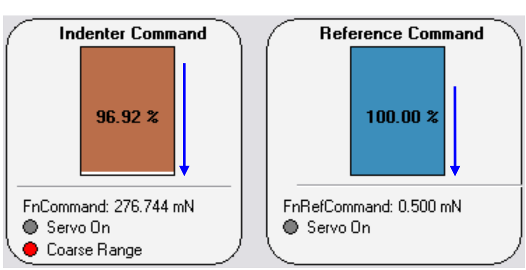
The indenter and reference return/retract (move up) to the previously set values:





Then the motorized Z table retracts (moves down) to its rest position.

And then with **STeP 4/6**, the motorized head module retracts (moves up).

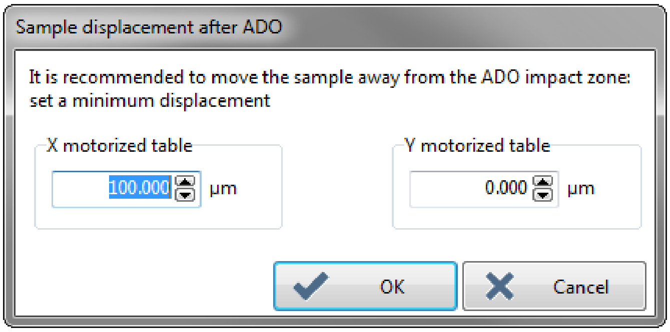


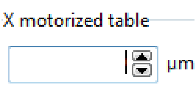
At the end, both indenter and reference return (move down) to their extended rest positions (*Commands* to 100 %).

Sample displacement after ADO

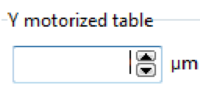
After the ADO process, the **3rd** procedure window allows setting of a minimum displacement to move the sample.

⚠ To **avoid** performing the following calibration/measurement indent inside the ADO indent (current position), the sample/motorized table(s) position **should** be shifted of a minimum displacement[1)] (otherwise the sample topography may vary).

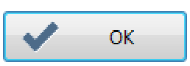




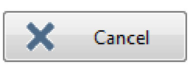
To set another minimum displacement value[1)] on X table.



If necessary, to set a minimum displacement value[1)] on Y table.



To move the motorized table(s) to the position values set above; wait.



To cancel (no move). However **use** the *Position control* to move the sample into another suitable position; refer to the ***Common Scratch & Indentation software manual - chap. Managing the instrument - Control of the sample position***.

If the ADO procedure has been **successfully** performed, a green disk with a tick appears on  (main toolbar).

[1)] it depends on the current sample material: approx. 20 x h_m

4.4.2 NHT ADO

The **1st** procedure window allows setting of the parameters which will be used to perform the ADO automatic process (**2nd** window).

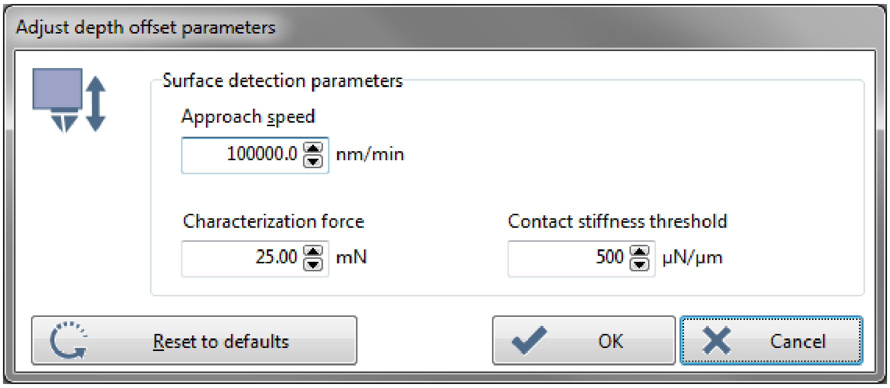
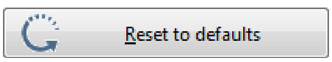


Fig.32 NHT ADO parameters window

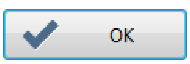
E.g. parameters shown on [*Fig.32*] are the default values which are normally suitable to perform a successful ADO.

Otherwise set other field values according to the application.

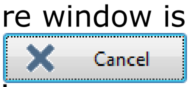


To reset all fields with the default values.

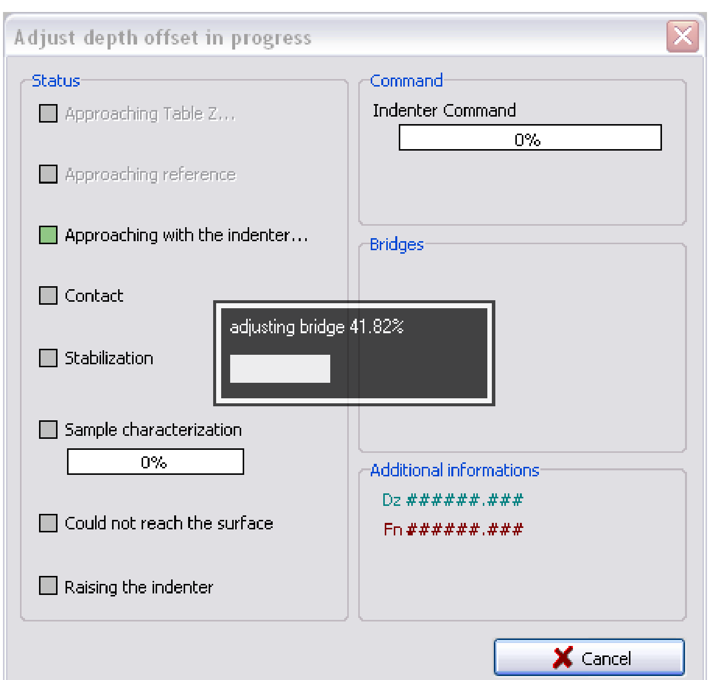
For ***Contact stiffness threshold*** details, see identical information as described in ***chap. 4.6.5.8*** (indentation measurement parameters)***, p. 119***.

Click 

to start the following automatic ADO process.

The **2nd** procedure window is performing the automatic ADO process (steps). If necessary, click 

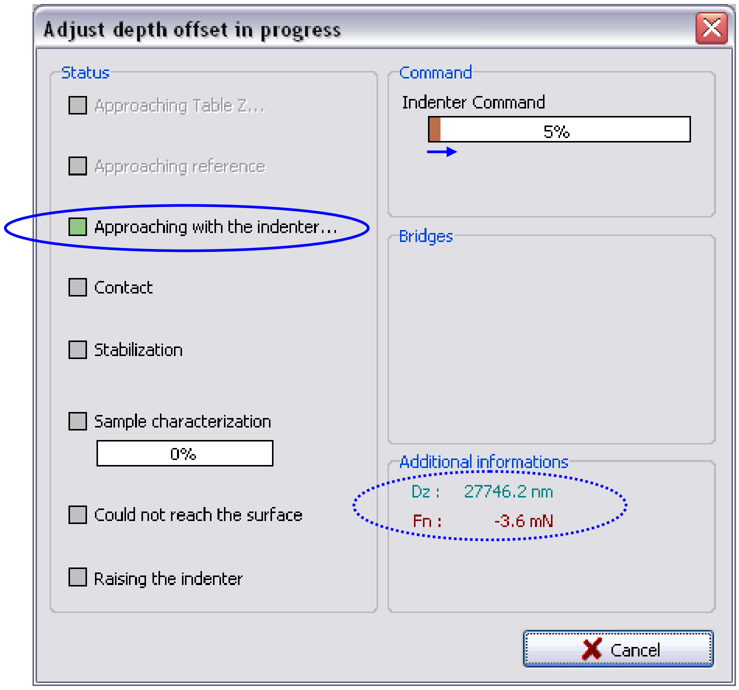
to stop the process and cancel the ADO. Otherwise wait until the **3rd** procedure window appears.



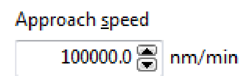
With **STeP 4/6** and **TTX**, the motorized head module approaches (moves down).

Then with **STeP 4/6**, the Z motorized table approaches (moves up) until the sample contacts the reference ring.

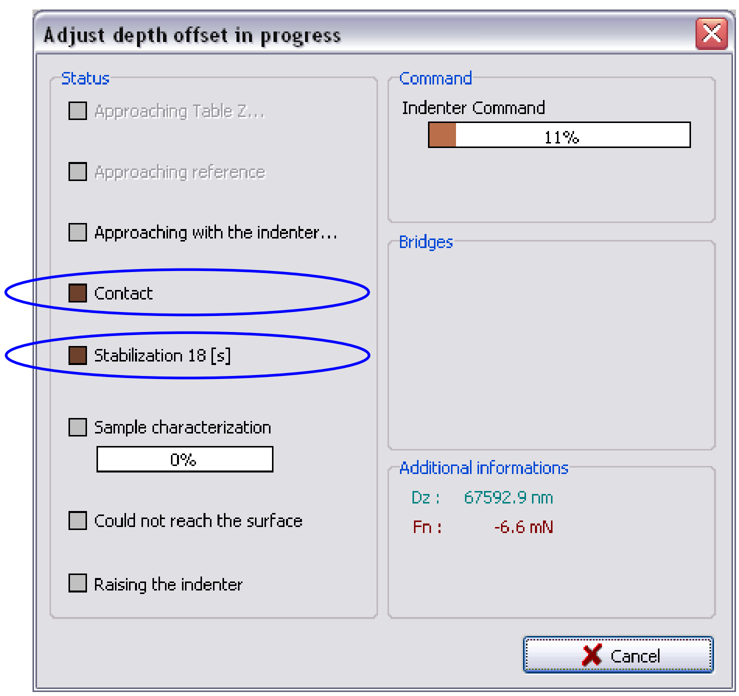
And then the indenter pre-approaches (moves down) and the Dz sensor bridge is automatically adjusted a 1st time.



The indenter approaches (moves down) with the previously set:

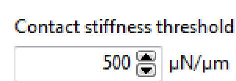


until ...

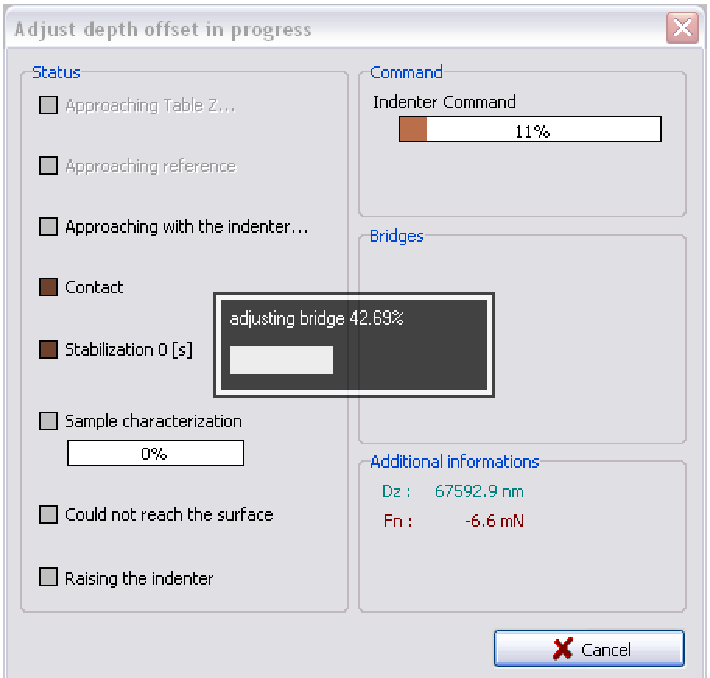


... it contacts the sample:

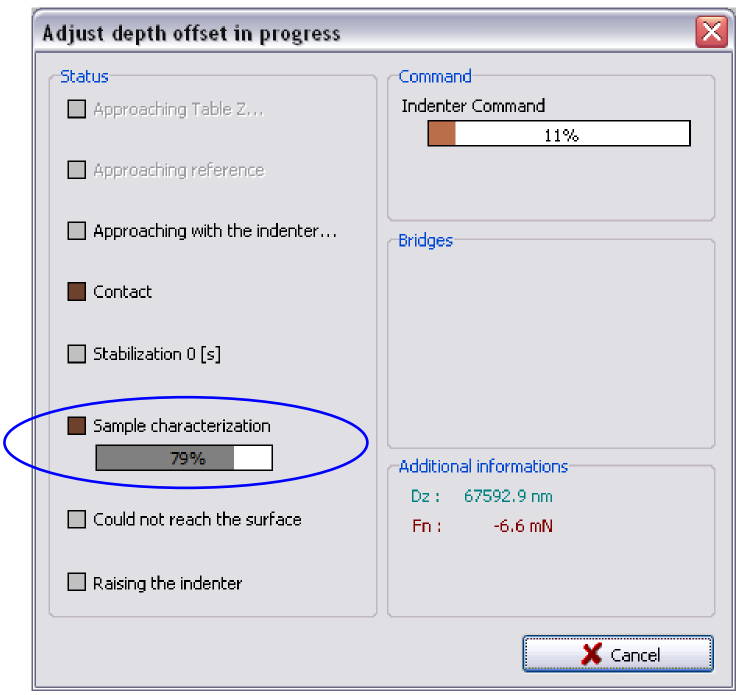
The indenter has reached the previously set:



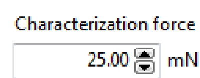
Then wait for the stabilization; see ***chap. 3.1.4.2 Stabilization (cancel drift), p. 26***.



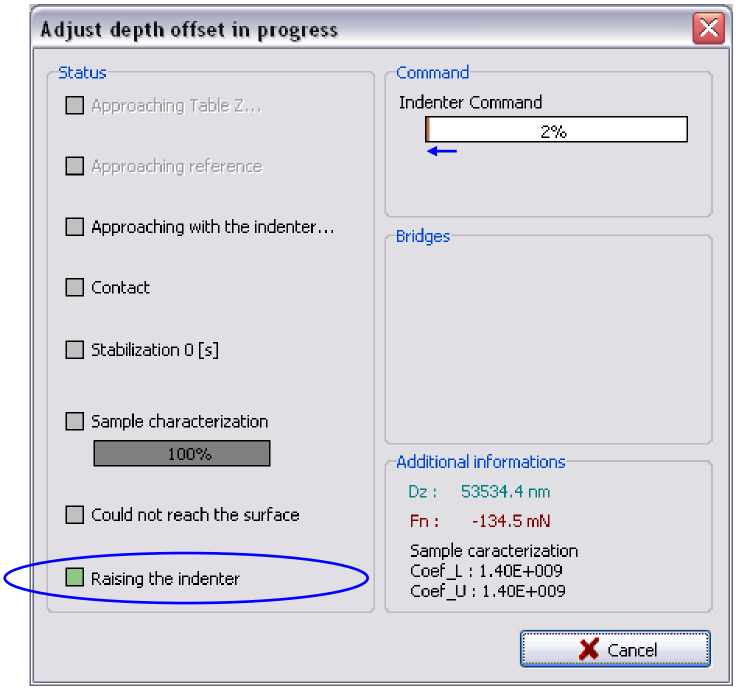
The Dz sensor bridge is automatically adjusted a 2nd time.



An indentation with the previously set:



is performed to evaluate the sample mechanical properties.



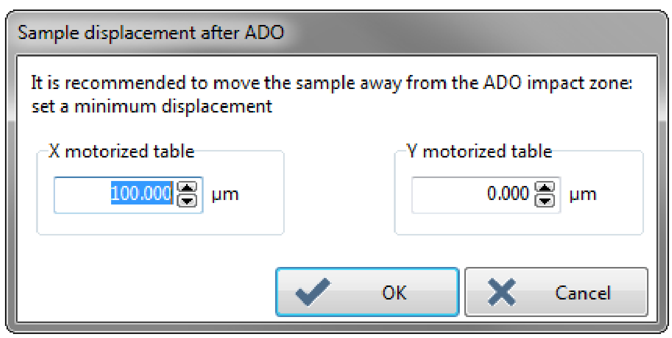
The ADO process is completed.

The indenter is retracted (rises) until top position (0 %).

With **STeP 4/6** and **TTX**, the motorized head module retracts (moves up).

Then the **STeP 4/6** Z motorized table retracts (moves down).

Read *Sample displacement after ADO, p. 65* (same description as for the UNHT)



If the ADO procedure has been **successfully** performed, a green disk with a tick appears on ADO (main toolbar).

4.4.3 MHT ADO

The **1st** procedure window allows setting of the parameters which will be used to perform the ADO semi-automatic process (**2nd** window).

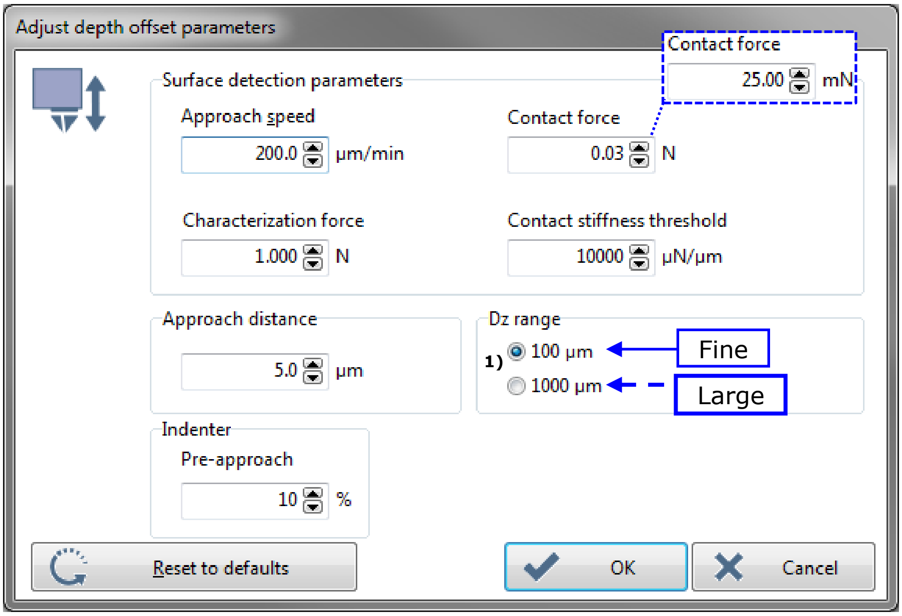


Fig.33 MHT ADO parameters window

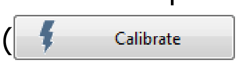
E.g. parameters shown on Fig.33 are the default values which are normally suitable to perform a successful ADO.

Otherwise set other field values according to the application.

1) *Dz range* values can be different for old MCT versions.

To reset all fields with the default values.

Dz range

If the ADO procedure is started from the indenter calibration (

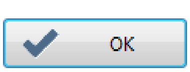
chap. 3.4.1 Indenter properties window, p. 37), the **fine** *Dz range* **must** be selected (e.g. 100 µm).

Otherwise select a suitable *Dz range* according to the sample used/application; it is recommended to use the fine *Dz range* but if the depth saturates, then select the large *Dz range*.

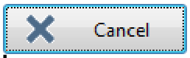
The measurement preferences ***Depth range*** which will be selected later in ***chap. 4.6.5.6, p. 117*** **should** be the same as the ADO ***Dz range*** selected for the current successful ADO (fine: e.g. 100 µm). Otherwise an error message will appear; see ***chap. 6.2, p. 173***.

The ***Indenter Pre-approach*** parameter moves down the indenter out of its rest position (top end stop 0 %) before the first approach step. The minimum and recommended value for this parameter is 10 %.

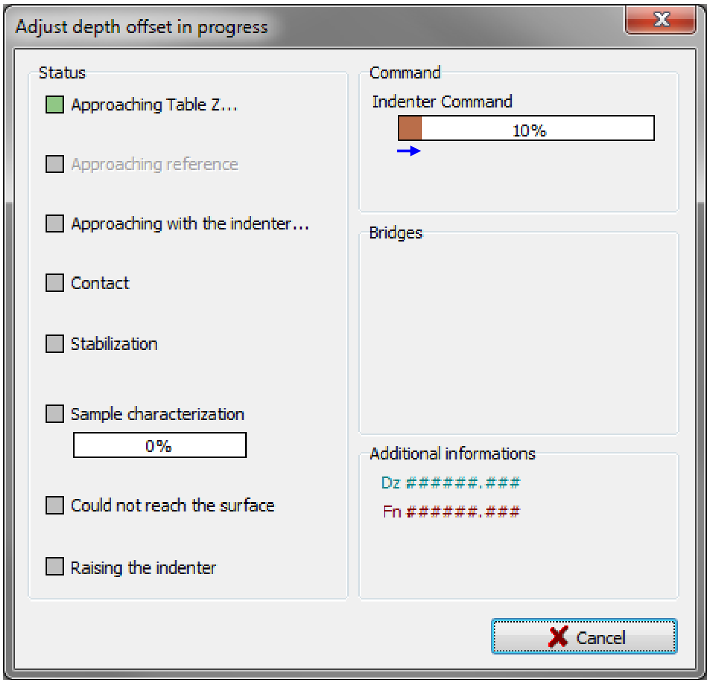
For ***Contact stiffness threshold*** details, see identical information as described in ***chap. 4.6.5.8*** (indentation measurement parameters)***, p. 119***.

Click 

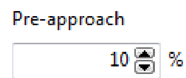
to start the following semi-automatic ADO process.

The **2nd** procedure window is performing the semi-automatic ADO process (steps). If necessary, click 

to stop the process and cancel the ADO. Otherwise wait until the **3rd** procedure window appears.

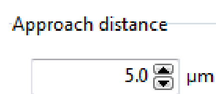


The indenter pre-approach (moves down) to the previously set value:

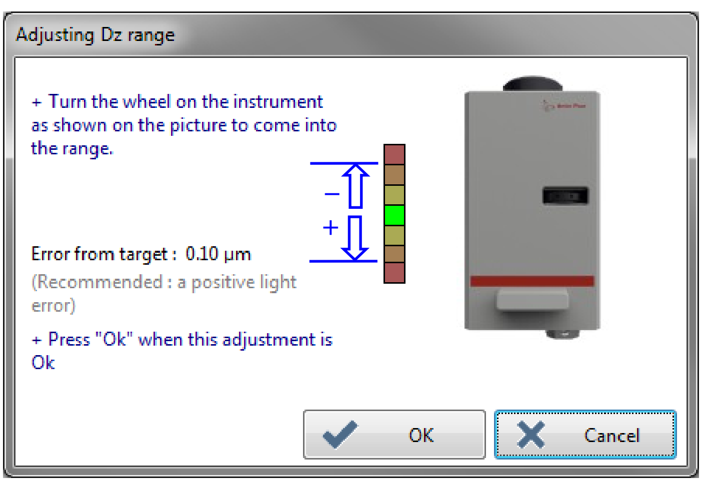


Dz range adjustment

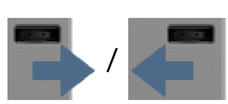
Turn[1] the wheel to adjust the previously set:



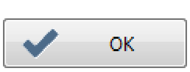
for the following indentation calibration or measurement(s) which will be performed later, after this ADO procedure:



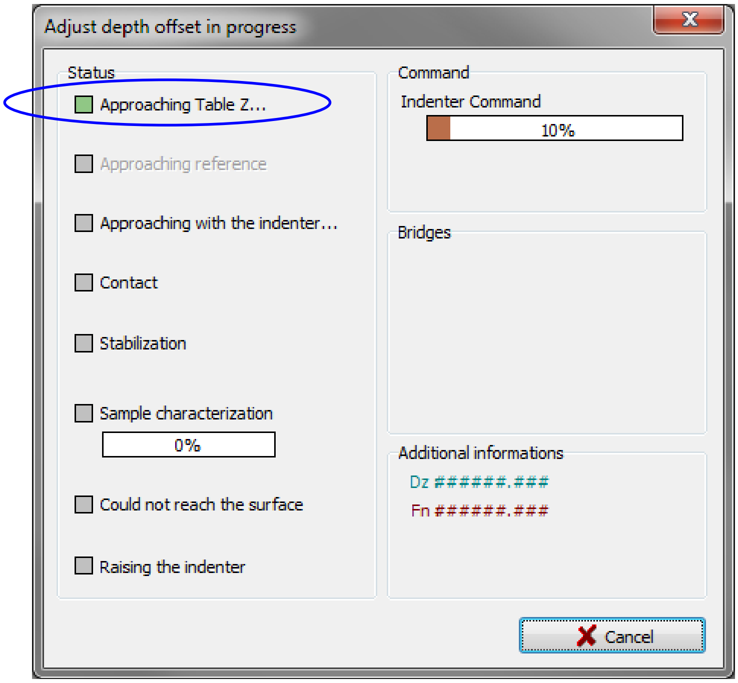
With the special tool long pin (or with the old centering tool, or a small Allen key), turn[1] the wheel to adjust the Dz vertical cursor preferably into the central green position or into any yellow (down: positive error from target/up: negative error from target).



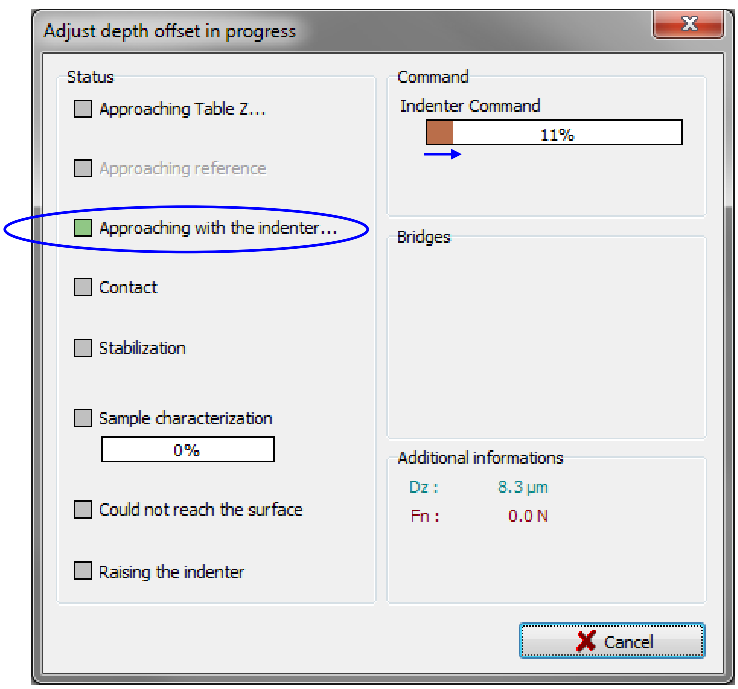
[1] the rotation direction (an arrow) is displayed on this extra *Adjusting Dz range* window

Then click 

.

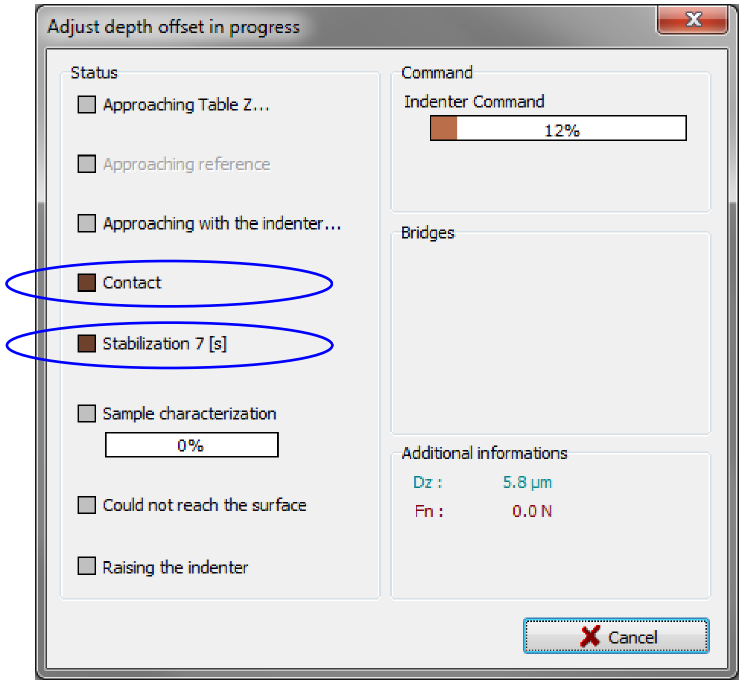


Then the Z motorized table approaches (moves up) until the sample contacts the reference fork.



The indenter approaches (moves down) with the previously set:

until ...



... it contacts the sample:

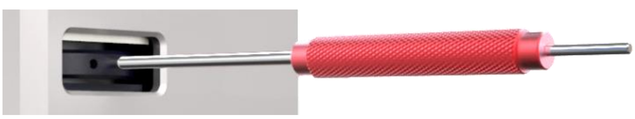
The indenter has either reached the previously set:

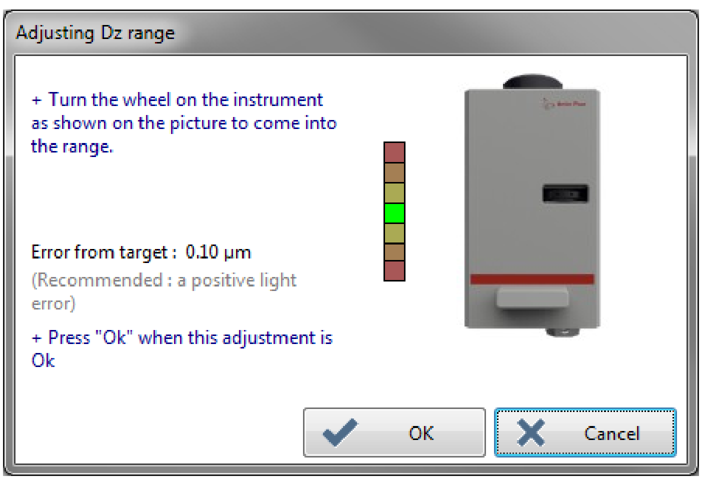
Contact stiffness threshold
10000 µN/µm

OR

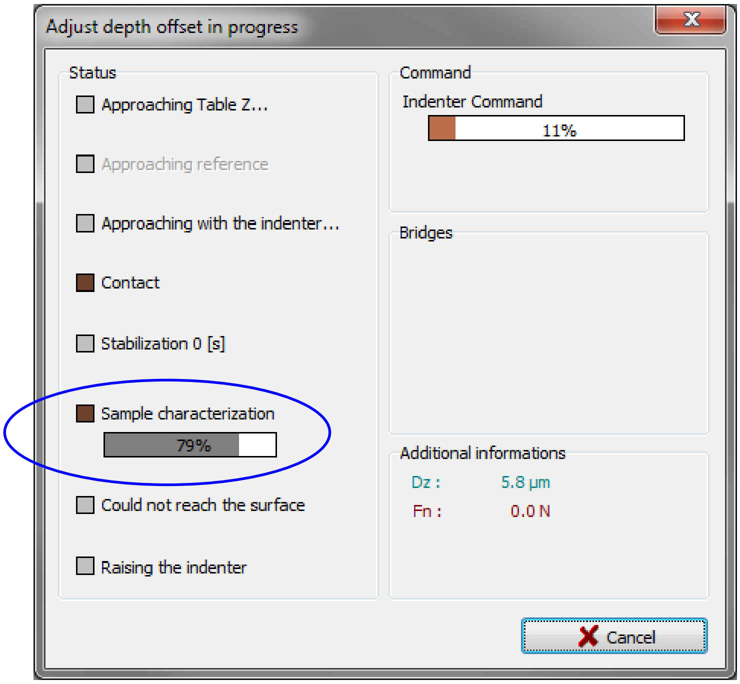
Contact force
0.03 N.

Then wait for the stabilization; see ***chap. 3.1.4.2 Stabilization (cancel drift), p. 26***.

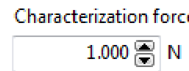




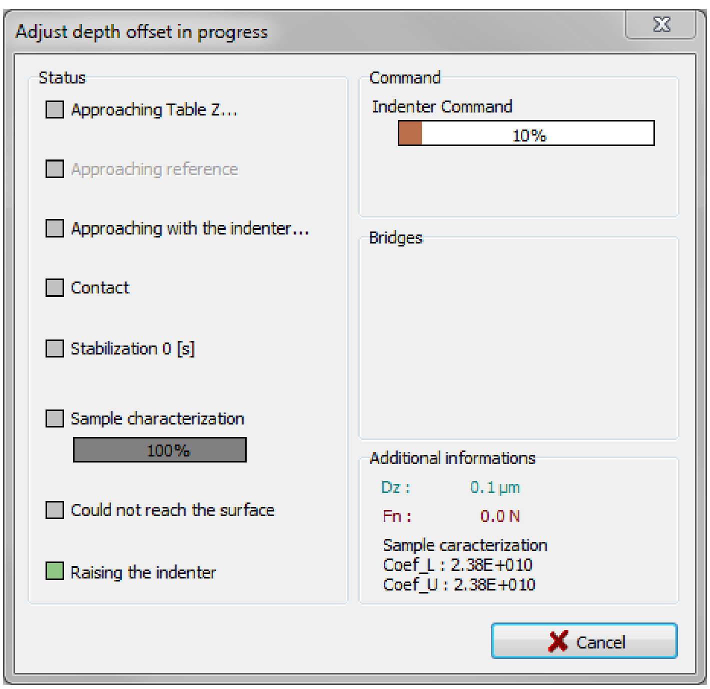
Same information as described in ***Dz range adjustment, p. 71*** (for the other Dz range).



An indentation with the specified characterization force

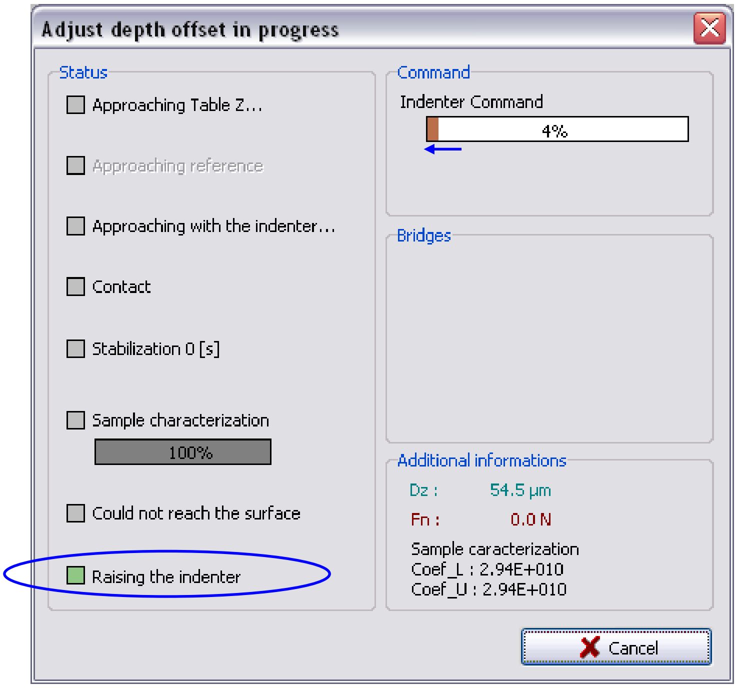


is performed to evaluate the sample mechanical properties.



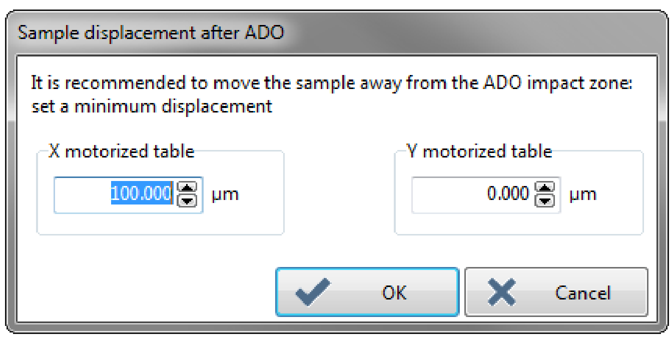
The ADO process is completed.

The Z motorized table retracts (moves down).



The indenter is retracted (rises) until top position (0 %).

Read ***Sample displacement after ADO, p. 65*** (same description as for UNHT).

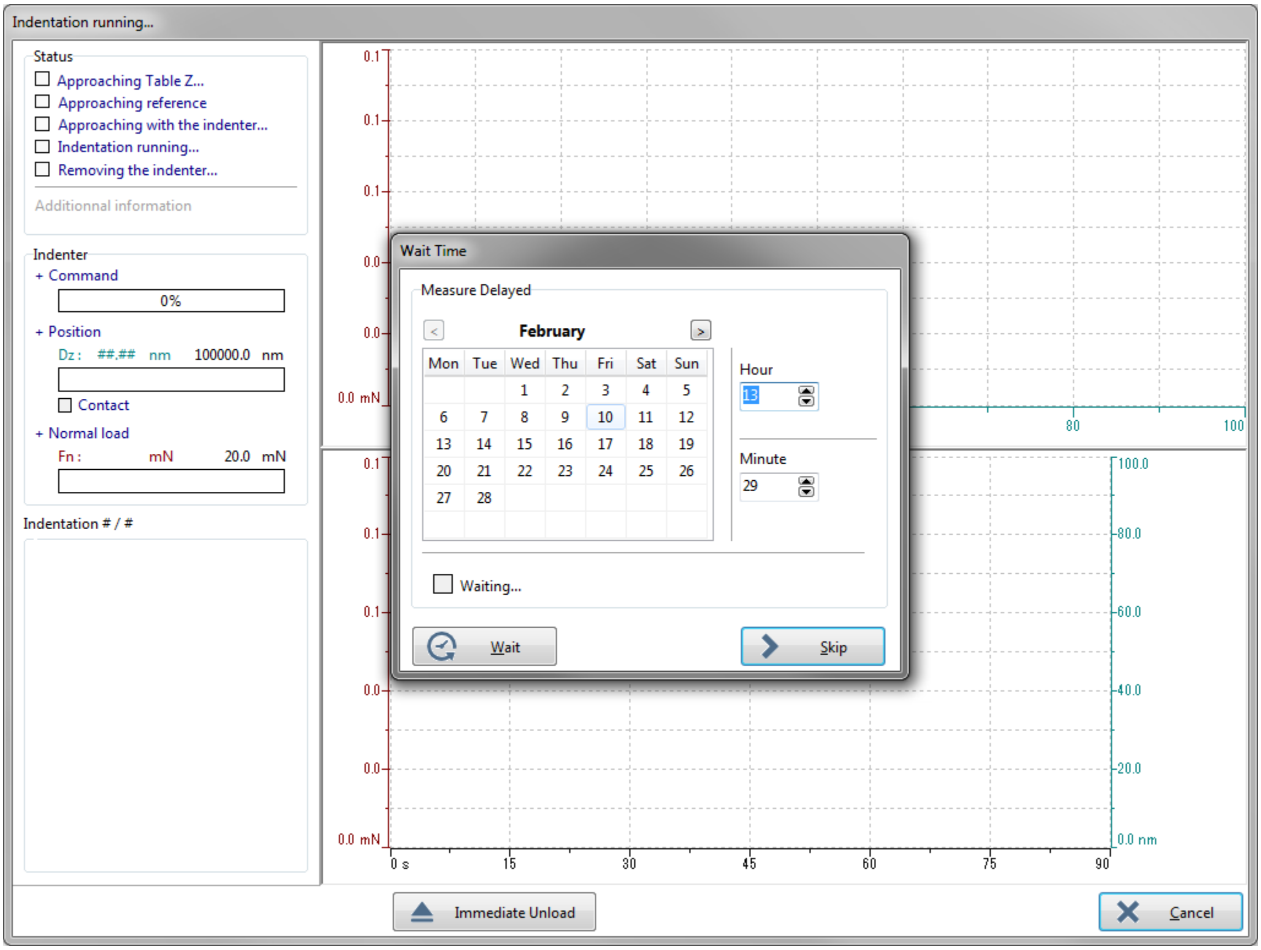


If the ADO procedure has been **successfully** performed, a green disk with a tick appears on  (main toolbar).

4.5 Delaying the measurement(s)

A delay for any measurement can be set and activated.

Click on the toolbar to enable it (re-click to disable).
When is enabled: Before any measurement is started[1], the *Wait time* window appears.

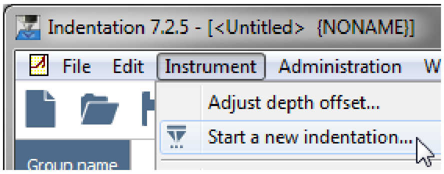


See the same information than described in ***Wait time*, p. 40** (for the indenter calibration matrix of measurements), **exception:** it is applicable for a single measurement or for a matrix of measurements.

A delay of max. 2 months can be set.

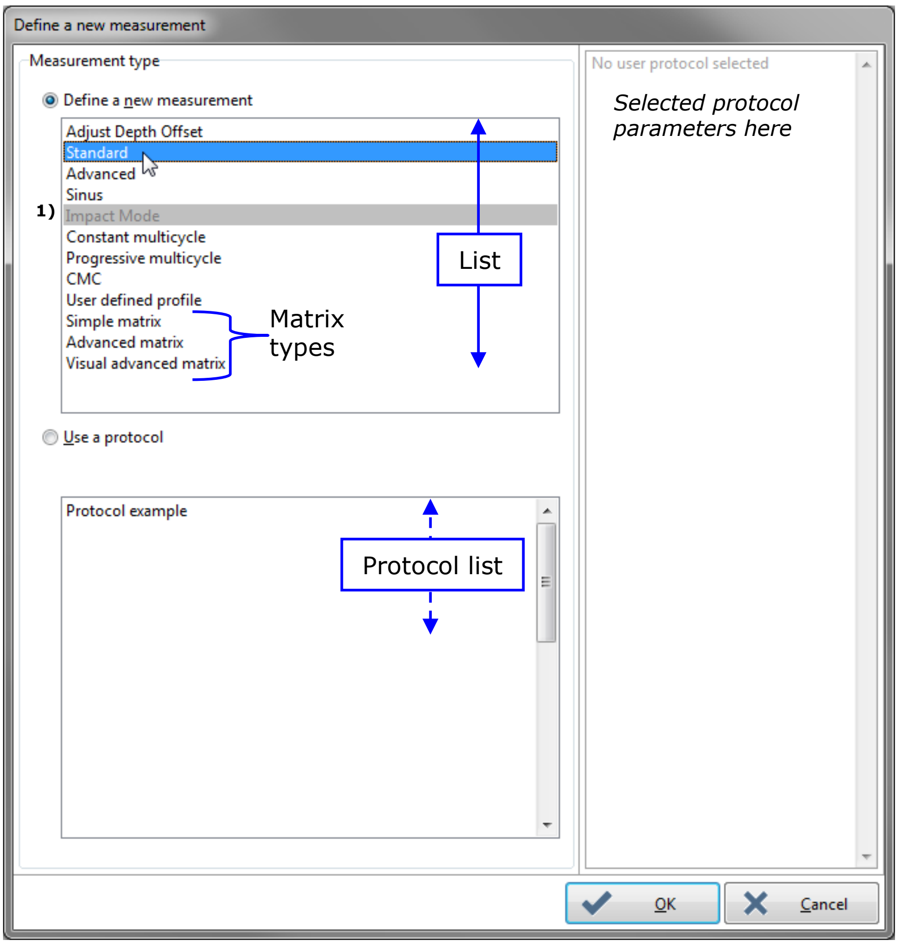
[1] see ***chap. 4.6.4 Measurement type parameters, p. 81***

4.6 Selecting the measurement type & setting its parameters



Select ***Instrument/Start a new indentation…*** from the menu bar or click on the toolbar.

The window below allows selection of a new measurement type (single indentation measurement or **matrix** of several indentation measurements).



In the list, select an active measurement type (double click).

OR

Select a protocol in the protocol list; see ***chap. 4.6.6, p. 121*** (how to save a protocol).

1) each inactive (grayed out) measurement type cannot be selected as it is not applicable for the current measurement head

Fig.34 Define a new measurement window

Then the corresponding measurement type window will appear and allow setting the required parameters before starting the measurement(s); see the following chapters for:

- the main **description** of a measurement type window ***chap. 4.6.1, p. 78***
- the common **loading rate** parameter description ***chap. 4.6.2, p. 79***
- the common **acquisition rate** parameter description ***chap. 4.6.3, p. 80***
- all required **parameters** for each measurement type window; see from ***chap. 4.6.4, p. 81***
- the **preference parameters** dedicated for each measurement head; see from ***chap. 4.6.5, p. 111***

4.6.1 Main description of a measurement type window

A measurement type is selected in the *Define a new measurement* window *Fig.34, p. 77*.

Legends: **Parameters to be defined: set/select** **Information**

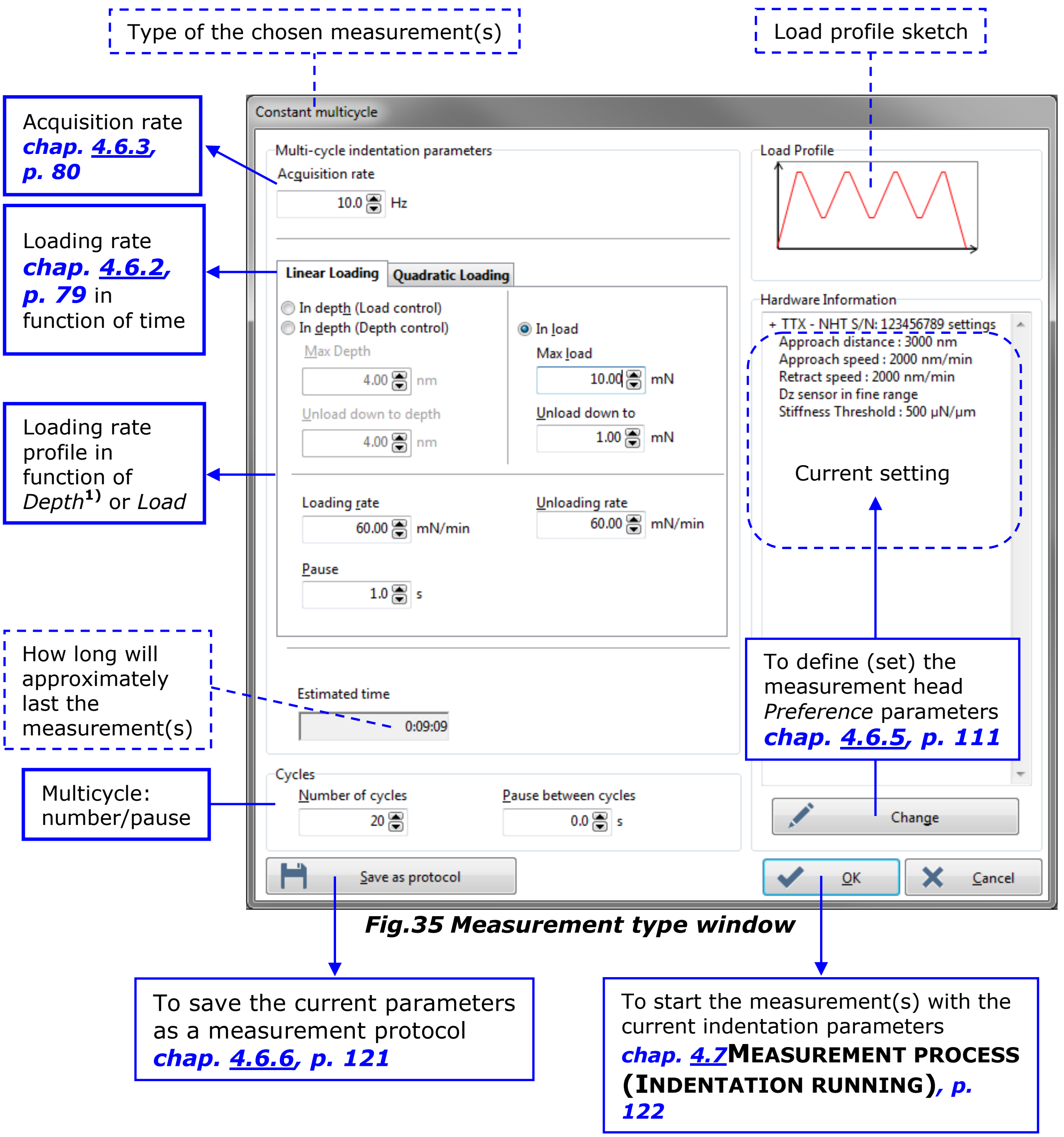


Fig.35 Measurement type window

From ***chap. 4.6.4, p. 81***, see the specific required parameters for each measurement type window.

1) with *Load* or *Depth control*

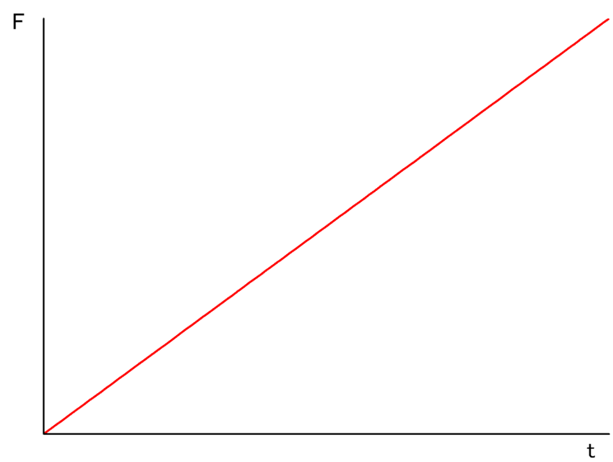
4.6.2 LOADING PROFILES

The measurement(s) will be performed with one of the loading profiles described below. Depending on the selected measurement type (in *Define a new measurement* window *Fig.34, p. 77*), several loading profiles are proposed (one can be selected).

4.6.2.1 Linear loading/Constant time loading

The linear loading or constant time loading applies the indenter force following the equation below:

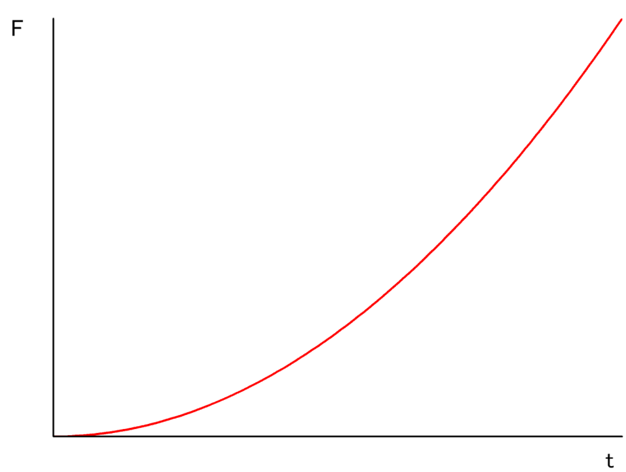
$$F = k \cdot t$$



4.6.2.2 Quadratic loading

The quadratic loading applies the indenter force following the equation below:

$$F = k \cdot t^2$$

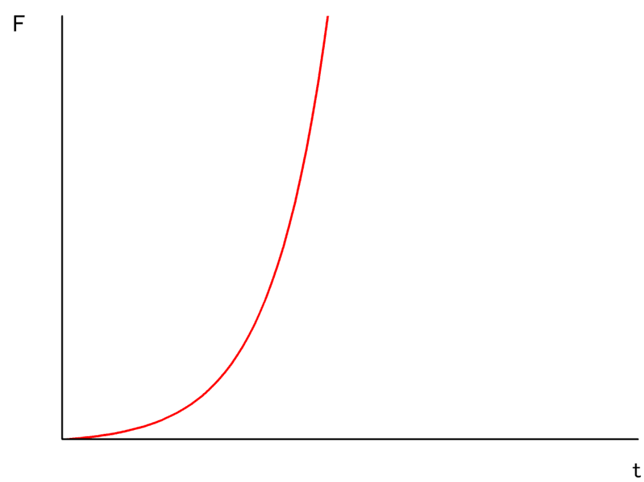


4.6.2.3 Constants strain rate (CSR)

This profile is recommended for materials having viscoelastic properties.

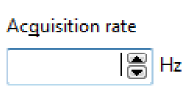
The constant strain rate (CSR) applies the indenter force following the equation below:

$$\frac{dP}{dt} \cdot \frac{1}{P} = cte$$



4.6.3 Common acquisition rate parameter

Common parameter to all measurement types; see from ***chap. 4.6.4, p. 81***.



To set the acquisition rate. The value corresponds to the number of data point recorded per second during the measurement(s).

Initial value is 10 Hz.

Min. value is 1 Hz and max. value is 400 Hz

However, for:

- *Standard* measurement type ***chap. 4.6.4.1, p. 81***, there is no field to set, the value is fixed to 10 Hz
- *Sinus* measurement type ***chap. 4.6.4.3, p. 85***, there is no field to set, the value is automatically calculated (20x the Sinus frequency value)
- *User defined profile* measurement type ***chap. 4.6.4.7, p. 95***, it depends on the load profile segments which are created.

4.6.4 Measurement type parameters

A measurement type is selected in the *Define a new measurement* window Fig.34, p. 77.

See the following sections which show all windows of each measurement type and describe the corresponding parameters which should be set before starting the measurement(s).

4.6.4.1 Standard

The *Standard* measurement type is the simplest **single** indentation measurement, performed in **1 cycle** of automatic linear loading/unloading ***chap. 4.6.2.1, p. 79***.

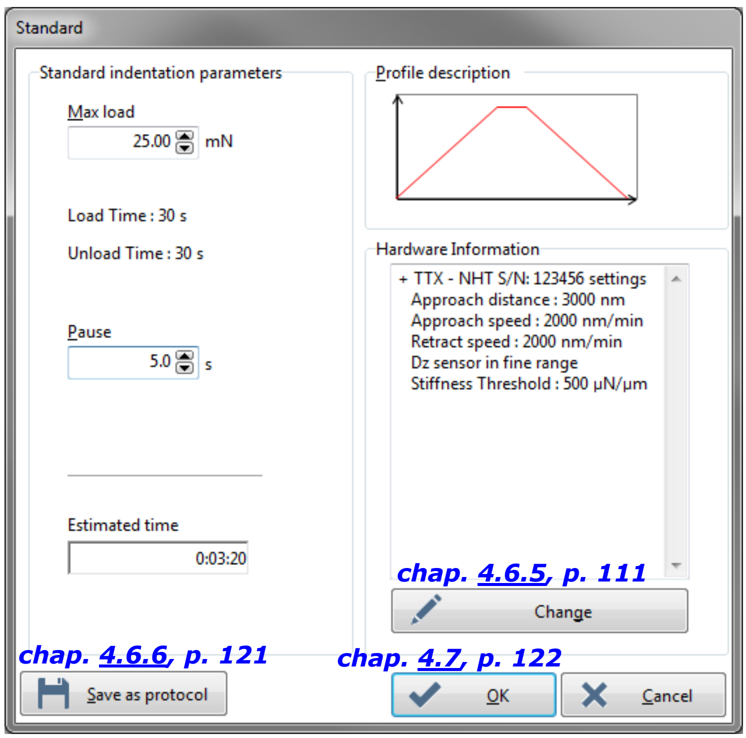


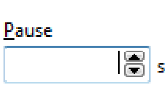
Fig.36 Standard window parameters

About the acquisition rate, see ***chap. 4.6.3, p. 80***.

To set the maximum load.

Load Time : 30 s

A linear loading rate will be computed to reach the maximum load (set above) within 30 sec.



To set a pause at the maximum load before unloading.

Set the value to 0 for “no pause”.

Unload Time : 30 s

After the pause, a linear unloading rate will be computed to fully unload within 30 sec.

4.6.4.2 Advanced

The *Advanced* measurement type is a **single** indentation measurement, performed in **1 cycle** of loading/unloading defined by the user.

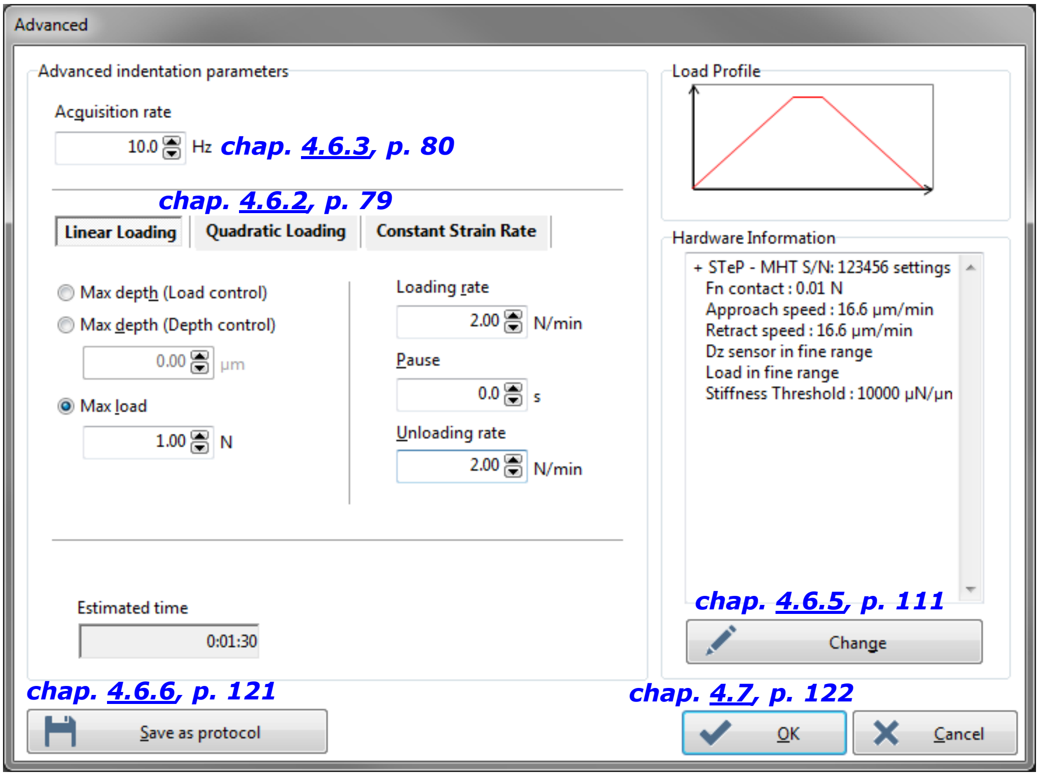


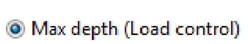
Fig.37 Advanced window parameters

To select a loading profile. The corresponding set of parameters is described in the following sections:

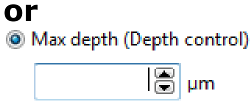
Linear loading	***below***
Quadratic loading	***p. 83***
Constant strain rate (CSR)	***p. 84***

Linear loading

See *Fig.37 above*.

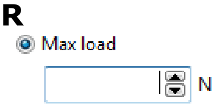


or



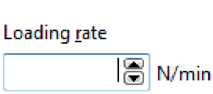
To select the maximum depth controlled by the load
or
by the depth,
and set the maximum depth.

OR



OR

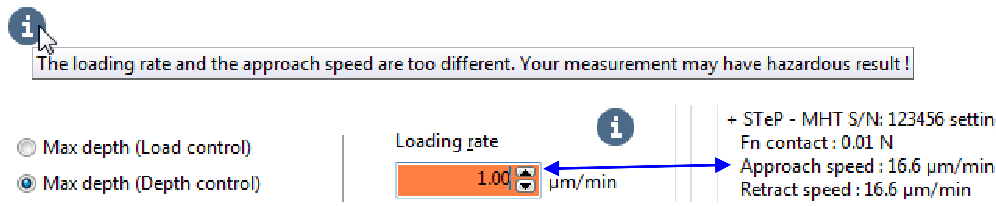
To select and set the maximum load.

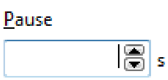


To set the loading rate to reach the maximum depth **OR** load (set above).

Hazardous result

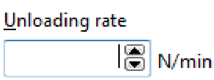
with ◉ Max depth (Depth control) selected, if Approach speed : value in *Preferences* window (see ***chap. 4.6.5, p. 111***) is at least 4 times faster than Loading rate [ ] N/min value, the measurement **may have** hazardous results.





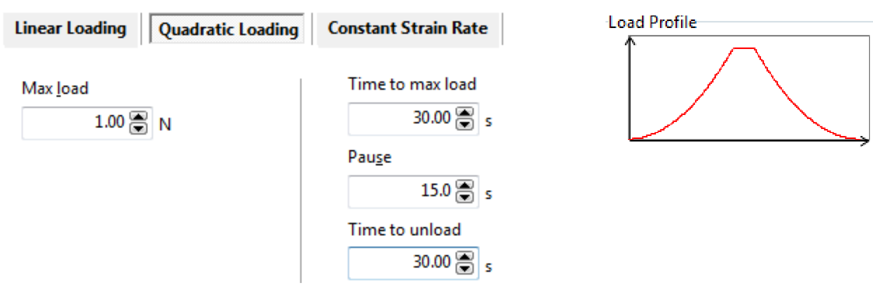
To set a pause at the maximum load **OR** depth (set above) before unloading.

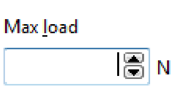
Set the value to 0 for "no pause".



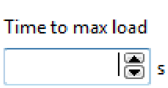
To set the unloading rate to fully unload after the pause (set above).

Quadratic loading

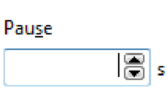




To set the maximum load.

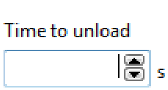


To set the time to reach the maximum load (set above).



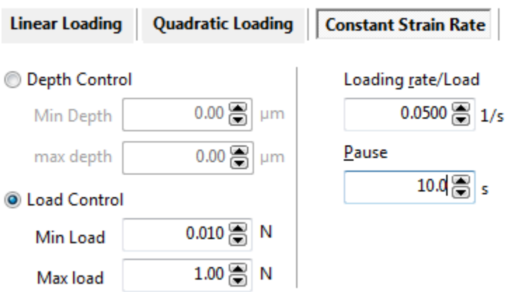
To set a pause at the maximum load (set above) before unloading.

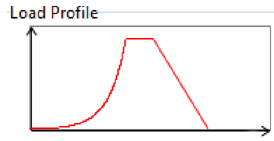
Set the value to 0 for "no pause".

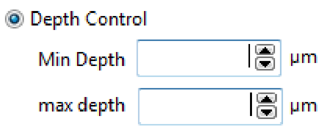


To set the time to fully unload after the pause (set above).

Constant strain rate (CSR)



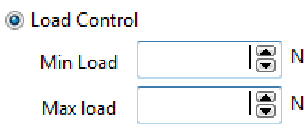




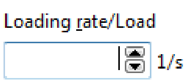
To select and set the minimum depth at which the constant strain rate starts and the maximum depth.

OR

OR

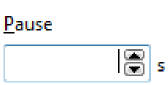


To select and set the minimum load at which the constant strain rate starts and the maximum load.



To set the loading rate/load to reach the maximum depth **OR** load (set above).

Typical range values from 0.01 to 0.1 [s^{-1}]



To set a pause at the maximum depth **OR** load (set above) before unloading.

Set the value to 0 for “no pause”.

A linear unloading rate to fully unload will be automatically performed after the pause (set above).

4.6.4.3 Sinus

Sinus measurement type is not available (

inactive/grayed out) in the list of *Fig.34, p. 77* for MHT, UNHT Bio, and NHT without the **optional** Sinus mode (see ***chap. 3.1.2.2 NHT, p. 14***).

The *Sinus* measurement type is a **single** indentation measurement, performed in **1 cycle** of loading/unloading defined by the user. A sine wave is added during the loading, and if necessary during the pause/unloading. This measurement type allows obtaining a depth related analysis; see ***chap. 5.7.1, p. 153***.

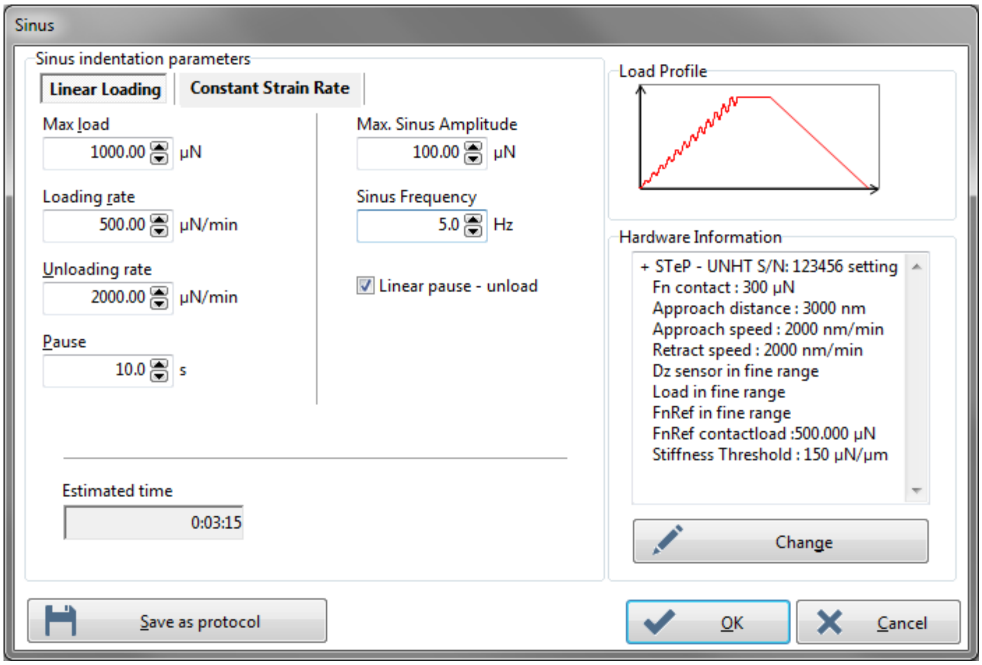


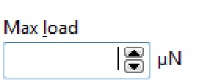
Fig.38 Sinus window parameters

To select a loading profile. The corresponding set of parameters is described in the following sections:

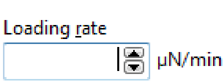
Linear loading ***below***
Constant strain rate (CSR) ***p. 86***

Linear loading

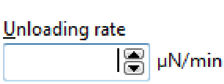
See *Fig.38 above*.



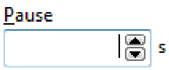
To set the maximum load.



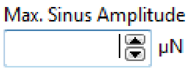
To set the loading rate to reach the maximum load (set above).



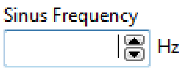
To set the linear **or** Sinus unloading rate to fully unload after the pause (set below).



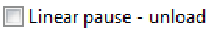
To set a linear **or** Sinus pause at the maximum load (set on previous page) before unloading.



To set the sine wave maximum amplitude at least for the loading.

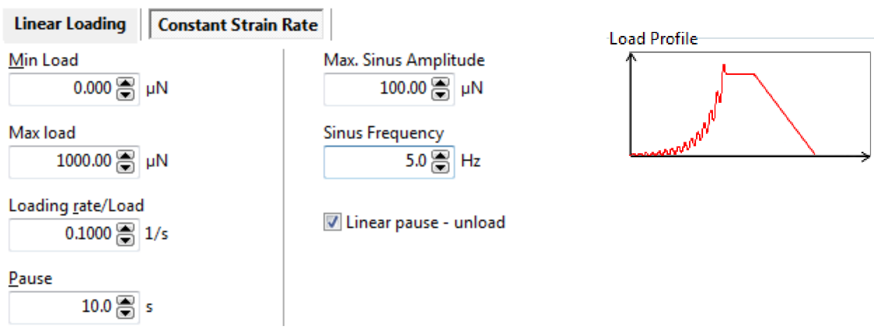


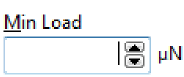
To set the sine wave frequency at least for the loading.



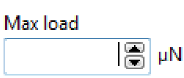
Uncheck this box to have the pause and unloading (set above) with the **sine wave** (2 fields set above). Otherwise (checked) the pause and unloading will be linear.

Constant strain rate (CSR)

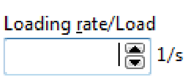




To set the minimum load at which the Sinus constant strain rate starts.



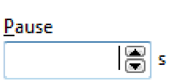
To set the maximum load.



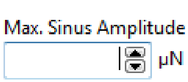
To set the loading rate/load to reach the maximum load (set above).

Typical range values from 0.01 to 0.1 [s^{-1}]

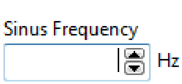
An automatic linear **or** Sinus unloading g rate will be performed to fully unload after the pause (set below).

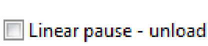


To set a pause at the maximum load (set above) before unloading.



3 same parameters than described for the *Linear loading* above.





4.6.4.4 Constant multicycle

The *Constant multicycle* measurement type is a **single** indentation measurement, performed in **several cycles** of loading/unloading defined by the user. Maximum and minimum depths or loads are the same for all measurement cycles.

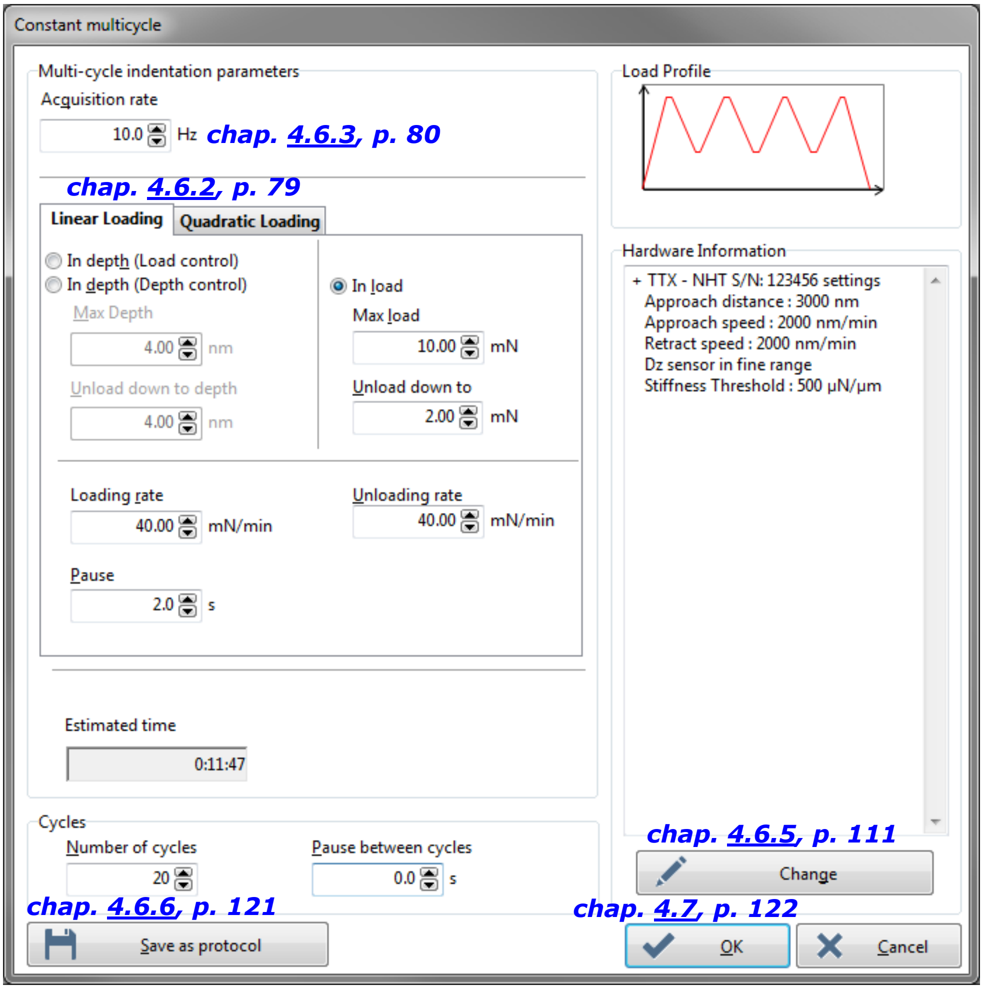
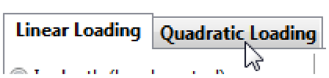


Fig.39 Constant multicycle window parameters

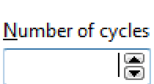


To select a loading profile. The corresponding set of parameters, the **same** for all cycles, is described in the following sections:

Linear loading ***p. 88***

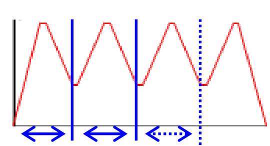
Quadratic loading ***p. 89***

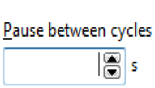
Cycles



To set the number of the cycles.

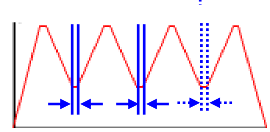
Min. value = 2





To set a pause between all cycles (set above).

Set the value to 0 for “no pause”.

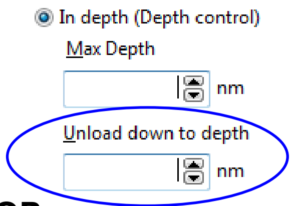


Linear loading

See *Fig.39, p. 87*.

The **same** parameters below will be applied for all cycle repetitions (set in ***Cycles, p. 87***).

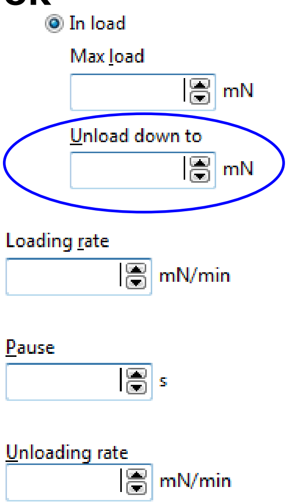
or



Same parameters than described in ***Linear loading, p. 82*** for the *Advanced* measurement type, **exception:**

To set a minimum depth for all cycles[1)]

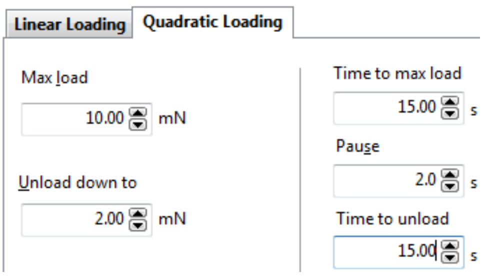
OR

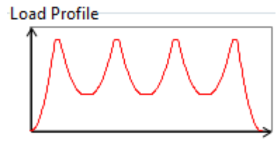


To set a minimum load for all cycles[1)]

[1)] **except** for the last cycle which will be fully unloaded

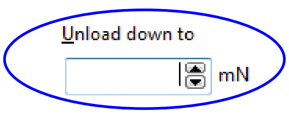
Quadratic loading



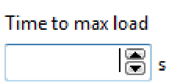


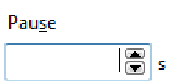
The **same** parameters below will be applied for all cycle repetitions (set in ***Cycles, p. 87***).

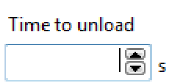
Same parameters than described in ***Quadratic loading, p. 83*** for the *Advanced* measurement type, **exception:**



To set a minimum load for all cycles.







[1)] **except** for the last cycle which will be fully unloaded

4.6.4.5 Progressive multicycle

The *Progressive multicycle* measurement type is a **single** indentation measurement, performed in **several cycles** of loading/unloading defined by the user. The only difference with the *Constant multicycle* measurement type is that the **maximum** depths or loads increase for each measurement cycle (the minimum depths or loads remain the same for all measurement cycles).

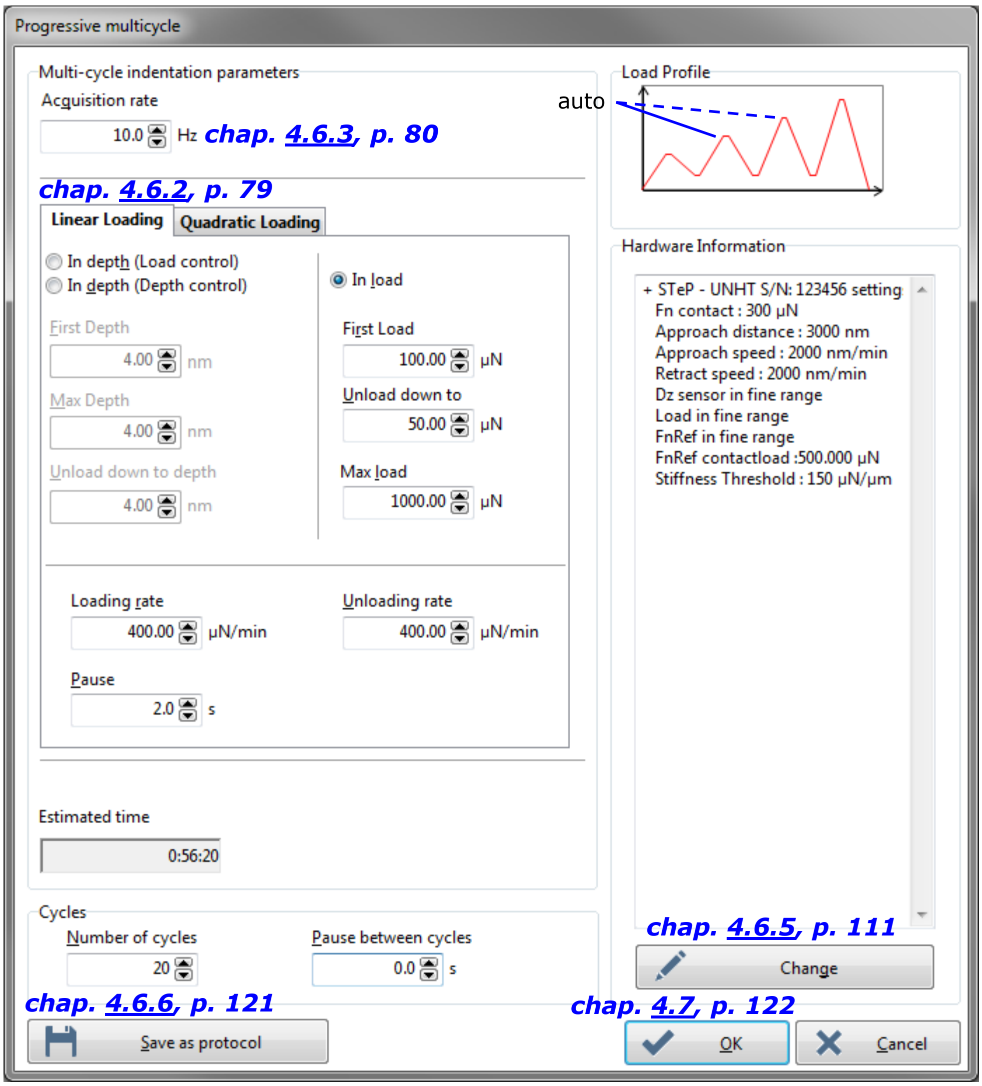
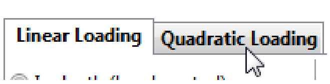


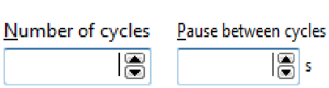
Fig.40 Progressive multicycle window parameters



To select a loading profile. The corresponding set of parameters is described in the following sections:

Linear loading ***p. 91***
Quadratic loading ***p. 92***

Cycles



Same parameters than described in ***Cycles, p. 87*** of the *Constant multicycle* measurement type.

Linear loading

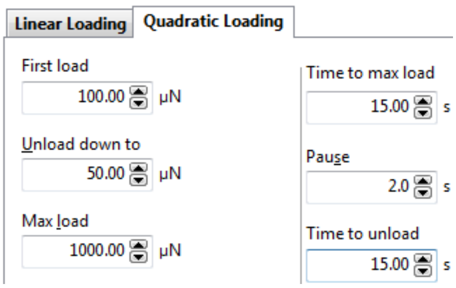
See *Fig.40, p. 90*.

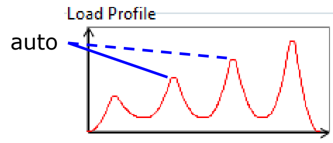
In depth (Load control) **or** In depth (Depth control)	To select the depth mode controlled by the load **or** by the depth and ...
First Depth [ ] nm	To set the first cycle maximum depth[1)]
Max Depth [ ] nm	To set the last cycle maximum depth[1)]
Unload down to depth [ ] nm	To set a minimum depth for all cycles[2)]
OR In load	**OR** To select the load mode and …
First Load [ ] mN	To set the first cycle maximum load[1)]
Unload down to [ ] mN	To set a minimum load for all cycles[2)]
Max load [ ] mN	To set the last cycle maximum load[1)]
Loading rate [ ] mN/min	To set the loading rate to reach each cycle maximum depth **OR** load; see the same information than described in ***Hazardous result, p. 83*** of *Advanced* measurement type.
Pause [ ] s	To set a pause at each cycle maximum depth **OR** load before unloading. Set the value to 0 for "no pause".
Unloading rate [ ] mN/min	To set the unloading rate to reach the minimum depth **OR** load of all cycles[2)] after the pause (set above).

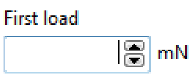
[1)] between the first and the last maximum depth/load and depending on the number of cycles, the software will compute a linear increment for each intermediate maximum depth/load

[2)] **exception:** the last cycle will be fully unloaded

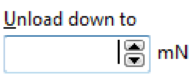
Quadratic loading



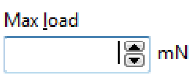




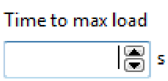
To set the first cycle maximum load[1)]



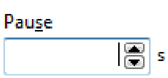
To set a minimum depth for all cycles[2)]



To set the last cycle maximum load[1)]

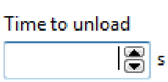


To set the time to reach each cycle maximum load.



To set a pause at each cycle maximum load before unloading.

Set the value to 0 for "no pause".



To set the time to reach the minimum load of all cycles[2)] after the pause (set above).

1) between the first and the last maximum depth/load and depending on the number of cycles, the software will compute a linear increment for each intermediate maximum depth/load

2) **exception:** the last cycle will be fully unloaded

4.6.4.6 Continuous multicycle (CMC)

The *CMC* measurement type is a single indentation measurement, performed in **several** cycles of loading/unloading defined by the user. The differences with the *Progressive multicycle* measurement type are:

- There is only a loading profile: constant time loading/unloading.
- It is only load controlled (no depth control).
- The minimum load increases for each measurement cycle (as well as the maximum load).

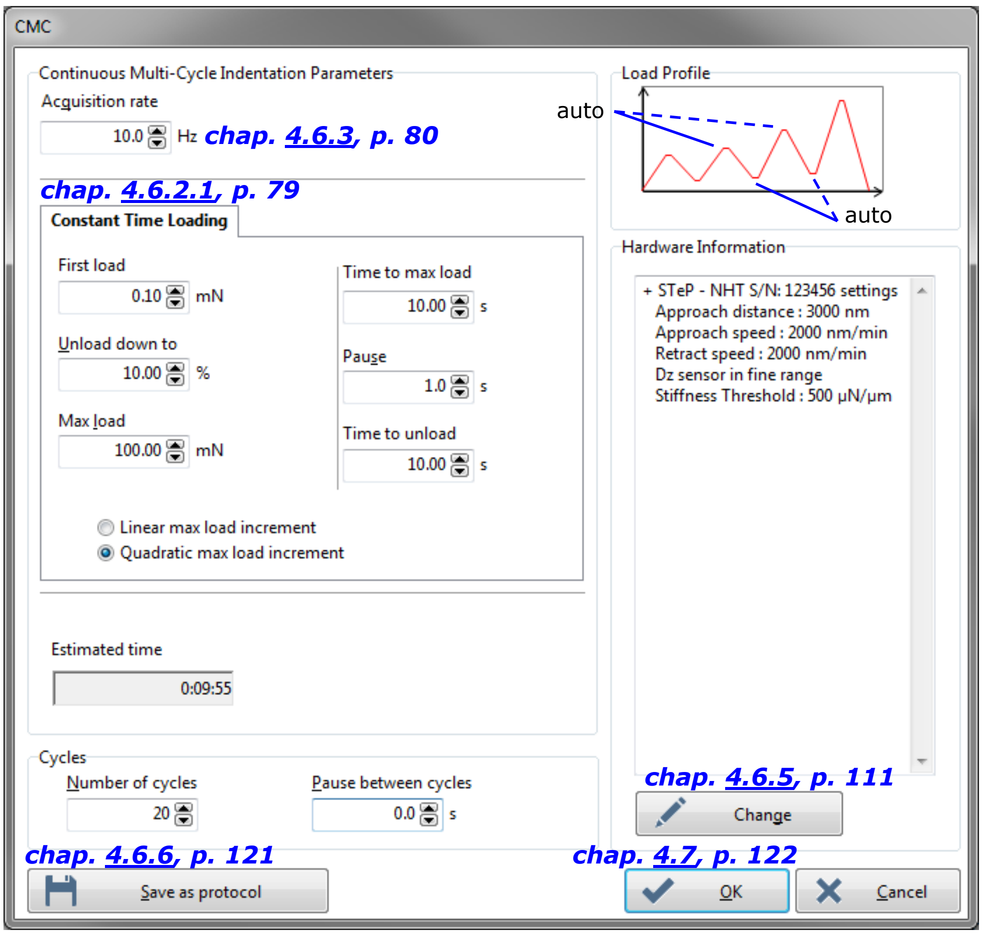
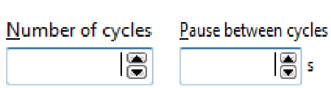


Fig.41 CMC window parameters

The default ***Constant time loading*** set of parameters is described in the following section, ***p. 94***.

Cycles

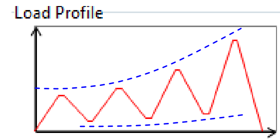


Same parameters than described in ***Cycles, p. 87*** of the *Constant multicycle* measurement type.

Constant time loading

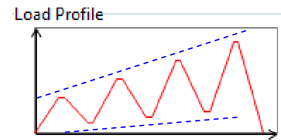
Quadratic max load increment

To select an automatic **quadratic** increment for each maximum load cycle until the last cycle.



Linear max load increment

To select automatic **linear** increment for each maximum load cycle until the last cycle.



First load (mN)

To set the first cycle maximum load.

Unload down to (%)

To set each cycle minimum load; this value is a percentage of each current cycle maximum load.

The recommended range value for Oliver & Pharr analysis is from 5 to 40 %

Only the last cycle will be fully unloaded.

Max load (mN)

To set the last cycle maximum load.

Time to max load (s)

To set the time to reach each cycle maximum load.

Pause (s)

To set a pause at each cycle maximum load before unloading.

Set the value to 0 for “no pause”.

Time to unload (s)

To set the time to reach each cycle minimum load after the pause (set above).

4.6.4.7 User defined profile

The *User defined profile* measurement type is a **single** indentation measurement, performed in **several segments** fully defined by the user. Each segment can be different from one to another.

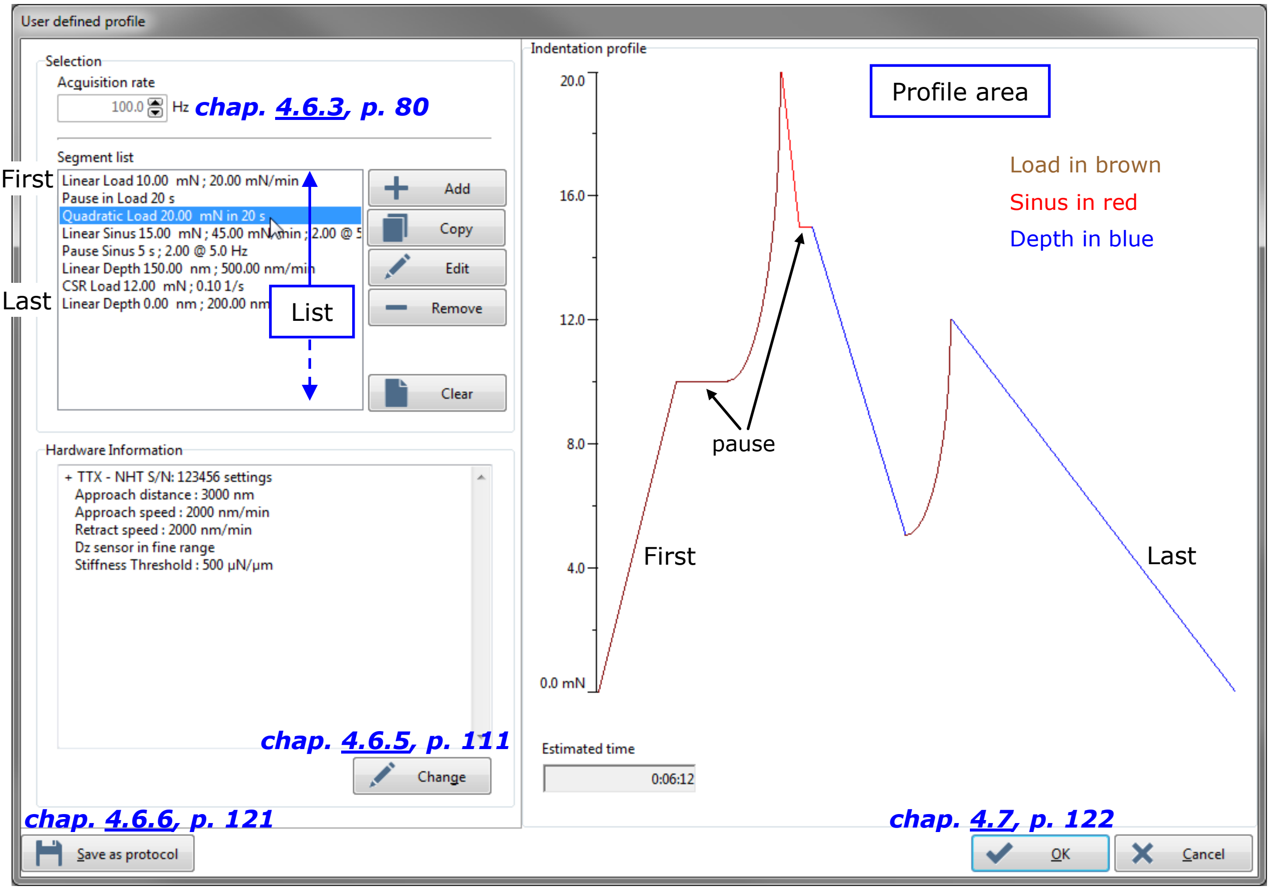
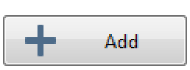


Fig.42 User defined profile window parameters

There are load profile or pause segment types. Each segment in the list from top to bottom is respectively displayed from the left to the right in the profile area and corresponds to the order/shape of the measurement.

The 3 following buttons open the *Edit segment* window *Fig.43, p. 96*.

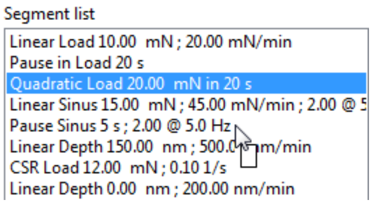


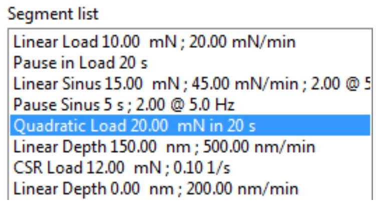
To create a new segment (type/parameters) at the bottom of the list.

To copy the selected (highlighted) segment at the bottom of the list.

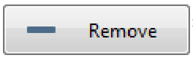
If necessary, the segment can be modified.

To modify the selected (highlighted) segment in the list.

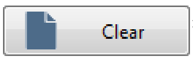




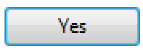
To change the order of any segment, select it (highlighted), drag it and drop it elsewhere in the list; the shape changes accordingly in the profile area.

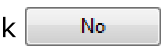


* To remove the selected (highlighted) segment from the list.



* To clear all segments from the list.

* click 

to confirm the removal/clearing **or** click 

to cancel

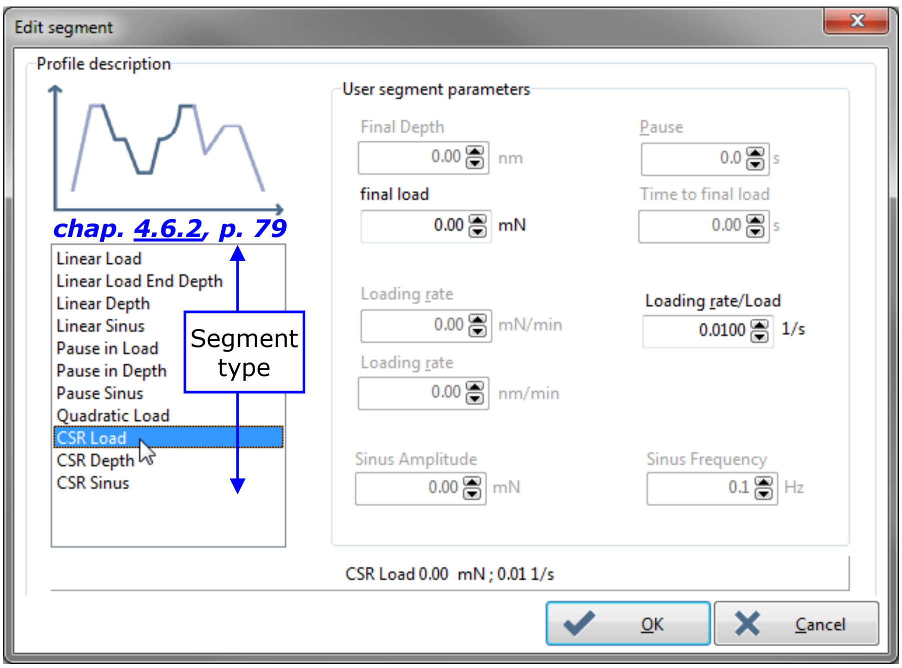


Fig.43 Edit segment window parameters

Select a segment type: a loading profile **or** a pause (becomes highlighted).

The corresponding parameter(s) are active and should be set; remaining parameters are inactive (grayed out).

The corresponding set of parameters is described in the following sections:

Loading profile parameters ***p. 97***
Pause parameters ***p. 97***

Loading profile parameters

Final Depth [ ] nm **or** final load [ ] mN

Linear Load End Depth *Linear/Quadratic Load*
Linear/CSR Depth *CSR Load/Sinus*

To set the final depth **or** load,

or Sinus Amplitude [ ] mN and Sinus Frequency [ ] Hz

Pause/CSR Sinus *Pause/CSR Sinus*

or the Sinus amplitude and frequency.

Warning: Outside operationnal frequencies 1-40Hz

To obtain a correct Sinus analysis, it is recommended to set its frequency value from 1 to 40 Hz (other values do not block the measurement).

Loading rate [ ] nm/min **or** Loading rate [ ] mN/min

Linear Depth *Linear Load End Depth*

To set one of the loading rate,

or Loading rate/Load [ ] 1/s *CSR Load/Depth/Sinus*

or the loading rate/load,

in order to reach the final depth **or** load (set above).

Or Time to final load [ ] s *Quadratic Load*

Or to set the time to reach the final load (set above).

Pause parameters

Pause [ ] s *Pause in Load/in Depth/Sinus*

To set a pause.

Sinus Amplitude [ ] mN and Sinus Frequency [ ] Hz

Pause/CSR Sinus *Pause/CSR Sinus*

With the *Pause Sinus*, the Sinus amplitude and frequency should also be set.

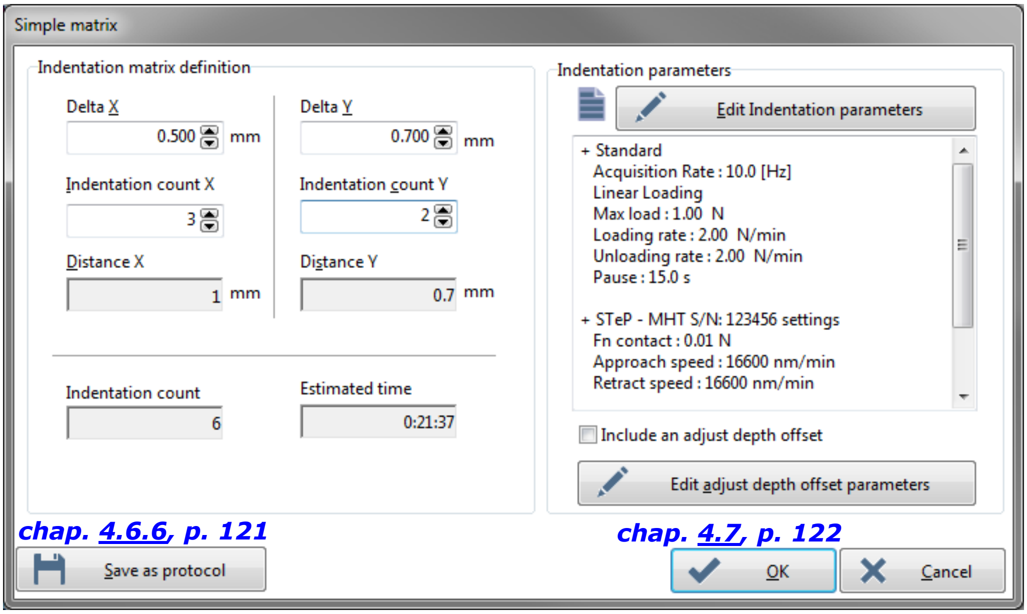
The last segment should be unloaded to "0".

Click OK to valid the current segment settings in the list *Fig.42, p. 95*.

An *Information* window message appears in case of a parameter in not properly set.

4.6.4.8 Simple matrix

The *Simple matrix* measurement type performs a **matrix** of **identical** indentation measurements with a (same) **defined** X & Y spacing.



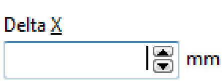
chap. 4.6.6, p. 121 ***chap. 4.7, p. 122***

Fig.44 Simple matrix window parameters

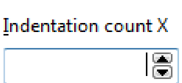
For certain instrument, if the Y table is manual the corresponding fields are inactive (grayed out).

The matrix of measurements will start from the current position of the tables.

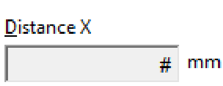
Matrix parameters



To set the (relative) distance between each measurement (set below) for the X axis.

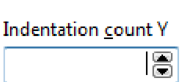


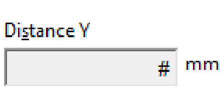
To set the number of measurement for the X axis.



According to the setting of the 2 parameters above, the distance between the first and the last measurement for the X axis is displayed as information.

Same descriptions than for the X axis parameters above, except there are applicable for the Y (motorized) axis.





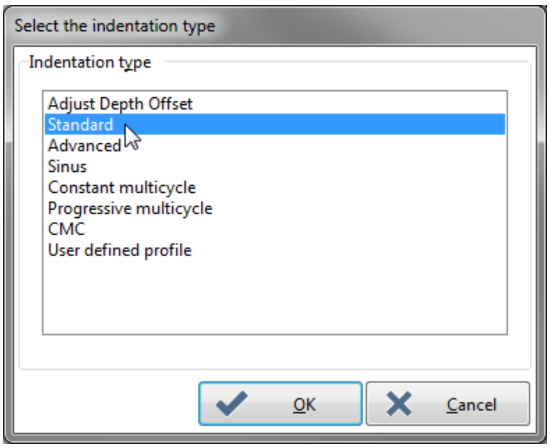
Indentation count #

The total number of the measurements which will be performed is displayed as information.

(Indentation count X multiplied by Indentation count Y).

Edit Indentation parameters

To select one of the following measurement types, the same one will be used to perform the **whole** matrix of measurements.



Select (double click) the desired measurement type. The corresponding parameters should be set as same as described in the following ***chapters***:

Standard	***4.6.4.1, p. 81***
Advanced	***4.6.4.2, p. 82***
Sinus	***4.6.4.3, p. 85***
Constant multicycle	***4.6.4.4, p. 87***
Progressive multicycle	***4.6.4.5, p. 90***
CMC	***4.6.4.6, p. 93***
User define profile	***4.6.4.7, p. 95***

Adjust Depth Offset measurement type (in the list above) is not useful for a *Simple matrix* of measurements; see ***Initial ADO below***.

Initial ADO

☑ Include an adjust depth offset

If necessary, check this box to **include** an (automatic) ADO before performing the matrix of measurements.

Edit adjust depth offset parameters

To set the parameters for the **included** ADO (if box is checked above); the same ADO window parameters as described for the corresponding head below should be set:

UNHT ADO	*Fig.29, p. 57*
UNHT Bio ADO	*Fig.30, p. 57*
NHT ADO	*Fig.32, p. 66*
MHT ADO	*Fig.33, p. 70*

The ADO procedure will automatically begin once the matrix of measurements will be started (OK is clicked in *Fig.44, p. 98*).

4.6.4.9 Advanced matrix

The *Advanced matrix* measurement type performs a list of indentation/ADO measurements. For each measurement definition which composes the matrix, a **different** position can be defined and a **different** measurement type (with its specific parameters) can be selected.

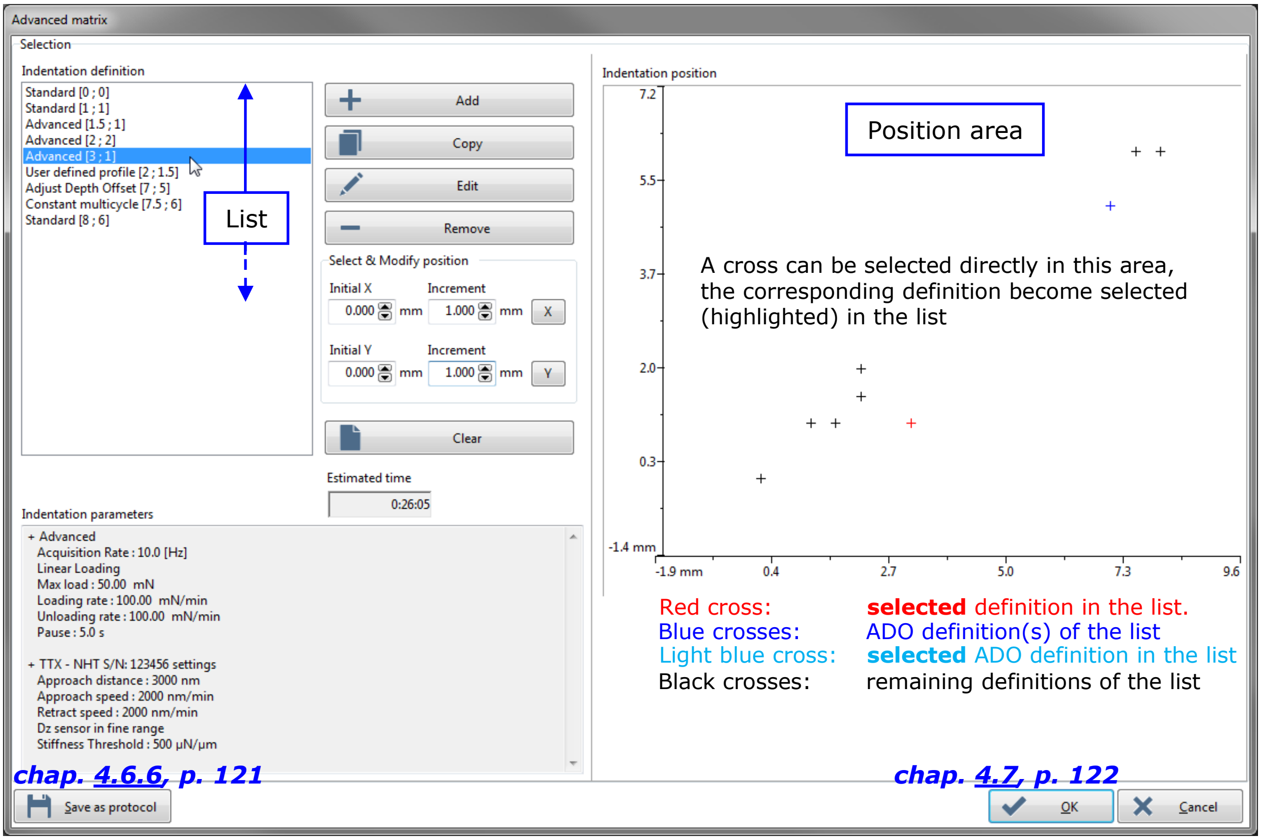
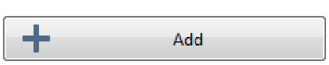


Fig.45 Advanced matrix window parameters

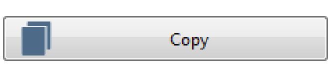
The corresponding position of each measurement definition from the list is represented with a cross in the position area. Each measurement definition will be performed in the chronological order of the list (from top to bottom).

Parameters to create and modify each new selected measurement definition

The 3 following buttons open the *Indentation position* window *Fig.46, p. 101*.

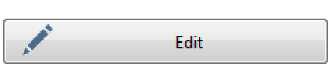


To create a new definition (type/parameters/position) at the bottom of the list.

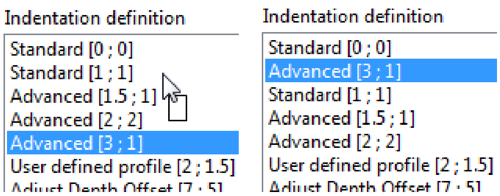


To copy the selected (highlighted) definition at the bottom of the list

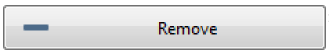
If necessary, the definition can be modified.



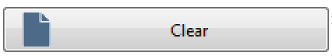
To modify the selected (highlighted) definition in the list.



To change the chronologic order of the measurements which will be performed, select any definition (highlighted), drag it and drop it elsewhere in the list.



* To remove the selected (highlighted) definition(s) from the list - several definitions can be selected using ***"Ctrl"*** (or ***"Shift"***) before selecting. (The definition square(s) also disappear from the Video screen)



* To clear all definitions from the list.

* click Yes to confirm the removal/clearing **or** click No to cancel

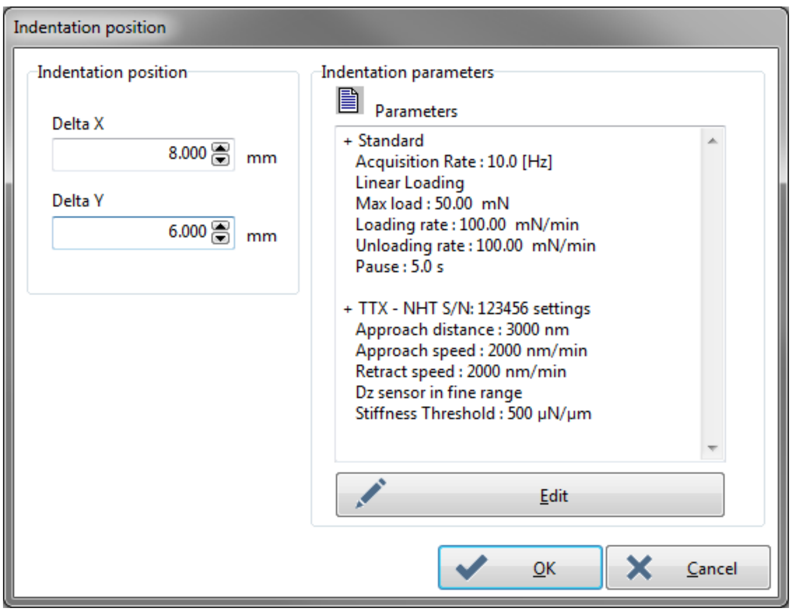
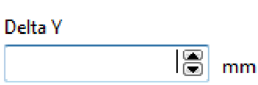


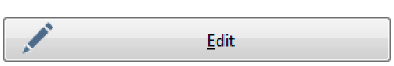
Fig.46 Indentation position window parameters

For each current (selected) definition:

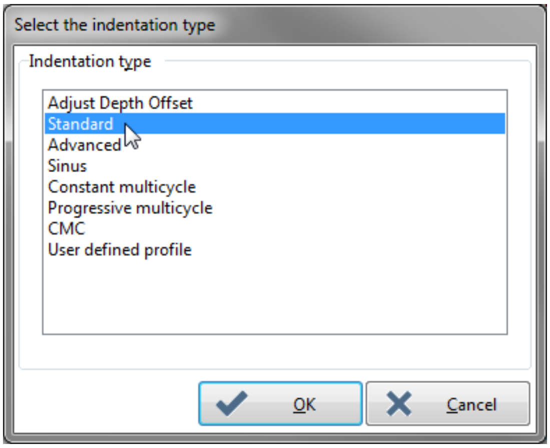
To set a relative position for the X axis.



To set a relative position for the Y axis.



To select one of the following measurement types.



(ADO or indentation measurement)

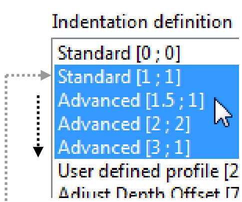
Select (double click) the desired measurement type. The corresponding parameters should be set as same as described in the following ***chapters***:

Standard	***4.6.4.1, p. 81***
Advanced	***4.6.4.2, p. 82***
Sinus	***4.6.4.3, p. 85***
Constant multicycle	***4.6.4.4, p. 87***
Progressive multicycle	***4.6.4.5, p. 90***
CMC	***4.6.4.6, p. 93***
User define profile	***4.6.4.7, p. 95***

Adjust Depth Offset, see ***chap. 4.6.4.11 Multi-ADO for advanced & visual advanced matrix, p. 110***

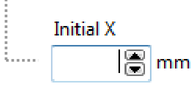
To modify positions for several measurement definitions (regular positions)

The following features can be useful to define a regular grid for the matrix; the initial position and a same distance increment can be applied for the X and/or Y axis of the selected definitions in the list (to modify their current positions).



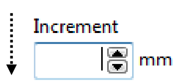
Press ***"Ctrl"*** (or ***"Shift"***) and select several definitions in the list (highlighted).

For the X axis



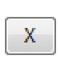
(e.g. 0)

To Set the initial (absolute) position for the first selected definition (highest position selected in the list)



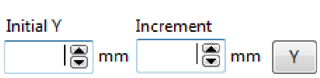
(e.g. 1)

To set the increment (relative) distance between each remaining selected definition (from top to bottom in the list).



To modify the current positions according to the selection and 2 settings described above.

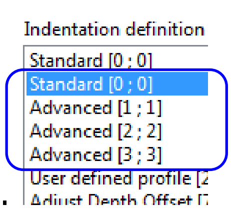
For the Y axis



(e.g. 0 and 1)

Same as described above, **exception:** it is applicable for the Y axis. The selection in the list should be done again.

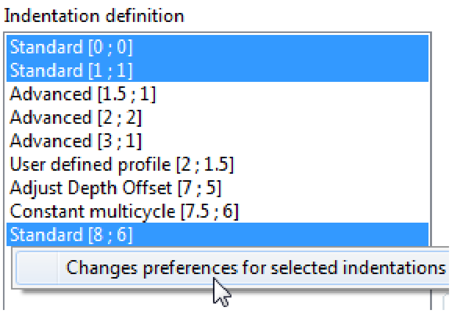
e.g.



E.g. the X and Y positions of the selected definitions have been modified.

To set same preferences for several measurement definitions

To set in one time the same preference parameters for several measurement definitions, see the descriptions below.

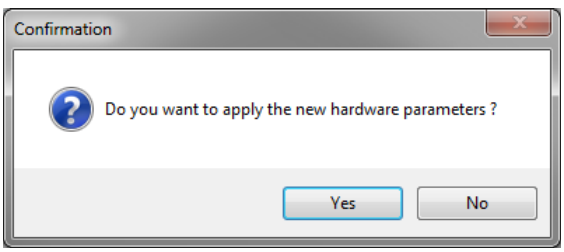


Press **"*Ctrl*"** or **"*Shift*"** and select several measurement definitions in the list (highlighted).

Then right click in the definition list area and click on *Changes preferences for selected indentations* context menu.

The same *Preferences* window parameters as described for the corresponding head below can be modified for all selected definitions in the list:

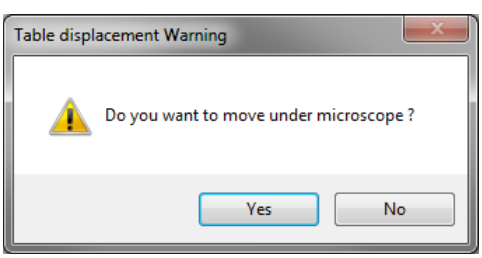
UNHT ***chap. 4.6.5.1, p. 112***
UNHT Bio ***chap. 4.6.5.2, p. 114***
NHT ***chap. 4.6.5.5, p. 116***
MHT ***chap. 4.6.5.6, p. 117***



Once the preference parameters are validate (OK is clicked in the *Preference* window), this *Confirmation* window ask if the new parameters should be applied. Click Yes to apply the modifications. Otherwise click No to not apply the modifications.

4.6.4.10 Visual advanced matrix

This measurement is only possible with an **optional** motorized Y table and a video system mounted on the instrument.



Click Yes to open the following *Visual advanced matrix* and *Video* windows.

The *Visual advanced matrix* measurement type performs a list of indentation/ADO measurements. For each measurement definition which composes the matrix, a **different** position can be visually[1)] **or** manually[2)] defined and a **different** measurement type (with its specific parameters) can be selected.

[1)] With following *Video* window
[2)] With following *Visual advanced matrix* window

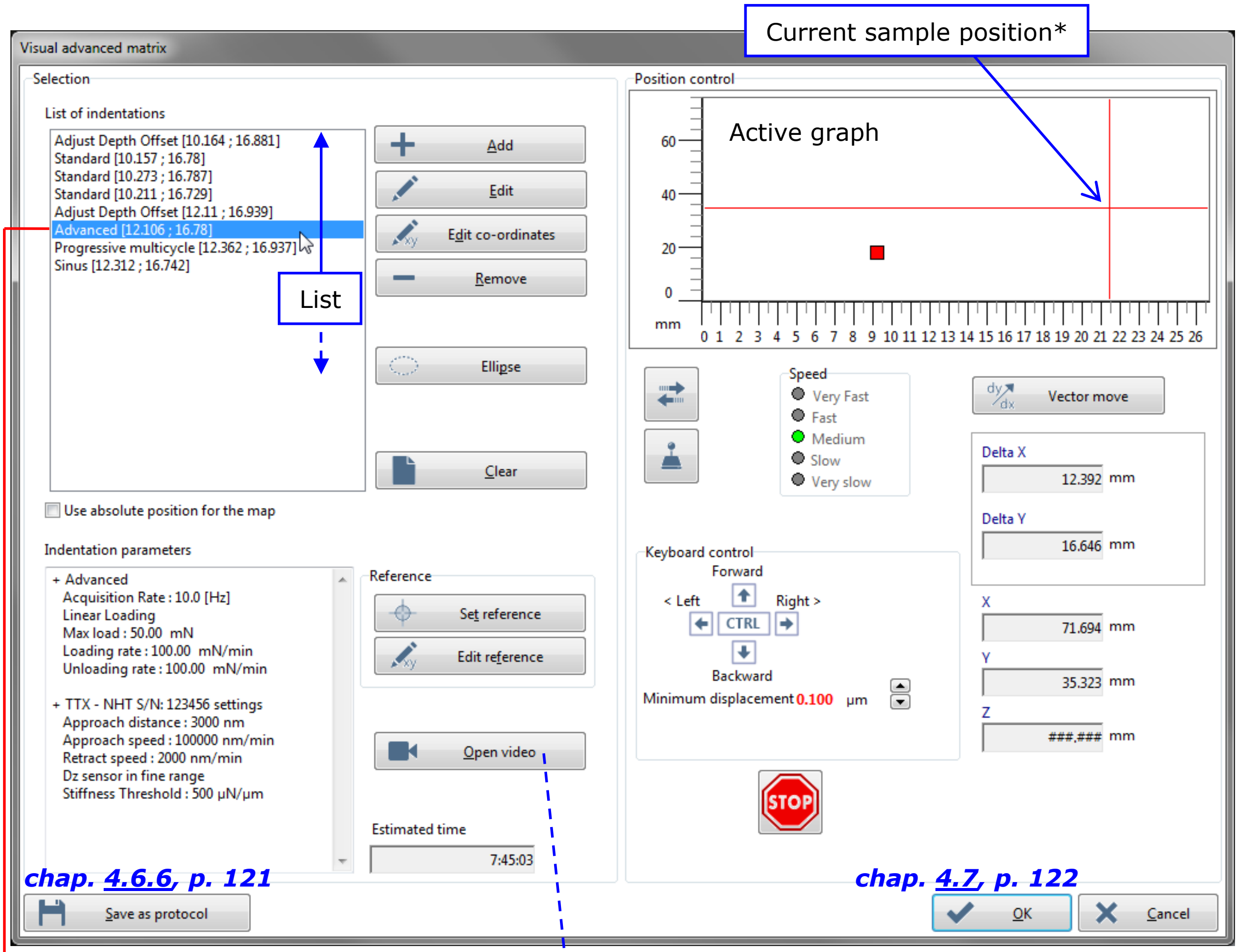


Fig.47 Visual advanced matrix window parameters

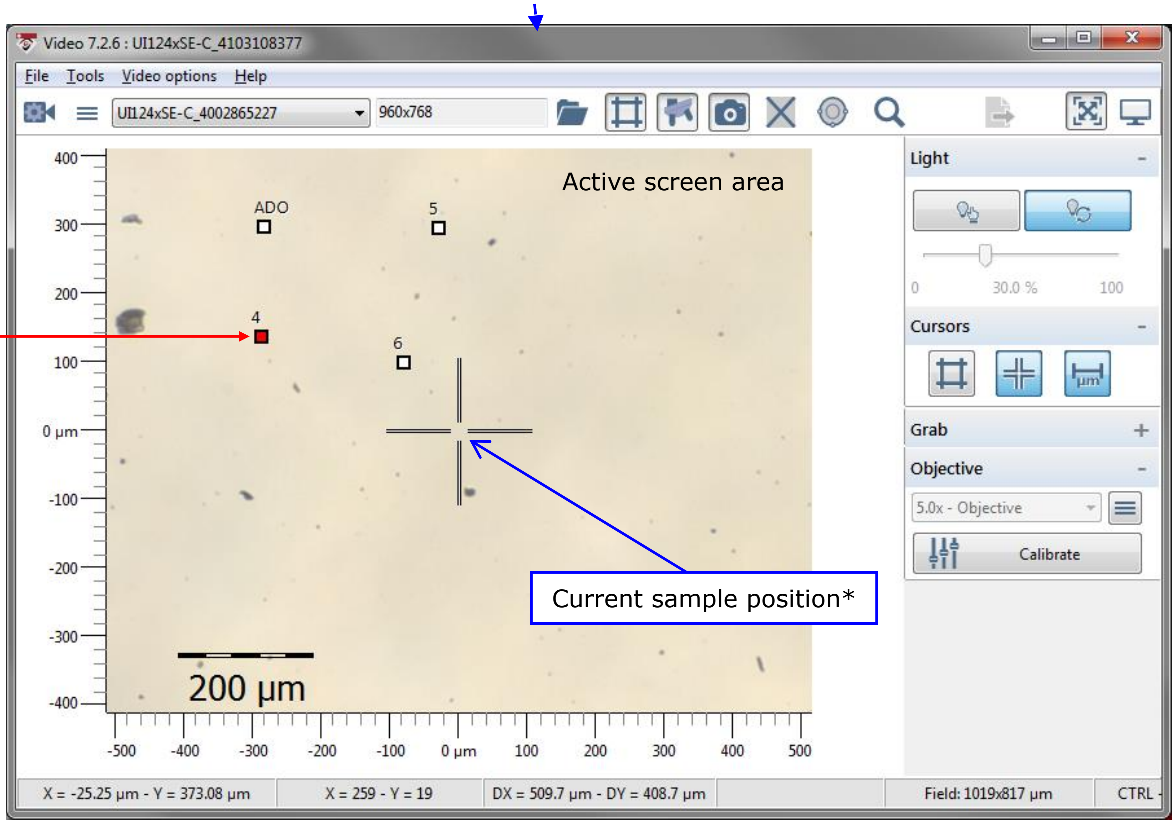


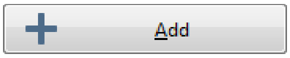
Fig.48 Video window with defined indentations

Parameters to create new measurement definitions

To create a new measurement definition at the bottom of the list, **click**:

- A position directly on the *Video* screen.

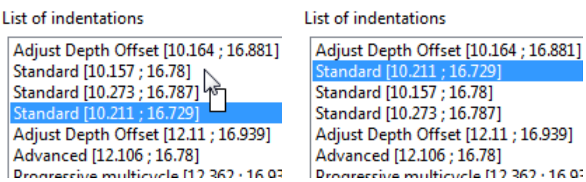
OR

- 

  The new measurement definition type (and parameters) are the same as the last selected (highlighted) definition in the list (a copy but with a different position); see how to modify the ***Measurement type/parameters below*** and the ***Position, p. 106***.

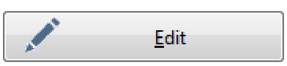
On the *Video* screen, each defined position is shown with a small square and a "number" or "ADO". Each "number" corresponds to the order of the indentation definitions in the list (from top to bottom) excluding the ADO. When the small square is in red color, it means it is the position of the current selected (highlighted) definition in the list.

Parameters for each selected measurement definition

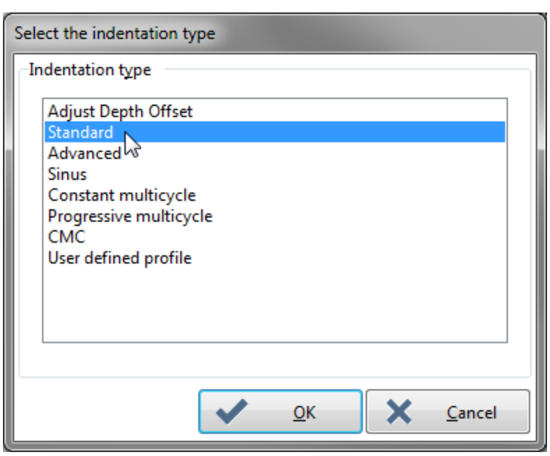


To change the chronologic order of the measurements which will be performed, select any definition (highlighted), drag it and drop it elsewhere in the list.

Measurement type/parameters



To modify the measurement type of the selected (highlighted) definition in the list:



(ADO or indentation measurement)

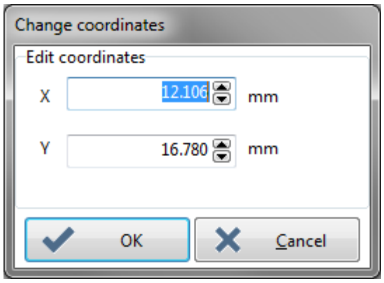
Select (double click) the desired measurement type. The corresponding parameters should be set as same as described in the following ***chapters***:

Standard	***4.6.4.1, p. 81***
Advanced	***4.6.4.2, p. 82***
Sinus	***4.6.4.3, p. 85***
Constant multicycle	***4.6.4.4, p. 87***
Progressive multicycle	***4.6.4.5, p. 90***
CMC	***4.6.4.6, p. 93***
User define profile	***4.6.4.7, p. 95***

Adjust Depth Offset, see ***chap. 4.6.4.11 Multi-ADO for advanced & visual advanced matrix, p. 110***

Position

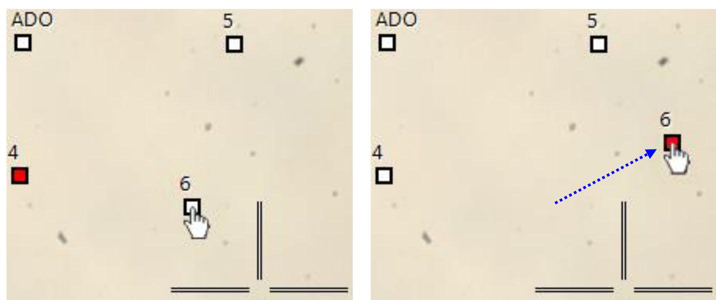
To manually change the position of the selected (highlighted) measurement definition in the list:



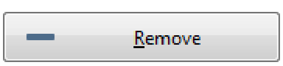
Set other coordinate value(s) than the current position.

OR

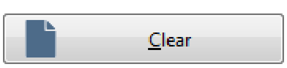
To visually change a measurement definition position from the *Video* screen, click in the middle of the desired square (the arrow mouse cursor **should** become a hand shape cursor, otherwise a new definition is created), then drag and drop the current red square on the *Video* screen.



before ***after***

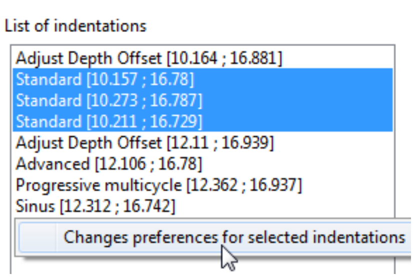


To remove the selected (highlighted) measurement definition(s) from the list - several definitions can be selected using ***"Ctrl"*** or ***"Shift"*** before selecting. (The definition square(s) also disappear from the *Video* screen)



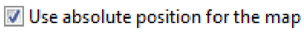
To clear all measurement definitions from the list (and from the *Video* screen).

To set same preferences for several measurement definitions



Same as described in ***To set same preferences for several measurement definitions,*** for the *Advanced Matrix* in ***p. 103***.

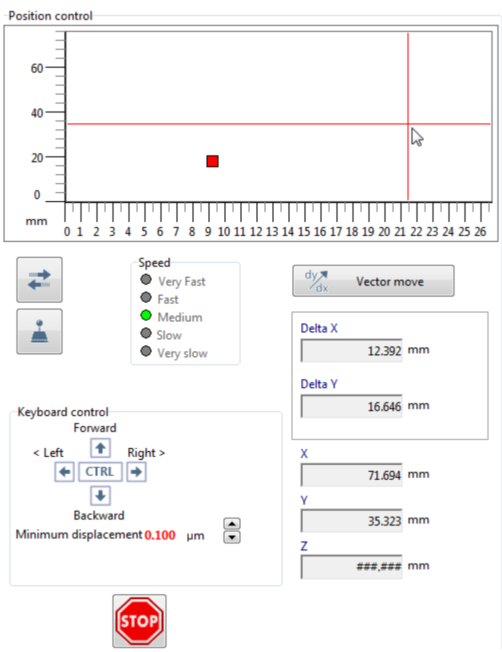
Absolute reference position for protocol



Check this box to always keep the same matrix reference if this *Visual advanced matrix* measurement type is saved as a protocol. Each time the saved protocol will be selected, the sample will be positioned at the same reference; see ***To change the reference position, p. 107***.

Otherwise (uncheck) the sample will be positioned at the current position.

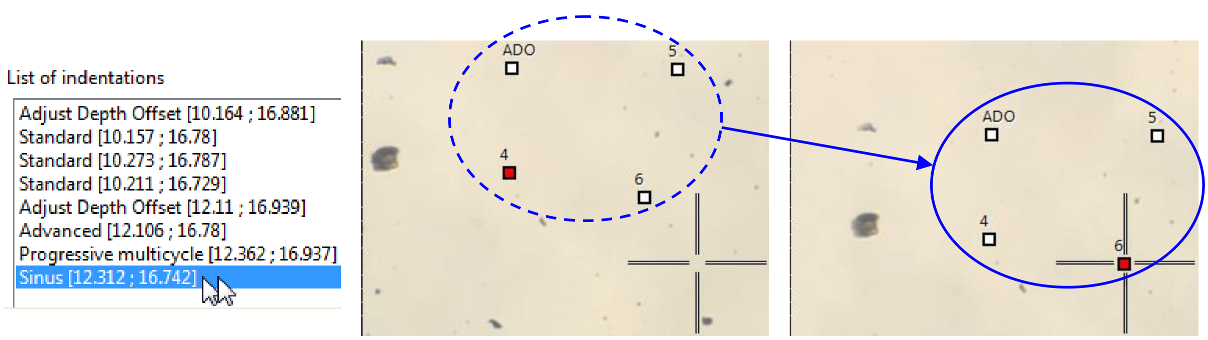
Methods to move



To move the sample/motorized table(s) use the *Position control* area; for descriptions, refer to the ***Common Scratch & Indentation software manual - chap. Managing the instrument - Control of the sample position***, **exception:** some functions are not applicable here.

OR

To move the sample/motorized tables to an existing measurement definition position, on the *Video* screen center (crosshair), double click on the desired definition in the list.

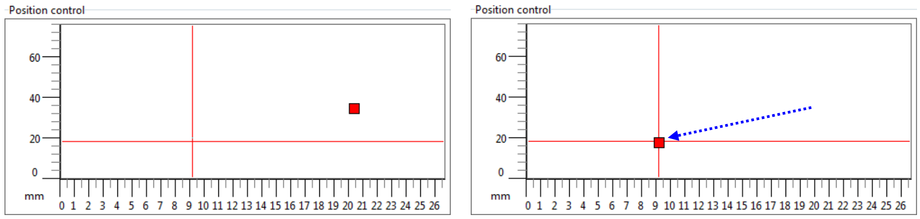


before ***after***

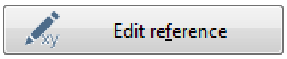
To change the reference position

To align the measurement definitions of the matrix with a specific reference position on the sample, see the following descriptions.

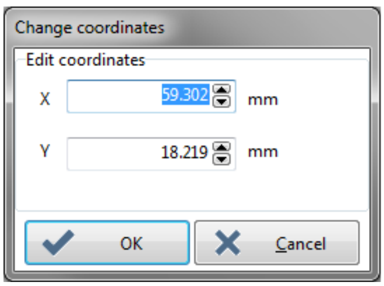
To set a new reference at the current sample/motorized tables position.



before **after**



To manually set a new reference ■ to another position:

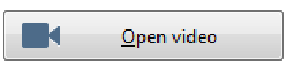


Set different coordinate field value(s) than the current position.

The current position value(s) can slightly differ from the one(s) shows on the *Position control* active graph due to the indenter-microscope distance calibration correction.

When a new reference is set (above), the X-Y deltas of the definitions in the list are not changed, only the origin of map is changed. This allows translation of all measurement definitions by selecting new reference/coordinates (origin).

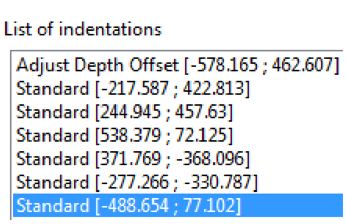
To reopen the Video

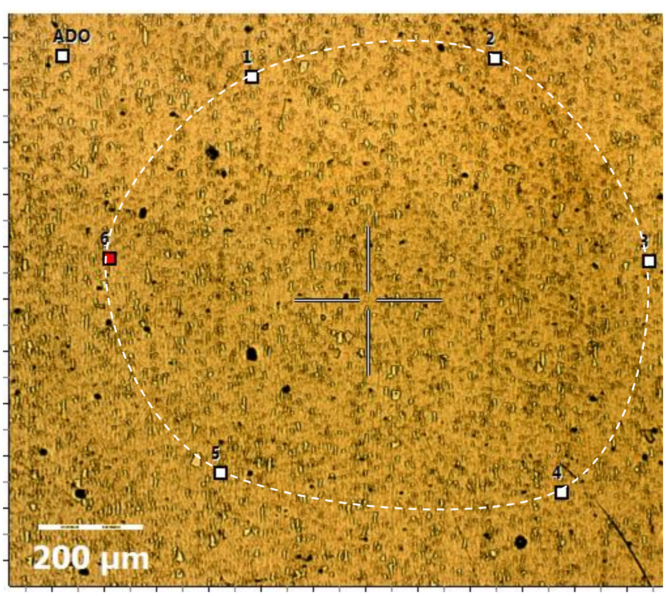


To reopen the *Video* window if it has been closed.

Ellipse

To fit an ellipse shape for the matrix, first **minimum** 6 indentations should be defined (round shape) in the list (which will be automatically erased later) - ADO(s) are not included.





To define the following ellipse parameters.

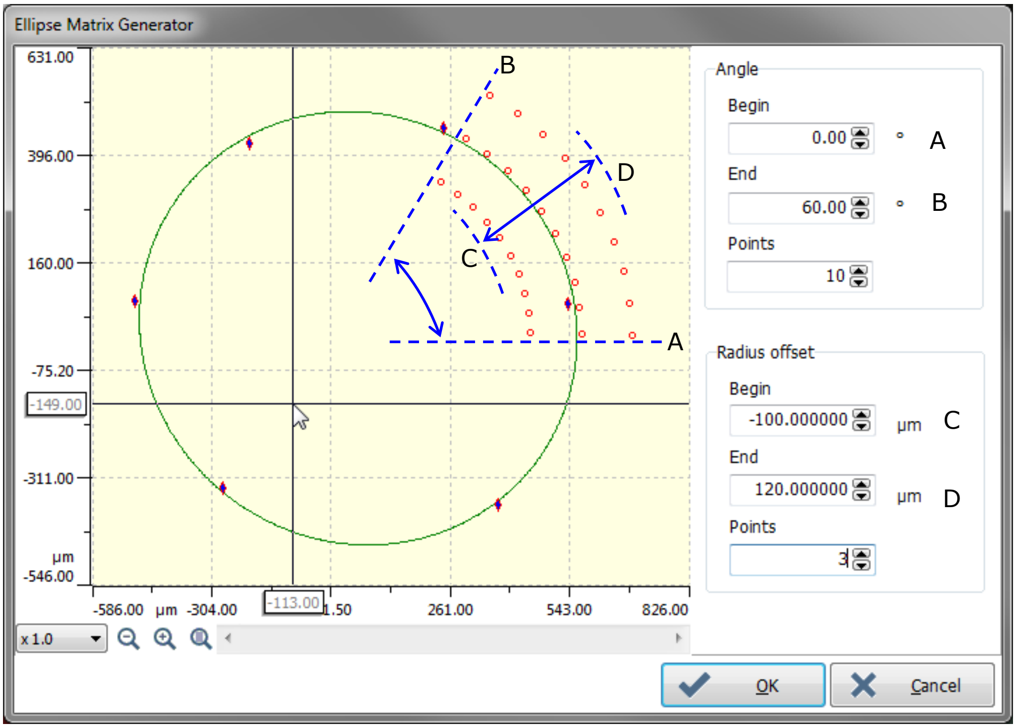
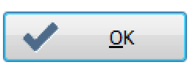


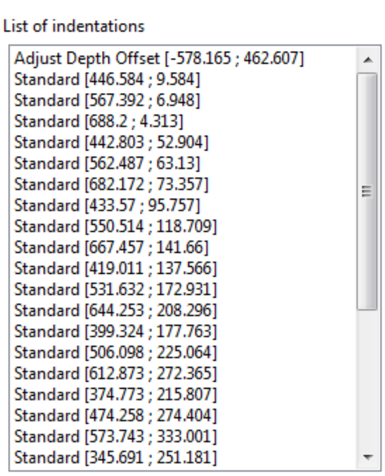
Fig.49 Ellipse Matrix Generator window parameters

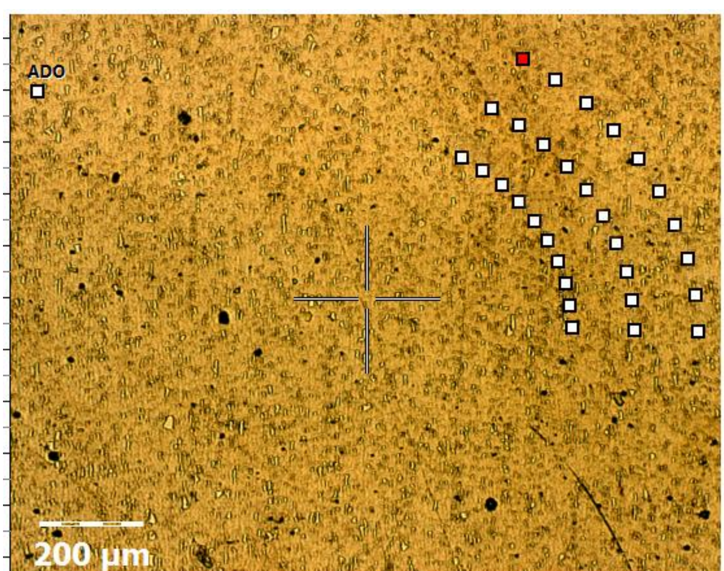
Set the field parameters in order the software computes new indentation definitions in the list for the elliptic fit matrix.

E.g. 10 ***Points*** (*Angle*) in 3 rows (*Radius offset* ***Points***) = 30 definitions.

When 

is clicked in *Fig.49 above*, the new indentation definitions replace the previous ones in list. (ADO definition(s) is kept in the list)





New computed indentation definitions (e.g. 30) for the elliptic matrix

4.6.4.11 Multi-ADO for advanced & visual advanced matrix

Reminder of the ADO purpose: read the beginning of the ***chap 4.4, p. 56***.

One or several automatic ADO(s) can be performed at the beginning and/or between the indentation measurements for the *Advanced matrix* ***chap. 4.6.4.9, p. 100*** or *Visual advanced matrix* ***chap. 4.6.4.10, p. 103***.

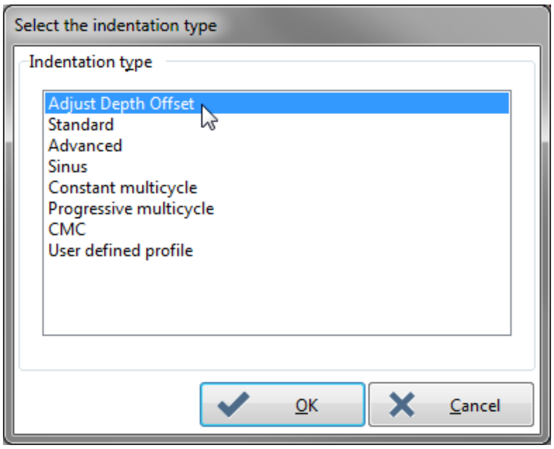


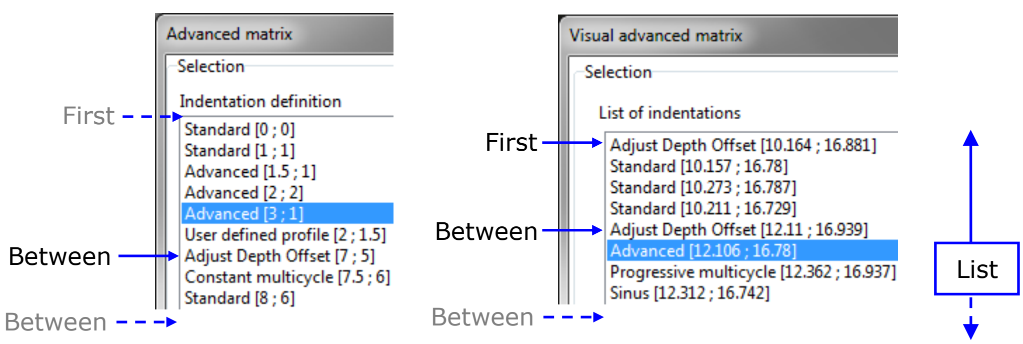
Fig.50 ADO selection

Select (double click) the *Adjust Depth Offset* (ADO) measurement type.

The same ADO window parameters as described for the corresponding head below should be set:

UNHT ADO	*Fig.29, p. 57*
UNHT Bio ADO	*Fig.30, p. 57*
NHT ADO	*Fig.32, p. 66*
MHT ADO	*Fig.33, p. 70*

- An ADO can be included at the **first** position in the definition list, before starting the indentation measurements of the matrix.
- One or several ADO(s) can be included **between** the indentation measurements of the matrix.



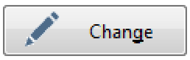
Before starting the matrix of measurements, if there is **no** at least an ADO in the first position of the list, a *Confirmation* window asks to continue:

Click Yes if a successful ( ) ADO has previously been performed and is suitable (location) for the whole matrix area. Otherwise click No and add an ADO definition in the first position of the list, and elsewhere in the list where it is necessary.

4.6.5 Measurement preference parameters (head)

Located at the right (or left*) bottom of the following measurement type window:

Standard	***4.6.4.1, p. 81***
Advanced	***4.6.4.2, p. 82***
Sinus	***4.6.4.3, p. 85***
Constant multicycle	***4.6.4.4, p. 87***
Progressive multicycle	***4.6.4.5, p. 90***
CMC	***4.6.4.6, p. 93***
**User define profile*	***4.6.4.7, p. 95***,

click 

/ 

to modify the parameters in the *Preferences* windows.

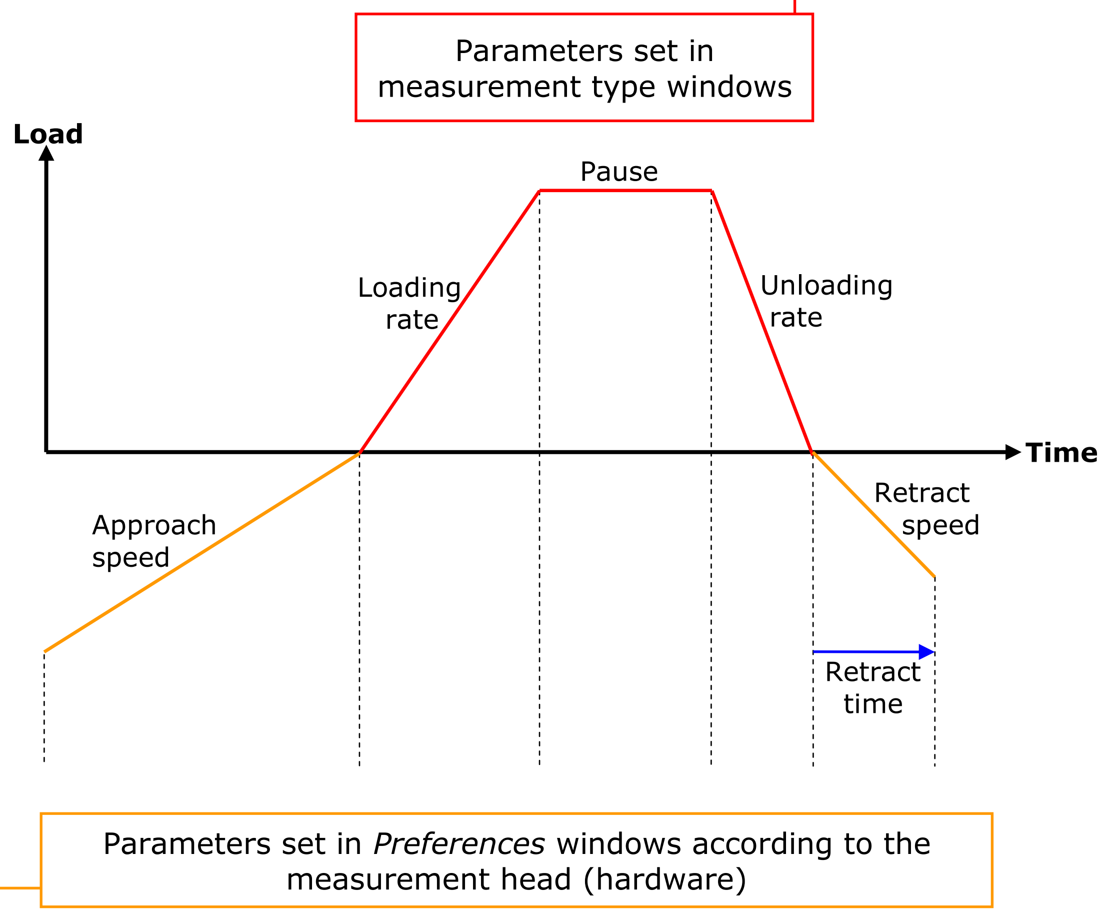


Fig.51 measurement schematic

See the following sections which described the *Preferences* window parameters dedicated for each type of measurement head (UNHT, UNHT Bio, NHT and MHT) and the common parameters for all types of measurement head (approach distance, contact stiffness threshold and adhesion).

4.6.5.1 UNHT Preferences tab parameters

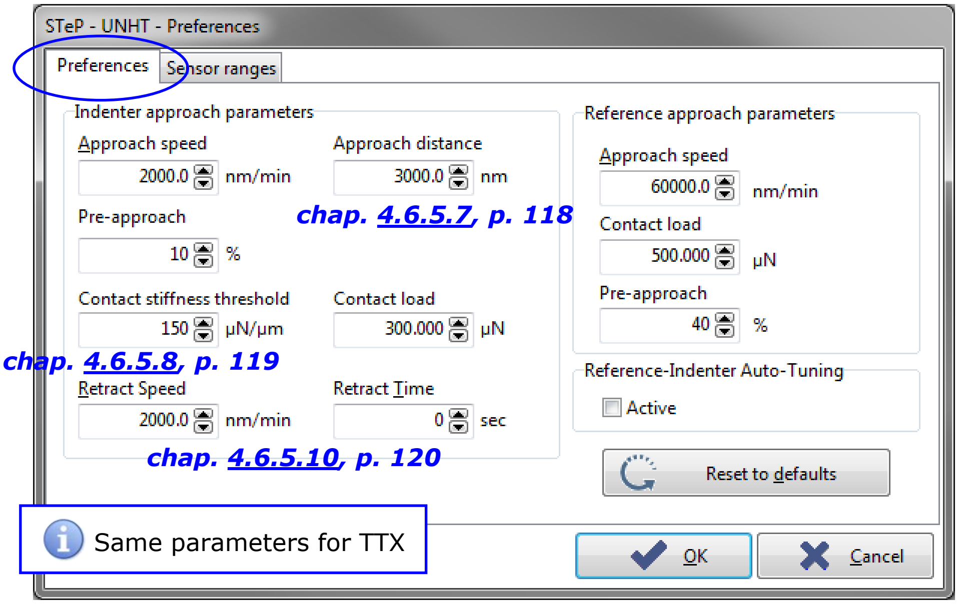
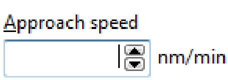


Fig.52 E.g. STeP - UNHT Preferences tab with default parameters

Set all parameters for the indenter & reference approach, contact detection and then for the retraction.

<u>Indenter</u>



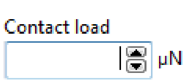
The ***Approach speed*** determines the velocity at which the indenter approaches the sample surface.

See the typical values in the table below:

1000 to **2000 nm/min**	For max. measurement load	Material
	20 to 1000 µN	fused silica (hard)

Tendency:

For maximum loads higher than 1000 µN, set a value higher than 2000 nm/min, especially for soft materials.



The indenter ***Contact load*** is used to detect the sample surface during the approach. The value depends on the desired max load value for the measurement. The following table gives indications on how to realize measurement in the best conditions:

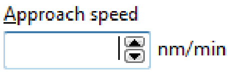
Recommended value	For max measurement load
= <10 µN	= <100 µN

Tendency:

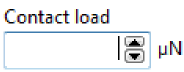
The lower the measurement max load value is, the lower the value should be set, in this case reduce the approach speed (set above) to keep enough acquisition data points in the curve.

For max measurement load higher than 100 µN, the value can be increased (10 % of max measurement load with max. 50 µN); see also ***chap. 4.6.5.9, p. 120***.

Reference



The ***Approach speed*** determines the velocity at which the reference approaches the sample surface; advised (standard) value **60000 nm/min**

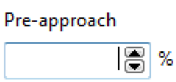


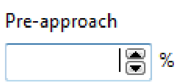
The reference ***Contact load*** is used to detect the sample surface; UNHT uses a patented active surface referencing system whose principle consists basically of a reference contacting the surface.

See the typical values in the table below:

Max. value	Material
500 or **1000 µN**	for most material

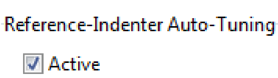
Indenter & reference

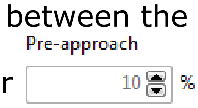


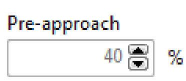


The indenter and reference ***Pre-approach*** fields are used to ensure that the indenter position is higher than the reference position before approaching the indenter and reference with the approach speed (set above). Standard values **10 %** for the indenter and **40 %** for the reference are most of the time suitable. However those values may be different depending on UNHT measurement configuration (type of mounted indenter/reference, mounting and geometry of the sample…).

OR



Check the reference-indenter auto-tuning box to perform an auto adjustment of the pre-approaches between the reference and the indenter: the indenter 

and reference 

become inactive (grayed out). According to the last successful ADO, the software will compute and optimize the best indenter and reference pre-approaches.

100 % is the lower/rest position.

4.6.5.2 UNHT Bio Preferences tab parameters

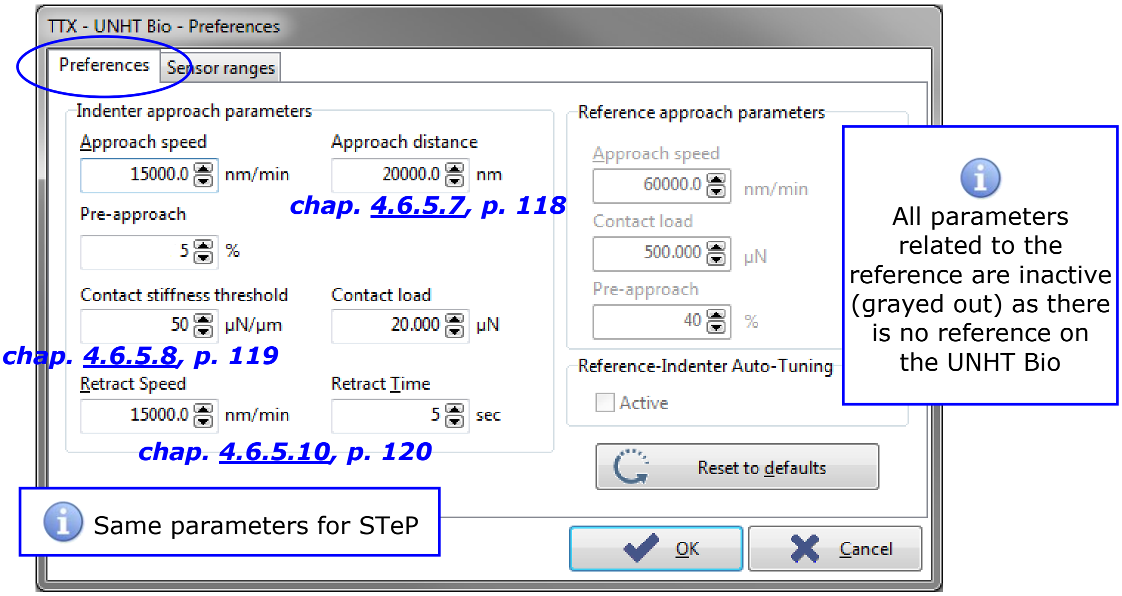
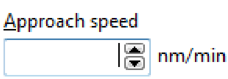
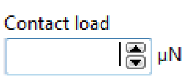


Fig.53 E.g. TTX-UNHT Bio Preferences tab with generic suitable parameters

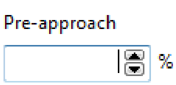
Set all parameters for the indenter approach, contact detection and then for the retraction.



The ***Approach speed*** determines the velocity at which the indenter approaches the sample surface.



The indenter ***Contact load*** is used to detect the sample surface during the approach; see also ***chap. 4.6.5.9, p. 120***.



The ***Pre-approach*** is used to pre-approach the indenter before approaching it with the approach speed above.

For the detailed explanations of those parameters, refer to the ***Anton Paar Bioindenter UNHT3 Bio User Manual - chap. Indentation measurement process - Performing an indentation measurement - Define indentation measurement parameters***.

4.6.5.3 UNHT Sensor ranges tab parameters

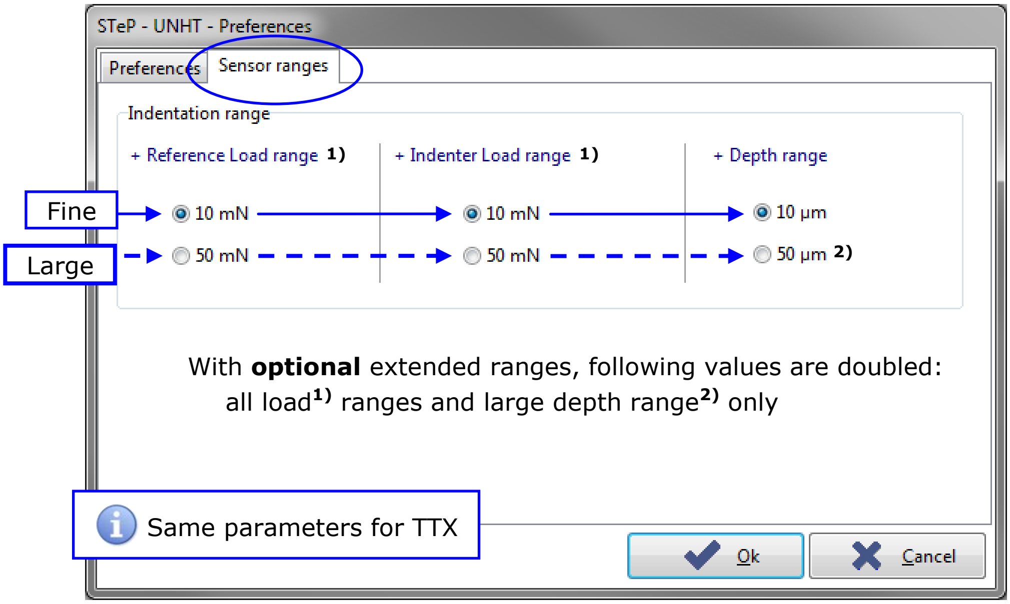


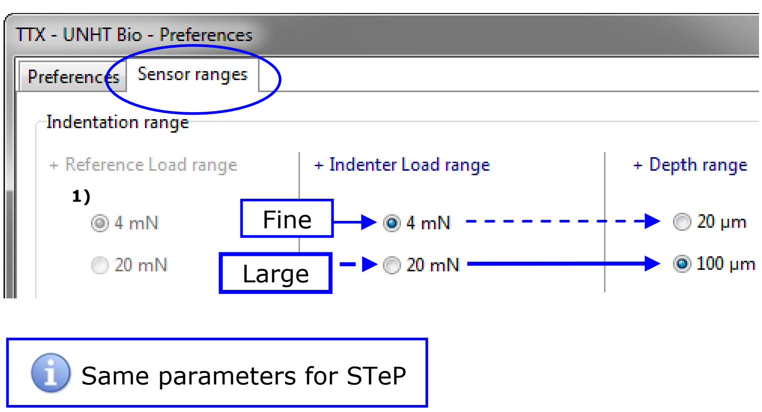
Fig.54 E.g. STeP - UNHT ***Sensor ranges tab with fine ranges***

Select suitable ***Reference Load range***, ***Indenter Load range*** and ***Depth range*** according to the used sample/application; it is recommended to use fine ranges (e.g. above), to obtain the optimal quality of the signals.

Use the large ranges only if the fine ranges are not sufficient to perform the measurement, or in case of saturation.

This tab is also available in the *Calibration* window ***chap. 3.3.1, p. 29***.

4.6.5.4 UNHT Bio Sensor ranges tab parameters



Similar than UNHT ***chap. 4.6.5.3 above***, **exception:**

- No reference.
- Range values are different.
- It is recommended to use the large **depth** range.

4.6.5.5 NHT Preferences tab parameters

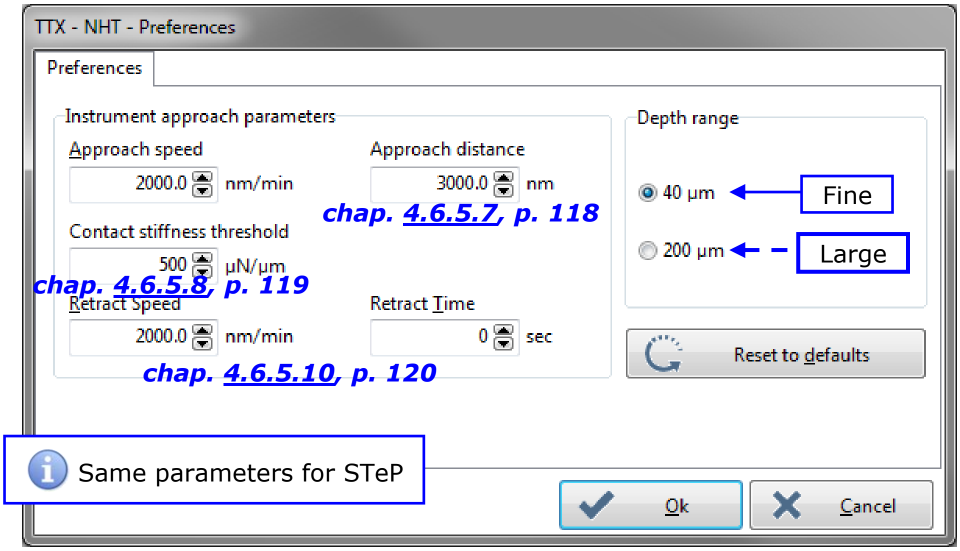
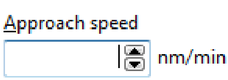


Fig.55 E.g. TTX-NHT Preferences tab with default parameters and fine depth range

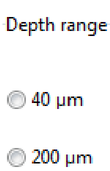
Set all parameters for the indenter approach, contact detection and then for the retraction.



The ***Approach speed*** determines the velocity at which the indenter approaches the surface.

See typical values in the table below:

Hard material		Soft material
< 1 mN	> 1 mN	
1000 to **1500 nm/min**	**2000 nm/min**	**4000 nm/min**



Select a suitable ***Depth range*** according to the used sample/application; it is recommended to use the fine range (e.g. above) but if the depth saturates during the following measurement, then select the large depth range.

4.6.5.6 MHT Preference tab parameters

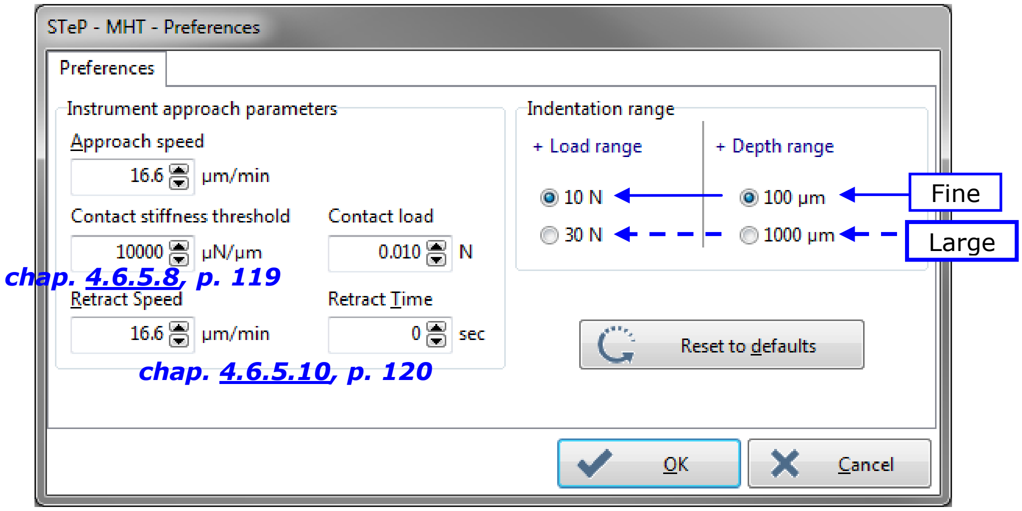
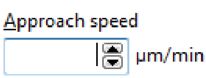


Fig.56 E.g. STeP - MHT Preferences tab with standard parameters and fine ranges

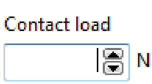
Set all parameters for the indenter approach, contact detection and then for the retraction.



The ***Approach speed*** determines the velocity at which the indenter approaches the sample surface.

See the typical values in the table below:

Hard material		
100 µm	- *Depth range* -	1000 µm
8 or **16.6 µm/min**		**16.6 µm/min**

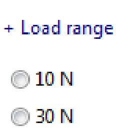


The ***Contact load*** is used to detect the sample surface during the approach; see also ***chap. 4.6.5.9, p. 120***.

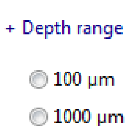
See the typical values in the table below:

Hard material		
100 µm	- *Depth range* -	1000 µm
0.01 N		**0.03 N**

1)



1)

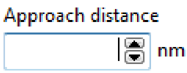


Select suitable ***Load range*** and ***Depth range*** according to the used sample/application; it is recommended to use fine ranges (e.g. above) to obtain the optimal quality of the signals. Use the large ranges only if the fine ranges are not sufficient to perform the measurement, or in case of saturation.

⚠ The *Depth range* **should** be the same as the ADO ***Dz range, p. 70*** which has been selected for the current successful ADO. Otherwise an error message will appear; see ***chap. 6.2, p. 173***.

1) range values can be different with old MCT version

4.6.5.7 Approach distance parameter (indenter)



This parameter is **only** available for the measurement heads equipped with an electronic bridge, such as the UNHT, UNHT Bio and the NHT, and can be changed **for each new measurement** in *Preferences* window/tab; see from ***chap. 4.6.5, p. 111***.

This parameter allows the increasing or decreasing of the indenter approach distance before starting to record the measurement.

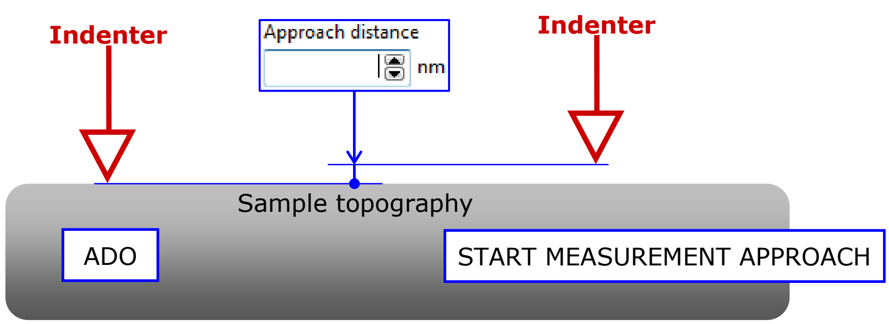
The default value is suitable for most sample materials.
However the value may have to be adapted (e.g. for very soft materials).

MHT approach distance

Otherwise for MHT without electronic bridge, this parameter can be **only** changed in the current ADO parameters window; see ***chap. 4.4.3, p. 70***. Therefore the approach distance will remain **the same for each following measurement**.

The parameter is applied according to the last successful ADO. When the approach distance value is reached by the indenter, the software starts recording of the measurement acquisition data (points).

The sketch below supposes that the sample surface topography is totally flat (no holes, no bumps, and no roughness) and the sample is not too soft:



The approach distance value which is set can be approximately seen on the following *Set the contact point* window *Fig.57, p. 119*, after the measurement has been performed.

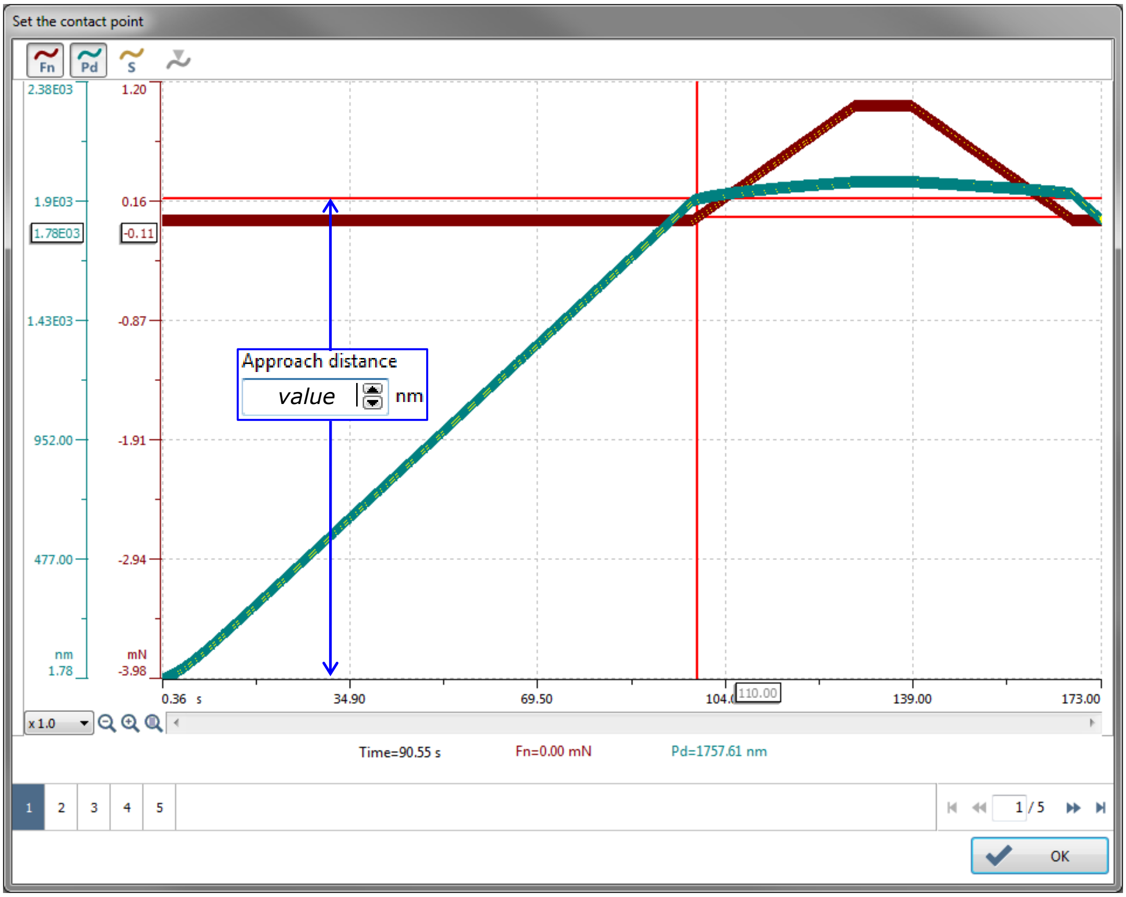
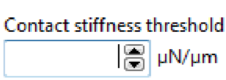


Fig.57 Approach distance on Set the contact point window

The approach distance cannot be exactly as same as the set value because it depends on the sample topography (tilt+ roughness) and the sample material (soft or hard); see ***chap. 5.1.1 Setting the contact point, p. 132***.

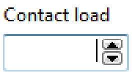
4.6.5.8 Contact stiffness threshold parameter



The value can be changed for each new measurement in *Preferences* window/ tab; see from ***chap. 4.6.5, p. 111***, but it is recommended to set the default value for each instrument.

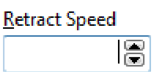
All the indentation measurement heads use this parameter for contact detection of the sample surface.
If necessary (for more accuracy or for very soft sample materials), it is possible to slightly decrease the default value;  however by **decreasing** too much the value, the contact can be detected in the air.

4.6.5.9 Contact load detection with UNHT/Bio & MHT

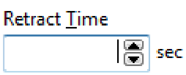


Additionally to the standard contact stiffness method *chap. 4.6.5.8, p. 119*, the UNHT, UNHT Bio and MHT instruments also can use the contact load parameter (unit selected in options). The sample surface is detected as soon as one of these methods finds it (most of the time the stiffness is detected sooner than the force).

4.6.5.10 Retract speed & time parameters for Adhesion



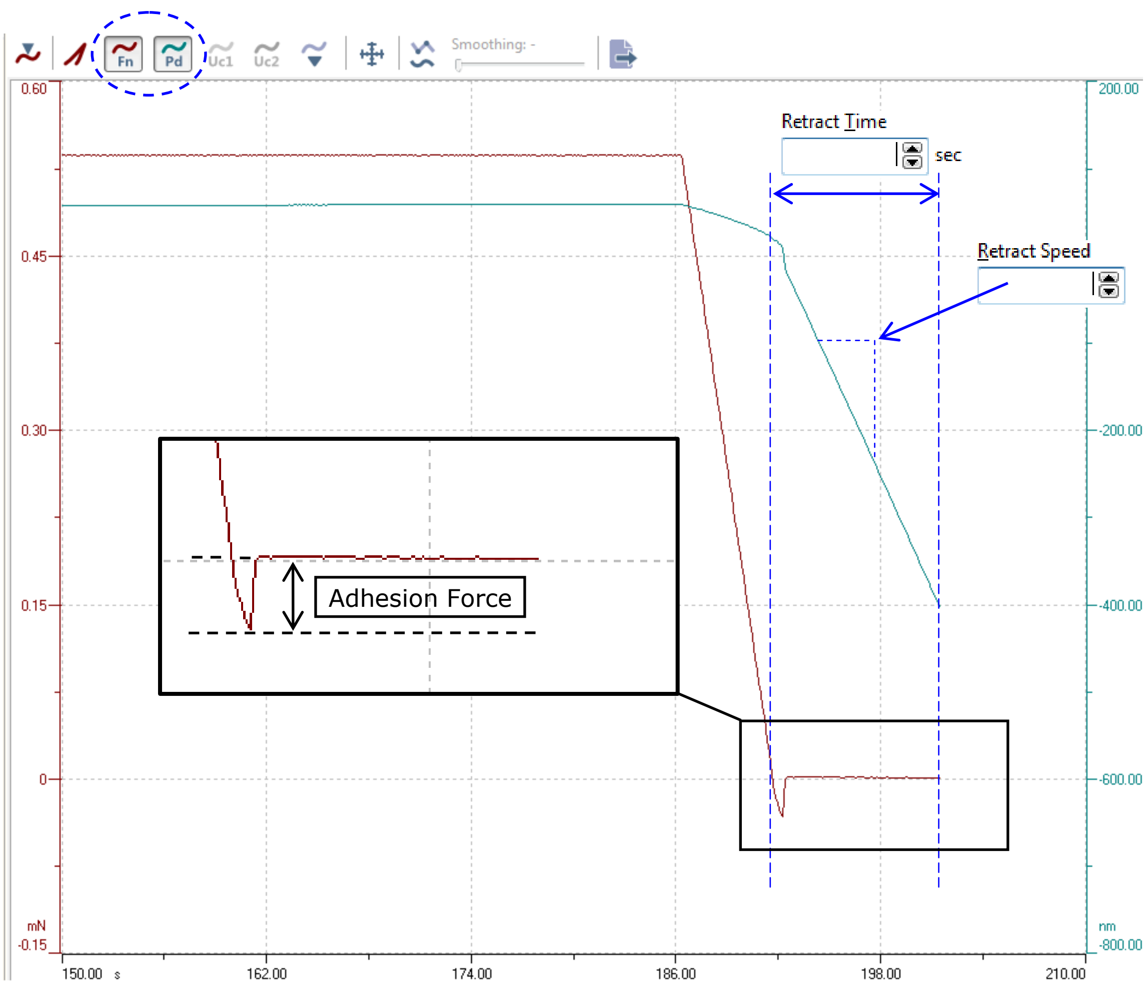
(unit selected in options)



Retract speed and ***Retract Time*** values can be changed for each new measurement in *Preferences* window and tab; see from *chap. 4.6.5, p. 111*.

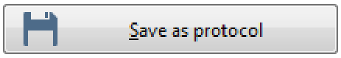
The value of these parameters allows studying the adhesion between the indenter and the sample.

Both parameters manage the unloading during the adhesion phenomenon.



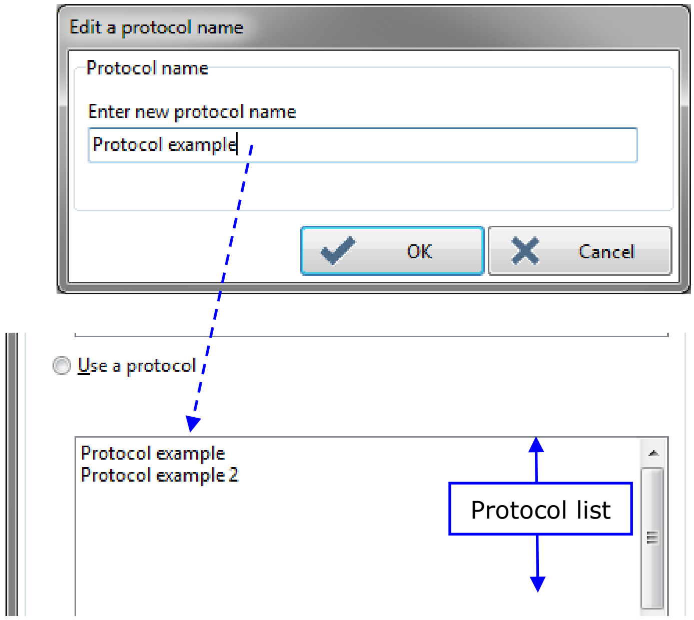
See *chap. 5.5, p. 149* to obtain the Adhesion Force.

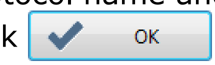
4.6.6 Save as protocol (current measurement type setting)



Located at the left bottom of each measurement type window (see from ***chap. 4.6.4, p. 81***)

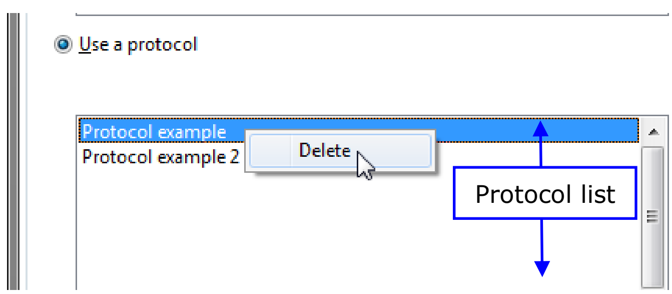
To save the current setting of all parameters as a measurement protocol (including preference parameters ***chap. 4.6.5, p. 111***).



Edit (type) a new protocol name and click 

to save the protocol.

Each saved protocol will appear in the protocol list of the *Define a new measurement* window *Fig.34 p. 77* and can be selected later.



To erase a protocol, only from the list of the *Define a new measurement* window *Fig.34, p. 77*, right click on a protocol and select ***Delete*** in the context menu.

4.7 MEASUREMENT PROCESS (INDENTATION RUNNING)

Once the measurement starts, the window below displays the real-time status, indenter progression bars and the acquisition curves.

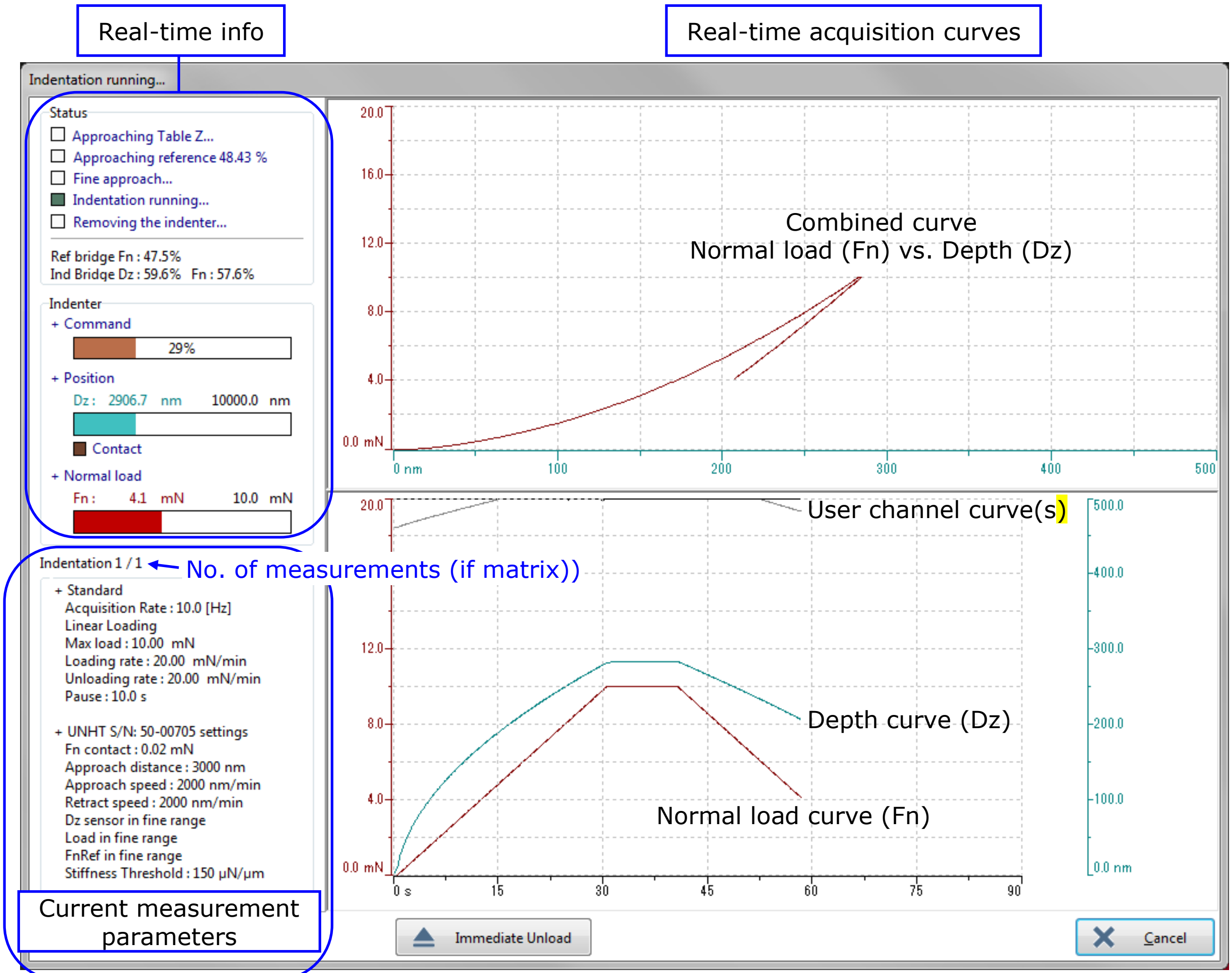


Fig.58 Indentation running… window

It is recommended not to use any other software whilst acquisition is in progress, as this may interrupt the scheduler and cause discontinuities in the acquisition process. Ensure that no screen saver or other time consuming applications could start during the acquisition process.

There are 5 real-time action blinking squares in the *Status* area:

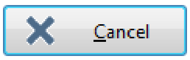
- Approaching Table Z... / Approaching Table Z... (inactive with TTX-NHT)
- Approaching reference 48.43 % / Approaching reference (active with UNHT)
- Approaching with the indenter... / Approaching Indenter / Stabilization 30 [s]
- Indentation running...
- Removing the indenter...

Stabilization

Before the indentation starts (Indentation running...), Stabilization 30 [s] is blinking and displays a decreasing time info (e.g. starts from 30 [s]); the stabilization time is set in ***chap. 3.1.4.2 Stabilization (cancel drift), p. 26***.

As soon as the stabilization time is elapsed 0 [s], the indentation measurement starts.

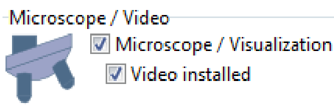
To unload the current measurement applied force and start the next measurement (if matrix).



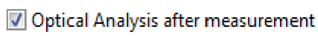
To stop all measurement(s) (if matrix), the indenter/motorized Z table are immediately retracted.

With UNHT and UNHT Bio, the extra *UNHT Approach Monitor* window *Fig.28, p. 52* can be displayed or deactivated with the UNHT.INI file; see ***chap. 3.5, p. 51***.

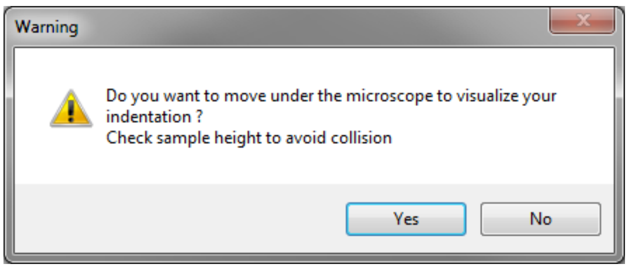
4.8 ANALYZING/VISUALIZING INDENTATION(S)



This chapter is applicable if the instrument is equipped with the video microscope and if these boxes are checked; refers to the ***Common Scratch & Indentation software manual - chap. Managing the instrument - Hardware configuration - My configuration tab***.



With **UNHT Bio**, check this box if an optical analysis is needed (spherical indenter does not let mark on very soft material).



At the end of the indentation measurement process: when the *Indentation running…* window *Fig.58, p. 122* closes, this *Warning* window appears.

Click [Yes] to open,

the *Video* window *Fig.60, p. 126* and *Analyze indentation* window *Fig.59 below*, in order to (if necessary):

- Refine the indenter-microscope distance calibration.
- Analyze/visualize the indentation measurement(s) and capture image(s).

Or click [No] and go to ***chap. 5, p. 130***.

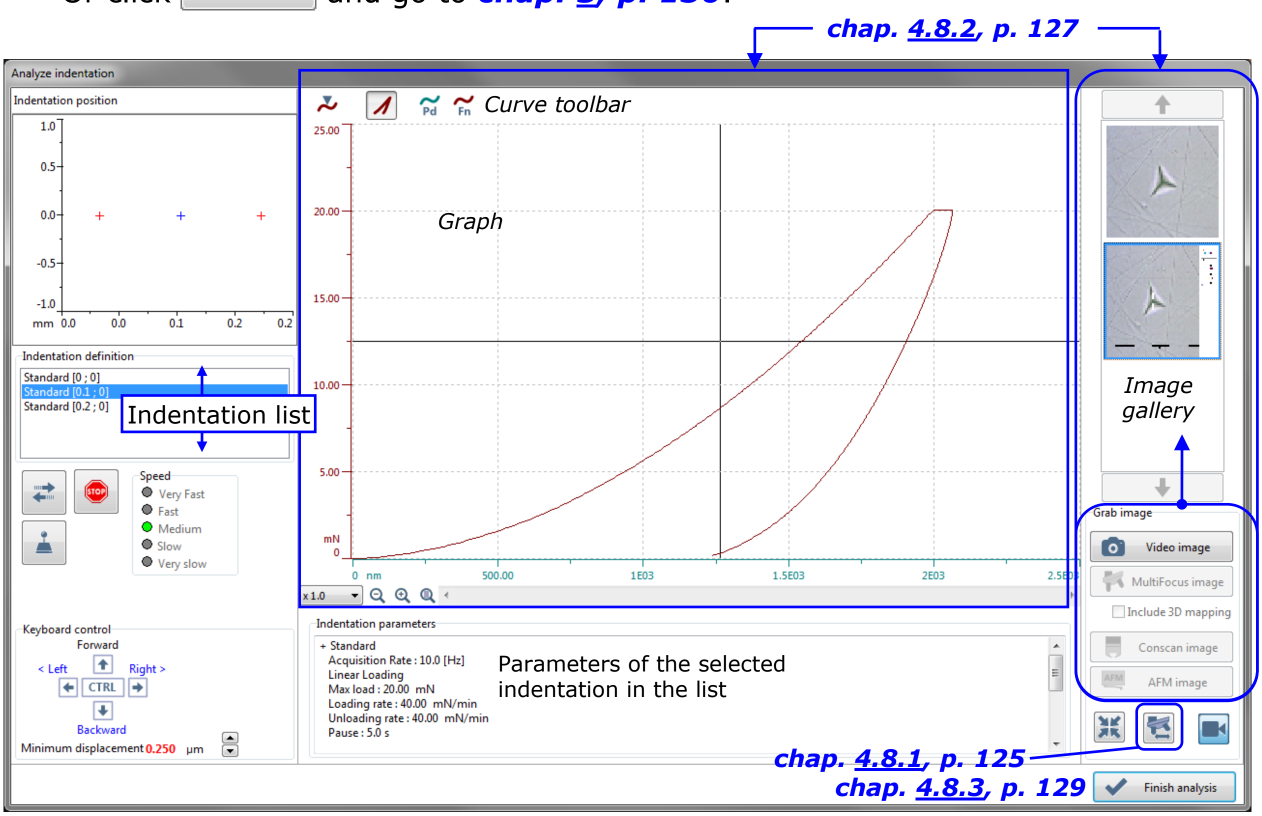
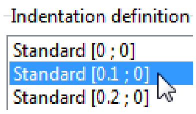


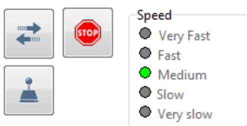
Fig.59 Analyze indentation window

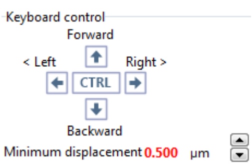
To reopen the *Video* widow.



Selecting an indentation

E.g. if a matrix of measurements has been performed, select an indentation in the list to automatically move to the corresponding area.





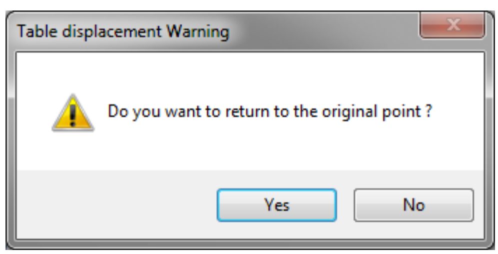
Methods to move for adjustment

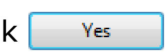
Use these functions to adjust the sample position; refer to the ***Common Scratch & Indentation software manual - chap. Managing the instrument - Control of the sample position*** (some described functions are not available here).

The displacement area is limited in the zone of the selected indentation in the list.

Original indentation position

To move back to the original position (of the selected indentation in the list).



Click  to confirm.

4.8.1 Refining indenter-microscope distance calibration

It is possible to refine the calibration of the distance between the indenter and the video microscope from this *Analyze indentation window* *Fig.59, p. 124*, and also using the *Video* window *Fig.60, p. 126*.

In case of a matrix, select any of the indentation in the list (chose only one); see ***Selecting an indentation above***.

Centering

Using the ***Methods to move for adjustment above***, precisely center the chosen indentation imprint under the *Video* screen crosshair *Fig.60 below*.

Be sure the imprint corresponds to the selected indentation in the list.

To have the crosshair in the middle of the *Video* screen, check ☑ Crosshair in the *Video* window; see ***Video software manual*** for all features description.

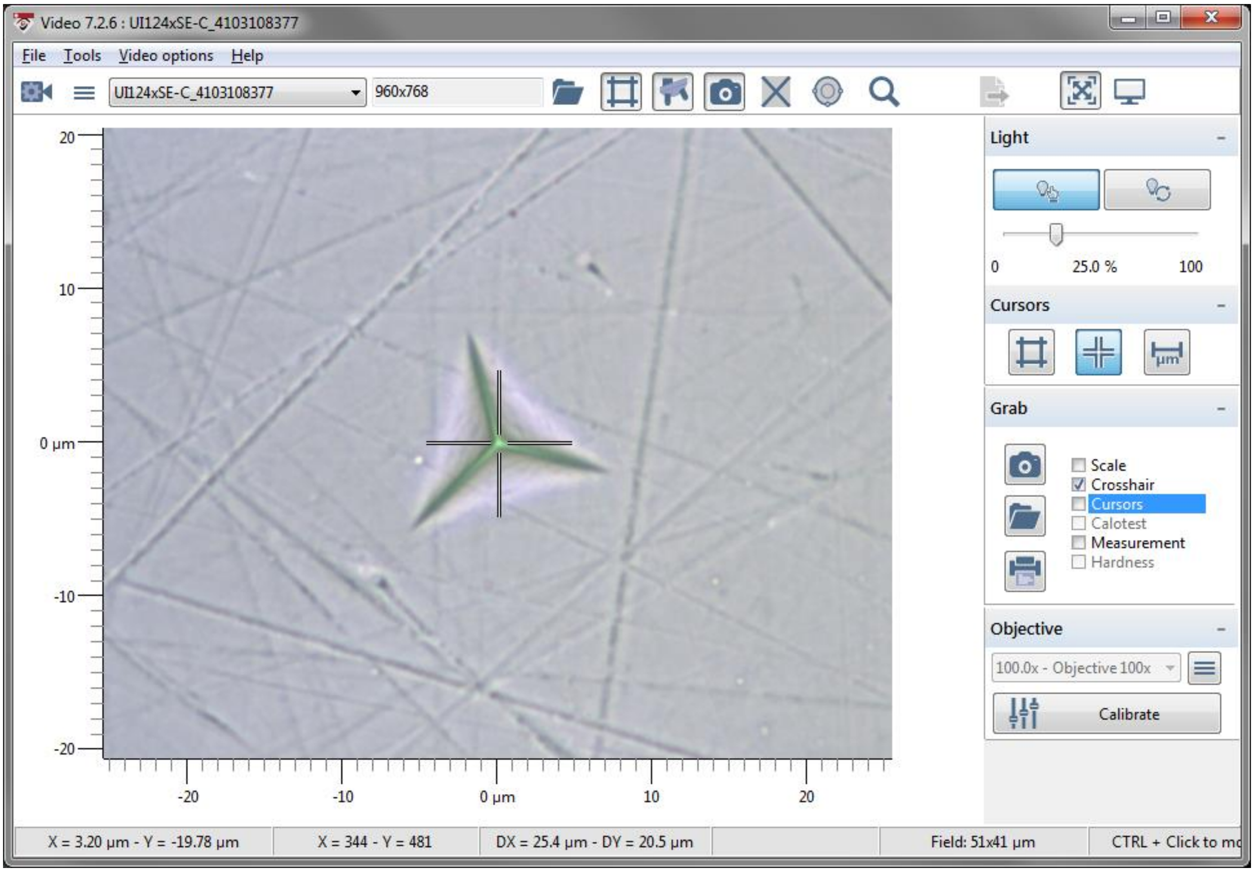
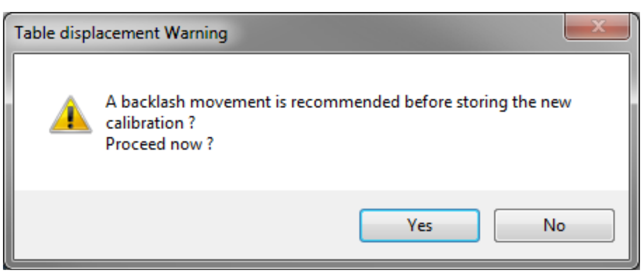
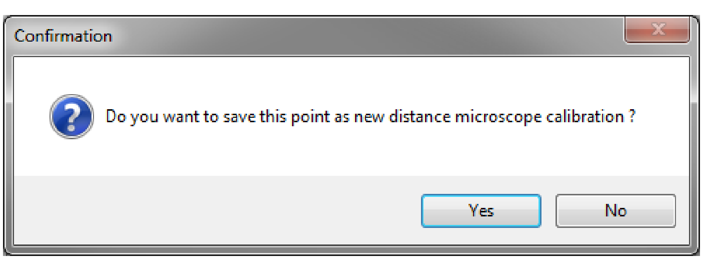


Fig.60 Indentation imprint centered under Video screen crosshair

To refine the calibration of the distance between the indenter and the video microscope, only when the indentation imprint is centered *Fig.60 above*.



It is recommended to click Yes in order the software performs a backlash movement before storing the new calibration; wait.



Click Yes to save the new calibration of the X/Y distances between the indenter and microscope in the *Calibration* window; *Fig.15, p. 30*.

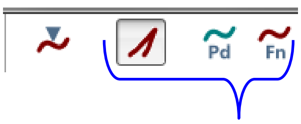
Otherwise click No and restart from ***Centering, p. 125*** until the imprint is centered.

4.8.2 Optical analysis (includes setting contact point)

Standard images and depending on the configuration/settings, Multifocus images can be captured from the *Video* screen. Depending on the available options/settings, AFM or conscan confocal images can also be captured.

One by one, for each selected measurement in the list; see ***Selecting an indentation, p. 125***, the features below can be used:

Contact point



See ***chap. 5.1.2 Indentation curve display, p. 137***.

Curve toolbar

If necessary, the contact point can be refined from here. Otherwise it can be refined later during the result analysis; see the similar explanations as described from ***chap. 5.1.1.1 Contact point features, p. 133***.

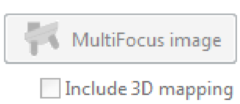
Grab image(s)

Each of the following active buttons from this *Analyze indentation window Fig.59, p. 124* allows image capture(s) from the current *Video* screen *Fig.60, p. 126*: *Edit an image* window appears *Fig.61, p. 128*.

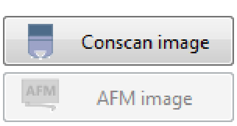
Before capturing image(s) below, ensure the focus is adjusted (with Z motorized table, see ***Methods to move for adjustment, p. 125*** with TTX-UNHT use the thumbwheels).

To capture image(s) from the live *Video* screen,

(standard) images.



Multifocus image only if the instrument is equipped with a motorized Z table. Otherwise the button is inactive (grayed out); see ***MultiFocus image(s), p. 128***.



To capture images from the conscan and/or AFM, if the corresponding options are available; otherwise the buttons are inactive (grayed out).

This window below allows some settings on the opened image (Title name, comments, image features…); refer to the ***Common Scratch & Indentation software manual - Manipulating document windows - Managing images gallery - Managing picture***.

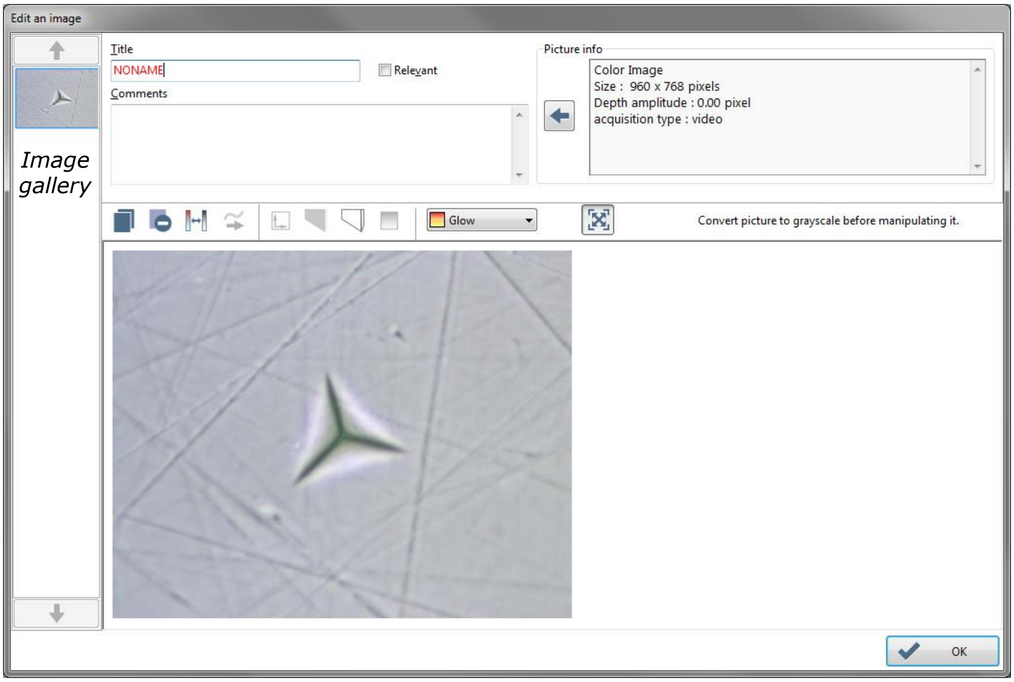
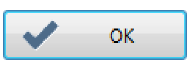
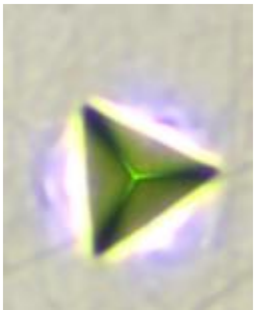


Fig.61 Edit an image

When  is clicked, each image is stored (as thumbnails) in the image gallery of *Fig.61 above* but also of the *Analyze indentation window* *Fig.59, p. 124*; in each image gallery, double click on a thumbnail to (re)open the corresponding image (if there are more than 3 thumbnails, use  /  to see the previous or following thumbnails in the gallery).

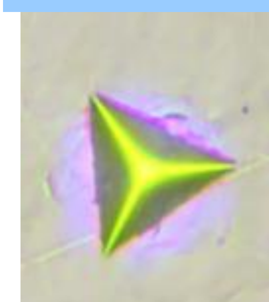
MultiFocus image(s)

A Multifocus image is an image build with an infinite depth of field. We use the motorized Z table to capture several images of the same indentation at different focus plan (different heights), and after computing all sharpness regions the software rebuilds one single image with an infinite depth of field, called Multifocus image.

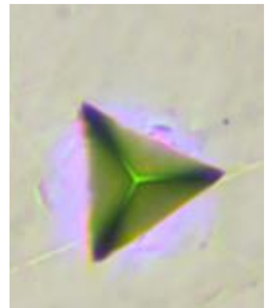


Lower focus

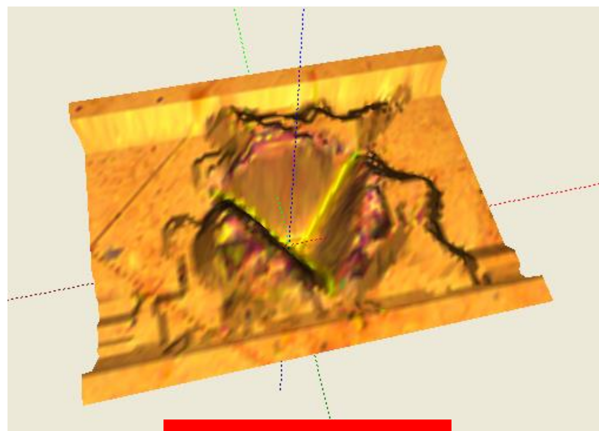
Middle focus



Surface focus

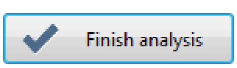


Multifocus image

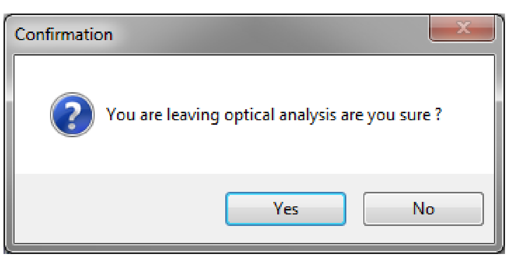


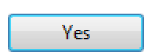
3D mapping

4.8.3 ENDING THE OPTICAL ANALYSIS



To end the optical analysis.



Click 

to close the *Analyze indentation window* [*Fig.59*, p. 124],

 it will **not** possible to come back.

5 RESULT ANALYSIS

After the measurement process of the indentation(s) is completed, the main result analysis window appears *Fig.62 below*.

Adjustments (analysis method, curve display, contact point, overlays…) and parameter changes (indenter, Poisson's ration…) can be performed from this window. After most of the parameter changes, an automatic recalculation of the analysis result is performed by the software.

By default, the curve view is selected on the main toolbar.

For the main toolbar and ; refer to the ***Common Scratch & Indentation software manual - chap. Understanding documents - Document window - Customizing curve view display areas***.

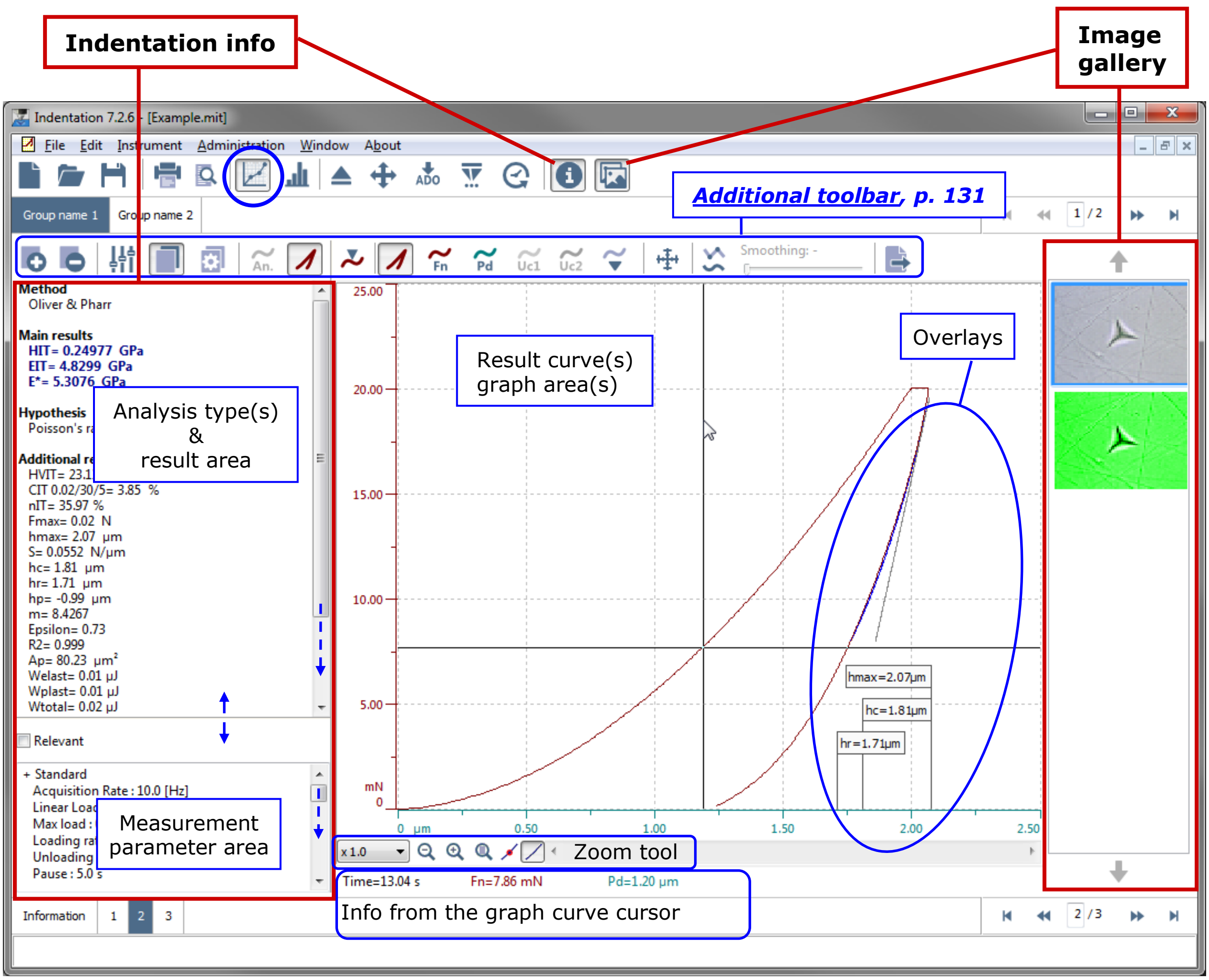
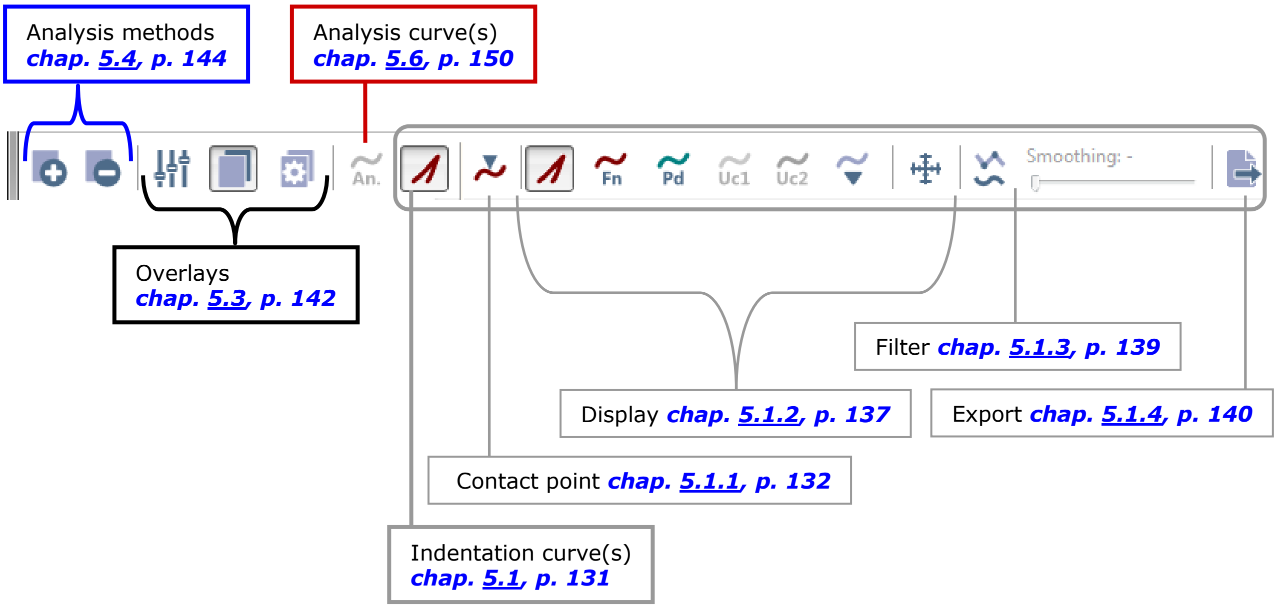


Fig.62 Result analysis window (curve view default setting)

Additional toolbar



5.1 Indentation curve(s)

For each active measurement

 The **indentation curve** icon in the additional toolbar shows (selected):

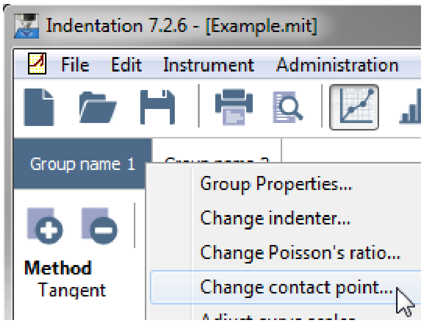
- The displayed indentation curve(s) ***chap. 5.1.2, p. 137***
- The indentation curve features:

  Contact point(s) ***chap. 5.1.1, p. 132***
  Filter ***chap. 5.1.3, p. 139***
  Export ***chap. 5.1.4, p. 140***

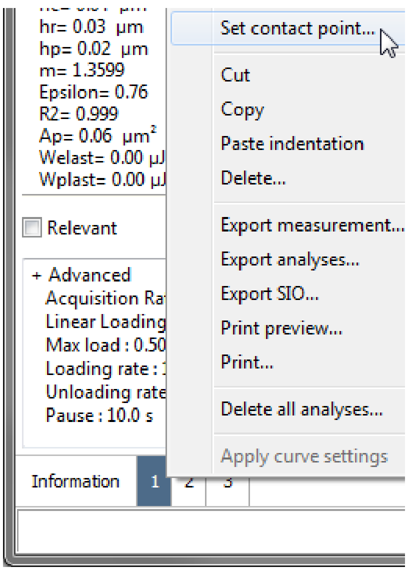
The indentation curve(s) and features can be hidden (if unselected).Only if the analysis curve(s) is active and selected  ***chap. 5.6, p. 150***.

5.1.1 SETTING THE CONTACT POINT

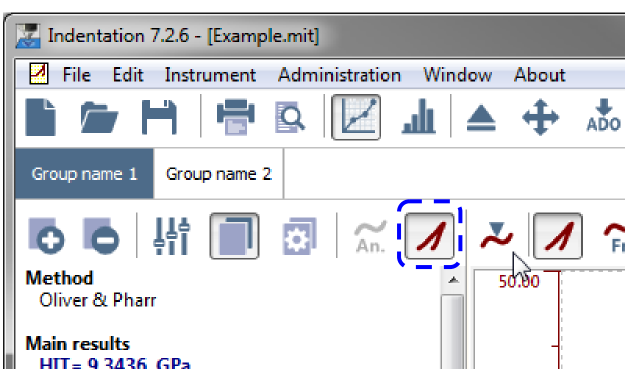
From the result analysis window *Fig.62, p. 130*, there are several ways to open the *Set the contact point* window *Fig.63, p. 133*, which allows to verify, refine (change) the contact point for each available measurement of each desired active group:



- For the active **"*group name*"** tab, select ***Edit/Group ▸/Change contact point...*** from the menu bar.
- Right click on the desired **"*group name*"** tab and select ***Change contact point...*** from the context menu.



- For the active **"*measurement #*"** tab Select ***Edit/Indentation ▸/ Set contact point...*** from the menu bar (only the contact point for this measurement will be opened).
- Right click any **"*measurement #*"** tab and select ***Set contact point...*** from the context menu.



- For the active **"*group name*"** tab, click  on the additional toolbar.

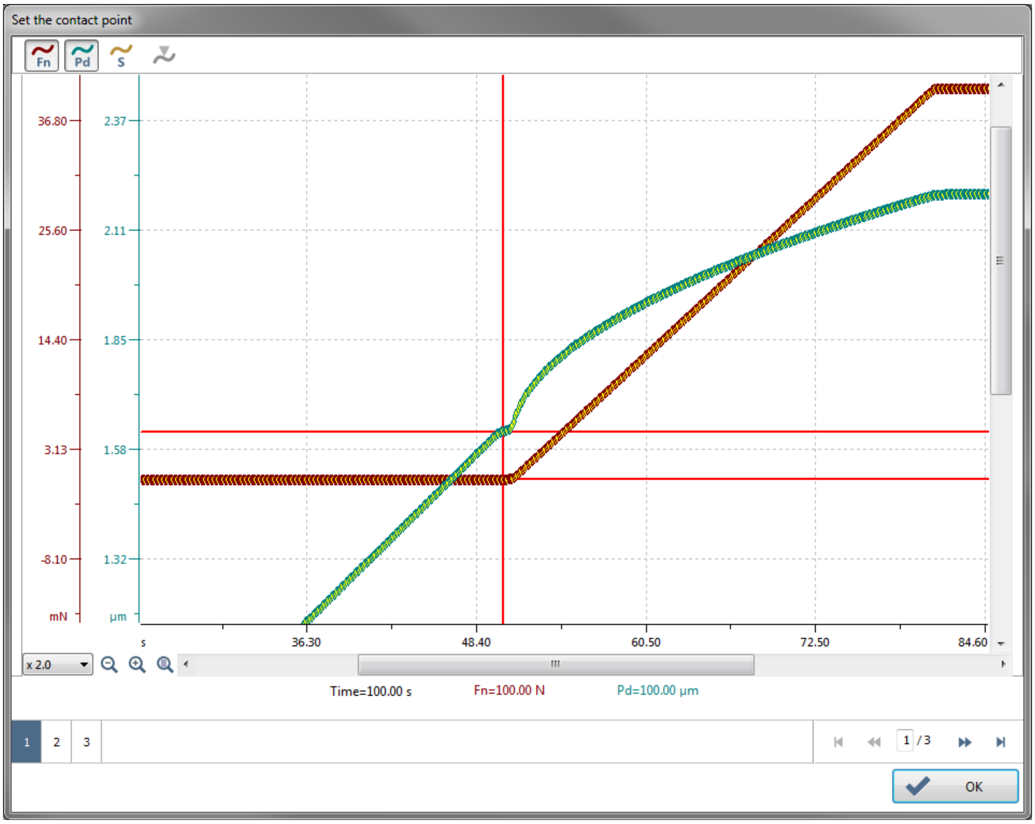
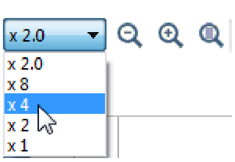
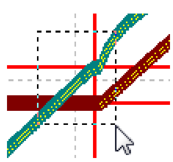


Fig.63 Set the contact point window (default settings)

5.1.1.1 Contact point features

<u>For the active (selected) measurement</u>





The zoom tools and cursor information are available; refer to the similar explanations as described in the ***Common Scratch & Indentation software manual - chapters Understanding documents - Features on graph area(s) - Zoom*** and ***- Cursor information***.

To display/hide the following indentation curve(s) in/from the graph:

depth **h** vs. time

and/or

force **F** vs. time

By default they are both displayed Pd Fn, which is advised.

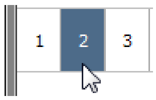
To use the contact point automatically detected by the software.

By default after the measurement process, the contact point for each available measurement is automatically detected (grayed out).

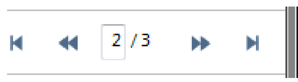
See ***chap. 5.1.1.2 <u>Verifying/refining the contact point</u>, p. 135***.

Selecting another measurement

To verify or refine (change) the contact point of the other available indentation measurements (if available), directly from this window:



- Click on the ***"measurement #"*** tab



- Use the tab selector
- Press the following:
    - ***"Ctrl"*** + ***"left arrow"*** (same as ◀◀)
    - ***"Ctrl"*** + ***"right arrow"*** (same as ▶▶)

Refer to the similar explanations described in the ***Common Scratch & Indentation software manual - chap. Manipulating document windows - Using tabs - Selecting a measurement***.

5.1.1.2 Verifying/refining the contact point

The contact point is automatically detected (as shown in the window below) with a **"slope" rupture** of the **h** (indentation depth Pd) and **F** (indentation force Fn) curves (depends on the material, speed, indenter).

The contact point is defined where the vertical X red graph cursor is located.

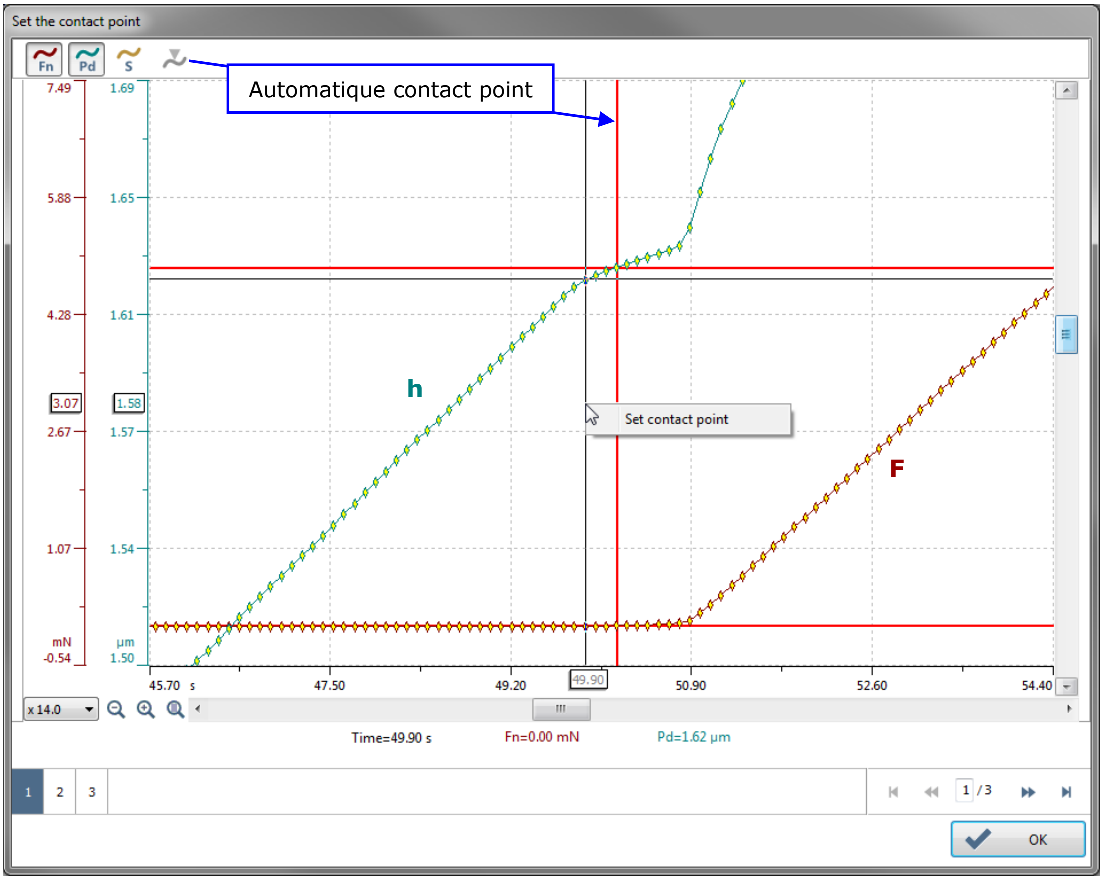
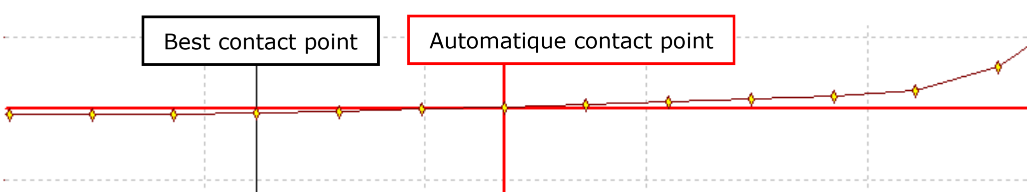


Fig.64 Automatic contact point will be manually refined

The best contact point is the first break point in the approach slope of the **h** depth curve, and is the first point with a no zero force of the **F** force curve. Therefore it is necessary to zoom to this zone; see the previous ***Contact point features*, p. 133**.

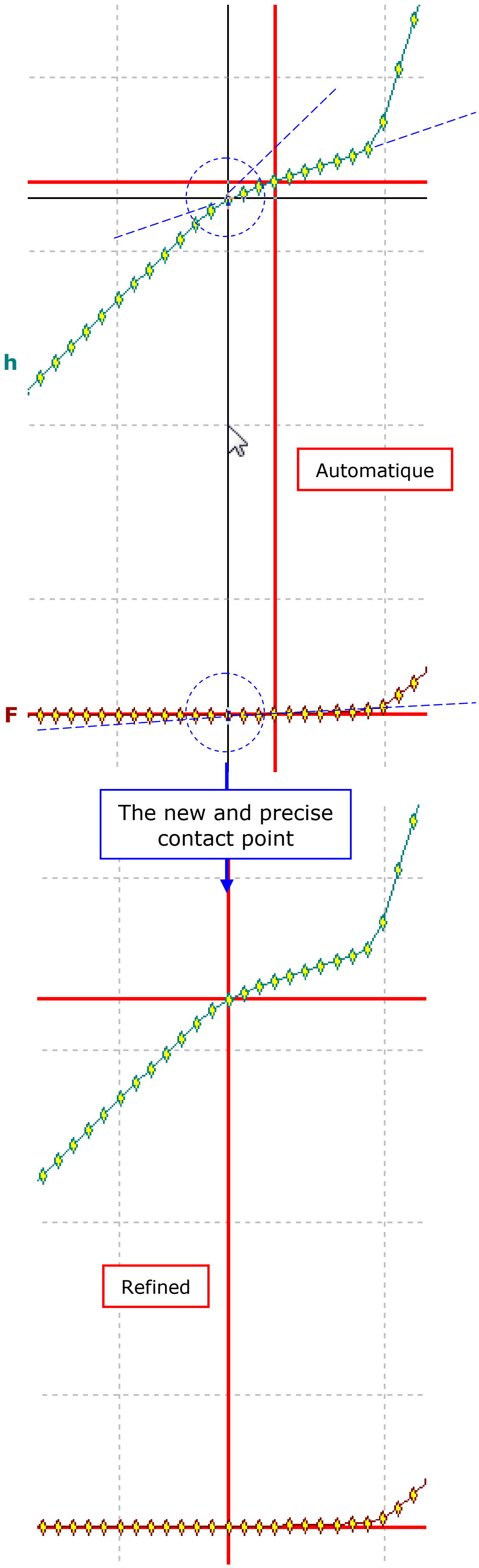
For high load measurement, it is difficult to see the change in the **F** curve,



Large zoom (e.g. 90x) on F curve

therefore it is better using the **h** curve to refine the contact point.

To manually refine (change) the current contact point, see the following descriptions.



<u>To manually set the contact point</u>

Place the vertical black cursor (X scale) on the graph where:

h curve starts to peak
F curve starts to rise,
and at this specific location:

- Double click

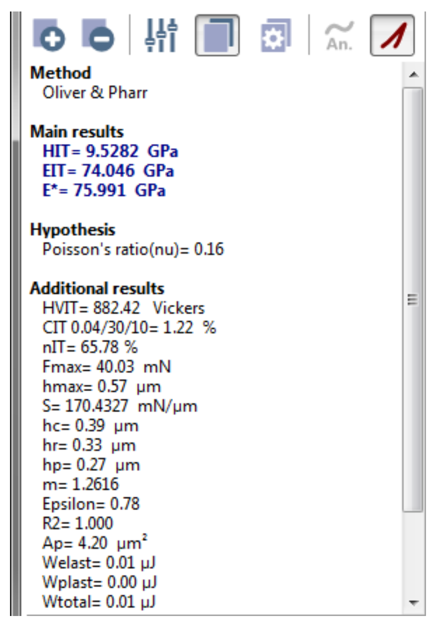
OR

- Right click and select ***Set contact point*** from the context menu.

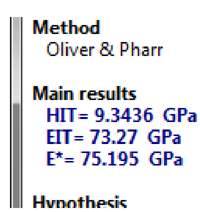
becomes (again) active in the window *Fig.64, p. 135*:

If necessary, click  to automatically re-define the contact point.

When the contact point changes (different location), the related ***Main*** and ***Additional results*** are recalculated in the analysis result area:



Automatic

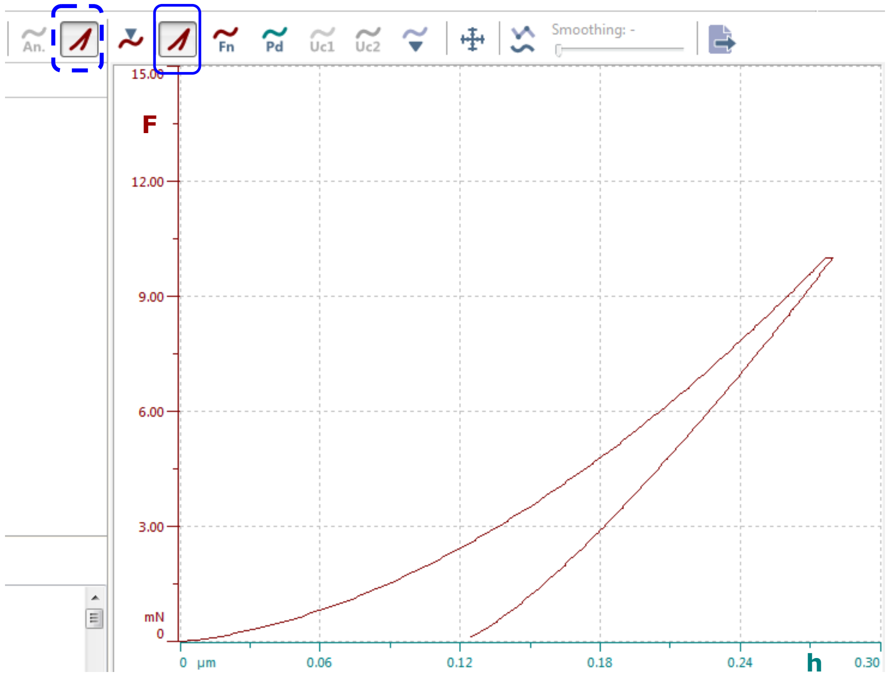


...

Refined

5.1.2 INDENTATION CURVE DISPLAY

To display (by default) the force **F** vs. depth **h** combined curve.



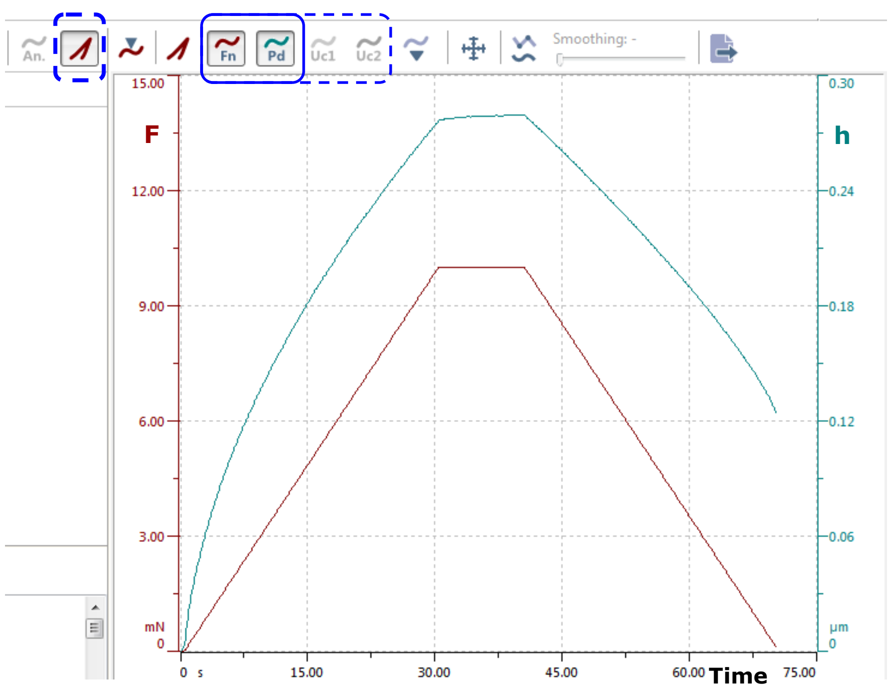
OR

To display/hide the following curve(s):

Force **F** vs. time

and/or

Depth **h** vs. time

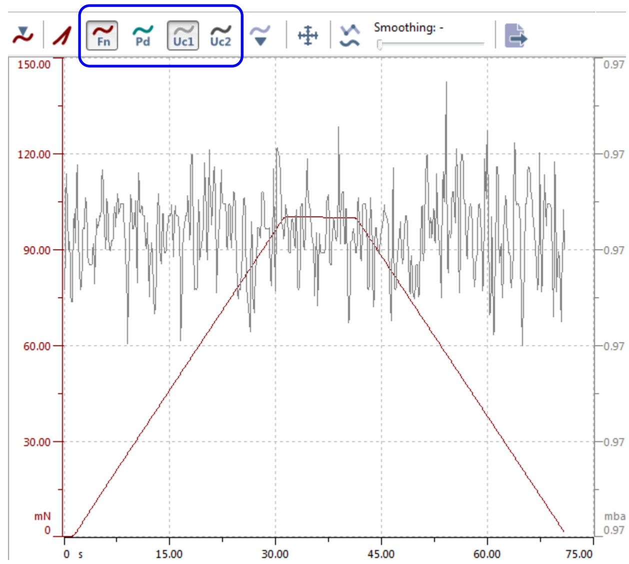


and/or ...

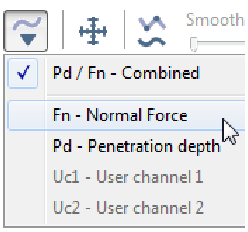
...

User channel 1
and/or
User channel 2,

if activated
and set prior to the
measurement(s).

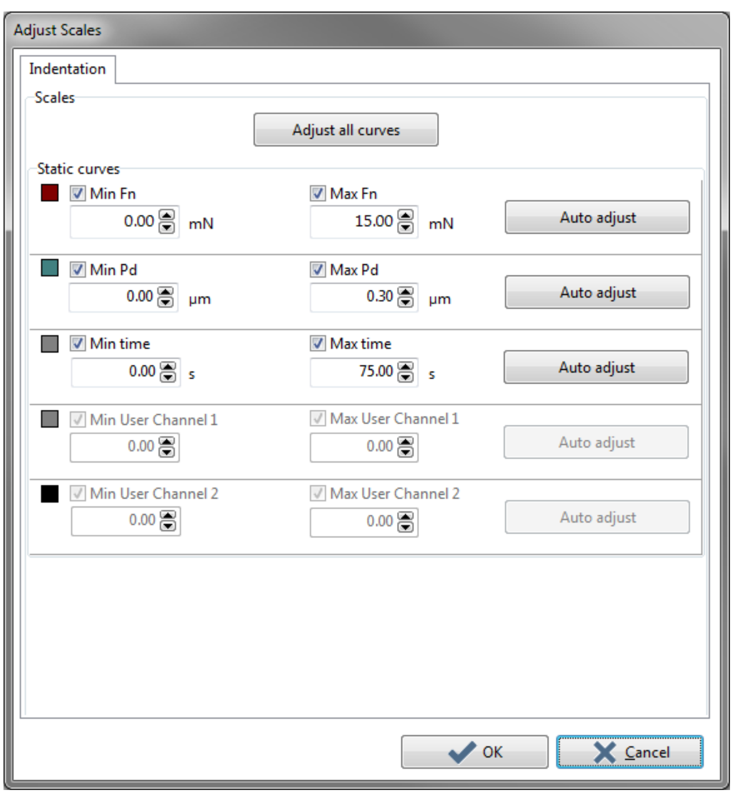


To also display/hide the previous described curves on/from the graph.



The context menu allows a quick selection (overview) of the curves.

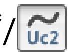
To adjust the graph scale(s) for the displayed indentation curve(s).

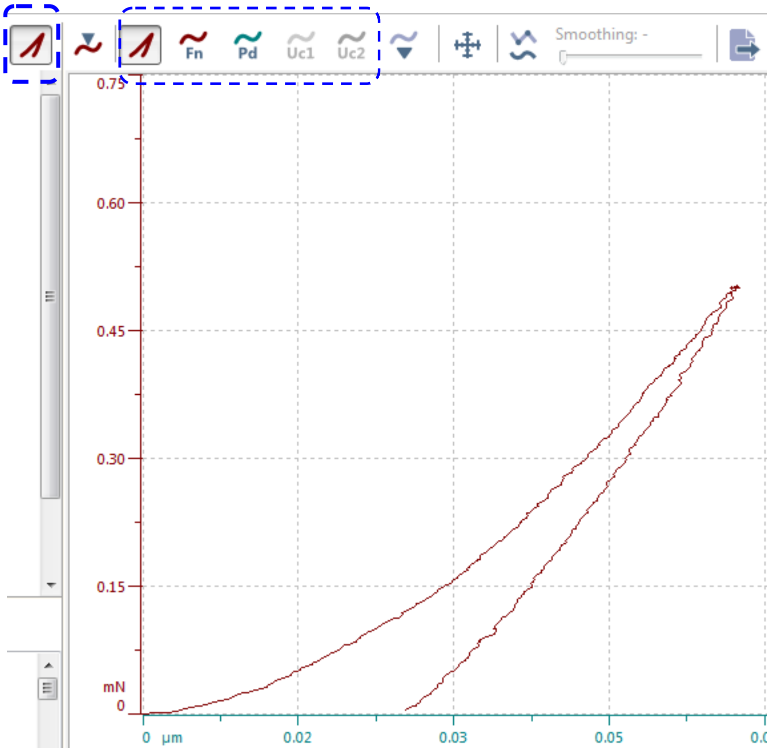


Also select ***Edit/Document ▸/ Adjust curves scales*** from the menu bar to open this window.

For the detailed description of this window, refer to the ***Common Scratch & Indentation software manual - chap. Manipulating document windows - Adapting curve ranges***.

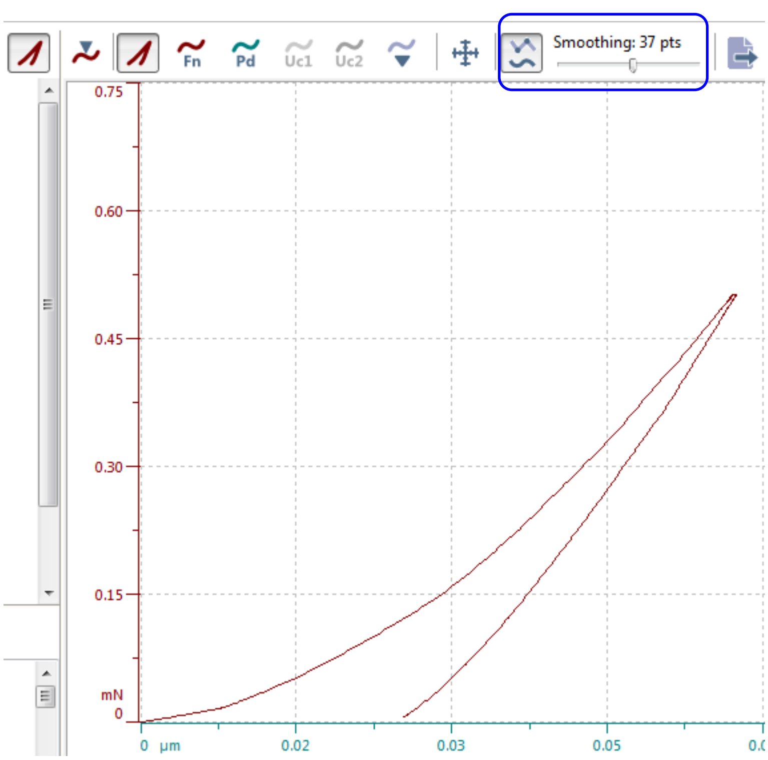
5.1.3 FILTERING THE INDENTATION CURVE(S)

This feature is applicable with any indentation displayed curve(s)  **or** //  *￼/ * on the graph; see ***chap. 5.1.2, p. 137***. *if activated

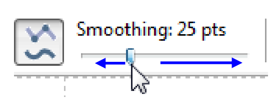


E.g. there is noise on the displayed combined curve.

 To activate the *Smoothing* (filter) slider on the additional toolbar.



With the mouse cursor,

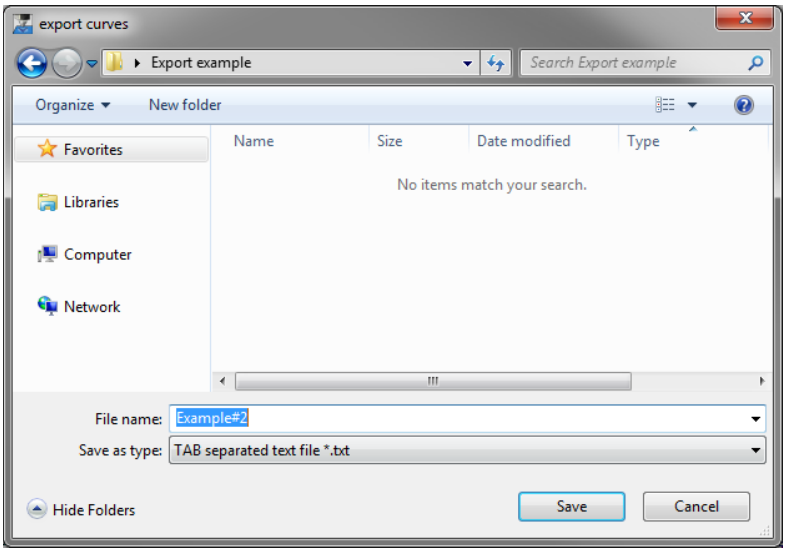


move the slider to select a filter size (sliding average) which is applied on the displayed curve(s).

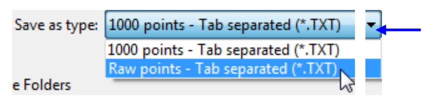
5.1.4 EXPORTING ALL INDENTATION CURVES

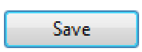
 To export **all** indentation curves.

This window allows:

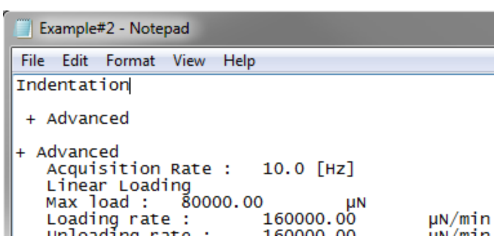


- Choosing a location where to save the export text file.
- Modification of the default ***File name***: corresponding to the measurement file name with current measurement #.
- Changing of the default 1000 points[1)] .TXT file format.



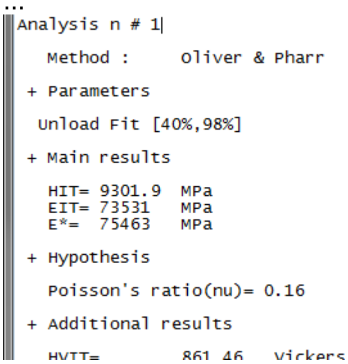
Then click .

In the saved text file, there are from top to bottom:



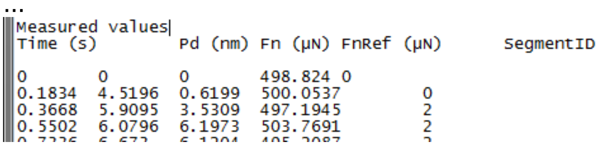
- The indentation measurement type and its parameters.

...



- All current analysis number(s) and their results.

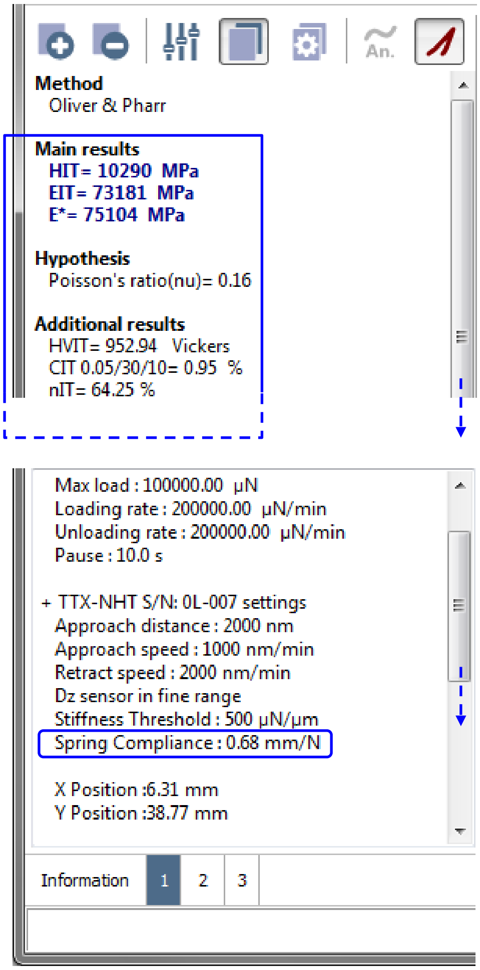
...



- [1)] The point values for each curve: 1000 points (resampling) or raw points (measured points) selected above when exporting.

5.2 NHT SPRING COMPLIANCE

This chapter is only applicable for **NHT**.

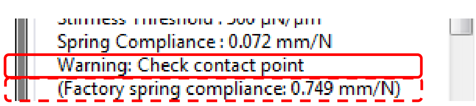


The spring compliance value is taken to calculate the ***Main*** and ***Additional*** results.

This spring compliance value is computed by the software: it uses the Fn curve zone (approach) just before the contact point.

If the contact point is changed ***chap. 5.1.1 Setting the contact point, p. 132***, the value is recomputed and the results recalculated.

Warning



If the difference between the computed value (described above) and the factory[1)] value is larger than 20 %, the message "*Warning: Check contact point*" appears in the measurement parameter area. Therefore check the contact point ***chap. 5.1.1 Setting the contact point, p. 132***.

The additional *message "(Factory spring compliance: value*[1)]*)*" is also displayed in the measurement area.

[1)] factory value was set in the ***Factory spring compliance*** field of the NHT **"*Ranges*"** tab *Fig.4, p. 17* (hardware configuration); see from ***chap. 3.1.3, p. 15***.

5.3 OVERLAY PROPERTIES (INDENTATION COMBINED CURVE)

The surrounded icons on the additional toolbar below are only applicable with the *Oliver & Pharr*, *Tangent* and *Hertz* analysis methods; see ***chap. 5.4, p. 144***, and with the indentation combined curve  displayed on the graph; see ***chap. 5.1, p. 131***.

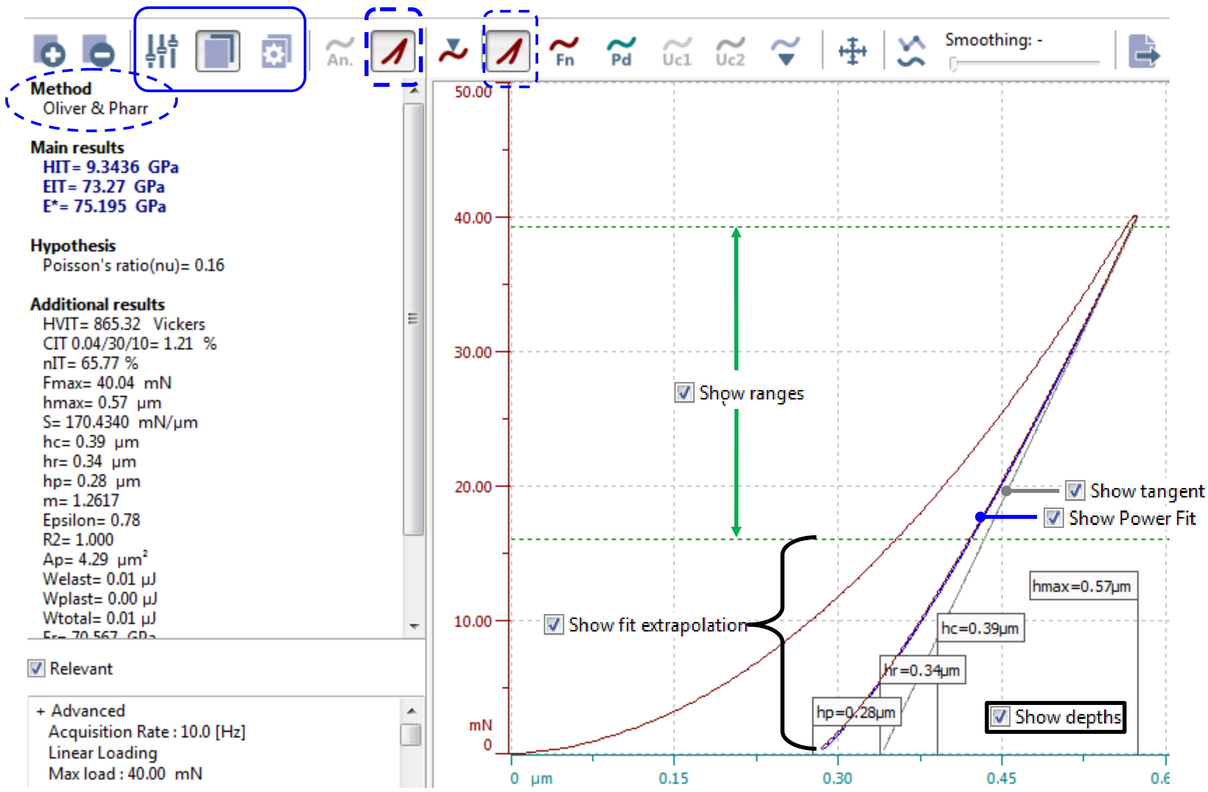
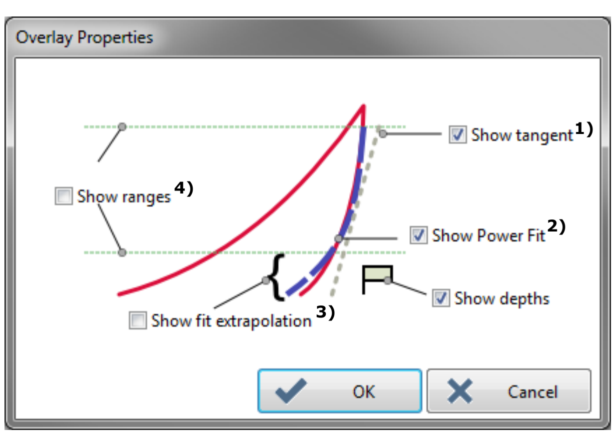


Fig.65 E.g. all overlay properties are displayed

<u>Display</u>

 To display or hide on/from the graph the overlay properties which are selected below.

 To select the overlay properties which should be shown.



Default setting, see *Fig.62, p. 130*

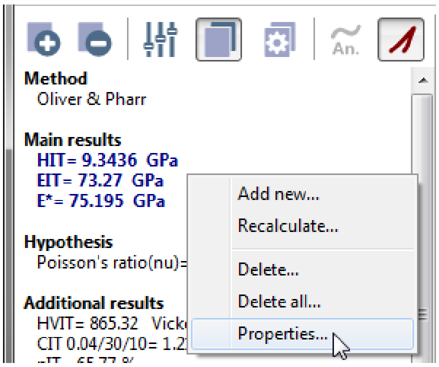
Check each overlay property box which should be displayed (uncheck to hide).

1) linear
2) power law
3) in addition tangent is extended
4) upper and lower bounds for the fit and tangent; see ***Set range, p. 143***

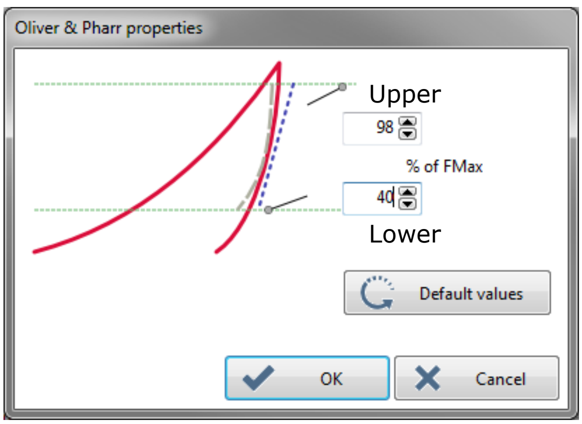
Set range

To set the upper/lower bounds for the fit and the tangent (not for *Hertz*) of the current analysis (e.g. *Oliver & Pharr*):

- Click this icon on the additional toolbar.



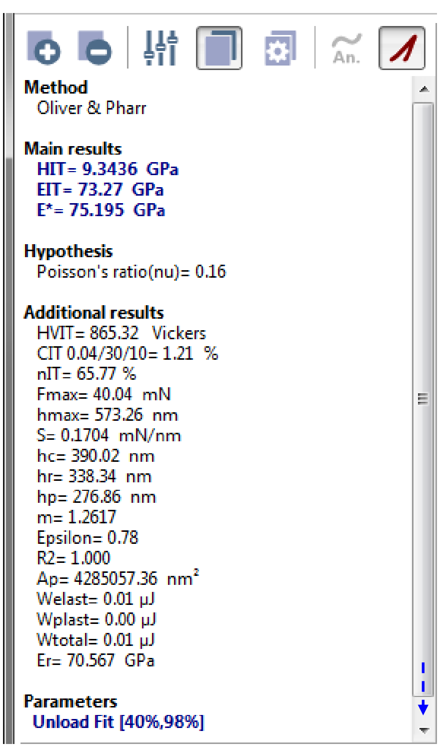
- Right click in the analysis result area and select ***Properties...*** from the context menu.



Set a percentage of Fmax to define the upper **and/or** lower bounds for the unload fit (*Oliver & Pharr* and *Tangent* analyses) or for the load fit (*Hertz* analysis).

Default analysis values:

Oliver & Pharr	98 % and 40 %
Tangent	95 % and 70 %
Hertz	98 % and 10 %



With new value(s) set above,

the ***Main*** and ***Additional results*** are recalculated in the analysis result area.

If necessary, scroll down in the result analysis area to display the current upper and lower bounds values (Unload fit or Load fit for *Hertz* analysis) under ***Parameters*** section.

5.4 Managing the analysis methods

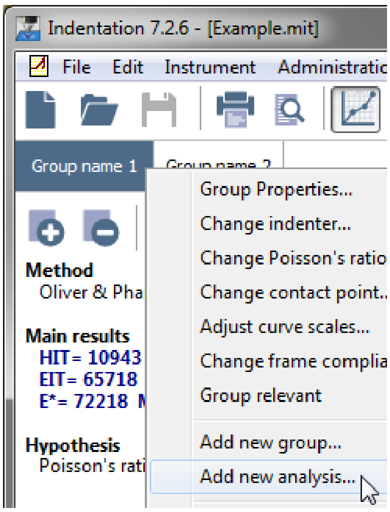
5.4.1 Adding (manually) analysis method(s)

From the results, to manually add new analysis method(s) for each:

Active document (all measurements of its groups)

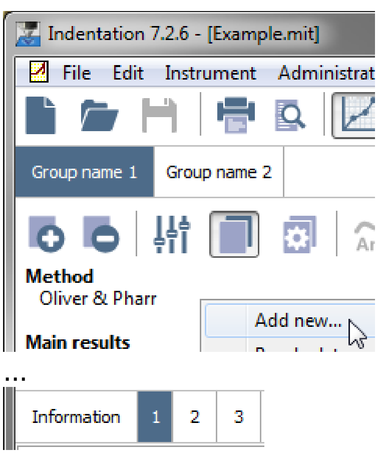
- Select ***Edit/Document ▸/Add new analysis…*** from the menu bar.

Active group (all its measurements)



- Select ***Edit/Group ▸/Add new analysis…*** from the menu bar.
- Right click on the ***"group name"*** tab and select ***Add new analysis…*** from the context menu.

Active measurement



- Select ***Edit/Analysis ▸/Add new…*** from the menu bar.
- Click on the additional toolbar.
- Right click in the analysis result area and select ***Add new…*** from the context menu.

See the following *Create a new analysis* window *Fig.66, p. 145*.

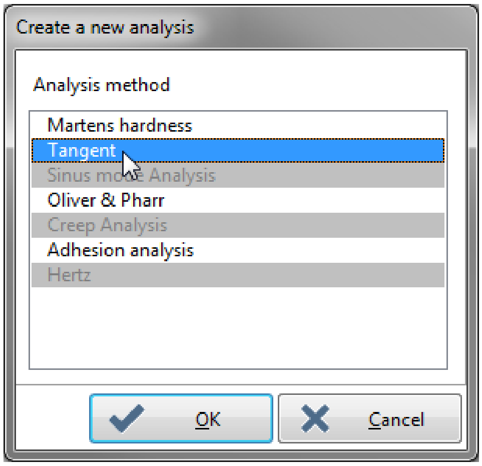
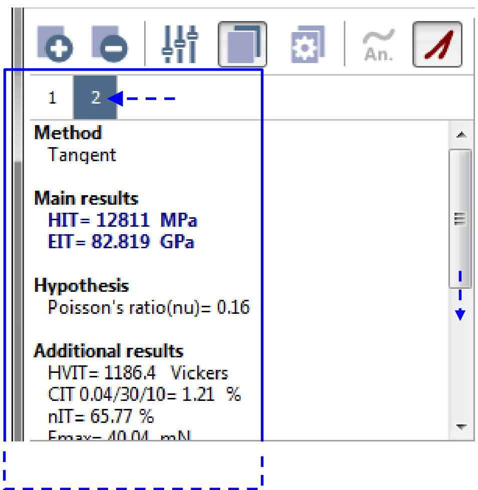


Fig.66 Create a new analysis window

Select (double click) the desired analysis method, e.g. Tangent.



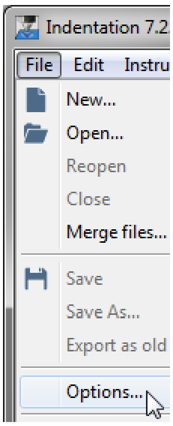
If there is already more than one analysis, a new analysis method **"#"** tab (e.g. **"2"**) appears and calculates the ***Main results*** and ***Additional results*** for this new (current) analysis method;

see each detailed analysis method results from ***chap. 5.5, p. 149*** to ***chap. 5.9, p. 158***.

5.4.2 AUTOMATIC ANALYSIS METHOD(S)

It is possible to automatically add several analysis methods at the end of the measurement process for each measurement.

The following setting should be done before starting the measurement(s).



Select ***File/Options...*** from the menu bar.

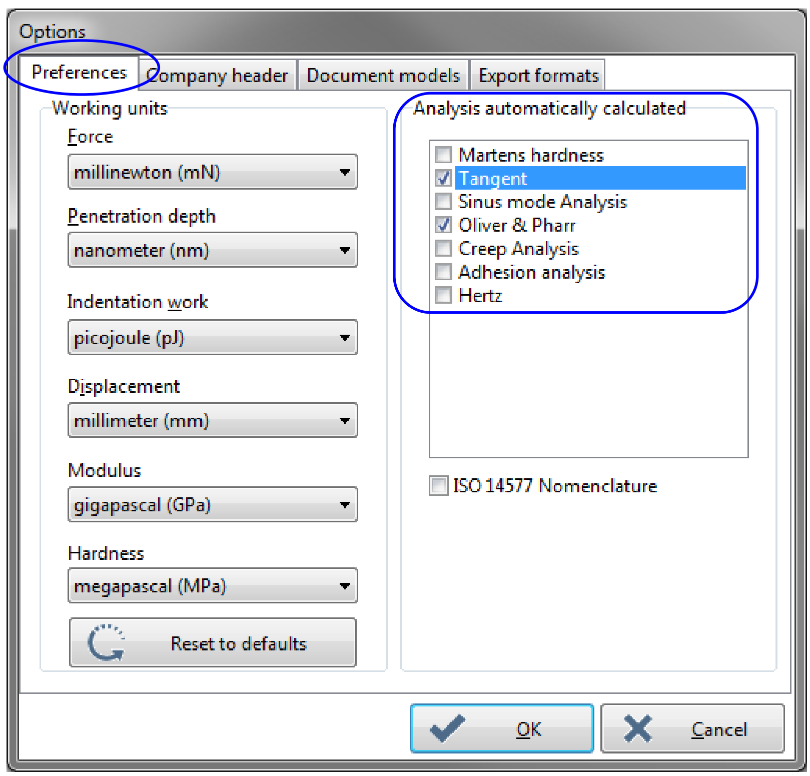
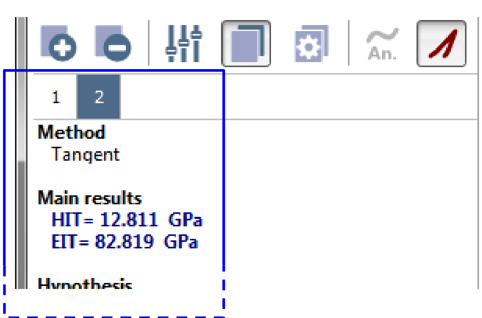


Fig.67 Preferences tab in Options window

In the *Analysis automatically calculated* area, check each desired analysis method box which should be automatically calculated after each measurement.



E.g. **"1"** tab *Oliver & Pharr* and active **"2"** tab *Tangent* analysis methods are automatically created in the analysis result area after the measurement(s);

see each detailed analysis method results/curves from ***chap. 5.5, p. 149*** to ***chap. 5.9, p. 158***.

5.4.3 DELETING ANALYSIS METHOD(S)

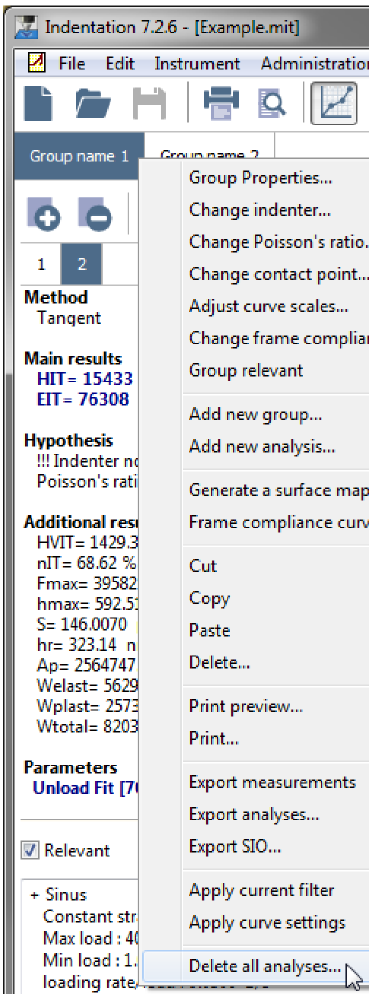
Delete all methods

To delete **all** the analysis methods for each:

Active document (all measurements of its groups)

- Select ***Edit/Document ▸/Delete all analyses…*** from the menu bar.

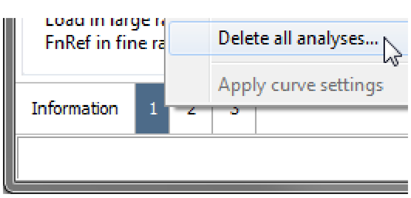
Active group (all its measurements)



- Select ***Edit/Group ▸/Delete all analyses…*** from the menu bar.
- Right click on the ***"group name"*** tab and select ***Delete all analyses…*** from the context menu.

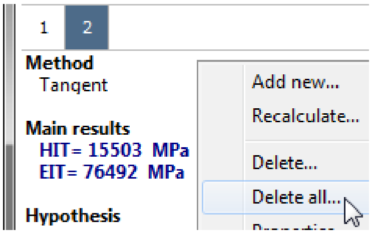
Active measurement

- Select ***Edit/Indentation ▸/Delete all analyses…*** from the menu bar.



- Right click on the ***"group name"*** tab and select ***Delete all analyses…*** from the context menu.

Active analysis method

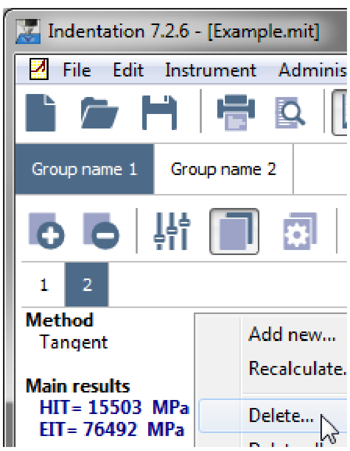


- Right click on the ***"analysis method #"*** tab **or** on the analysis result area and select ***Delete all...*** from the context menu.

A *Warning* window appears, Click Yes to confirm the selected deletions or click No to keep them.

Delete the active method

To delete the active analysis method:



- Select ***Edit/Analysis ▸/Delete...*** from the menu bar.

- Click  on the additional toolbar.

- Right click on the ***"analysis method #"*** tab **or** on the analysis result area and select ***Delete...*** from the context menu.

A *Warning* window appears. Click Yes to confirm the active method deletion or click No to keep them.

5.5 Adhesion analysis method & results

See also ***chap.4.6.5.10 Retract speed & time parameters for Adhesion, p. 120*** (measurement preference parameters).

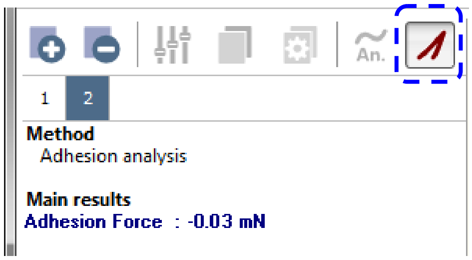
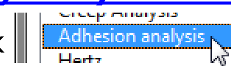
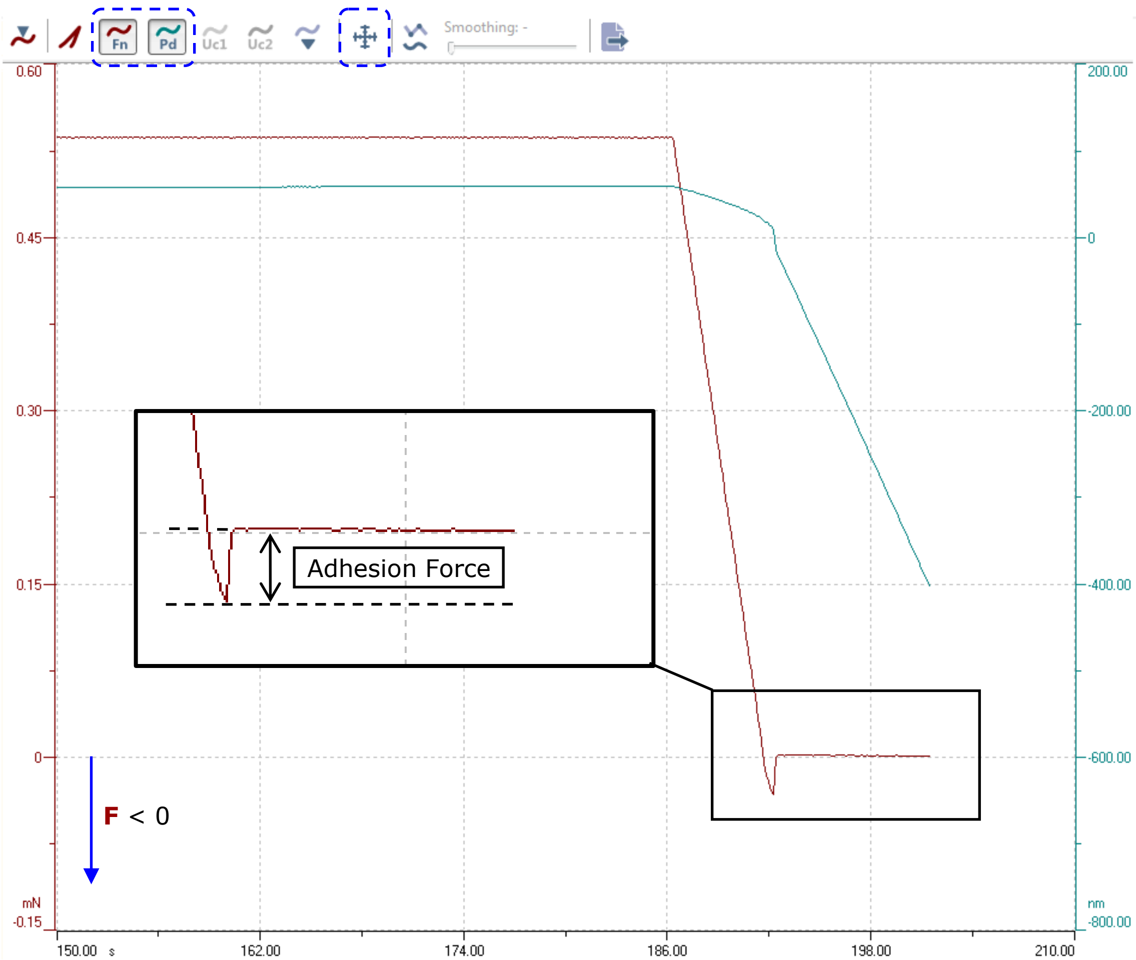


Fig.68 Adhesion Force of current measurement is displayed

After a measurement(s), to manually create an adhesion analysis, see ***chap. 5.4.1 Adding (manually) analysis method(s), p. 144*** and double click 

Otherwise before a measurement(s), see ***chap. 5.4.2 Automatic analysis method(s), p. 146***, this 

box was checked.



Click  on the additional toolbar and adjust the ***Min Fn*** scale (Fn<0); refer to the ***Common Scratch & Indentation software manual - chap. Manipulating document windows - Adapting curve ranges***.

5.6 ANALYSIS CURVE(S)

For each active measurement

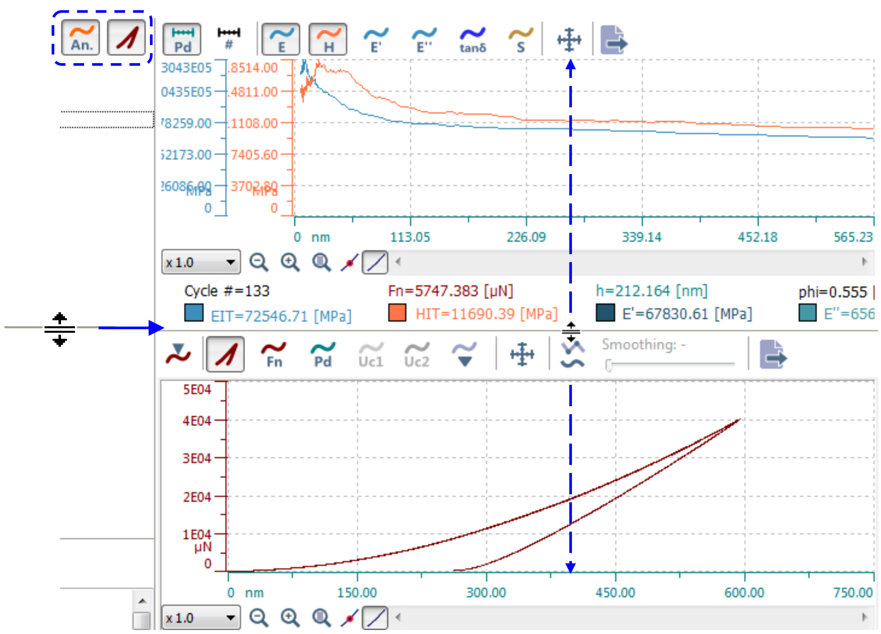
This icon is active on the additional toolbar only with:

- *Martens hardness* analysis method
- *Sinus mode Analysis* method (only with a *Sinus* measurement)
- *Oliver & Pharr* analysis method only with a *Progressive multicycle* or a *CMC* measurement type.

To show/hide:

- The displayed **analysis curve(s)**.
- The analysis curve features: depth or cycle mode, scale adjustment(s), export.

See the following chapters for descriptions of the related icons.



Analysis and **indentation** curves ***chap. 5.1, p. 131*** can be displayed on the same time. In that case, each analysis curve is displayed on the **upper** graph and each indentation curve is displayed in the **lower** graph. The height size of the graphs can be adjusted by moving up/down the cursor between the 2 graph areas

5.6.1 ANALYSIS CURVE DISPLAY

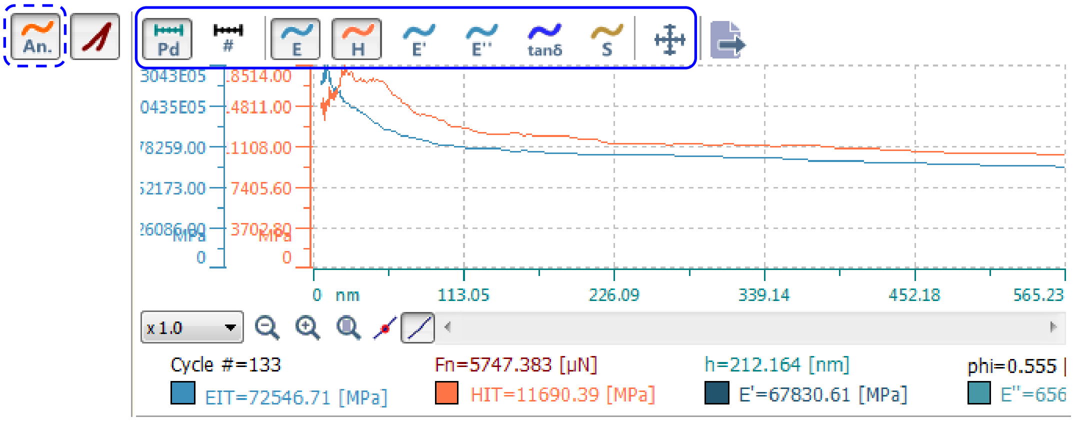


Fig.69 Displayed analysis curves on the graph

With *Martens* analysis method, only ✥ is available below.

To switch between the 2 modes below (X axis scale):

Pd — Depth mode; curves are displayed as a function of penetration depth (default)

OR

— Cycle mode; curves are displayed as a function of the cycle numbers.

E — To display (by default)/hide the elasticity curve.

H — To display (by default)/hide the hardness curve.

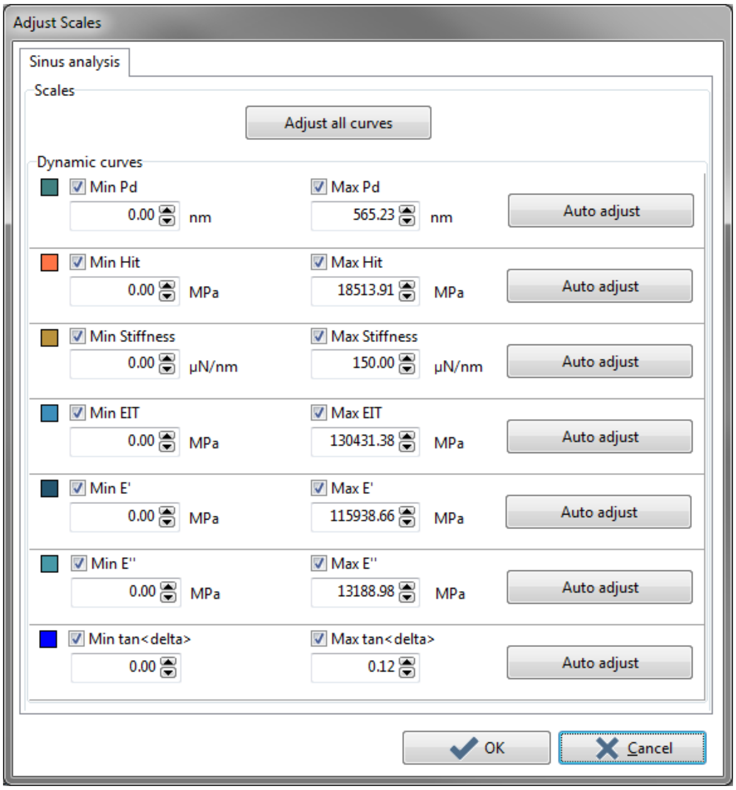
E' — To display/hide the storage modulus curve.

E'' — To display/hide the loss modulus curve.

tanδ — To display the tangent curve.

S — To display the stiffness curve.

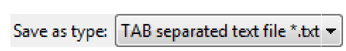
✥ — To adjust the graph scale(s) for the displayed analysis curve(s); see the following window.



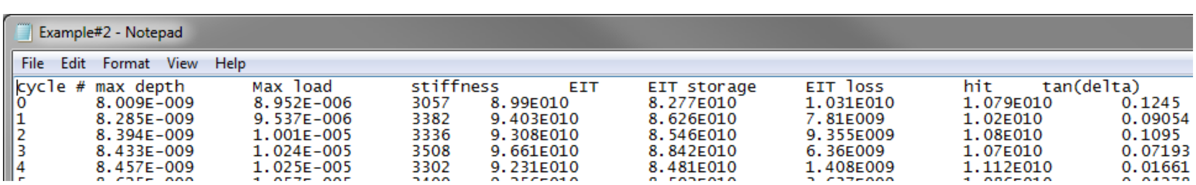
For the detailed description of this window, refer to the ***Common Scratch & Indentation software manual - chap. Manipulating document windows - Adapting curve ranges***.

5.6.2 EXPORTING ALL ANALYSIS CURVES

To export **all** analysis curves, even if they are hidden from the graph; refer to the similar explanations as described in ***chap. 5.1.4 Exporting all indentation curves, p. 140***, **exceptions:**

- Type a ***File name***:
- There is only one .TXT file format available  (raw).

- The saved text file contains only the points for each curve (raw: measured points).

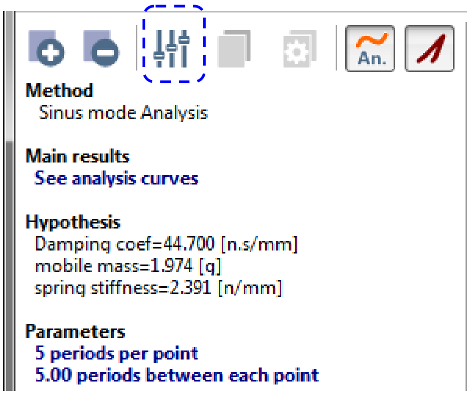


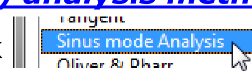
cycle #	max depth	Max load	stiffness	EIT	EIT storage	EIT loss	hit	tan(delta)
0	8.009E-009	8.952E-006	3057	8.99E010	8.277E010	1.031E010	1.079E010	0.1245
1	8.285E-009	9.537E-006	3382	9.403E010	8.626E010	7.81E009	1.02E010	0.09054
2	8.394E-009	1.001E-005	3336	9.308E010	8.546E010	9.355E009	1.08E010	0.1095
3	8.433E-009	1.024E-005	3508	9.661E010	8.842E010	6.36E009	1.07E010	0.07193
4	8.457E-009	1.025E-005	3302	9.231E010	8.481E010	1.408E009	1.112E010	0.01661

5.7 Dynamic analyses

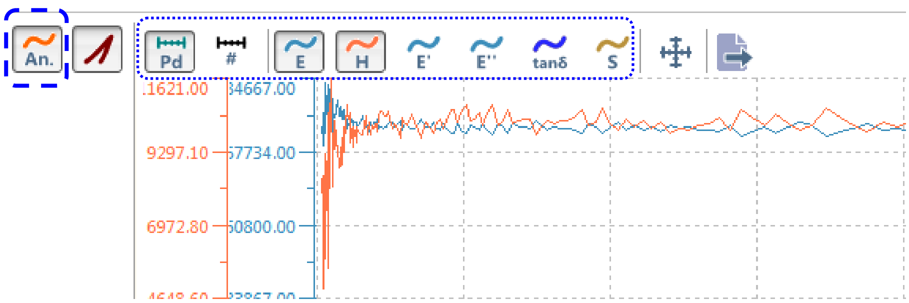
See also ***chap. 5.6 Analysis curve(s), p. 150***.

5.7.1 Sinus mode analysis method & curve results

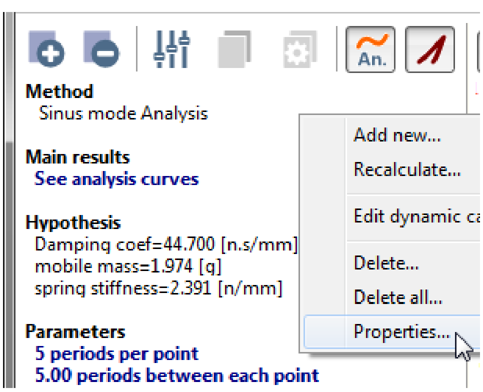


After a sinus measurement(s), to manually create a dynamic sinus analysis, see ***chap. 5.4.1 Adding (manually) analysis method(s), p. 144*** and double click 

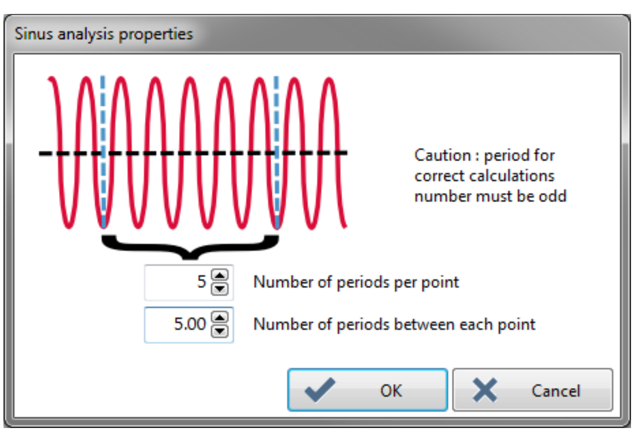
Otherwise, before a measurement(s), see ***chap. 5.4.2 Automatic analysis method(s), p. 146***, this box  was checked.



The ***Main results*** are the curves themselves.

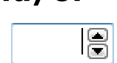


To filter **and/or** to display more points for the displayed sinus analysis curve(s), click on the additional toolbar **or** right click on the analysis result area and select ***Properties...***



To set the following number of periods, ⚠ with odd numbers:

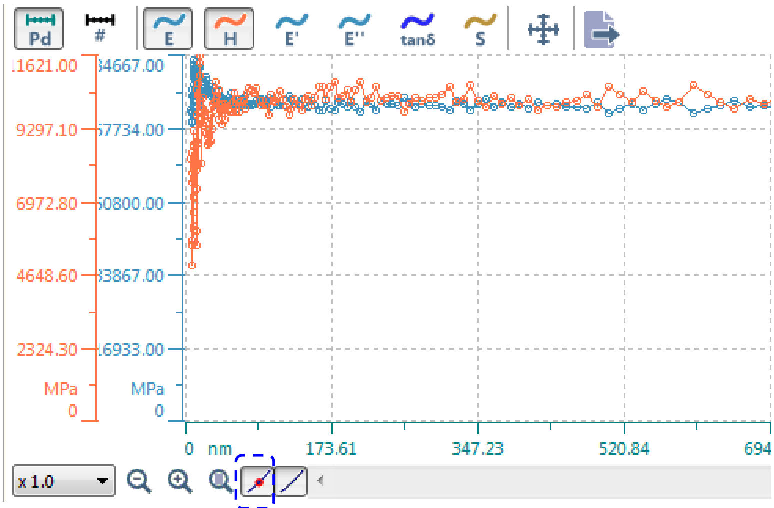
and/or



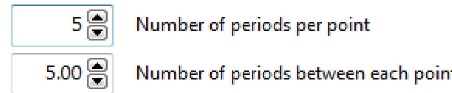
See the following parameter effects on the analysis displayed curves(s) only.

Number of periods per point: number of sinus periods used to compute each point of the displayed analysis curve(s).

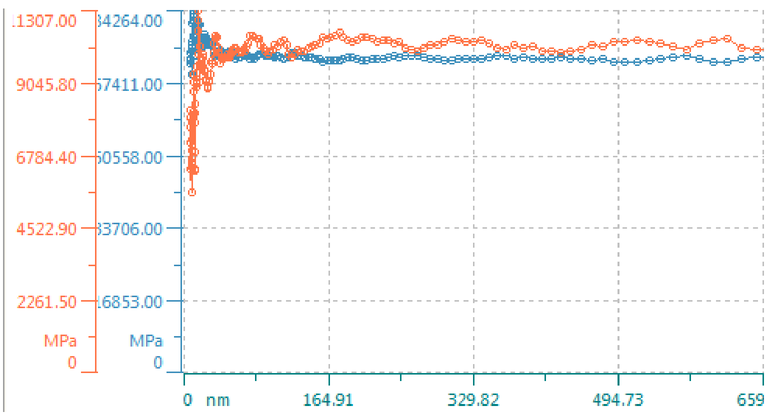
Number of periods between each point: spacing (in period) between the computed points (2 consecutive) of the displayed analysis curve(s).



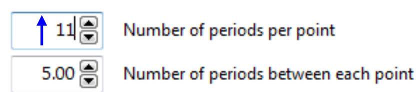
With both default values = 5

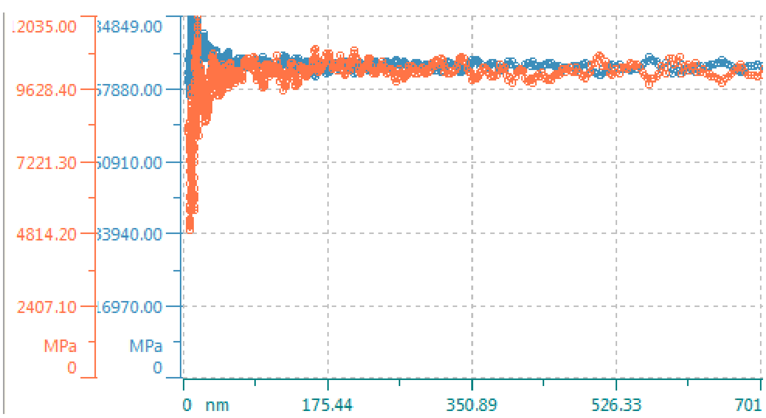


and with the curve points displayed for a better understanding; see the ***Common Scratch & Indentation software manual - chap. Understanding documents - Features on graph areas - Show curve acquisition points***.

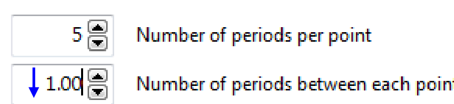


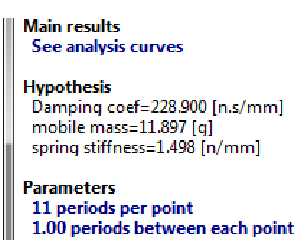
If the *Number of periods* ***per point*** value is increased, e.g. 11, each displayed curve is filtered.





If the *Number of periods* ***between each point*** value is decreased, e.g. 1, there are more points displayed for each displayed curve.

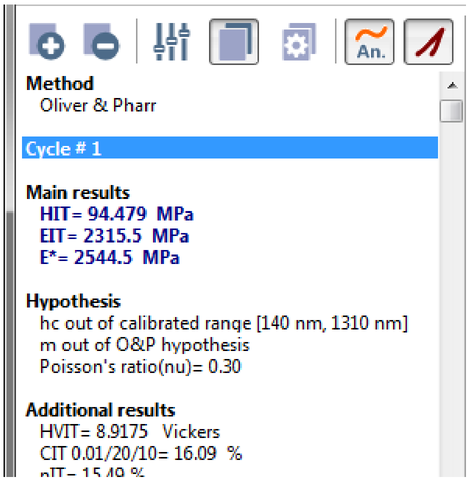


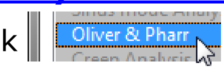


The ***Hypothesis*** values are coming from the ***UNHT & NHT Dynamic calibration (Sinus), p. 20***.

The current ***Parameters*** set above (*Number of periods*) are also displayed in the analysis result area.

5.7.2 Oliver & Pharr analysis curve(s) for CMC measurement type

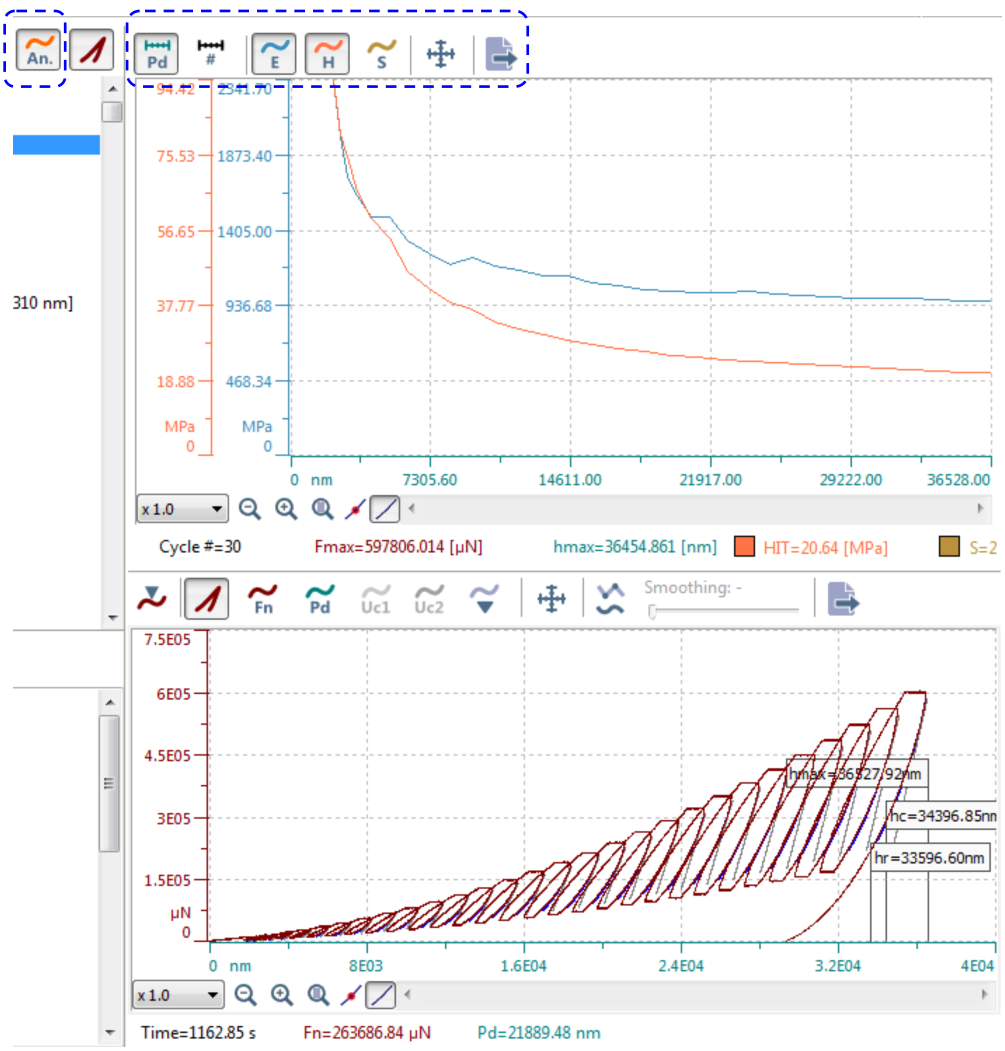


After a CMC measurement(s), to manually create a Oliver & Pharr analysis, see ***chap. 5.4.1 Adding (manually) analysis method(s), p. 144*** and double click 

Otherwise, before a measurement(s), see ***chap. 5.4.2 Automatic analysis method(s), p. 146***, this box 

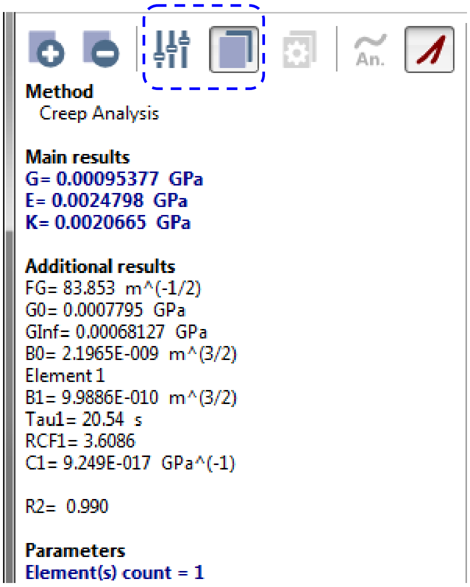
was checked.

In addition to the indentation curves, the analysis curves are available for such type of measurement (CMC).



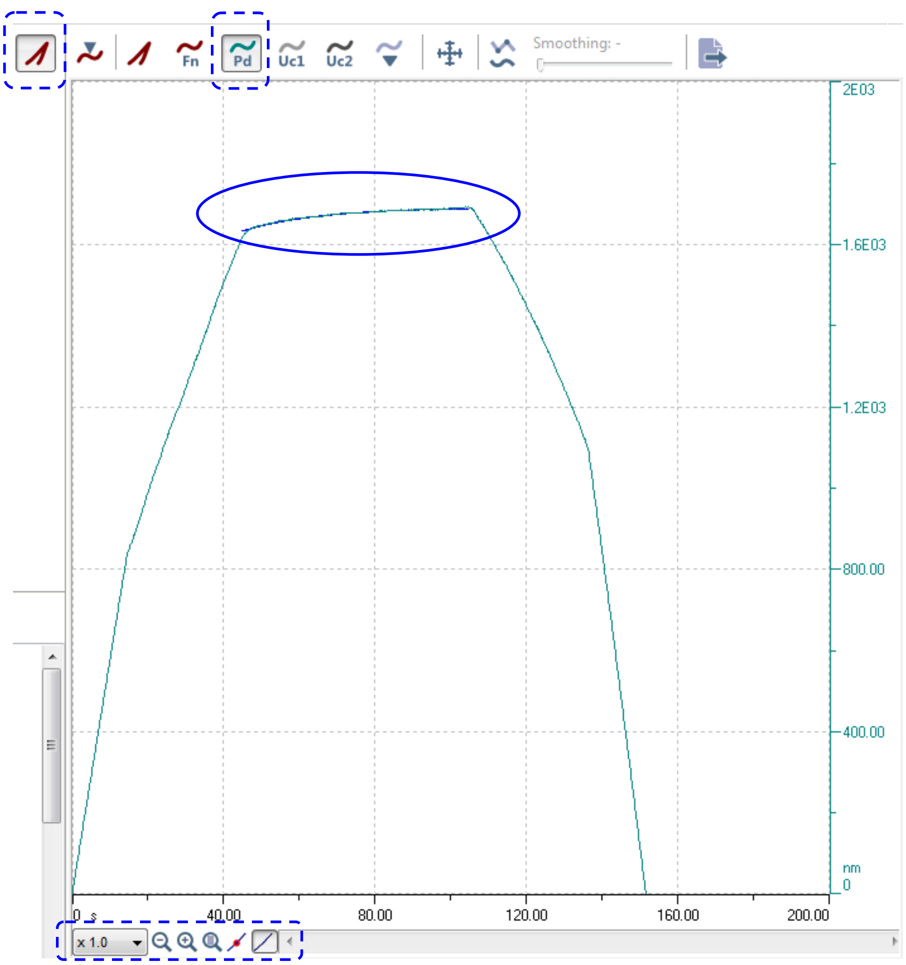
5.8 Creep analysis method & results

Creep analysis method is only available for measurement(s) with spherical indenter; otherwise it is inactive (grayed out).



After a measurement(s), preferably with a constant force and a significant pause time, to manually create a creep analysis, see ***chap. 5.4.1 Adding (manually) analysis method(s), p. 144*** and double click Creep Analysis.

Otherwise before a measurement(s), see ***chap. 5.4.2 Automatic analysis method(s), p. 146***, this box ☑ Creep Analysis was checked.

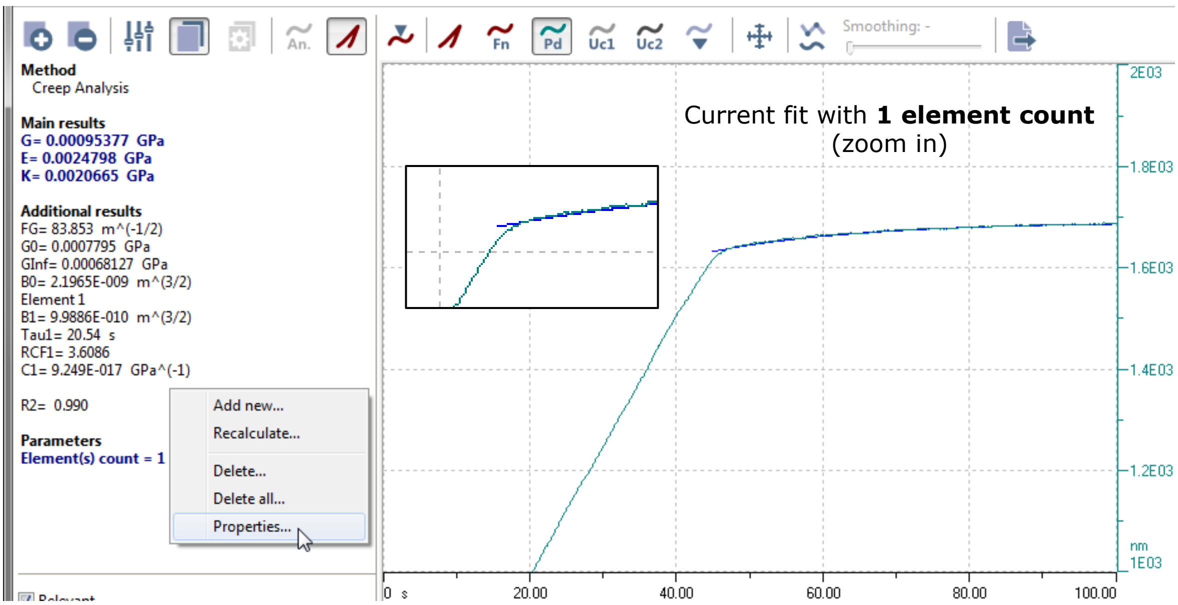


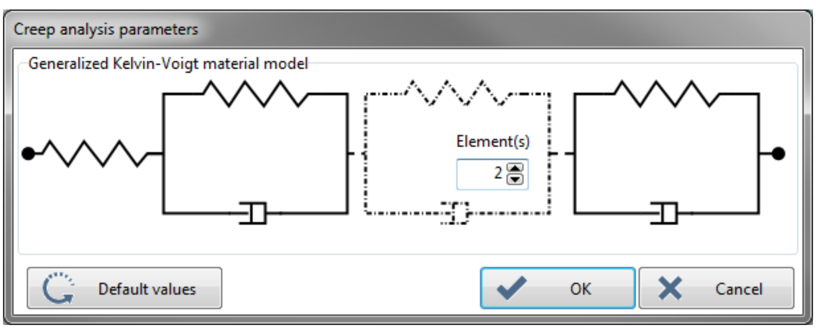
Only display the h depth (Pd) curve and display the single overlay fir for this analysis (Kelvin-Voigt material model element).

Use the zoom tools (x 4.0) to better see the fit on the pause; see the ***Common Scratch & Indentation software manual - chap. Understanding documents - Features on graph areas - Show curve acquisition points***.

Element(s) setting

To increase/decrease the Kelvin-Voigt material model elements, click [icon] on the additional toolbar **or** right click on the analysis result area and select ***Properties...***

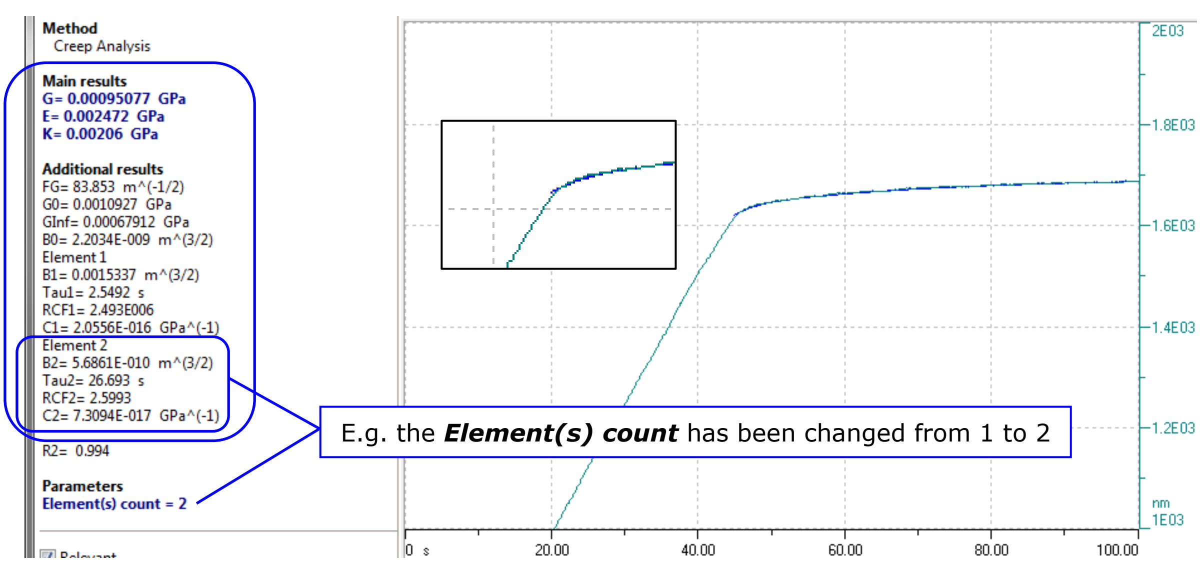




To set (increase or decrease) the Element(s) [spin box] count value; e.g. increase to 2.

[Default values] = 1 element as shown above.

For each change of the element count above: the fit on the curve is adapted and in the analysis result area, the ***Main*** and ***Additional results*** are recalculated, and the current ***Element(s) count*** value is displayed.



5.9 Hertz analysis method & results

Hertz analysis method is only available for measurement(s) with spherical indenter; otherwise it is inactive (grayed out).

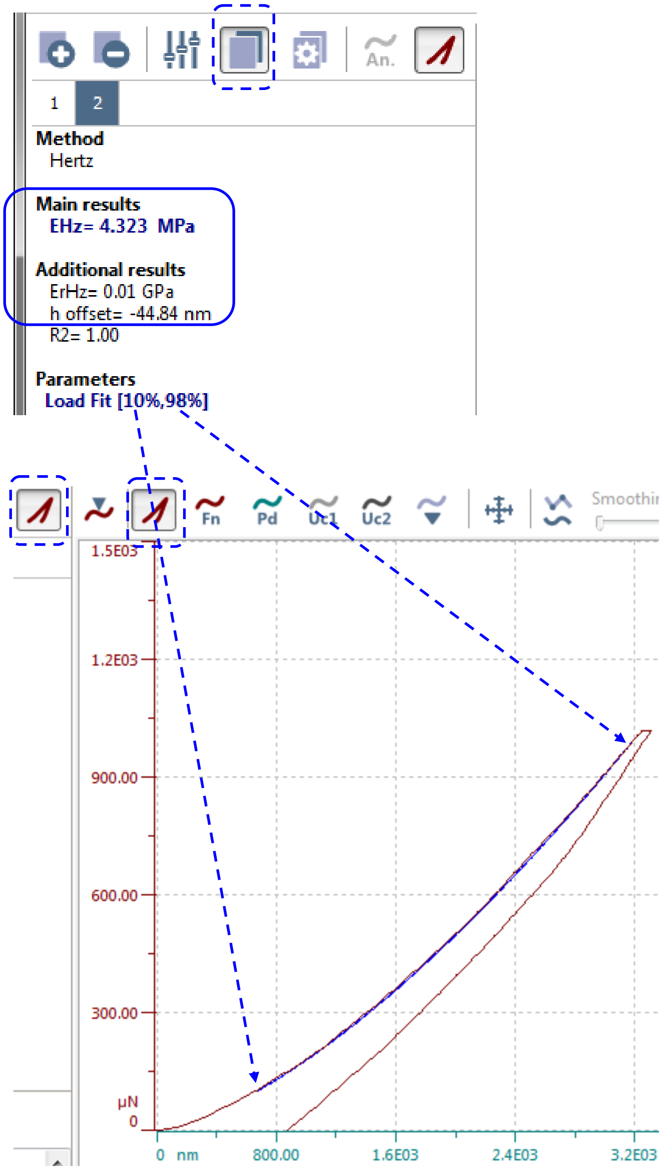
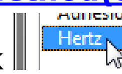


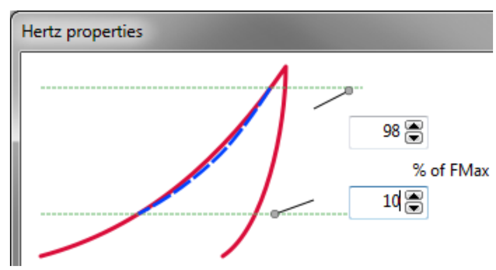
Fig.70 Hertz analysis

After a measurement(s), to manually create a *Hertz* analysis, see ***chap. 5.4.1 Adding (manually) analysis method(s), p. 144*** and double click 

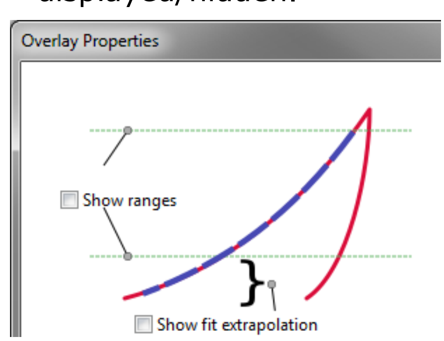
Otherwise before a measurement(s), see ***chap. 5.4.2 Automatic analysis method(s), p. 146***, this box  was checked.

The upper **and/or** lower bound value(s) for the load fit can be changed; see the similar overlay properties ***chap. 5.3, p. 142*** descriptions, **exceptions:**

- Here they are for the **load** fit.



- The load fit is **always displayed** and only the upper/lower bound values (range) **and/or** extrapolation fit can be displayed/hidden.



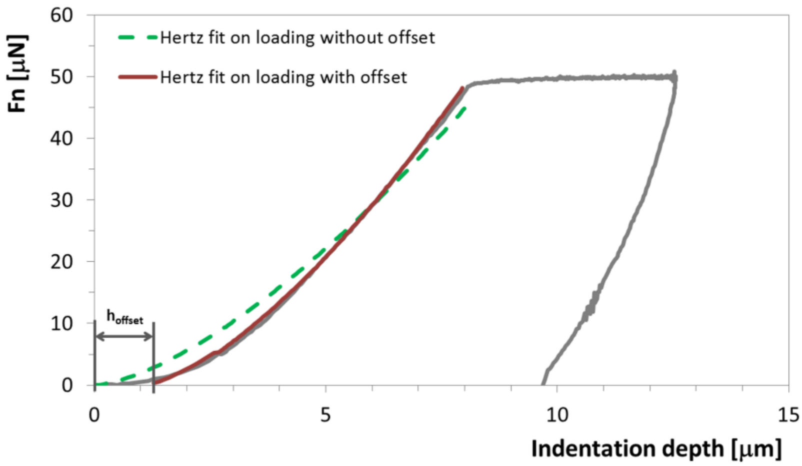
For each change of the upper/lower bound, the load fit on the curve is adapted and in the result analysis area, the ***Main*** and ***Additional results*** are recalculated, and the **Load fit** values are displayed.

Information

Hertz’s model is used for spherical contact with plane for the following reasons:

- Some soft materials do not comply with O&P conditions (no plastic deformation).
- Elastic (poroelastic) deformation is predominant.
- Very often spherical indenter is used.

<u>Depth offset is included to account for soft layers ‘floating’ above the surface</u>



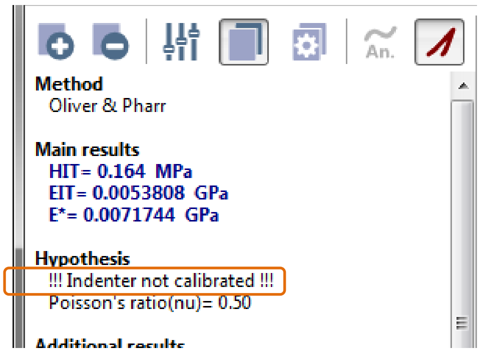
Hertz’s analysis included in the *Indentation Software* is

$$F = \frac{4}{3} \cdot E_r \sqrt{R} \cdot \left(h - h_{offset}\right)^{3/2}$$

5.10 Hypothesis

For each active measurement, in the analysis result area under the ***Hypothesis*** section, several warning messages can appear and the Poisson's ratio is displayed and can be changed; see the following chapters for the detailed descriptions.

5.10.1 Indenter not calibrated

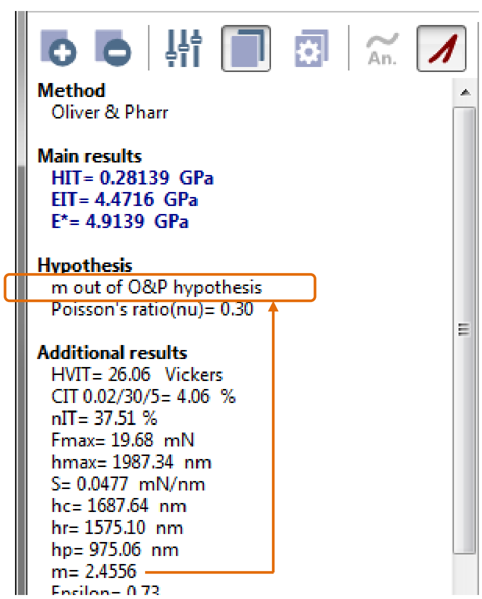


If the used indenter was not calibrated before performing the measurement (*Indenter properties* window *Fig.20, p. 37*), the warning message "*!!! Indenter not calibrated !!!*" appears.

With the UNHT Bio, most of the time spherical indenters are used and do not need to be calibrated.

If necessary, the indenter can be changed with another one which was calibrated; see ***chap. 5.11.2, p. 166***.

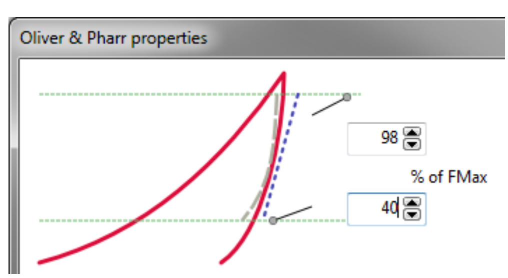
5.10.2 m out of O&P hypothesis



Under ***Additional results***, if "*m*" (exponent in the O&P fit of the indentation curve unloading part) is > 2, the warning message "*m out of O&P hypothesis*" appears.

This message appears most of the time with soft material samples as they do not necessarily comply with the Oliver & Pharr (O&P) hypothesis; that is why other types of analysis are more appropriate, e.g. *Hertz* analysis ***chap. 5.9, p. 158***.

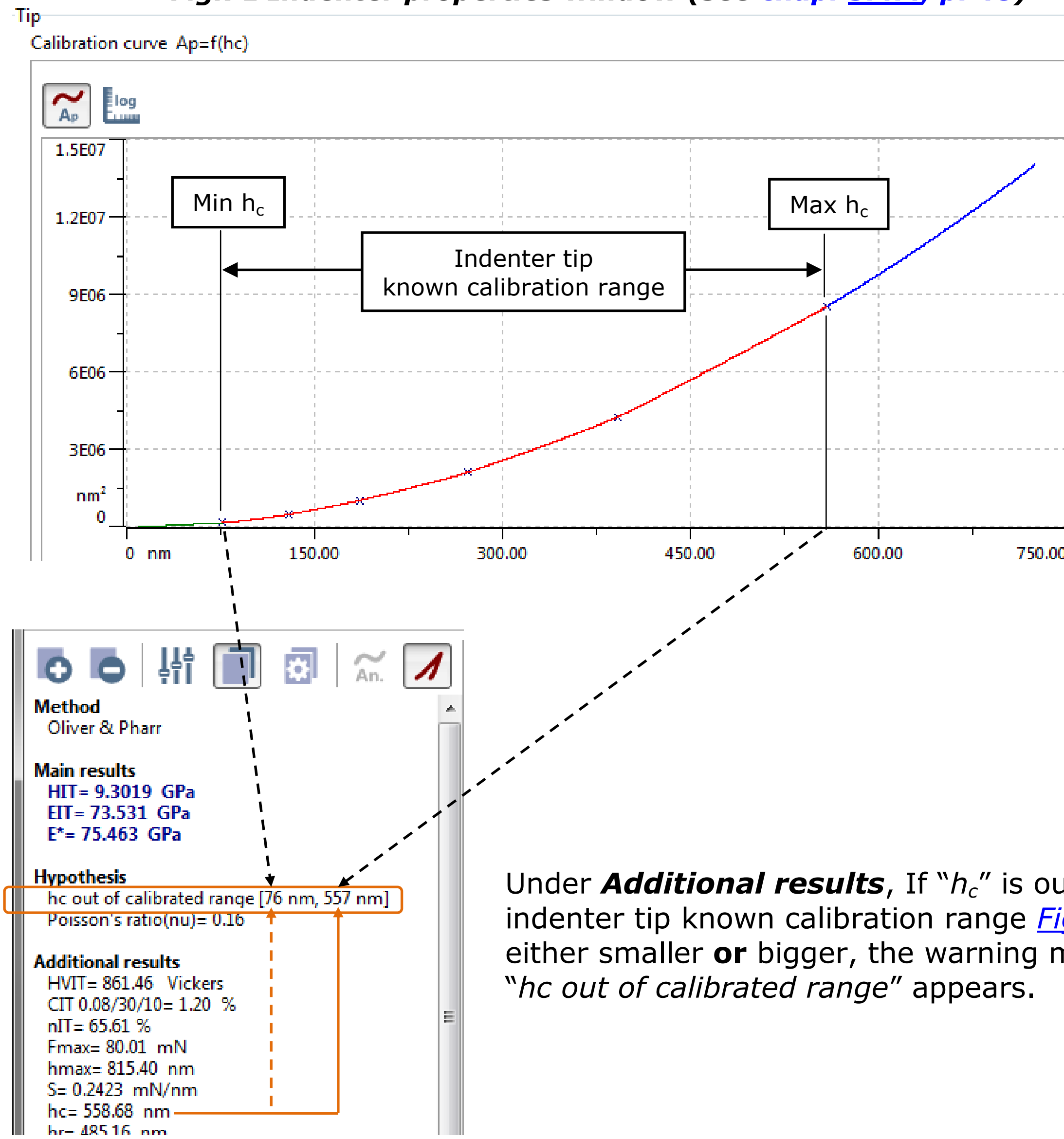
"*m*" value can be changed (a little) by changing the upper/lower value of the bounds; see the overlay properties ***chap. 5.3, p. 142***.



5.10.3 OUT OF INDENTER TIP CALIBRATION

The indenter tip calibration process is performed between a minimum and a maximum force resulting in a known contact depth range, h_c

Fig.71 Indenter properties window (see chap. 3.4.4, p. 48)



Under ***Additional results***, If "h_c" is out of the indenter tip known calibration range *Fig.71 above*, either smaller **or** bigger, the warning message "*hc out of calibrated range*" appears.

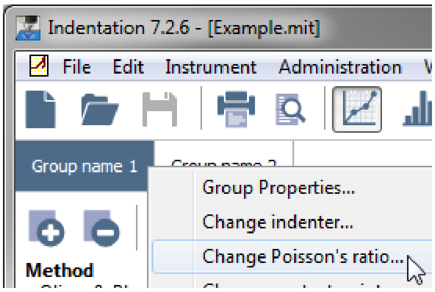
5.10.4 CHANGING THE POISSON'S RATIO

To change the current Poisson's ratio for each:

Active document (all measurements of its groups)

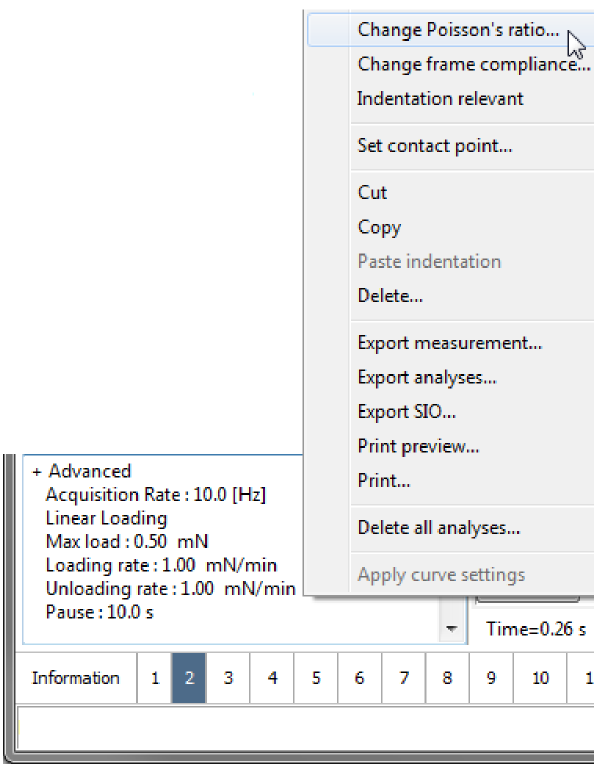
- Select ***Edit/Document ▸/Change Poisson's ratio…*** from the menu bar.

Active group (all its measurements)

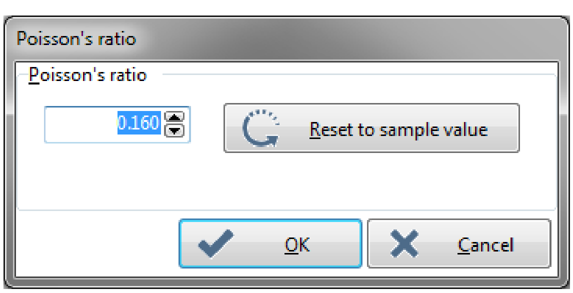


- Select ***Edit/Group ▸/Change Poisson's ratio…*** from the menu bar
- Right click on the ***"group name"*** tab and select ***Change Poisson's ratio…*** from the context menu

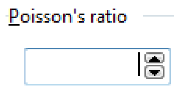
Active measurement



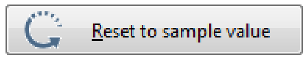
- Select ***Edit/Indentation ▸/ Change Poisson's ratio…*** from the menu bar
- Right click in the measurement parameter area **or** on the ***"measurement #"*** tab, and select ***Change Poisson's ratio…***from the context menu



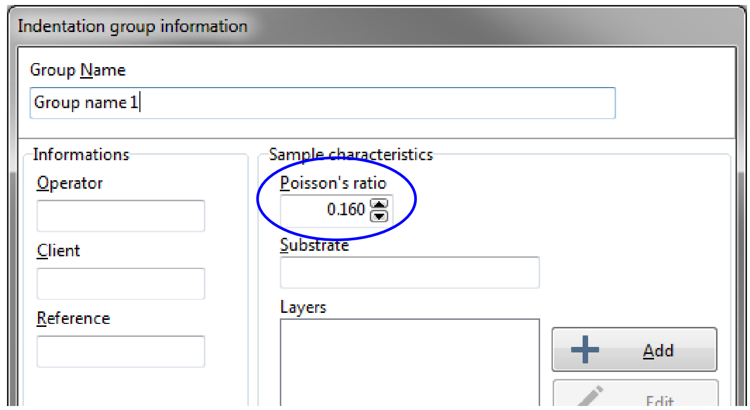
This window allows changing of the current Poisson's ratio value for the measurements(s) previously selected.

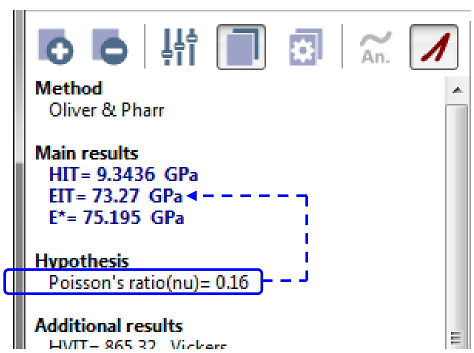


To set another Poisson’s ratio value.



To reset the Poisson’ ratio with the value set during the new document/group creation.

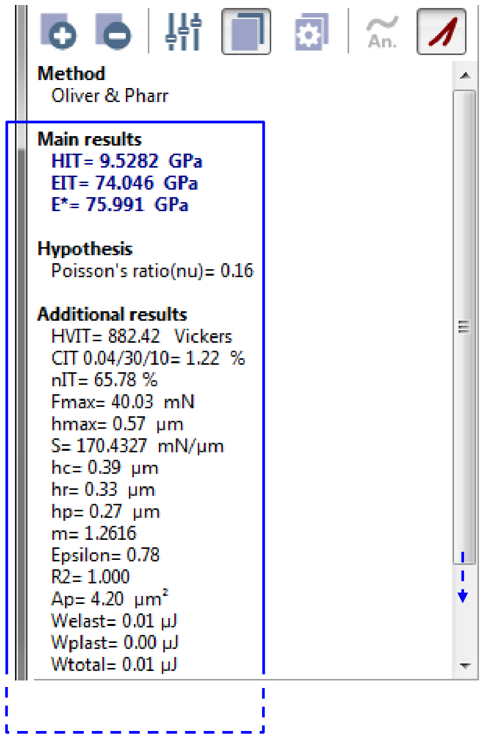




In the analysis result area, for each change of the Poisson’s ratio value (set above), a new value for ***EIT*** under ***Main results*** is recalculated accordingly.

5.11 MANAGING THE INDENTER IN THE RESULT ANALYSIS

The indenter or some of its parameters can be changed.



Recalculated results

For changes of the indenter properties (some parameters/fit method), ***chap. 5.11.1, p. 165***,

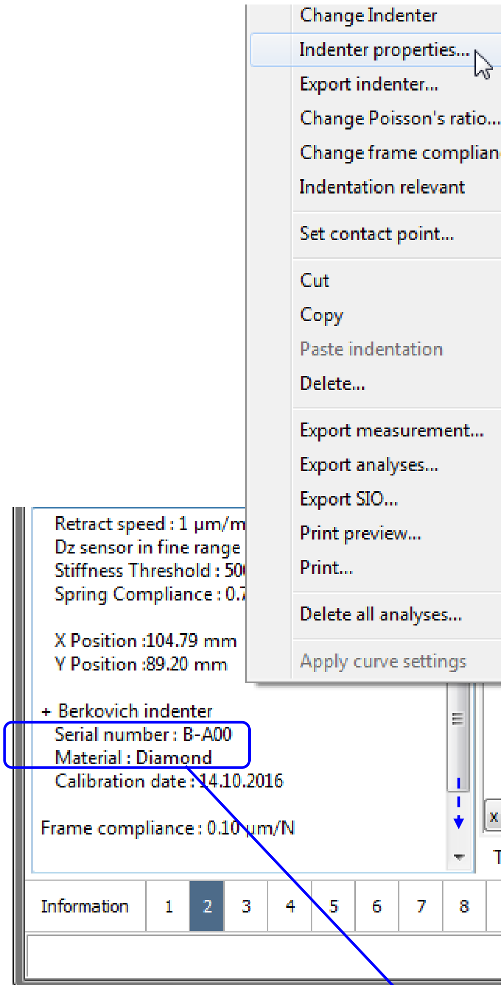
and/or

for each change of the indenter ***chap. 5.11.2, p. 166***,

the ***Main*** and ***Additional*** results in the analysis result area are recalculated for each concerned measurement.

5.11.1 INDENTER PROPERTIES

To change some parameters of the current indenter for each active measurement (only):



- Select ***Edit/Indentation ▸/Indenter properties...*** from the menu bar

- Right click in the measurement parameter area or on the "***measurement #***" tab, and select ***Indenter properties...*** from the context menu

If necessary, scroll down in the measurement parameter area to display the current indenter information.

The *Indenter properties* window appears and allows changing of:

- the indenter parameters, **except** the indenter ***Type***; see ***chap. 3.4.1, p. 37***, the indenter information are updated in the measurement parameter area
- the indenter fit method; see ***chap. 3.4.4, p. 48***.

From here it is not possible to calibrate the indenter (the button "***Calibrate***" is hidden).

For each change of the indenter properties, see ***Recalculated results, p. 164***.

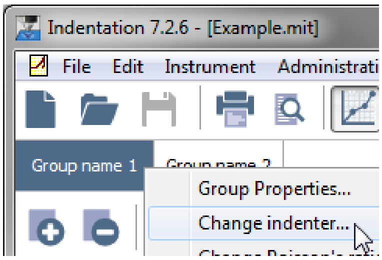
5.11.2 Changing the indenter

To change the current indenter for each:

<u>Active document (all measurements of its groups)</u>

- Select ***Edit/Document ▸/Change indenter...*** from the menu bar.

<u>Active group (all its measurements)</u>



- Select ***Edit/Group ▸/Change indenter...*** from the menu bar
- Right click on the ***"group name"*** tab and select ***Change indenter...*** from the context menu

<u>Active measurement</u>

- Select ***Edit/Indentation ▸/Change indenter...*** from the menu bar

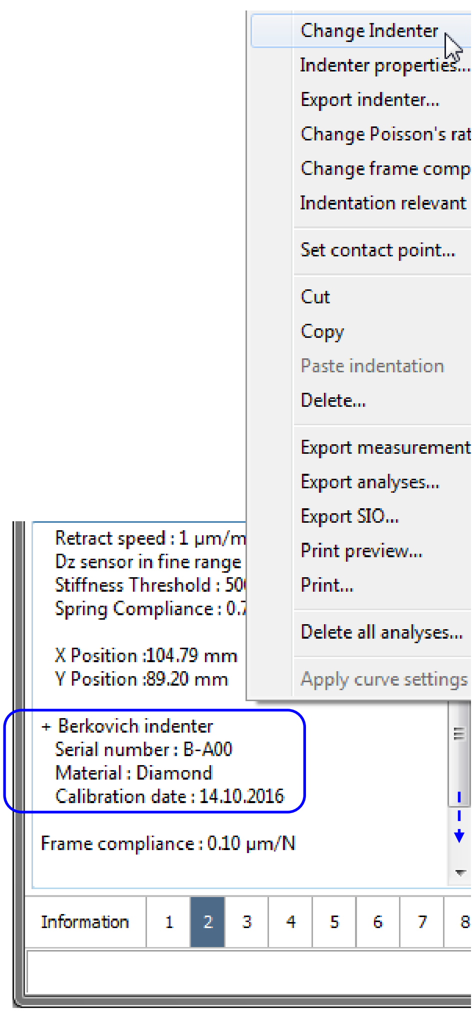
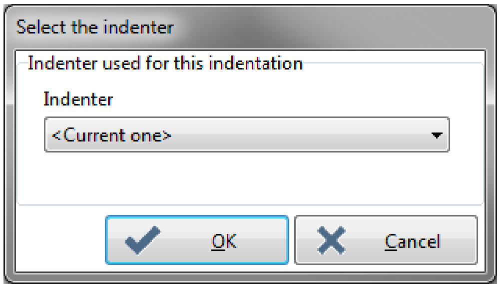


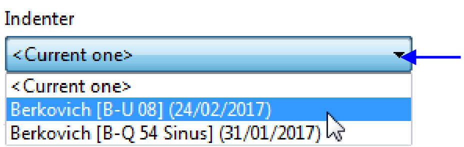
Fig.72 Measurement parameter area

- Right click in the measurement parameter area or on the ***"measurement #"*** tab, and select ***Change indenter*** from the context menu

ℹ If necessary, scroll down in the measurement parameter area to display the current indenter information.



This window allows changing of the current indenter for the measurement(s) previously selected.

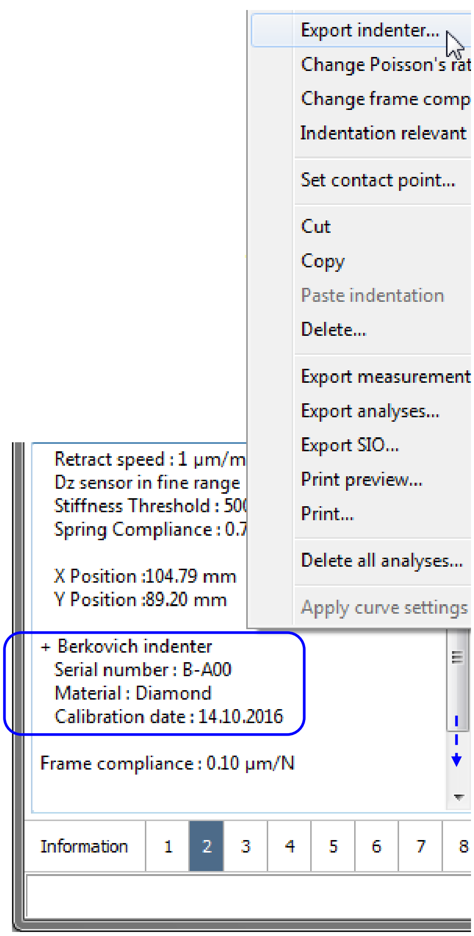


To change the current indenter, with another available one.

For each change of the indenter, see ***Recalculated results, p. 164***.

The indenter information is updated in the measurement parameter area *Fig.72, p. 166*.

5.11.3 Exporting the indenter



For each active measurement, right click in the measurement parameter area and select ***Export indenter...*** from the context menu.

The same *Export a indenter file* window as described in ***Import/export, p. 35*** appears.

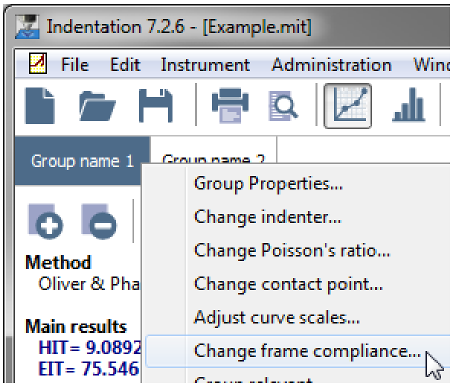
5.12 CHANGING THE FRAME COMPLIANCE

To change the current frame compliance value taken to calculate the results for each:

Active document (all measurements of its groups)

- Select ***Edit/Document ▸/Change frame compliance...*** from the menu bar.

Active group (all its measurements)



- Select ***Edit/Group ▸/Change frame compliance...*** from the menu bar.
- Right click on the ***"group name"*** tab and select ***Change frame compliance...*** from the context menu.

Active measurement

Select ***Edit/Indentation ▸/Change frame compliance...*** from the menu bar.

- Right click in the measurement parameter area or on the ***"measurement #"*** tab and select ***Change Frame Compliance*** from the context menu.

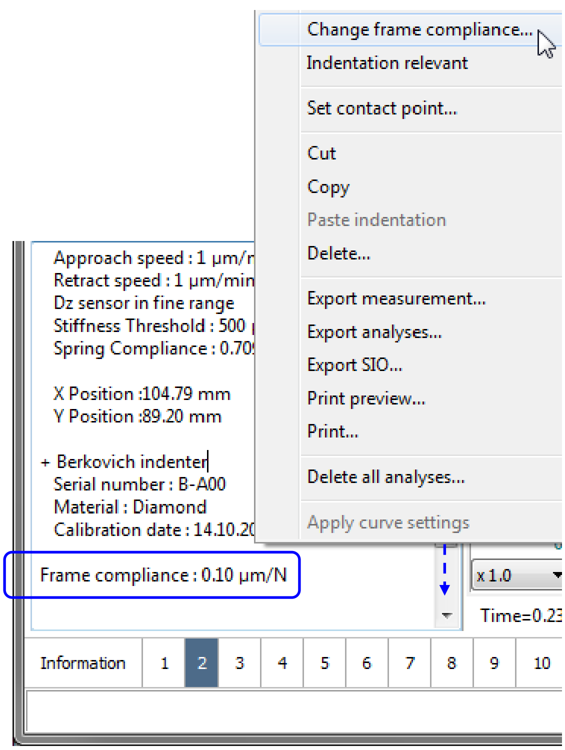
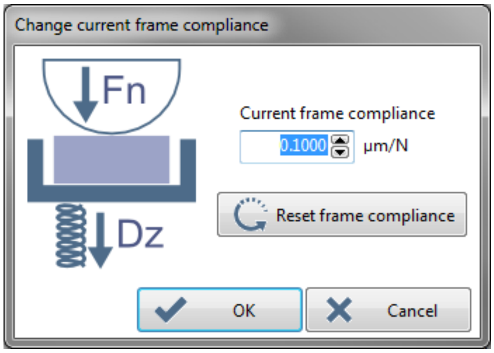
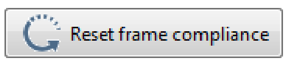


Fig.73 Frame compliance current value



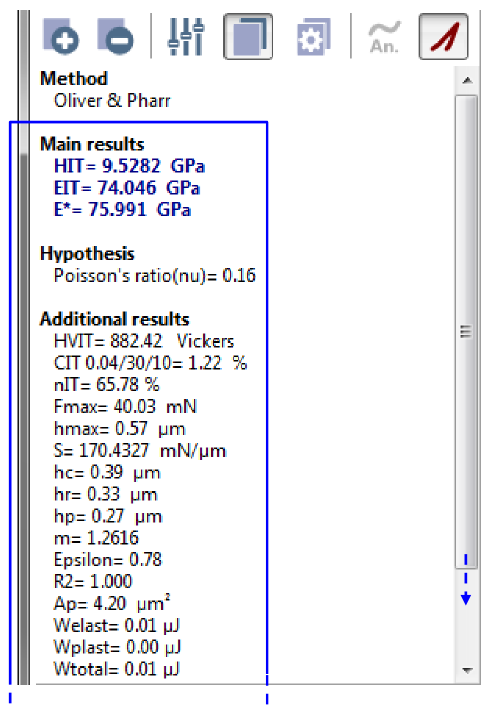
This window allows changing of the current frame compliance value for the measurement(s) previously selected.

To set another frame compliance value.



To reset the frame compliance with the initial[1)] value.

For each change of the frame compliance, the value is updated in the measurement parameter area *Fig.73, p. 168* and the ***Main*** and ***Additional*** results in the analysis result area (below) are recalculated for each concerned measurement.



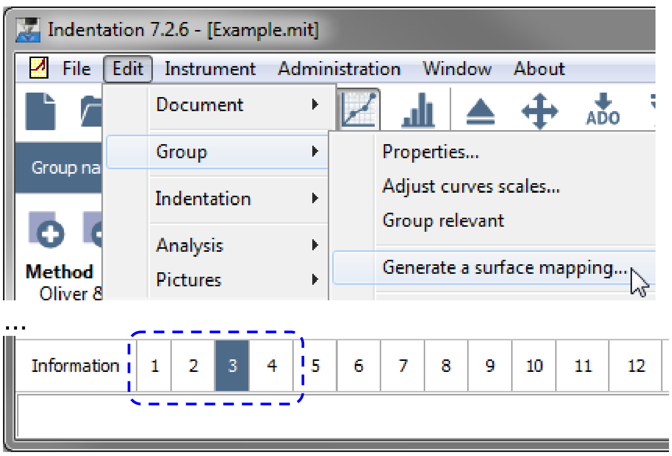
[1)] initial value was set in the ***Frame compliance*** field of the **"Indenter *Ranges*"** tab for UNHT *Fig.1, p. 15* or **"*Ranges*"** tab for NHT *Fig.4, p. 17*/MHT *Fig.9, p. 24* (hardware configuration); see from ***chap. 3.1.3, p. 15***

5.13 GENERATING SURFACE MAPPING (IMAGE)

The surface mapping feature is used to create 3D image(s) from each (one at a time) selected result parameter of a matrix of measurements, which were performed at different positions on the (same) sample.

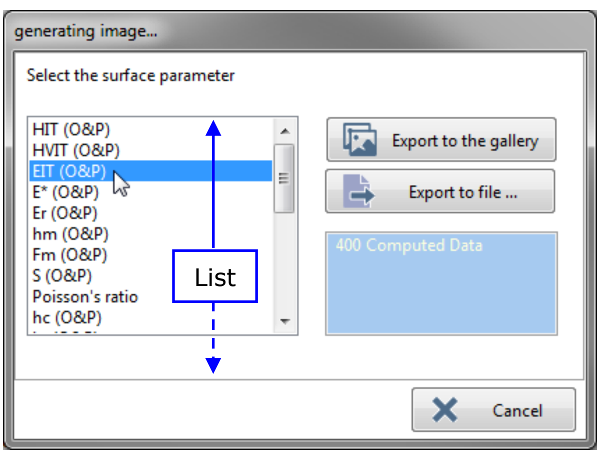
This feature generates image(s) where each pixel location represents a measurement position and each pixel color represents a different measurement value of the selected result parameter.

<u>For each active group (all its measurements)</u>



The (matrix) group should contains at least 4 measurements,

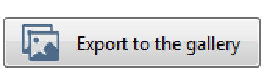
select ***Edit/Group ▸/ Document/Generate a surface mapping...*** from the menu bar.



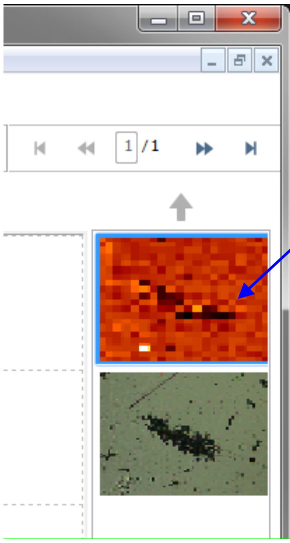
Select one result parameter in the list (standard O&P Oliver & Pharr analysis method, other method(s) in addition if available/added).

Generally the most interesting parameters are HIT, HVIT and EIT.

Shows the number of the measurements for the selected parameter, the min. number should be 4 otherwise an *Information* window will appear (If an analysis method is manually added (afterwards), it should be done for the other measurements of the current group, at least 4).



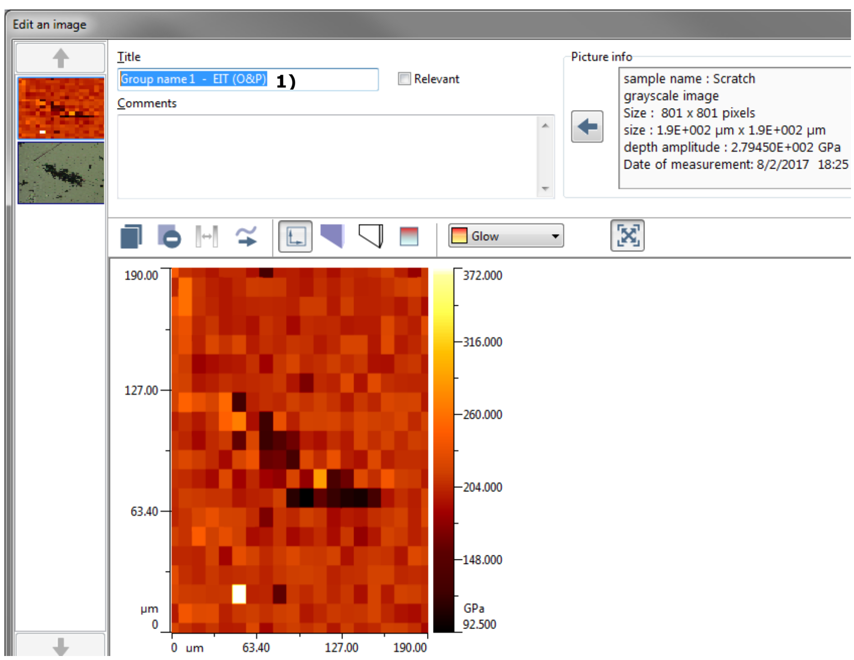
To export the corresponding image (parameter selection above) in the gallery of the result analysis window.



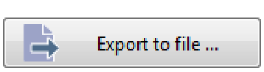
Surface mapping image are added to the gallery with other images (if previously grabbed).

Double click the image to open it in the window below.

The *Edit an image* window below allows some settings on the opened image (Title name, comments, image features…); refer to the ***Common Scratch & Indentation software manual - Manipulating document windows - Managing images gallery - Managing picture***.

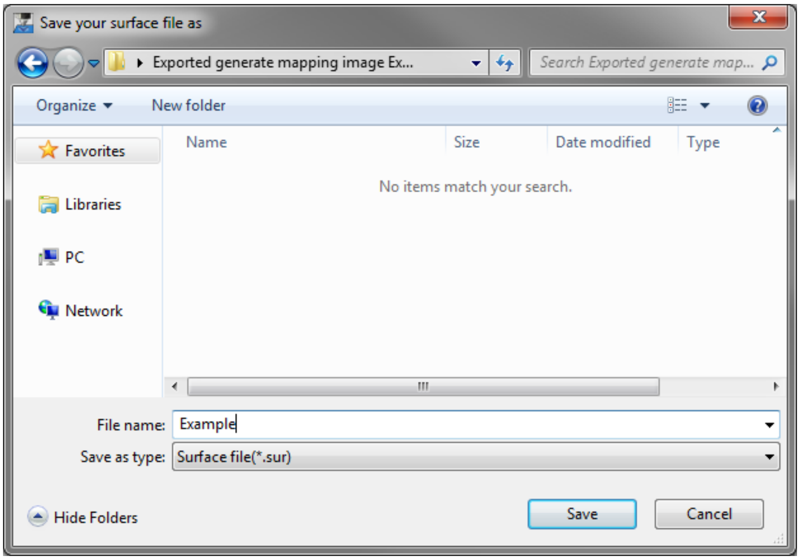


[1)] to know which measurement group tab and which parameter were previously selected to generate the image, the **Title** name field is automatically filled in with these information (can be changed if necessary)

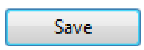


To export the corresponding image (previous parameter selection) in .SUR file format, for an external analysis with another software like Image Plus; refer to the ***Image Plus software manual***.

This window allows:



- Choosing a location where to save the surface file.
- Typing a ***File name***:
  The default file format is .SUR

Then click 

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6 TROUBLESHOOTING

6.1 F.A.Q.

Refer to the ***measurement head* user manual - chap. F.A.Q.***

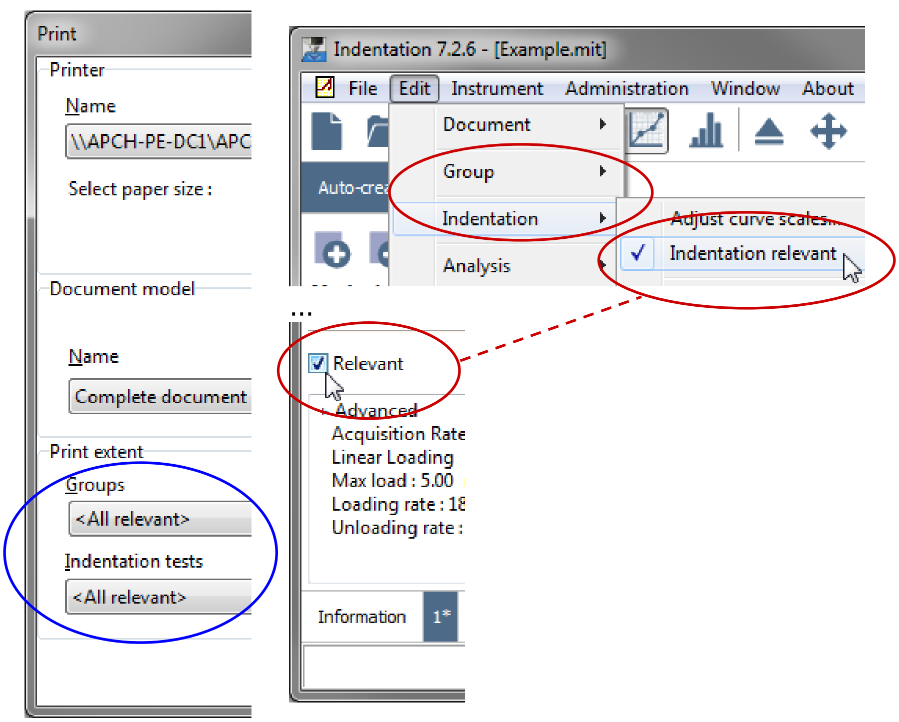
6.2 ERROR MESSAGES WHILE USING THE INSTRUMENT

Refer to the ***measurement head* user manual - chap. Blocking error messages***.

6.3 UNPRINTED ITEMS

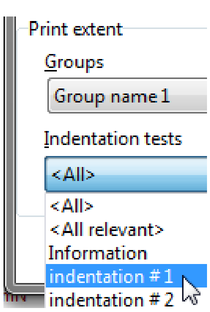
Some indentation measurements or images are not printed on the document; this may occur when:

<u>Measurements unprinted</u>



The *Print extent* for the ***<u>G</u>roups*** and/or the ***<u>I</u>ndentation tests*** specify that *<All relevant>* measurements should be printed, and some groups/measurements are not designated as relevant;

change the group(s)/ measurement(s) as relevant.



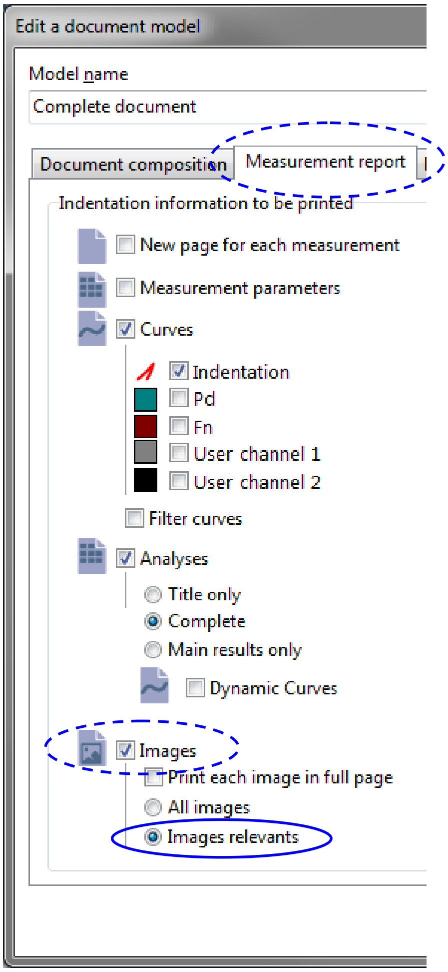
Otherwise select the *Print extent* for the desired,

<u>G</u>roups:
<ALL> **or** *"Group name"*

AND/OR

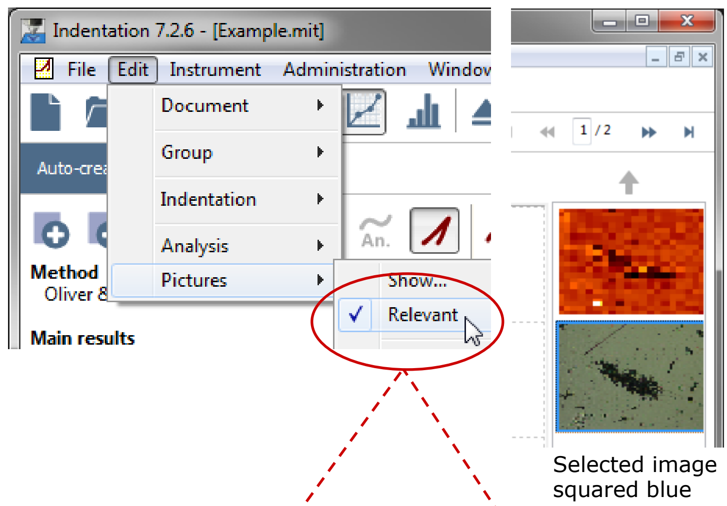
Indentation test:
<ALL> **or** *"indentation #"* measurement(s).

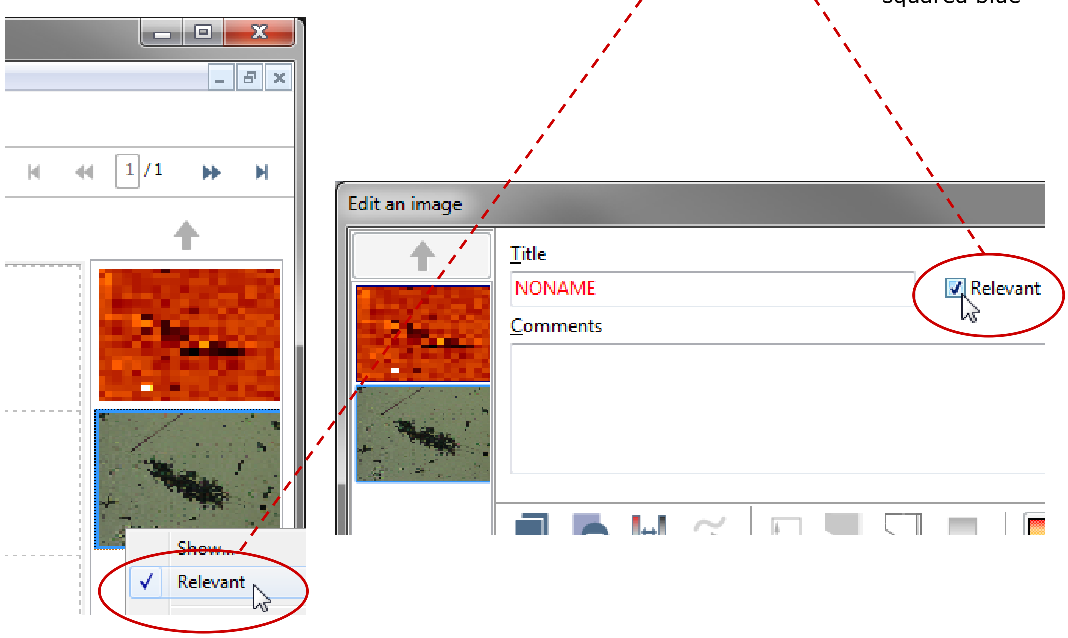
Images unprinted

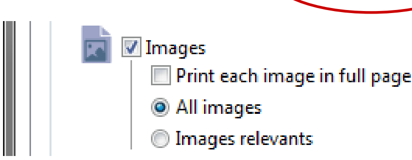


The document model specifies that only the relevant images should be printed, and some images are not designated as relevant;

change the relevant attribute of each necessary image







Otherwise select to print ***"all images"*** in the document model.

6.4 INSTRUMENT SEEMS TO BEHAVE STRANGELY

Verify that the field values of the ***'Ranges'*** tabs[1)] (in *Hardware configuration* window) match with the values stated on the calibrations certificates, which are provided with the corresponding instrument. Otherwise change them accordingly. Refer to the ***Common Scratch & Indentation software manual - chap. 'Ranges' tab(s)***.

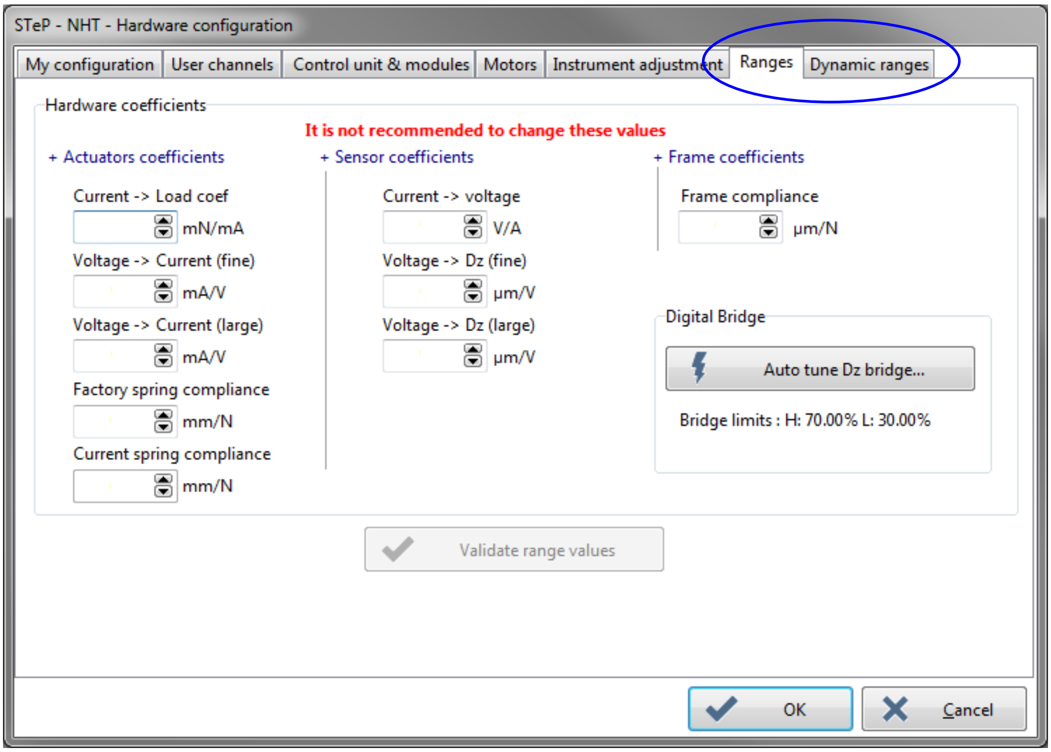
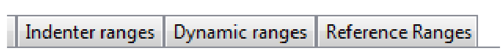
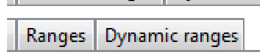
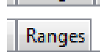


Fig.74 'Ranges' tabs (e.g. NHT)

[1)] UNHT has 3 ***'Ranges'*** tabs 

NHT has 2 ***'Ranges'*** tabs 

MHT has only 1 ***"Ranges"*** tab 

7 SOFTWARE FORMULAS

Graphical views of indentation parameters:

7.1 TYPICAL INDENTATION CURVE

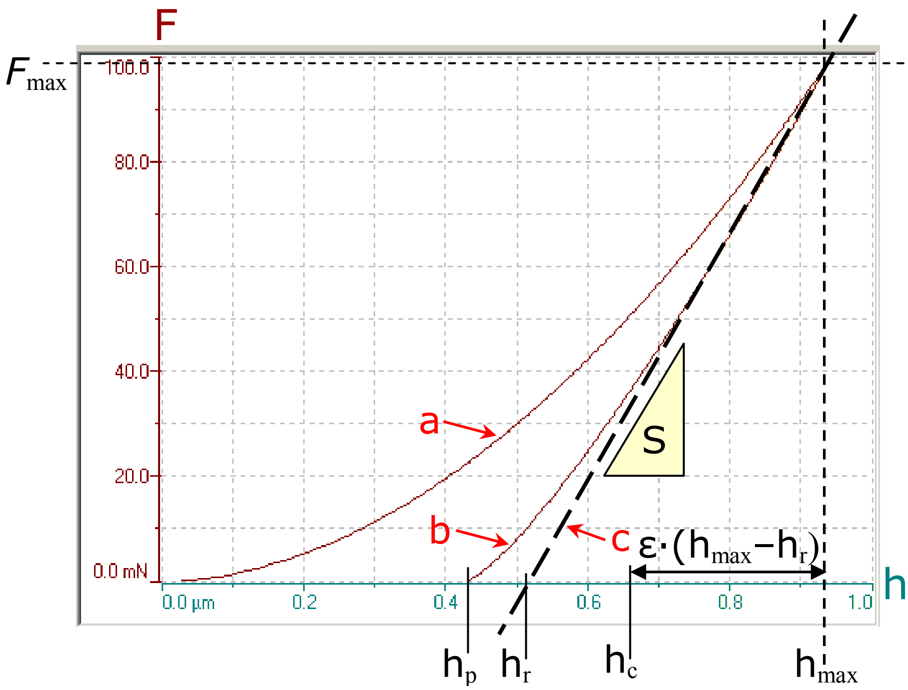


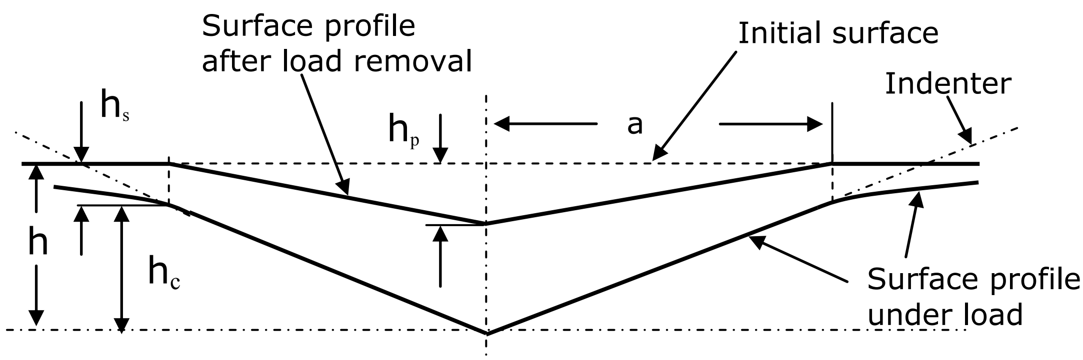
Fig.75 Indentation test

<u>Legend</u>

- a : Application of F
- b : Removal of F
- c : Tangent to curve b at F_{max}
  - F : test force
  - F_{max} : maximum test force

- h_p : permanent indentation depth
- h_r : tangent indentation depth
- h_c : contact depth of the indenter with the sample at F_{max}
- h_{max} : maximum indentation depth
- S : contact stiffness
- ε : geometric constant

7.2 Schematic representation of indenter - sample contact



7.3 Parameters determination

F_{max}: Directly on curve

S (Tangent method): <u>Tangent fit:</u> Fit start: 95 % of F_{max}
Fit end: 70 % of F_{max}

$$S = \left(\frac{dF}{dh}\right)_m$$

m, h_{max}, h_p and S (O&P method):

<u>Power law fit of unloading curve:</u>

Fit start: 98 % of F_{max}
Fit end: 40 % of F_{max}

Equation:

$$F = F_{max} \cdot \left(\frac{h - h_p}{h_{max} - h_p}\right)^m$$

Where m, h_{max}, h_p are fitting parameters.

- In case of creep or viscoelasticity still occurring during unloading, it may happen that the h_{max} value in the results cannot be seen as a data point on the curve.

- Due to complex behavior of contact mechanics at the end of the unloading curve (roughness, tip shape, creep, viscoelasticity…), it may happen that the h_p value in the results cannot be seen as a data point on the curve.

Calculation of S: $$S = m \cdot F_{max} \cdot (h_{max} - h_p)^{-1}$$

h_r: Intercept of the tangent to the load-displacement data at the maximum load on unloading (S) with the depth axis.

$$h_r = h_{max} - F_{max} / S$$

h_c: $$h_c = h_{max} - \varepsilon \cdot (h_{max} - h_r)$$

ε: Depending on the diamond shape

Indenter Shape	**m**	ε
Flat Punch	1.0	1.0000
Cone	2.0	$2(\pi - 2) / \pi = 0.7268$
Sphere/Paraboloïd	1.5	0.7500

In our case, ε is estimated using the m value!
(Table of 10 values and linear extrapolation between 2 values)

Ref.: J. Woirgard and al./Surface and coatings Technology 100-101 (1998) 103-109

β: Geometric factor (diamond shape dependent)

Circular $\beta = 1.000$
Triangular $\beta = 1.034$
Square $\beta = 1.012$

A_p: (theoretical or calibrated)

$$A_p = f(h)$$

7.4 INDENTATION HARDNESS (H_{IT})

7.4.1 DESIGNATION OF H_{IT}

H_{IT} = 0.5/10/20/30 = 222 000 N/mm²

- 222 000: H_{IT}
- 30: Time taken to remove F during the fitted portion of F removal curve in sec.
- 20: Time for holding F_{max} in sec.
- 10: Application time of F in sec.
- 0.5: F in Newton

7.4.2 DETERMINATION OF H_{IT}

H_{IT} is a measure of the resistance to permanent deformation or damage.

$$H_{IT} = \frac{F_{max}}{A_p} \text{ in Pascal}$$

A_p (theoretical or calibrated)

The determination of the exact area function for the given indenter is required for indentation depth < 0.006mm (tip defect).

7.5 INDENTATION MODULUS (E_{IT})

7.5.1 DESIGNATION OF E_{IT}

E_{IT} = 0.5/10/20/30 = 222 000 N/mm^2

- 222 000: E_{IT}
- 30: Unloading time from holding time end to last contact point
- 20: Holding time in sec. at F_{max} in sec.
- 10: Loading time in sec. from contact to F_{max}
- 0.5: F in Newton

7.5.2 DETERMINATION OF REDUCED MODULUS (ER)

The deduced modulus is calculated from the following equation:

$$E_r = \frac{\sqrt{\pi} \cdot S}{2 \cdot \beta \cdot \sqrt{A_p(h_c)}}$$

7.5.3 DETERMINATION OF PLANE STRAIN MODULUS (E*)

E* is calculated from the following equation:

$$E^* = \frac{1}{\frac{1}{E_r} - \frac{1-\nu_i^2}{E_i}}$$

With:

E_i = Elastic modulus of the indenter (diamond 1141 GPa)
ν_i = Poisson’s ratio of the indenter (diamond 0.07)

7.5.4 DETERMINATION OF E_{IT}

E_{IT} calculated from the E* using a an estimated sample Poisson's ratio (ν_s):

$$E_{IT} = E^* \cdot (1 - \nu_s^{\ 2})$$

As a reminder, typical values of ν_s are:

- Ceramic: 0.1 to 0.3
- Metal: 0.2 to 0.4
- Polymer: 0.3 to 0.4

7.6 STANDARD MEASUREMENT OF VICKERS HARDNESS (HV)

7.6.1 DESIGNATION OF HV

HV = <u>0.1</u> Vickers

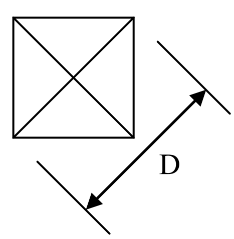
Hardness value

7.6.2 DETERMINATION OF HV

$$HV = \frac{F_{max}}{9.81 \cdot A_c(h_c)}$$ in Vickers (kgf/mm^2)

(diagonal measurement)

$$HV = \frac{F[kgf]}{A_d} = \frac{F}{A_p} \cdot \sin 68° = \frac{2 \cdot F}{D^2} \cdot \sin 68°$$



$$HV \approx 1.8544 \cdot \frac{F}{D^2}$$

$$\frac{D}{h} = 2\sqrt{2} \cdot \tan 68° \approx 7$$

Where:
h is the indentation depth under applied load (corresponding to diagonal D)

7.7 ESTIMATION OF HV_{IT} WITH INDENTATION HARDNESS (H_{IT})

$$H_{IT}[MPa] = \frac{F[N]}{A_p} = \frac{9.81 \cdot F[kg]}{A_d \cdot \sin\alpha} = \frac{9.81}{\sin\alpha} \cdot HV_{IT}[Vickers]$$

With Vickers indenter:

$$HV_{IT} \approx H_{IT}/10.580$$

With Modified Berkovich indenter (M. Berkovich):

$$HV_{IT} \approx H_{IT}/10.800$$

7.8 INDENTER DEFINITION & SPECS, WITH AREA FUNCTION RELATIONSHIPS

For indentation depth > 0.006mm, a first approximation to the projected area may be used:

	Vickers	Berkovich	M. Berkovich	Cube Corner
α_t	136°	141.9°	142.3°	90°
α	68°	65.03°	65.27°	35.264°
A_d / h^2	$4 \cdot \frac{\sin\alpha}{\cos^2\alpha}$	$3\sqrt{3} \cdot \frac{\sin\alpha}{\cos^2\alpha}$	$3\sqrt{3} \cdot \frac{\sin\alpha}{\cos^2\alpha}$	$9/2$
	≈26.43	**≈26.43**	≈26.97	=4.5
A_p / h^2	$4 \cdot \tan^2\alpha$	$3\sqrt{3} \cdot \tan^2\alpha$	$3\sqrt{3} \cdot \tan^2\alpha$	$3\sqrt{3}/2$
	≈24.504	≈23.96	**≈24.494**	**≈2.598**
A_d / A_p	$1/\sin\alpha$	$1/\sin\alpha$	$1/\sin\alpha$	$1/\sin\alpha = 3/\sqrt{3}$
	≈1.0785	≈1.1031	≈1.1010	≈1.7320

α_t = total included angle
α = angle between the axis of the diamond pyramid and the 3 faces
A_d = A_c = A_s = (developed) contact area

Reminder:

A_p = projected contact area

7.9 Martens hardness (HM) (former design: Universal hardness HU)

7.9.1 Designation of HM

HM = 0.5/20/20 = 8700 N/mm²

- 8700: HM
- 20 (second): Duration time of F in sec.
- 20 (first): Application time of F in sec.
- 0.5: F in Newton

7.9.2 Determination of HM

HM is measured under applied F.
HM is determined from the values given by the F/h curve during load time, preferably after reaching the specified F.
HM includes the plastic and elastic deformation, thus this hardness value can be calculated for all materials. HM value is defined for both pyramidal indenters (Vickers and Berkovich). It is not defined for the Knoop or ball indenters.

HM is defined as F divided by the surface contact area of the indenter penetrating beyond the zero point of the contact:

$$HM = \frac{F}{A_s(h)}$$

- Vickers indenter:

$$A_s(h) = \frac{4 \cdot \sin(\alpha)}{\cos^2(\alpha)} \cdot h^2 \quad \text{and} \quad HM = \frac{F}{A_s(h)} \approx \frac{F}{26.43 \cdot h^2}$$

- Perfect Berkovich indenter:

$$A_s(h) = \frac{3 \cdot \sqrt{3} \cdot \tan(\alpha)}{\cos(\alpha)} \cdot h^2 \quad \text{and} \quad HM = \frac{F}{A_s(h)} \approx \frac{F}{26.43 \cdot h^2}$$

- Modified Berkovich indenter:

$$A_s(h) = \frac{3 \cdot \sqrt{3} \cdot \tan(\alpha)}{\cos(\alpha)} \cdot h^2 \quad \text{and} \quad HM = \frac{F}{A_s(h)} \approx \frac{F}{26.97 \cdot h^2}$$

HM is usually followed by the test condition in the following order:

- F in N,
- the time for the application of F in sec.
- the time during F_{max} is kept constant in sec.
- after equals sign, HM value.

Examples:

- HM 0.5/20/20 = 8700 N/mm^2

HM is 8700 N/mm^2, determined with a F of 0.5N, applied in 20s, constant during 20s.

- HM(Berkovich) 0.5/20/20 = 8700 N/mm^2

Same as above but with a Berkovich tip instead of the standard Vickers tip.

7.10 INDENTATION CREEP (C_{IT})

7.10.1 DESIGNATION OF C_{IT}

C_{IT} = 0.5/10/50 = 2.5 %

- C_{IT} (relative change of indentation depth)
- Time ($t_2 - t_1$) for holding constant F in sec. See Fig.76, p. 185
- Application time of F in sec.
- F in Newton

7.10.2 DETERMINATION OF C_{IT}

$$C_{IT} = \frac{h_2 - h_1}{h_1} \cdot 100$$

Where:

h_1 is the indentation depth at time t_1 of reaching F (which is kept constant)

h_2 is the indentation depth_at time t_2 of holding the constant F

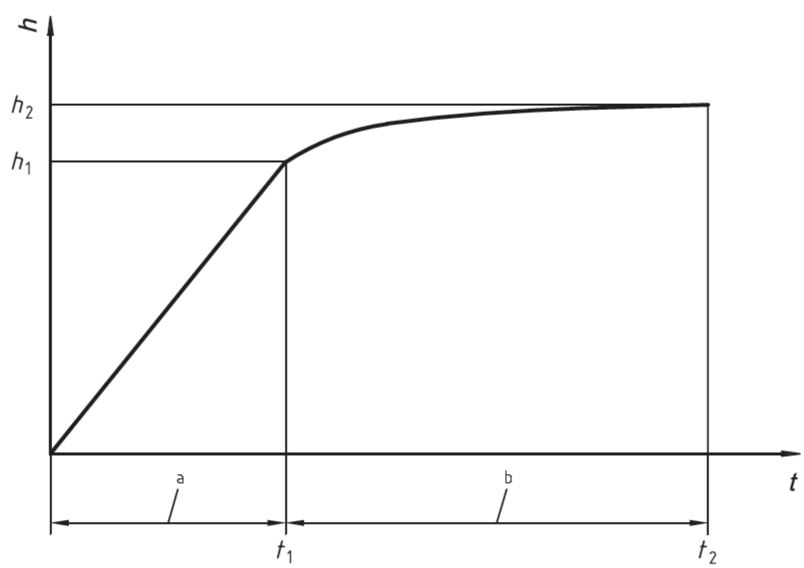
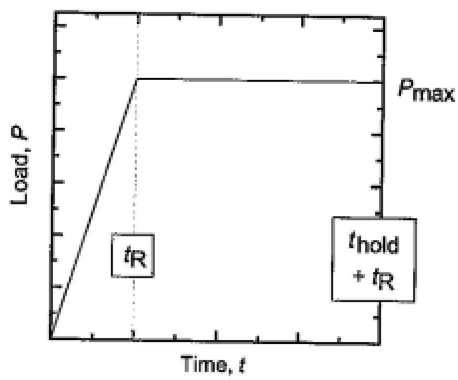


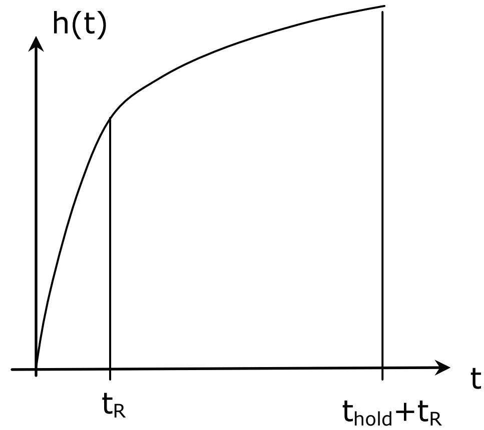
Fig.76 Expression of C_{IT}

a: Application of F
b: F constant from t_1 to t_2

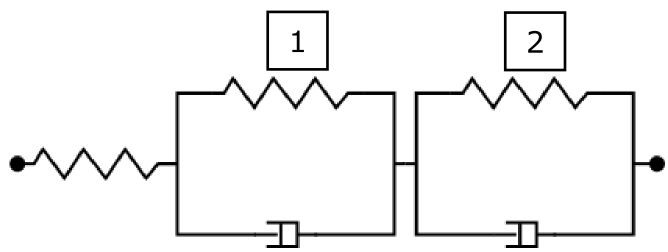
7.10.3 Creep analysis

This analysis is used to determine the viscoelastic properties from the creep curve (pause at constant force) with a sphere only.





Example for the case of 2 elements



The material response can be described with the following creep function:

(1) $J(t) = C_0 - C_1 \exp(-t/\tau_1) - C_2 \exp(-t/\tau_2)$

Then the indentation depth follows the below equation:

(2) $h^{3/2}(t) = B_0 - B_1 \exp(-t/\tau_1) - B_2 \exp(-t/\tau_2)$

(for 1 element the constant terms are B0 and B1 whereas for 3 elements there are B0, B1, B2 et B3)

The analysis performs a fit of the indentation depth h(t) between t_R and ($t_{hold}+t_R$) using the equation (2) giving the fit parameters of B_0, B_1, B_2, τ_1 et τ_2

Then the results are calculated using the following equations:

(3) $F_G = 3/(8\sqrt{R})$ tip Geometry Factor, where R is sphere radius

(4) $RCF_1 = \frac{\tau_1}{t_R}\left[\exp(t_R/\tau_1) - 1\right]$ Ramp Correction Factor

(5) $RCF_2 = \frac{\tau_2}{t_R}\left[\exp(t_R/\tau_2) - 1\right]$

(6) $$C_0 = \frac{B_0}{F_m F_G}$$ where F_m is the max. test force

(7) $$C_1 = \frac{B_1}{F_m F_G \cdot RCF_1}$$

(8) $$C_2 = \frac{B_2}{F_m F_G \cdot RCF_2}$$

(9) $$G_0 = \frac{1}{2(C_0 - C_1 - C_2)}$$

(10) $$G_\infty = \frac{1}{2C_0}$$

(11) $$G^\nu = 2G_\infty(1-\nu)$$ shear modulus - where ν is the tested material Poisson’s ratio

(12) $$E = 2G^\nu(1+\nu)$$ elastic modulus

(13) $$K = \frac{E}{3(1-2\nu)}$$ bulk modulus

7.11 Indentation relaxation (R_{IT})

7.11.1 Designation of R_{IT}

R_{IT} = 3/10/50 = 0.01 %

- 0.01 — R_{IT} (relative change of F)
- 50 — Time ($t_2 - t_1$) for holding constant F in sec. See Fig.77, p. 188
- 10 — Application time of F in sec.
- 3 — F in Newton

7.11.2 Determination of R_{IT}

$$R_{IT} = \frac{F_1 - F_2}{F_1} \cdot 100$$

Where:

F_1 is the force at reaching the indentation depth, which was kept constant, in N

F_2 is the force after the time during which the indentation depth was kept constant, in N

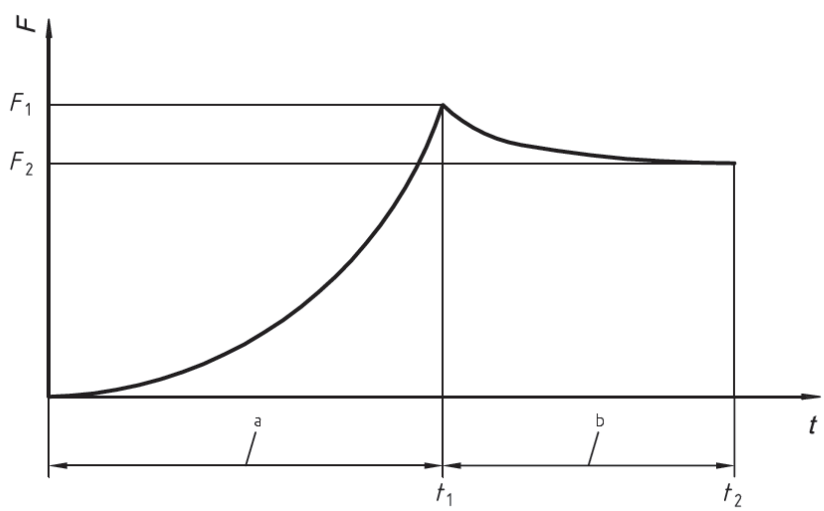


Fig.77 Expression of R_{IT}

a : Application of the indentation depth
b : Indentation depth kept constant from t_1 to t_2

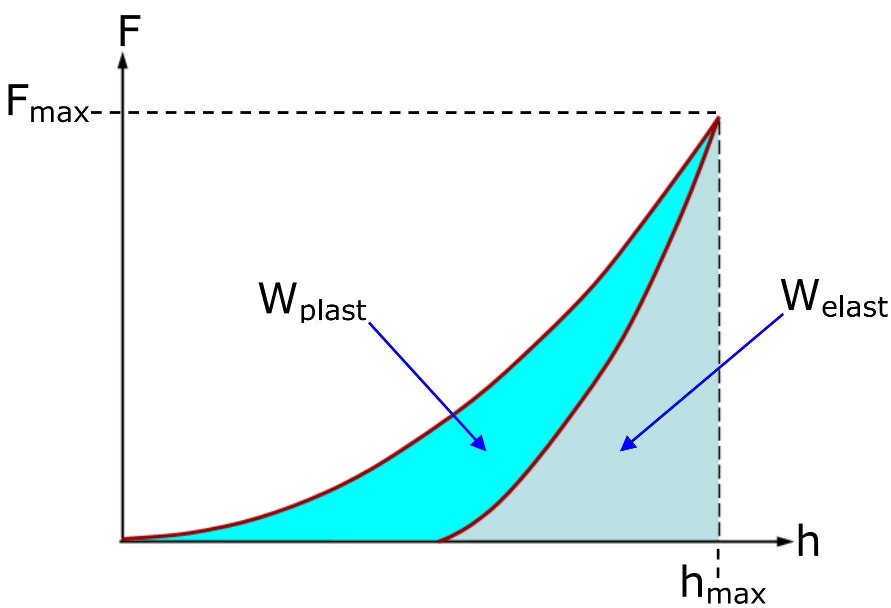
7.12 Elastic part of indentation work

$$\eta_{IT} = \frac{W_{elast}}{W_{total}} \cdot 100$$

With:

$W_{total} = W_{elast} + W_{plast}$

Plastic part W_{plast} / W_{total} follows as 100 % − η_{IT}



7.13 TANGENT METHOD

The Tangent Method is also called the Linear Extrapolation Method. This assumes that the **first portion of the unloading curve is linear and simply extrapolates that linear portion to intercept the displacement axis**. This method is applicable to materials that show a high degree of stiffness and a large deformation so that the unloading curve is, to a good approximation, linear.

A simple linear fit through the upper part of the unloading data intersects the depth axis at h_r

S is given by the slope of this line

h_c is then calculated as:

$$\mathrm{h_c} = h_{\max} - \varepsilon \cdot \left(h_{\max} - h_r\right)$$

Where:

ε depends on the indenter shape.

7.14 POWER LAW METHOD (OLIVER & PHARR)

The Power Law Method recognizes the fact that the **first portion of the unloading curve may not be linear, and can be described by a simple power law relationship**:

$$\mathrm{F} = \mathrm{k} \cdot \left(\mathrm{h} - \mathrm{h_p}\right)^{\mathrm{m}}$$

Where:

k is a constant and m is an exponent which depends on indenter geometry

A power law function is used to describe the upper part of the unloading data.

$$\mathrm{F} = \mathrm{F_{max}} \cdot \left(\frac{\mathrm{h} - \mathrm{h_p}}{\mathrm{h_{max}} - \mathrm{h_p}}\right)^{\mathrm{m}}$$

Where:

The constants m and h_p are determined by a least squares fitting procedure

S (= 1 / C) is given by the derivative at peak load:

$$\mathrm{S} = \left(\frac{\mathrm{dF}}{\mathrm{dh}}\right)_{\mathrm{max}} = \mathrm{m} \cdot \mathrm{F_{max}} \cdot \left[\frac{\left(\mathrm{h_{max}} - \mathrm{h_p}\right)^{\mathrm{m}-1}}{\left(\mathrm{h_{max}} - \mathrm{h_p}\right)^{\mathrm{m}}}\right] = \mathrm{m} \cdot \mathrm{F_{max}} \cdot \left(\mathrm{h_{max}} - \mathrm{h_p}\right)^{-1}$$

h_r is thus given by:

$$h_r = h_{max} - \frac{F_{max}}{S}$$

h_c is then:

$$h_c = h_{max} - \varepsilon \cdot (h_{max} - h_r)$$

Where:

ε now depends on m

The tangent is found by differentiating the unloading curve and evaluating at F_{max}

The intercept of this tangent with the displacement axis yields h_r

7.15 REFERENCES

ISO/DIS Standard 14577-1:2002
DIN Standard 50359-1

*Meyer, E., Z. Ver. Dtsch. Ing. 52 (1908) 645

*Doerner, M.F., and Nix, W.D., "A method for interpreting the data from depth sensing indentation instruments", J. Mat. Res., 1, (1986), 601-609

*Oliver, W.C., Pharr, G.M., "An improved technique for determining hardness and elastic modulus using load and displacement sensing indentation experiments", J. Mat. Res., 7(6), June 1992, 1564-1583

*ISO/DIS Standard 14577-1, ISO/DIS 14577-2

*J. Woirgard and al./Surface and coatings Technology 100-101 (1998) 103-109

If problems should be encountered, refer to this manual and to the others mentioned.

Otherwise contact us,

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