Correcting time dependent displacement effects in nanoindentation analysis

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Motivation

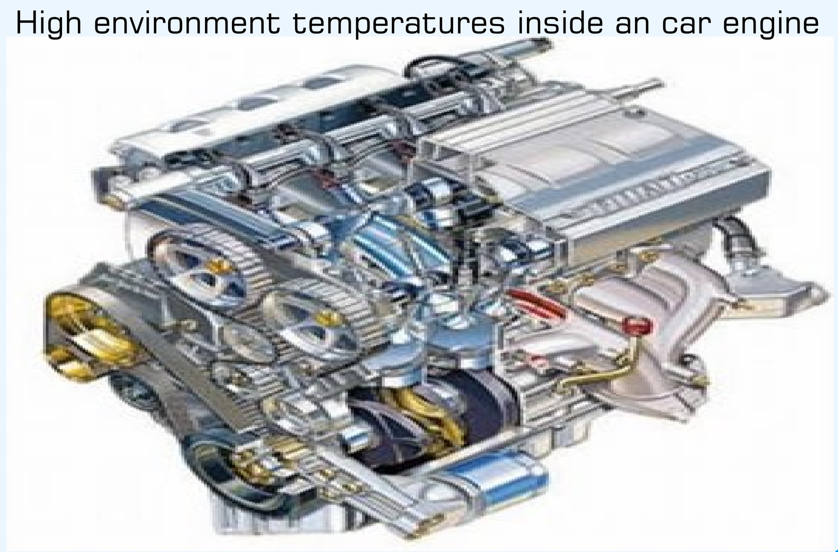
Instrumented nanoindentation is now a commonly used tool in assessing the properties of materials for a wide range of applications. Analysis of nanoindentation data is typically carried out using the methods popularised by Oliver and Pharr, with Young's modulus and hardness determined by a power law fit to the unloading data of the load displacement plot. One of the key limitations of this analysis technique is that it does not allow consideration of time dependent deformation mechanisms such as creep or visco-elastic behavior exhibited by some materials. Hence if testing such materials experimentalists find Young's modulus values which are dependent on the experimental unloading rate.

Conventional nanoindentation techniques use a fast unloading rate in order to minimise the influence of time dependent deformation on calculated Young's modulus. Such techniques have been used on two representative samples - a visco-elastic polymer and gold, tested at room temperature and higher (creep) temperatures respectively. Oliver and Pharr analysis of this data returns acceptable Young's moduli but there is still an unloading rate dependence in the results. Additionally, failure to account for time dependent depth change can lead to physically unrealistic fitting constants in the power law.

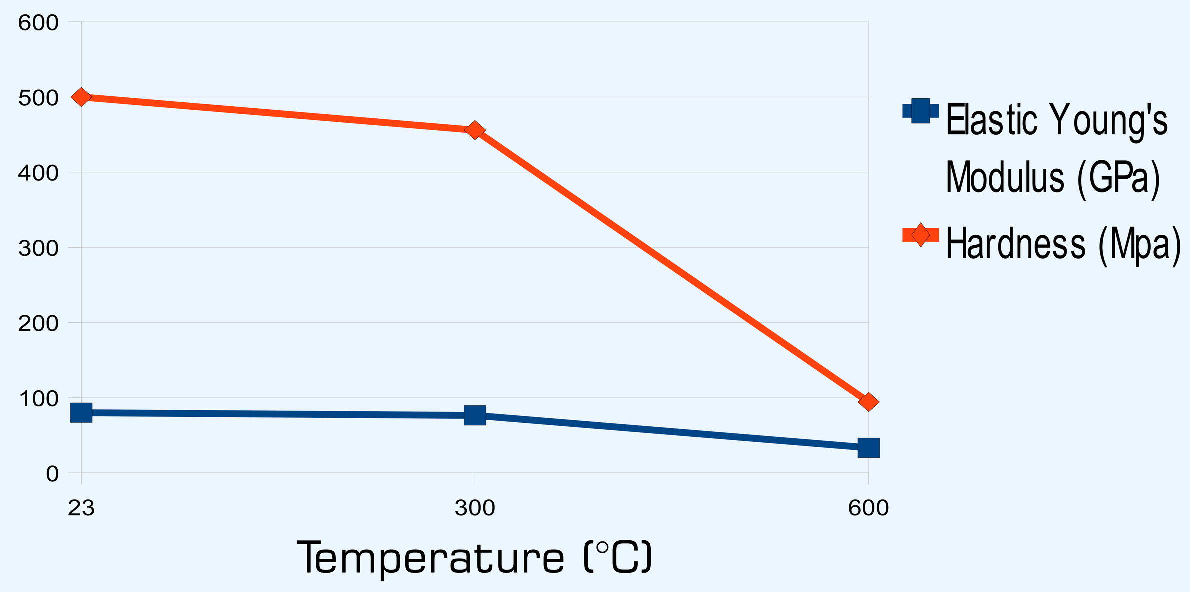
Results using a new analysis method which allows determination of the time dependent contributions to the Nanoindentation depth will be presented. This enables calculation of a Young's modulus independent of the unloading rate and with physically meaningful fitting constants in the power law. As well as extracting true material properties, such analysis conveys the advantage that testing procedures can become more standardised since no special experimental treatment is needed for materials which have time dependent deformation mechanisms.

High temperatures occur during the drilling process

High environment temperatures inside an car engine



Temperature dependent properties



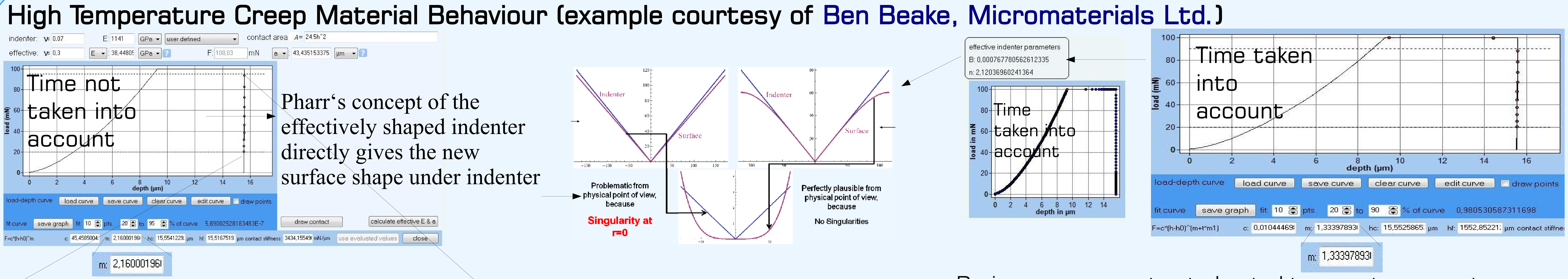
Often mechanical parameters are characterized at different temperatures than they will appear in the real contact situation. For most materials these temperature differences can lead to complete different mechanical parameters. That is why you should characterize your material at the temperature which will occur in the real contact situation. With the NanoTest hot stage (seen on the right side image) of MicroMaterials you can measure mechanical properties at temperatures up to 750°C.

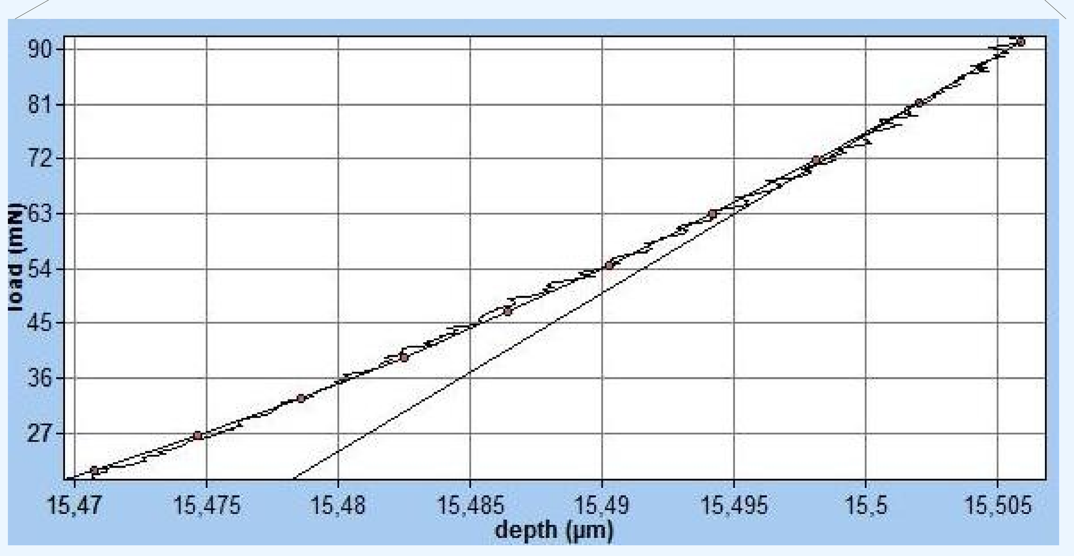
In the screenshot on the left you can see the result from a measurement at different temperatures and how the Young's modulus changes.

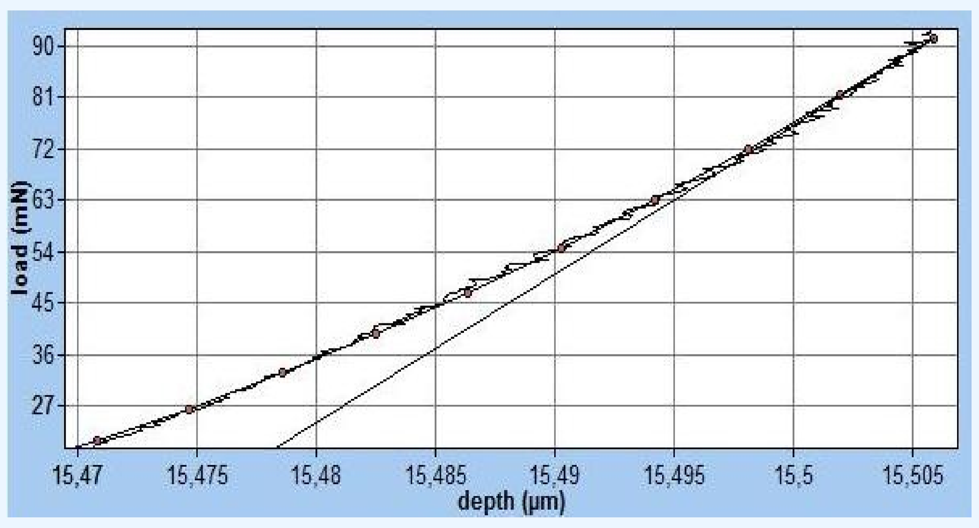
Caution: Most materials will creep at high temperatures. Without this taken into account, you will get physical nonsense, like m>2 (see below).

Detailed information on www.siomec.de/pub/2010/003

High Temperature Creep Material Behaviour (example courtesy of Ben Beake, Micromaterials Ltd.)



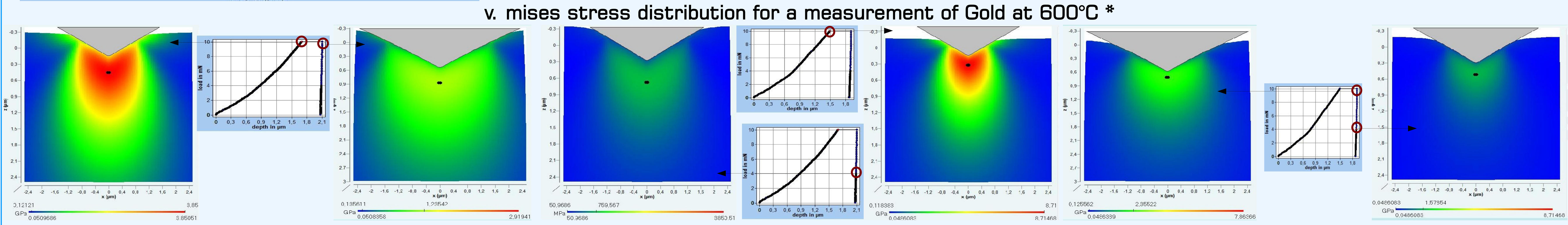




During measurements at elevated temperatures most materials will creep. The standard analyze methods can't take this material behaviour into account. SIO has developed an adaption of the classical Oliver & Pharr method, by using the hold-time part and the unloading part of the measured indentation curve (screenshots above). The results of this new method are time depending values for the young's modulus and the effective Indenter.

The screenshots on the left side show the results for the two different fitting procedures.

v. mises stress distribution for a measurement of Gold at 600°C *



10s unloading time

20s unloading time

* Absolute values changed for NDA reasons. [1] University of Nottingham, Nottingham, United Kingdom [2] Micro. Materials Ltd., Wrexham, United Kingdom

Benefits

- ✔ Get your real mechanical parameters for your working situation
- ✔ Allows you to optimize your materials faster
- ✔ Allows more precisely lifetime prediction
- ✔ Ward off unjustified customer complaints

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