



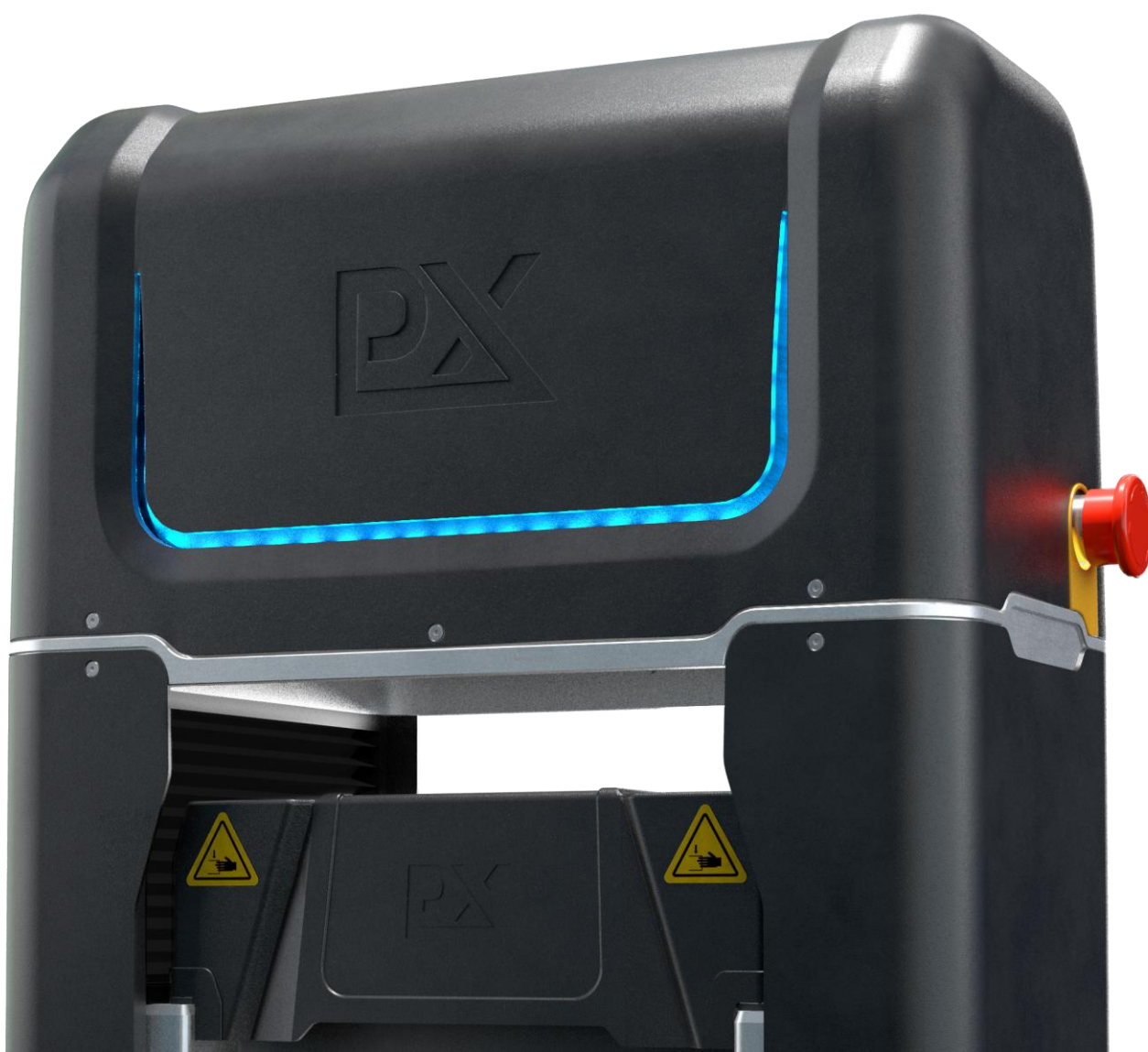
PLX-HotStage User Manual



PLASTOMETREX

Contents

1	PLX-HotStage Introduction	3
2	PLX-HotStage Overview	4
3	PLX-HotStage Setup and CORSICA	10
4	Sample Requirements	23
5	Contact Details	24



1 PLX-HotStage Introduction

1.1 Introduction

The PLX-HotStage module from Plastometrex is designed to be used with the PLX-Benchtop to extract metal stress-strain curves from indentation tests at temperatures of up to 800°C. There are three elements to the PLX-HotStage:

1. **CORSICA:** a local software application for controlling the hardware system and guiding users through the test procedure. The data analysis procedure used in CORSICA enables calculation of tensile stress-strain curves from indentation data through a numerical approach. This technique is known as Profilometry-based Indentation Plastometry (PIP).
2. **PLX-HotStage Module:** the hardware required to run a controlled high temperature PIP test, shown in Figure 1.1. The module has 3 parts: the heater assembly, indenter, and peripherals (fans, LVDT and, terminal box). The heater assembly is concentric on the load cell but is not fixed upon it. The peripherals are fixed on the baseplate and the indenter is fixed to the crosshead. The indenter has a floating design to accommodate different sample sizes.

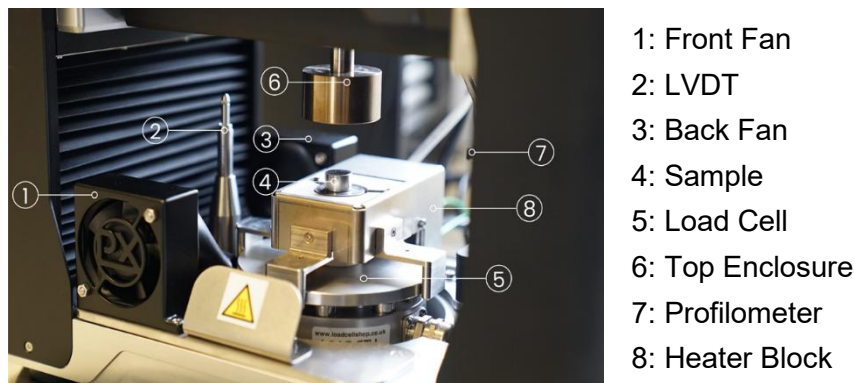


Figure 1.1 Key components of the PLX-Hotstage Module.

3. **PLX-Hotstage Electronics Box:** a box for all the PLX-HotStage related electronics. It acts as an interface between CORSICA and the PLX-HotStage Module.

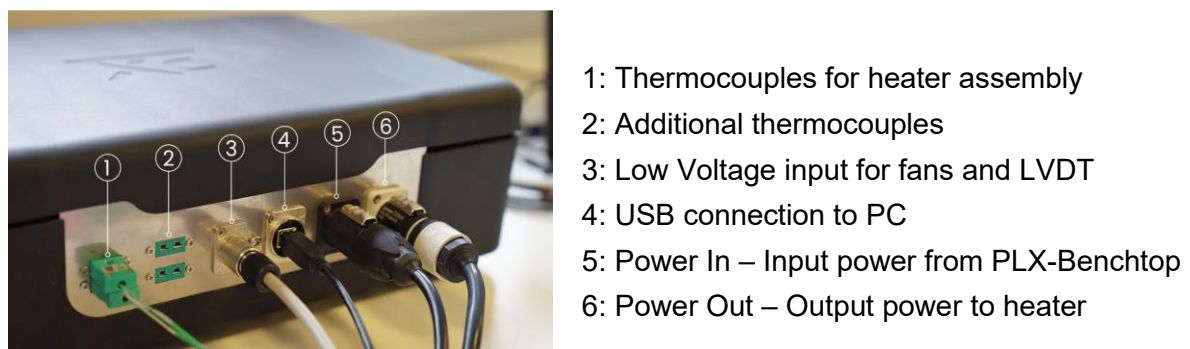


Figure 1.2 Key connections of the PLX-Hotstage Electronics Box

2 PLX-HotStage Overview

2.1 Technical Specification

Feature	Requirements	
Electrical Supply	220-240 V, 50/60 Hz Class 1 equipment must be connected to an earthed supply. Mains plug acts as disconnect device and should be readily accessible.	
Support Surface	Stable bench or table (Machine weight ~ 40 kg)	
PC Specification	Windows 10 or Windows 11 operating system CPU with a clock speed of 3.5 GHz or higher At least 16 GB of RAM Standard Ethernet and USB ports	
Ethernet	Ethernet connection is local	
Force Capacity	8 kN	
Overload Characteristics	200%	
Load Resolution	0.1 N	
LVDT Resolution	0.3 µm	
Profilometer Resolution	0.1 - 0.4 µm	
Position Control Resolution	1 µm	
Indenter Material	Si ₃ N ₄	
Indenter Radius	1 mm	
Maximum Vertical Sample Size	10 mm	
PLX-HotStage Part	Module	Electronics Box
Height	140 mm	150 mm
Width	310 mm	400 mm
Depth	210 mm	300 mm
Weight	2 kg	5 kg
Room Operating Temperature	5 to 40°C	
Humidity	10 to 80% non-condensing	
Test Materials	Ductile Metallics (Yield Stresses < 3 GPa)	
Noise Levels	<70 dBA	

Force measurement accuracy

0.5% down to 1/100 of the load cell capacity, 1% from 1/100 to 1/500 of the load cell capacity. Linearity class 0.05% FRO.

Displacement measurement accuracy

$\pm 2 \mu\text{m}$ for a 200 μm indent.

Atmosphere

Designed for use under normal laboratory conditions. Indoor use and maximum altitude 2000 m.

Foreseeable Misuse

The machine must not be used outdoors or left unattended during operation. The user should not touch the test space when the sample is heating up, at temperature, cooling down, or when the crosshead of the Benchtop Plastometer is moving. The user should not use spare parts that are not approved by the manufacturer.

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the unit may be impaired.

2.2 CE Marking

All systems conform to all relevant European standards and carry CE marking. The CE Marking on the product label indicates that Plastometrex has checked that products meet all applicable EU Essential Requirements, Standards and Directives as declared on the “Declaration of Conformity” included with the product. These specifications were developed in accordance with Plastometrex standard procedures and are subject to change without notice.

UK/EC Declaration of Conformity

ORIGINAL



We

Plastometrex Ltd

Unit 204 Cambridge Science Park, Cambridge, CB4 0GZ

declare under our sole responsibility that the product:

Description	Model	Serial No.
Indentation Plastometer	PLX-HP	

to which this declaration relates are in conformity with all the essential requirements of Machinery Directive 2006/42/EC, EMC Directive 2014/30/EU, RoHS Directive 2011/65/EU and The Supply of Machinery (Safety) Regulations 2008 as amended, The Electromagnetic Compatibility Regulations 2016 as amended and The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012, as amended:

The following harmonised standards have been applied with respect to this product:

BS EN ISO 12100:2010

BS EN 61010-1:2010

BS EN ISO 13849-2:2012

BS EN 61326-1:2013

BS EN ISO 13850:2015

BS EN IEC 63000:2018

Person Authorised to Compile Technical File & EU Authorised Representative

Hold Tech Files Ltd,

Dun Iseal, Newtown, Gaulsmills, Ferrybank, Waterford X91F638

Person Empowered to draw up Declaration

Dr. James Dean

Chief Executive



Signed at: Cambridge, UK

December 2023

Figure 2.1 UK/EC Declaration of Conformity

2.3 PLX-HotStage Safety

The use of the PLX-HotStage carries risks related to hot surfaces that may cause burns and significant forces that present a crushing hazard. Carefully read all the relevant manuals and observe all warnings. Ensure that the system is correctly installed, calibrated and that the tests you will be performing pose no hazard to yourself or others. The following section details general warnings that you must heed at all times.

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the unit may be impaired.

2.3.1 Thermal Burn Hazard

The furnace and control systems are potentially hazardous, as surfaces may be hot. You must be aware of all potentially hazardous parts. This includes, but is not limited to, the heater assembly (lower and upper), the support legs for the heater assembly and the junction box to the rear of the heater assembly. These regions are capable of being at temperatures above 60°C and are therefore capable of causing burns and personal injury. The user should wait until any surfaces and parts of the furnace that they must touch have cooled to ambient temperature.

The PLX-HotStage module is marked with a hot surface hazard sticker as shown in Figure 2.2. Please ensure that hands are always removed from the test space when the sample is heating up, at temperature, or cooling down.



Figure 2.2 Hot surface hazard symbol

2.3.2 Crushing Hazard

There is a potential crushing hazard when using the machine, particularly to the user's fingers. The machine is marked with four crushing hazard stickers as shown in Figure 2.3. Please ensure that fingers are always removed from the test space when the crosshead is moving. Do not place fingers on top of the crosshead cover for any reason.



Figure 2.3 Crushing hazard symbol.

2.3.3 Sample Suitability

Specimen requirements are given in §4 of the PLX-HotStage Manual. Samples that do not meet the requirements and/or present a danger in loading/testing should not be tested. In particular, the sample must be well supported underneath the indenter and not be at risk of toppling under the indentation load.

2.3.4 Personal Protective Equipment (PPE)

Safety goggles should be used when using the machine.

2.3.5 Emergency Stop

The emergency stop is located on the right-hand side of the PLX-Benchtop. If the emergency stop is pressed, all automated machine movement and heating will stop. Rotate the emergency stop button to release. The software should recover, and the user should be able to continue.

If the emergency stop was hit due to damage being sustained to the machine, contact Plastometrex at support@plastometrex.com in order to determine the possible damage before continuing to use the equipment.

2.3.6 Transportation

The PLX-HotStage module weighs 2 kg and the PLX-HotStage E-Box weighs 5 kg. One person is required to move either piece of hardware. The combined weight of the PLX-HotStage module when installed in the PLX-Benchtop is approximately 42 kg. It is not recommended to move the Plastometer with the PLX-HotStage module installed. For transportation over long distances, use the Peli Case supplied with the equipment.

2.3.7 Maintenance and Cleaning

Maintaining the machine is straightforward. The following procedures are recommended:

- Carry out the calibration operations regularly, when prompted by the software. The machine set up operation is required when a new tip is installed, and the

profilometer calibration is required daily.

- Regular general cleaning of the PLX-Benchtop and PLX-HotStage is recommended, depending on usage levels and environment. Care should be taken not to damage the profilometer. The indenter ball should also be cleaned after indentation to remove the lubricant. 70% alcohol pads or dampened towels could be used to clean the equipment. Do not use bleach- type products or liquids.

3 PLX-HotStage Setup and CORSICA

3.1 PLX-HotStage Setup

The following procedure should be followed to set up the PLX-HotStage Module and insert a sample for PLX-HotStage testing. It is also applicable to calibration samples.

1. Connect the PLX-Benchtop to a power supply and a computer via both USB and Ethernet. Switch on the PLX-Benchtop using the switch located on the rear of the machine.
2. Ensure that the latest version of CORSICA is installed on the computer and that an active license file with PLX-HotStage capability enabled (provided by Plastometrex) is present.
3. Launch CORSICA – PLX-HotStage Testing. If the PLX-HotStage module is not installed, follow these installation instructions:
 - 3.1. Ensure that the PLX-HotStage module is cool (i.e., not recently used) and unplugged from the PLX-HotStage electronics box. The crosshead will be raised to the upper limit switch.
 - 3.2. Remove the PLX-Benchtop indenter housing and LVDT assembly. Begin by disconnecting the LVDT connector. This is situated to the right of the machine under the crosshead. Rotate the connector and gently pull. With this done, detach the insert by taking out the three M3 bolts with a 2.5 mm Allen key. Take care to not damage the brass LVDT tip when removing the tip insert. Finally, remove the indenter housing by taking out the three M4 bolts with a 3 mm Allen key and the assembly should come out. To keep everything together, it is recommended that you return the insert to the indenter housing with the 3 bolts used to support the insert. Set this assembly aside in a safe space.
 - 3.3. Bolt the PLX-HotStage indenter holder to the PLX-Benchtop crosshead using the three M4 bolts supplied with the PLX-HotStage and highlighted in blue in Figure 3.1.

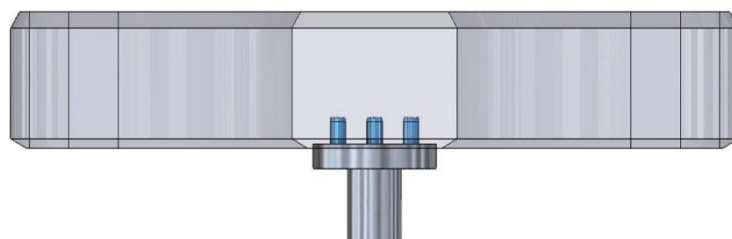


Figure 3.1 Installation of the PLX-HotStage indenter holder.

- 3.4. Screw in the indenter tip holder (blue) and enclosure as per Figure 3.2. First, attach the top enclosure and then screw in the indenter tip with your fingers. Use the 10 mm Hex wrench supplied with the PLX-HotStage to tighten the tip.

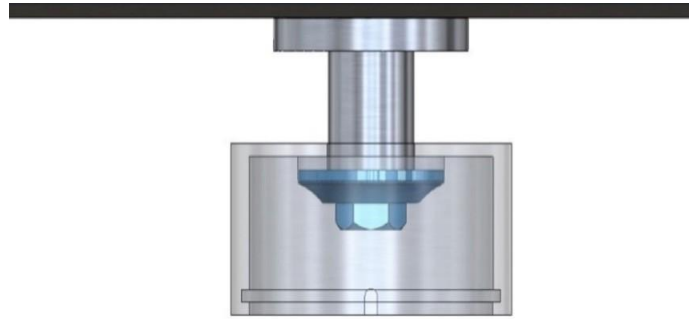


Figure 3.2 Installation of the tip holder and enclosure.

- 3.5. Insert the PLX-HotStage base plate with fans and LVDT into the PLX-Benchtop workspace from the rear, in the orientation shown in Figure 3.3. Fix down the base plate with the three countersunk head M3 bolts provided. The clearance holes are highlighted in blue in Figure 3.3. Place the heater assembly on the load cell using the legs highlighted in blue in Figure 3.4.

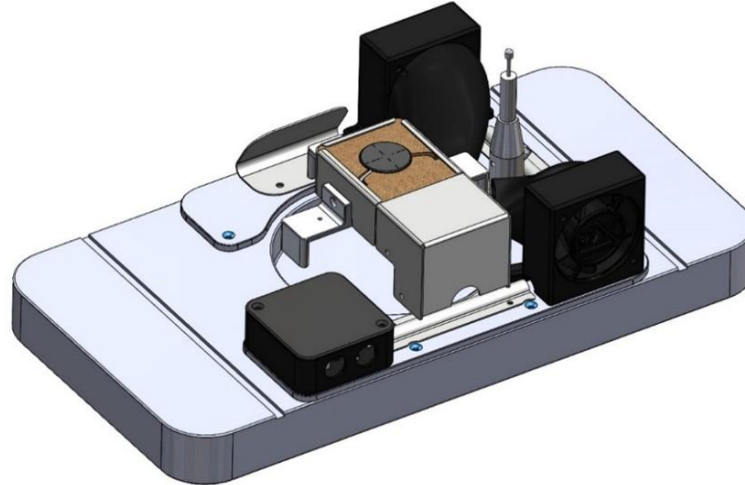


Figure 3.3 Installation of the PLX-HotStage base plate

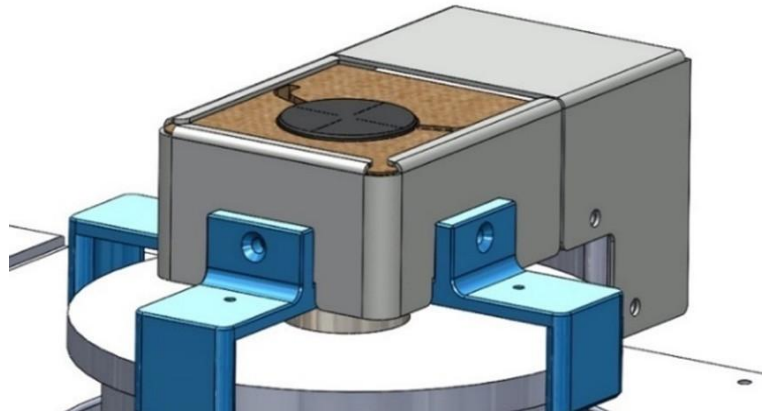


Figure 3.4 Installation of the PLX-HotStage heater assembly on the load cell.

3.6. Connect the electronics box ports to the PLX-Benchtop and computer:

- The PLX-HotStage Module has flying cables that attach/insert in the Power Out, Low Voltage Input and TC1&2 Ports.
- The Power In and the USB need separate cabling - supplied with the PLX-HotStage Machine.
- Thermocouples come with a male Duplex connector that can only be attached in a single orientation. TC ports 3 and 4 are for additional thermocouples that can be used at the user's discretion.
- The LV Input has a locking mechanism that needs to be pulled to release the connector.
- The Power connectors need to be rotated to lock and release.
- The USB on the E-Box can be either plugged into the side of the PLX-Benchtop or the computer.



Figure 3.5 PLX-HotStage electronics box.

4. After installing the PLX-HotStage Module, the boot sequence will be initiated, which is identified by a blue building light sequence in the PLX-Benchtop. When the booting sequence has been completed, the LED status lights will change from building (flashing blue) to steady blue and the 'Devices Ready' icon will be present in the bottom left corner of the CORSICA software. Table 3.1 details the meaning of the LED status lights.

Colour	Form	Meaning
Blue	Building/Flashing	Booting
Blue	Steady	Standby
Green	Building	Indentation Progress
Red	Building	Heating Progress
Yellow	Building	Profilometry Progress
Purple	Building	Calibration Progress
Red	Flashing	Error

Table 3.1 Meaning of LED status lights colour display.

5. Prepare your sample. Sample requirements for a PLX-HotStage test are detailed in Table 3.2. Samples that do not meet the requirements and/or present a danger in loading/testing should not be tested: the sample should be well supported underneath the indenter and not be at risk of toppling under the indentation load.

Feature	Requirements
Sample Thickness (1 mm radius indenter)	3 to 10 mm
Sample Width (1 mm radius indenter)	10 to 30 mm
Sample Surface Tilt	Up to 2°
Sample Surface Finish	Rz < 4 µm and Ra < 0.5 µm This can be obtained using P1200 abrasive paper

Table 3.2 Sample Requirements

6. Check that the PLX-Benchtop is in standby mode (constant blue LED), with the profilometer in the parked position.

7. The crosshead should be moved to a suitable height, such that the sample can be placed on the PLX-HotStage platen. This is carried out by using the up and down buttons in test control.
8. Place the sample on the PLX-HotStage platen. The proposed test location should be approximately under the indentation axis, which coincides with the centre of the platen (marked with four lines and shown in Figure 3.6).

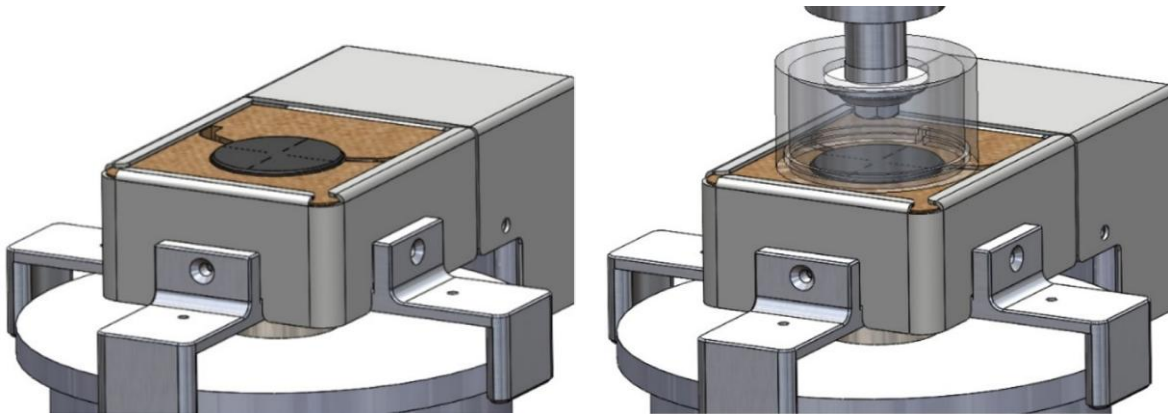


Figure 3.6 The PLX-HotStage platen

Figure 3.7 shows some of the considerations when placing a sample on the PLX-HotStage:

- For larger samples, care must be taken to not position the sample such that any part of it is outside the metal hotplate (30 mm diameter).
- The indent location should not be within 5 mm of an existing indent or 3 mm of a free edge for the 1 mm radius tip.

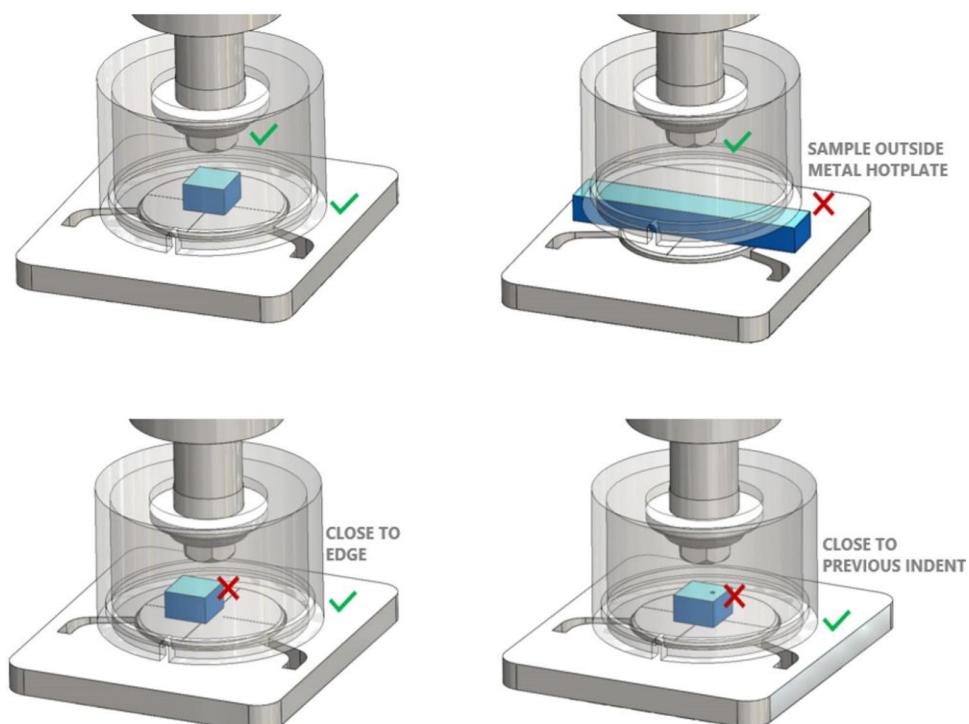


Figure 3.7 Sample Placement guide

3.2 Machine Set up and Profilometer Calibration

If the PLX-HotStage is being used for the first time, or after an overhaul of some type, the machine set up operation and profilometer calibration must be carried out.

3.2.1 Machine Set Up

The Machine Set Up operation can be accessed through **Tools > Machine Set Up**. This operation automatically carries out the LVDT Calibration and the Working Distances Calibration.

3.2.1.1 LVDT Calibration

This calibration takes about 90 seconds. It correlates the signal of the LVDT with the crosshead displacement. The procedure is as follows:

1. Ensure that there is no sample in the PLX-HotStage platen and click “OK”.
2. The indenter housing moves downward until the crosshead touches the LVDT.
3. The indenter housing moves downward at a fixed (slow) speed, periodically recording the LVDT output signal.
4. The indenter housing is retracted so that the crosshead is clear of the LVDT.

3.2.1.2 Working Distances Calibration

This calibration takes around 3 minutes. It involves finding the height of the profilometer and indenter tip, relative to that of the LVDT, allowing use of the LVDT to monitor the height of the sample surface. The procedure is as follows:

1. Place a sample on the HotStage platen.
2. A dialogue box appears. Enter the calibration sample thickness and click “OK”.
3. The indenter housing moves downward until the indenter touches the sample surface.
4. The indenter housing is retracted.
5. The profilometer moves across to the (x, y) location of the indentation axis.
6. The profilometer moves down until it touches the sample surface.
7. The profilometer is retracted and then returned to its parked position.
8. A dialogue box appears. The procedure is then terminated by clicking “Finish”.
9. Retrieve and store the calibration sample.

3.2.2 Profilometer Calibration

This operation takes about 5 minutes. It involves calibrating the profilometer signal using an indent with known dimensions. CORSICA will prompt the profilometer calibration based on both time (3 hours) and temperature fluctuations ($\pm 2.5^{\circ}\text{C}$). The procedure is as follows:

Position the crosshead at a suitable height and place the profilometer calibration sample provided by PLX on the platen, as described in Figure 3.7. The indent should be located (very approximately) on the indentation axis. If this calibration sample is lost or damaged, please contact Plastometrex at support@plastometrex.com.

1. Go to **Tools > Calibrate > Profilometer**. When ready, click “Start”.
2. A dialogue box appears. Enter the calibration sample thickness and the sample indent depth. These values can be found on the calibration sample and sample box. Click on “OK” when this is done.
3. The indenter housing moves downward until it is close to the sample surface.
4. The profilometer moves across to the (x, y) location of the indentation axis.
5. A dialogue box now appears, for positioning of the (x, y) location of the profilometer so that it can scan the indent. This is done via the x- and y-direction arrows within the dialogue box.
6. Move the profilometer so that it is above the indent – this is done with the appropriate arrows on screen. The profilometer tip should be positioned such that it is aligned with the centre of the indent in the x direction. This should be checked visually, looking through the workspace, as shown in Figure 3.7. When this is lined up close to the centre, use the y control to do the same in the y direction – this is less critical in terms of getting close to the indent, but an attempt should be made to get as close as possible. When this has been completed, click “Yes”.
7. The profilometer carries out a series of scans in the (x-y) plane, until the location of the centre of the indent has been established. It will then carry out further scans to calibrate the output. The profilometer then returns to its parked position.
8. A dialogue box appears. Click on “Finish”.
9. Retrieve and store the calibration sample.

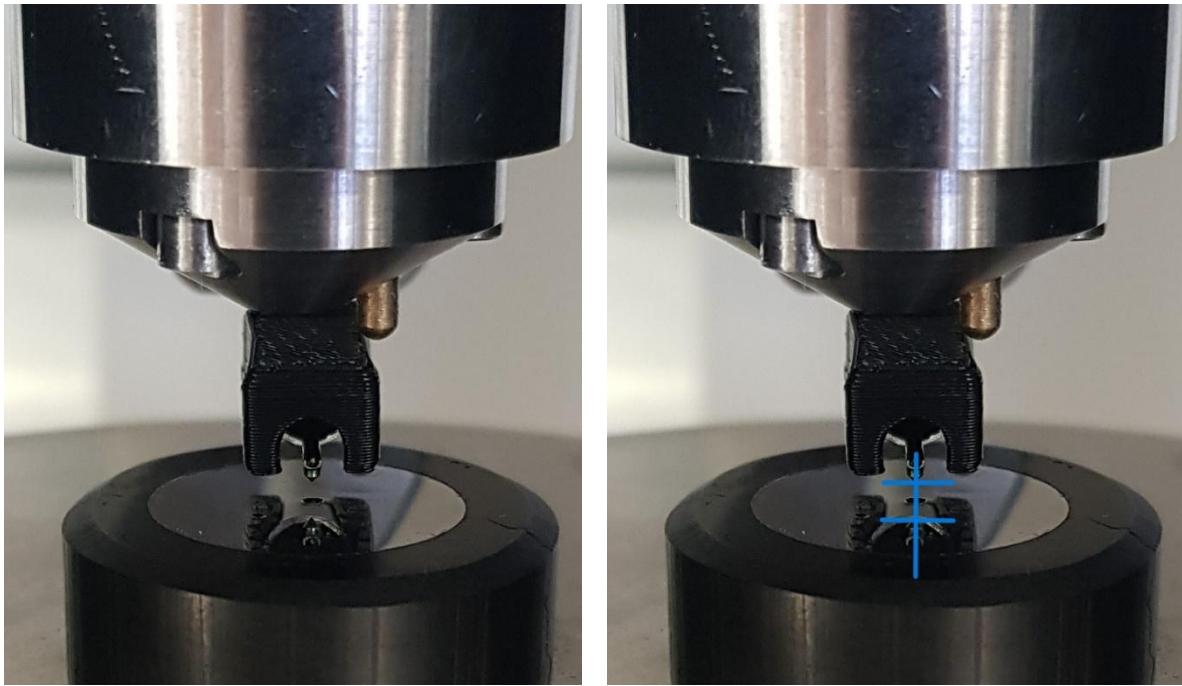


Figure 3.8 Profilometer positioning guide.

3.3 Data-Capture

With the PLX-HotStage setup and calibrations complete, the machine is ready to use. The primary functionality of PLX-HotStage CORSICA - Data Capture is the production of an indent at high temperature (up to 800°C) and the capture of the residual profile.

1. Place the sample within the test space on the platen, as shown in Figure 3.7.
2. Click the “Start” button located in Test Control. A dialogue box appears (shown in Figure 3.9), within which the user inputs the following:
 - File name and directory.
 - Test temperature.
 - Sample thickness.
 - Soak time.
 - Material type.
 - Thermal conductivity - a default thermal conductivity is assigned depending on the chosen material type, but the user can specify their own.
 - Option to populate the PLXUS data for the sample.
3. Once this has been completed, click “Start”.

Figure 3.9 Window to define the indentation test parameters in CORSICA for testing using the PLX-HotStage

4. A dialogue box appears. Add a small amount of the provided lubricant (Omega 35 - Ultimate High Temperature Grease), as shown in Figure 3.10, to the sample and press “OK” to continue.

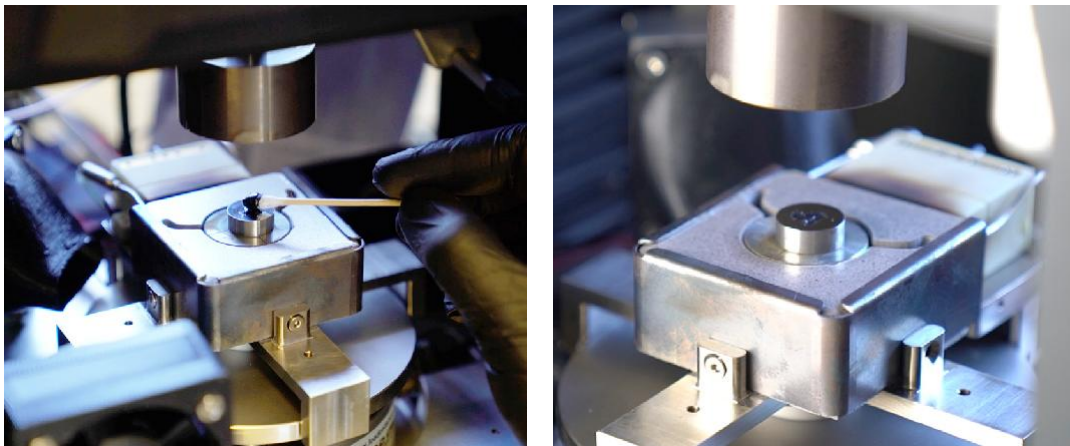


Figure 3.10 Application of lubricant to the sample

5. A safety dialogue box appears. Ensure that the testing area is clear and confirm when ready to continue. Hands should now not enter the workspace/furnace area until Step 11 of this instruction.
6. The indenter housing moves down until the indenter touches the sample surface.
7. The fans turn on and the heating phase starts. The calculated sample temperature can be monitored in the ‘Temperature Plot’ tab.
8. Once the test temperature is reached, the temperature is held constant for the specified soak time.

9. When the soak time is met, the indenter housing moves slowly down (after balancing the load cell to account for the small load cell drift), and indentation starts. During this process, the screen changes to the one shown in Figure 3.11. The load-displacement plot is progressively created during loading. Progress is represented by motion of the green LED status lights on the Plastometer and is also shown in a progress bar on the software.

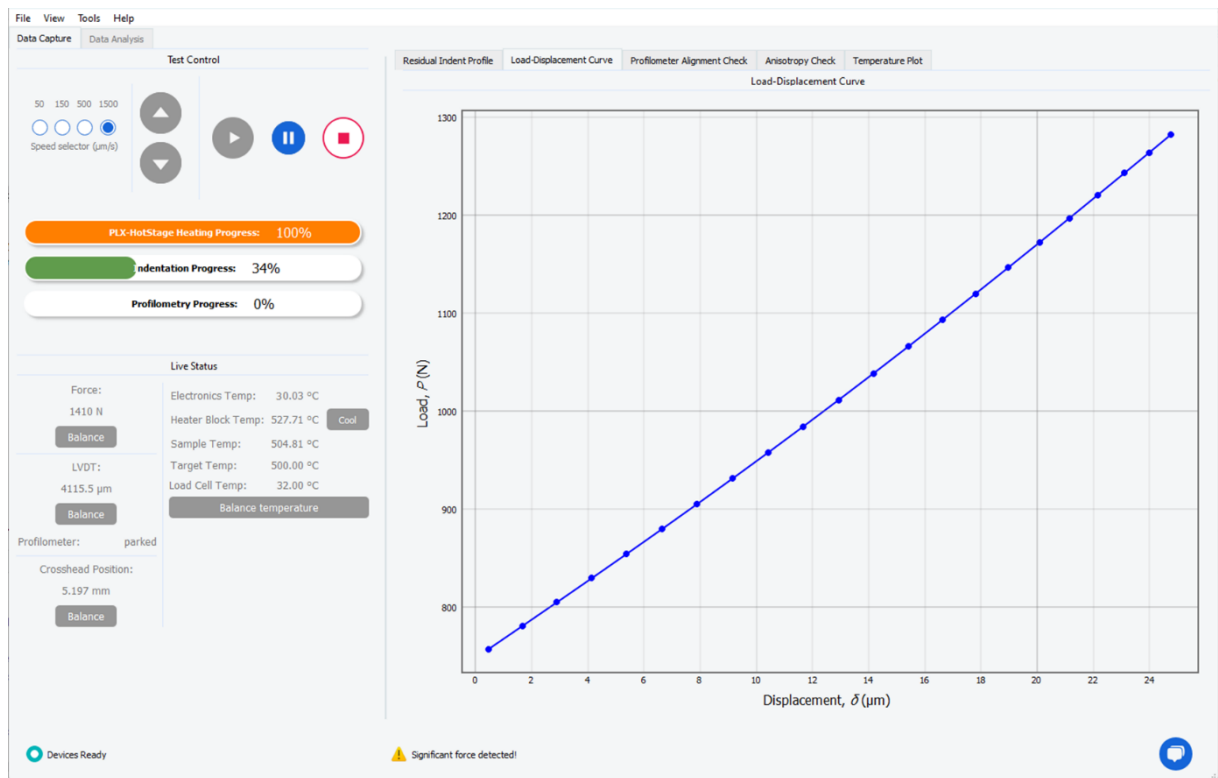


Figure 3.11 The window that appears when the indentation starts.

10. The sample is unloaded, and the indenter housing is retracted 6 mm above the sample platform (leaving a small gap to cool the sample, but such that the sample cannot be touched).
11. A safety dialogue box appears, warning the user to not touch the sample until it is below safe temperature (45°C).
12. When the sample is safe to touch, the indenter housing is retracted well above the sample and the fans turn off. Then, another dialogue box appears asking the user to remove the sample from the platen, clean it using an alcohol-based cleaning solvent, such as IPA and a cotton bud, and place it back in the same approximate location. Press “OK” to continue.

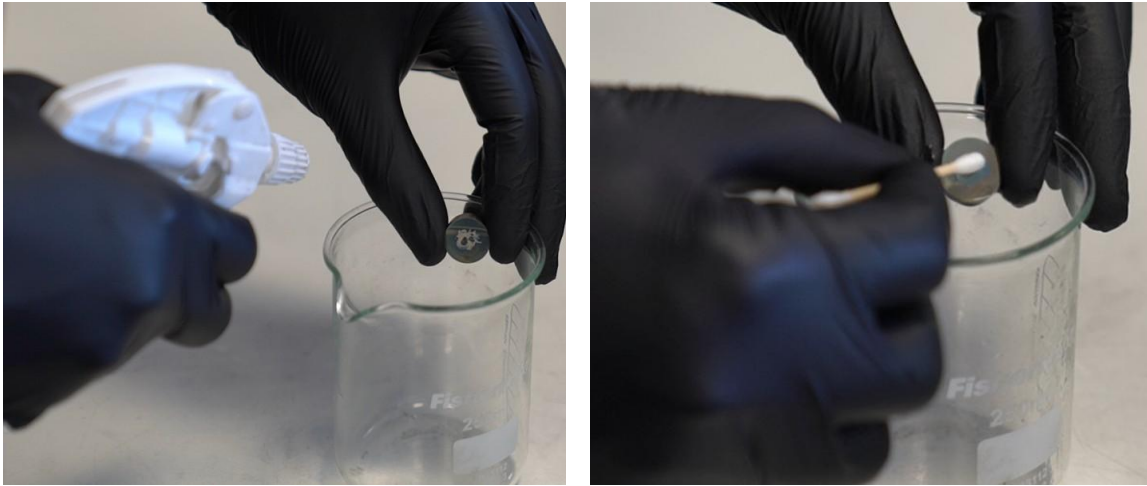


Figure 3.12 Cleaning the lubricant from a sample after the test.

13. The profilometer moves across to the (x, y) location of the indentation axis.
14. A dialogue box now appears, for positioning of the (x, y) location of the profilometer so that it can scan the indent. This is done via the x- and y-direction arrows within the dialogue box. The profilometer tip should be positioned such that it is aligned with the centre of the indent in the x direction. When this is lined up close to the centre, use the y control to do the same in the y direction. When this is completed, click “Yes”.
15. The profilometer will touch down on the sample surface. A quick search for the precise indent centre is carried out. The profilometer scans the indent. After completion of the scan, the resultant profile is displayed as shown in Figure 3.13.

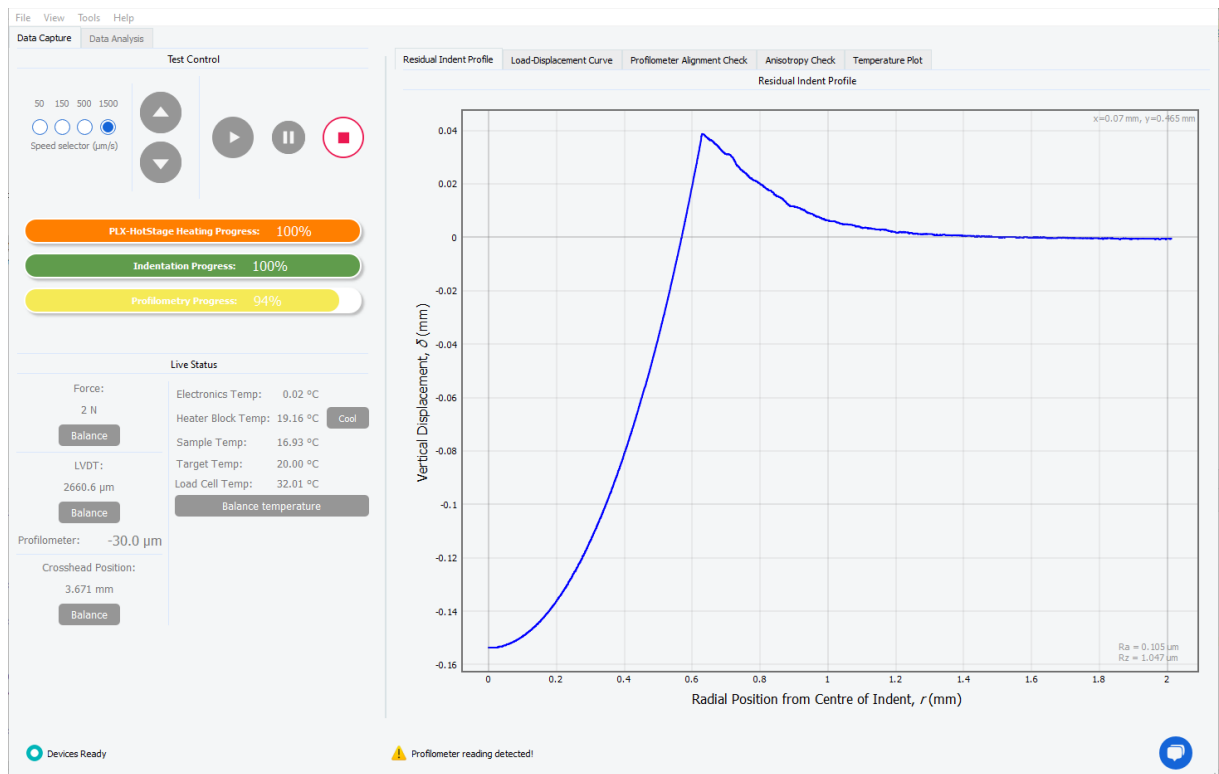


Figure 3.13 Residual indent profile shown in CORSICA post profilometry

16. Following the x and y scans, xy and yx scans will be carried out. This is done to attempt to further identify in-plane anisotropy in the sample. Further information can be found post-test in the Test Diagnostics panel. This will include a warning if anisotropy is detected.
17. The profilometer returns to its parked location.
18. The Test Diagnostics are presented providing information pertaining to the test. The user should consult the Test Diagnostics for warnings (highlighted in yellow) and errors (highlighted in red). An option to move on to Data Analysis is presented - click “Transfer to Data Analysis” when ready.

The plot options specific to the data capture are the Load-Displacement Curve, The Residual Profile, Profilometer Alignment Check, and Anisotropy Check. For further details on the Profilometer Alignment Check and the Anisotropy Check, see the PLX-Benchtop manual.

3.4 Data Analysis

A test file may be transferred from Data Capture (**Transfer to Data Analysis**) or located via the browse function (**Open File**) and loaded into Data Analysis. The analysis is carried out automatically, after which the screen shown in Figure 3.14 appears.

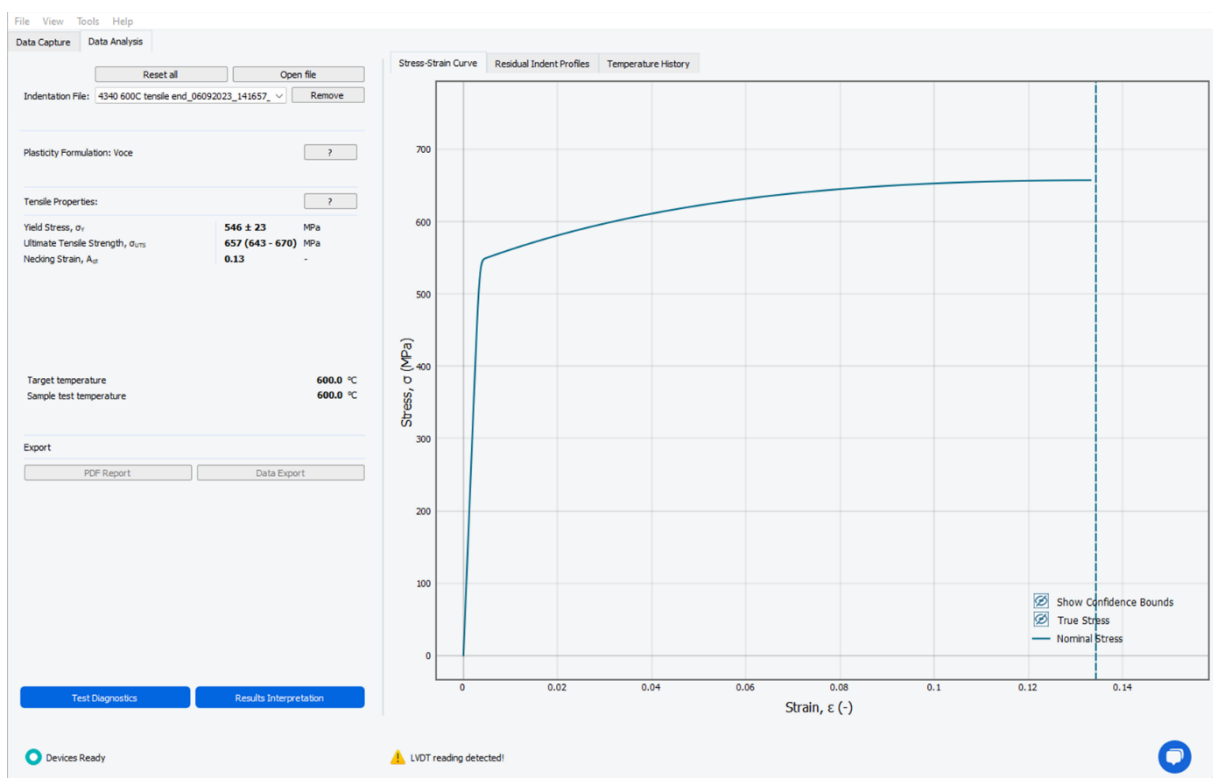


Figure 3.14 The Data Analysis window displayed after data analysis has been completed

For each test, the following can be found in the Data Analysis Control Panel. Further information about these outputs can be found in the relevant more information button.

- **Tensile stress-strain curve outcomes**

Yield Stress (σ_Y) - The yield strength presented with a confidence bound.

Ultimate Tensile Strength (σ_{UTS}) - The peak value of the nominal stress is displayed. The confidence bound is provided as a range.

Necking strain - The strain at UTS.

- **Voce Plasticity Parameters**

The best-fit values of the plasticity parameters in the Voce equation are obtained by clicking the “?” button next to Plasticity Formulation: Voce. These are the yield stress (σ_Y), the saturation stress (σ_S) and the characteristic strain (ϵ_0).

- **Test Diagnostics and Results Interpretation**

The option to bring up the “Test Diagnostics” summary shown at the end of data capture test is given. “Results Interpretation” gives further information about interpreting the PIP results.

- **Test Temperature**

Target temperature - the target temperature specified by the user at the start of the test.

Sample test temperature - the calculated sample temperature at the time of indentation.

- **Data Export**

The ability to export the data in PDF and CSV form are provided. Each of these include user options so exports can be tailored to the user’s requirements.

- **Stress-strain curve**

The inferred stress-strain curve is plotted in tensile nominal and true form. The Voce parameters will determine the form of both curves.

- **Indentation Profile**

The residual indent profile plot measured during Data Capture will be shown with the best fit FEM profile.

- **Temperature history**

The sample temperature vs time before and during indentation.

4 Sample Requirements

The sample requirements for the PLX-HotStage are the same as for the PLX-Benchtop with two exceptions, the sample dimensions and mounting requirements.

4.1 Sample Dimensions

The maximum and minimum sample dimensions are shown in Table 4.1Table 3.1.

Indenter tip radius (mm)	Min lateral dimensions (mm)	Max lateral dimensions (mm)	Min thickness (mm)	Max thickness (mm)
1	10	30	3	10

Table 4.1 Minimum and maximum sample dimensions for the PLX-HotStage.

The maximum sample dimensions for the PLX-HotStage are determined by the dimensions of the sample platen. The minimum lateral dimension is larger than in the PLX-Benchtop, to ensure that the indent is created away from the edge of the sample.

4.2 Mounting

For the PLX-HotStage, samples should not be mounted. This is because the mounting media is not designed to be exposed to such temperatures, and the sample must be in direct contact with the sample platen for optimal heating.

5 Contact Details

Plastometrex UK (Global Headquarters)

Unit 7 Technopark

Newmarket Road

Cambridge CB5 8PB

EU Authorised Representative

Hod Tech Files Ltd.

Dun Iseal House, Waterford

X91 F368, Republic of Ireland

Information, diagrams and instructions for the repair of the machine are available upon request, by contacting support@plastometrex.com