

VAMAS TWA20 Project 3

Characterisation of Specimens and Planning of the VAMAS TWA20
Intercomparison Exercise on XRD – Phase I

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Objective

- The main objective of the VAMAS TWA20 Project 3 is to examine various aspects of the measurement process associated with the XRD residual stress measurement, and contribute to an internationally agreed standard that is currently being developed through CEN/TC138/WG10 and the ASTM E28.13 subcommittee on Residual Stress Measurement.
- The project compliments the activity in CEN/TC138/WG10 by carrying out additional testing and characterisation in support of the proposed standard, through a series of intercomparison exercises on a range of different components.

Phase 1

- For the Phase I work, different aspects of the draft standard will be examined through an intercomparison exercise on a shot peened stainless steel component and will address-
 - the test protocol
 - reporting of results
 - the development and presentation of uncertainty budgets.
- Participants will carry out between 1 and 4 series of measurements, based on their capability and resource availability.



Proposed Test Programme

A series of specific experiments have been designed to examine the repeatability of the measurement, the ability of partners to measure the variation of stress with depth by using XRD combined with layer removal or electro-polishing, the effect of surface roughness, and measurements of the elastic constants of the material.

Test	Issue	Specimen	Measurands
1	Repeatability *	Block	Value \pm Uncertainty
2	Repeatability **	Block	Value \pm Uncertainty
3	Depth profile	Block	Stress profile to 0.4mm
4	Elastic Constants, with different surface finish	Rectangular bar	Values of elastic parameters

* Sample not removed from equipment between measurements.

** Sample removed and repositioned in nominally the same location between measurements.



Preparation of Samples "Ring and Plug"

- During the initial stages of this project much effort was spent on developing a suitable component for distribution and measurement.
- Initially a "ring and plug" sample was chosen, similar to that used previously within the VAMAS TWA20 project on neutron diffraction, because the stress field is well understood and can be modelled reasonably accurately.
- However, for the neutron work only one specimen was manufactured and all the laboratories involved measured this; the challenge for the XRD project was to produce a series of identical artefacts that could be distributed to all participants.



Preparation of Samples "Ring and Plug"

- An initial ring and plug sample was manufactured from 316 stainless steel and both X-ray diffraction (XRD) and fine incremental hole drilling measurements were then carried out by NPL to characterise the stress state in the central plug section.
- Three sets of measurements were made in the plug region on two samples with different interference fits.

Component ID	Interference Fit	Normal Stress, MPa	Error, \pm MPa
1	50-20	-181	11
		-155	11
		-174	8
2	50-40	-230	12
		-282	15
		-148 (rear face)	8

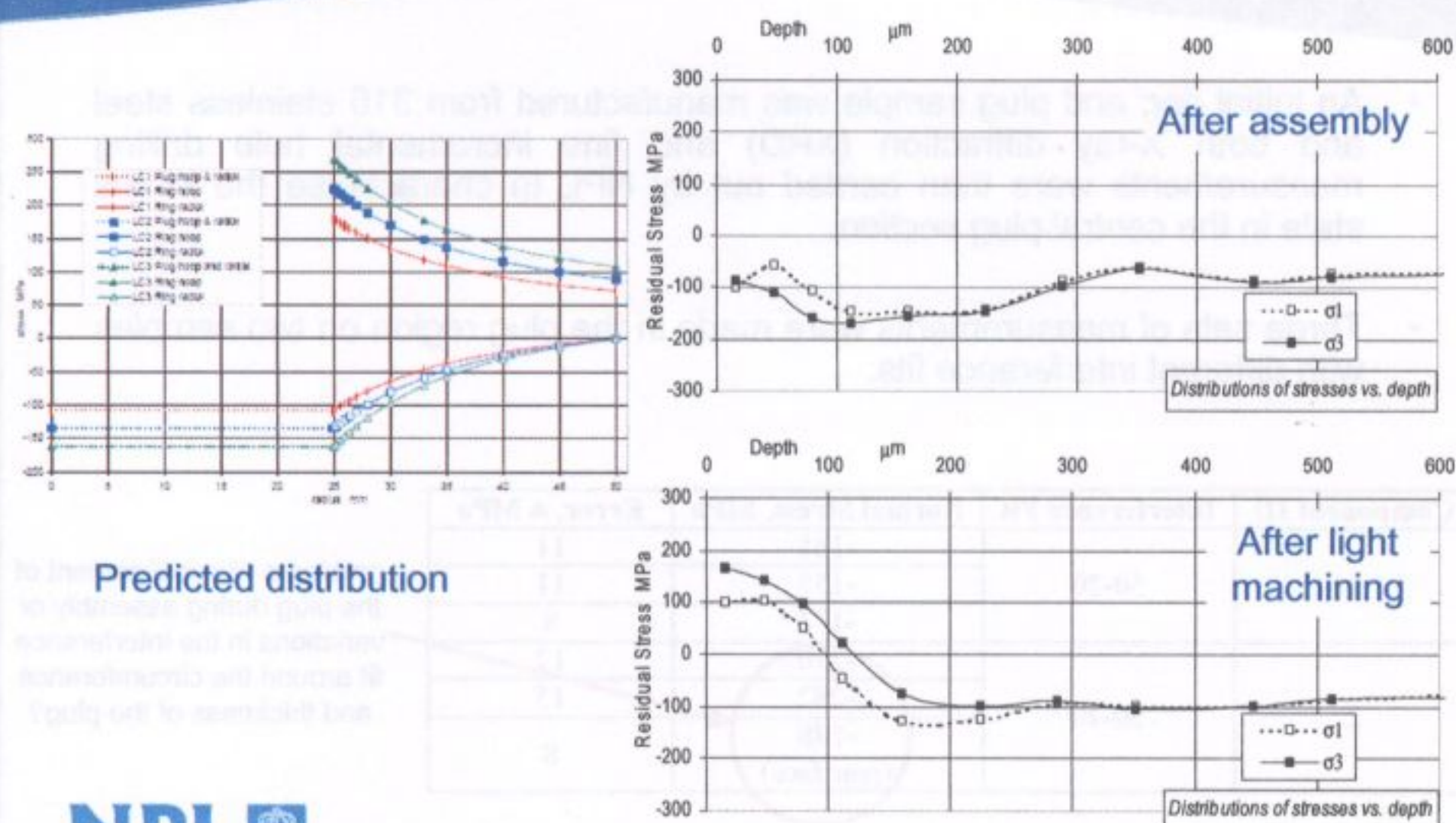
problems of misalignment of the plug during assembly or variations in the interference fit around the circumference and thickness of the plug?



Preparation of Samples "Ring and Plug"

- For comparison with the XRD data, hole drilling measurements were also made on the ring and plug component 1 in the as-manufactured state and then following light machining.
- Tests were carried out using a 062UL gauge and a series of fine depth increments of 4 x 32 μm , 4 x 64 μm , and 8 x 128 μm to a depth of ~1.4mm.
- Results were analysed using the Integral method.

Preparation of Samples "Ring and Plug"



Preparation of Samples "Ring and Plug"

- The hole drilling and XRD measurements agreed reasonably well with the FEA model, but the magnitudes of stress generated in the plug were quite low.
- Any associated error or uncertainty in the measurement is likely to be large compared to the mean stress value.
- There was also concern regarding the repeatability of the manufacturing process.
- Cost and feasibility of producing an adequate number of identical samples for the project, since one of the aims was to enable each participating country to retain a sample to use as a stressed reference sample, and some of the proposed tests were destructive.
- Due to the large number of laboratories taking part in the exercise it was deemed impractical, at this stage, to have a single artefact that could be passed around to all partners for measurement, although doing so would of course reduce the impact of variability in the material or component affecting the scatter and uncertainty in the measurements.



Preparation of Samples "Ring and Plug"

- A decision was therefore made to abandon the ring and plug geometry at this stage and replace it with a more simple component, that would have –
 - higher stress magnitudes
 - good repeatability
 - provide a significant measurement challenge
 - yet be produced cost effectively in the numbers required for the first intercomparison exercise.
- A shot peened stainless steel component was chosen to meet all these criteria, as it was expected to give a more consistent stress distribution between samples than the individual manufacturing of ring and plug samples, which could be compromised by small differences in dimensional tolerances and circularity, variation in the temperature distribution during manufacture, and misalignments between the ring and plug during assembly.



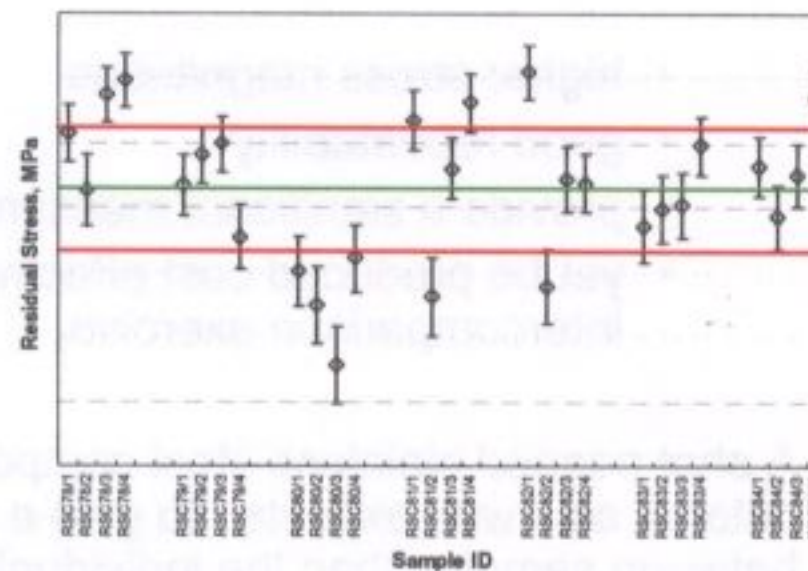
Preparation of Samples Shot-peened

- A 316 stainless steel plate was cut into 16 large sections and shot peened on one face by Metal Improvement Company, using MI 230 Hard media, an intensity of 0.010 *A and 200% coverage.
- This gave two stress states per sample –
 - as-received rolled surface
 - shot peened face.
- Eight of the sections were subsequently cut into smaller blocks, approximately 65mm x 50mm x 18mm in size for distribution to the participating laboratories.

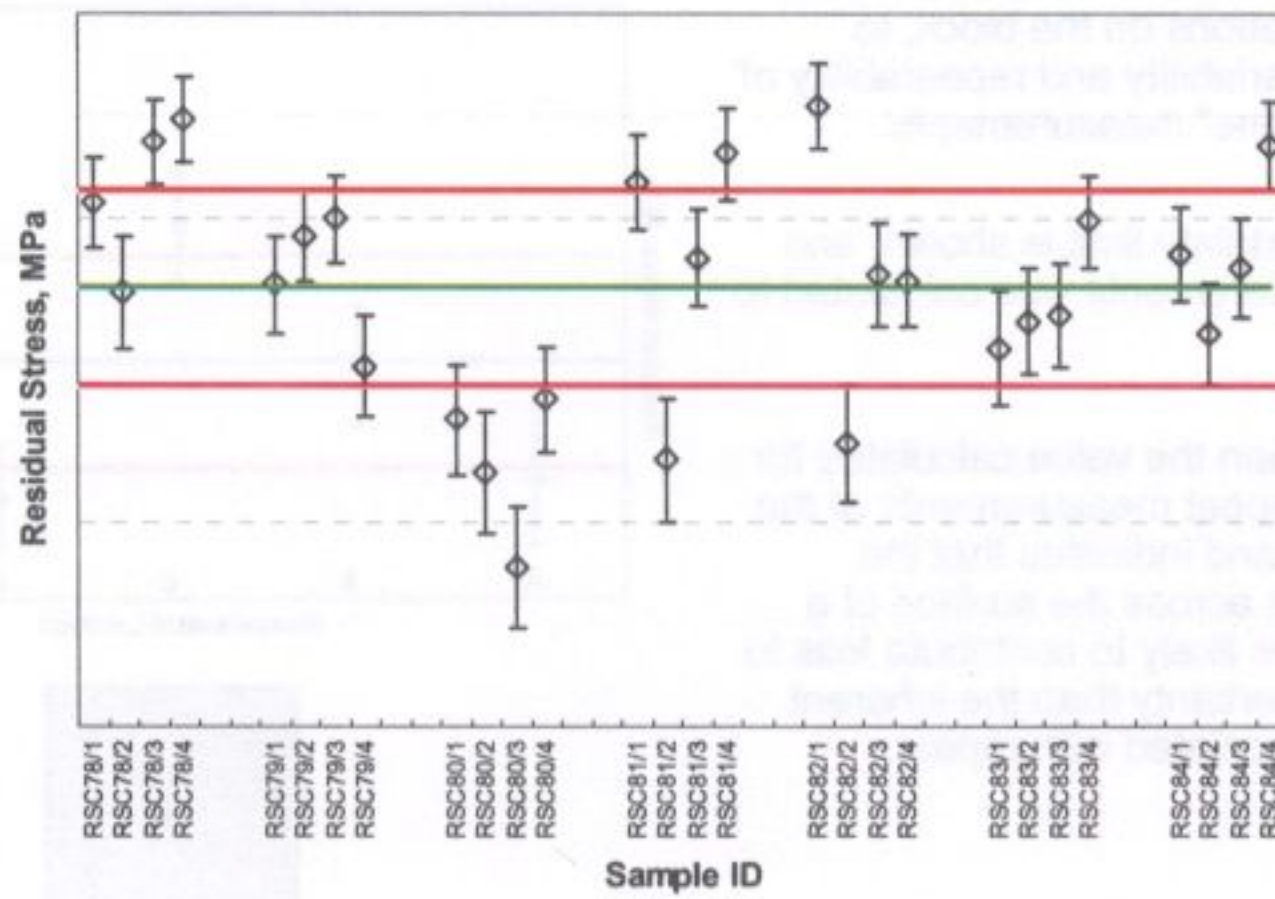


Preparation of Samples Shot-peened

- The NPL baseline measurements for all 28 samples showed a larger than expected spread in the values.
- There will be some inherent variability due to the shot peening process, but the scatter may also be due to material effects, such as preferred orientation effects.
- To reduce the effect of material variability in the first intercomparison exercise, a subset of specimens was chosen from those that fell within the 95% uncertainty limit.



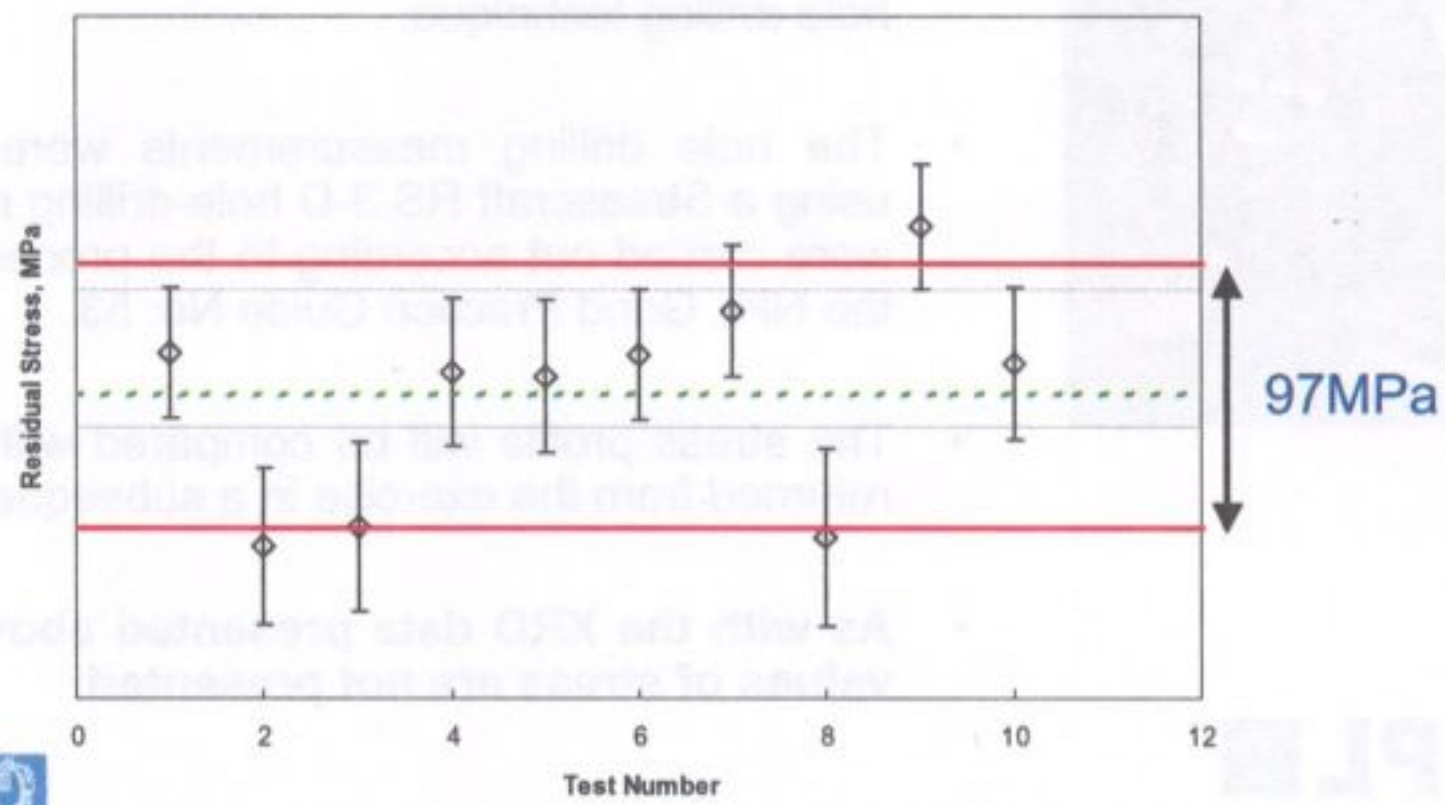
Preparation of Samples Shot-peened



The mean value from the set (green) and the uncertainty limit on this value, based on the 95% confidence limit (± 2 standard deviations), which corresponds to ± 48.5 MPa.

Preparation of Samples Shot-peened

To examine the effect of repeatability with the shot peened stainless steel samples being used in this exercise, a series of measurements were carried out on sample RSC78/2 to compare the uncertainty in the measurements through operator and equipment interaction, with the variation of the residual stress over the surface of the specimen.

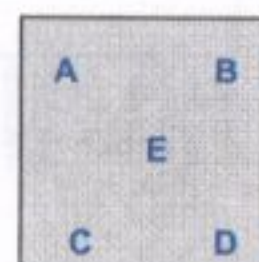
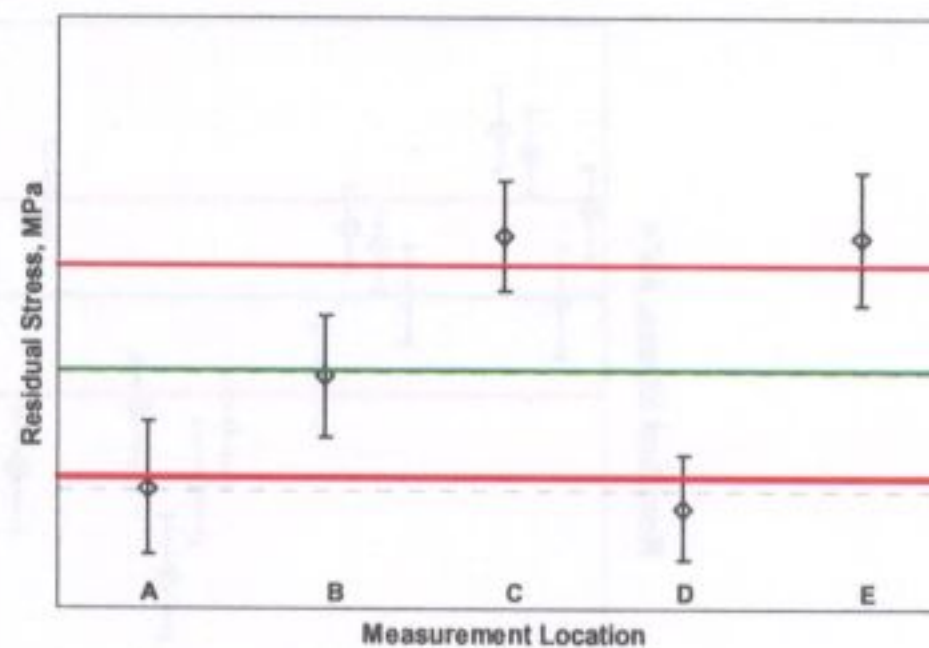


Preparation of Samples Shot-peened

Repeat measurements have been made at different locations on the block, to examine the variability and repeatability of the NPL "baseline" measurements.

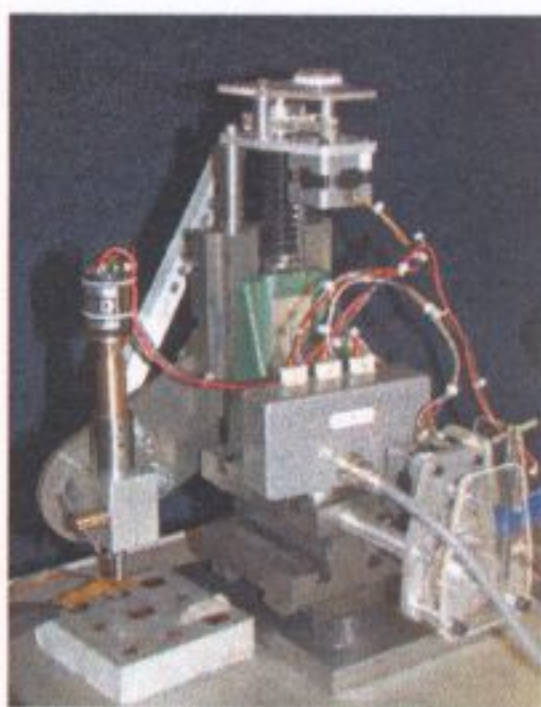
The 95% uncertainty limit is shown, and for these measurements was calculated to be ± 44 MPa.

This is lower than the value calculated for the series of repeat measurements at the same location and indicates that the stress variation across the surface of a single sample is likely to contribute less to the overall uncertainty than the inherent uncertainty associated with repeat measurements.



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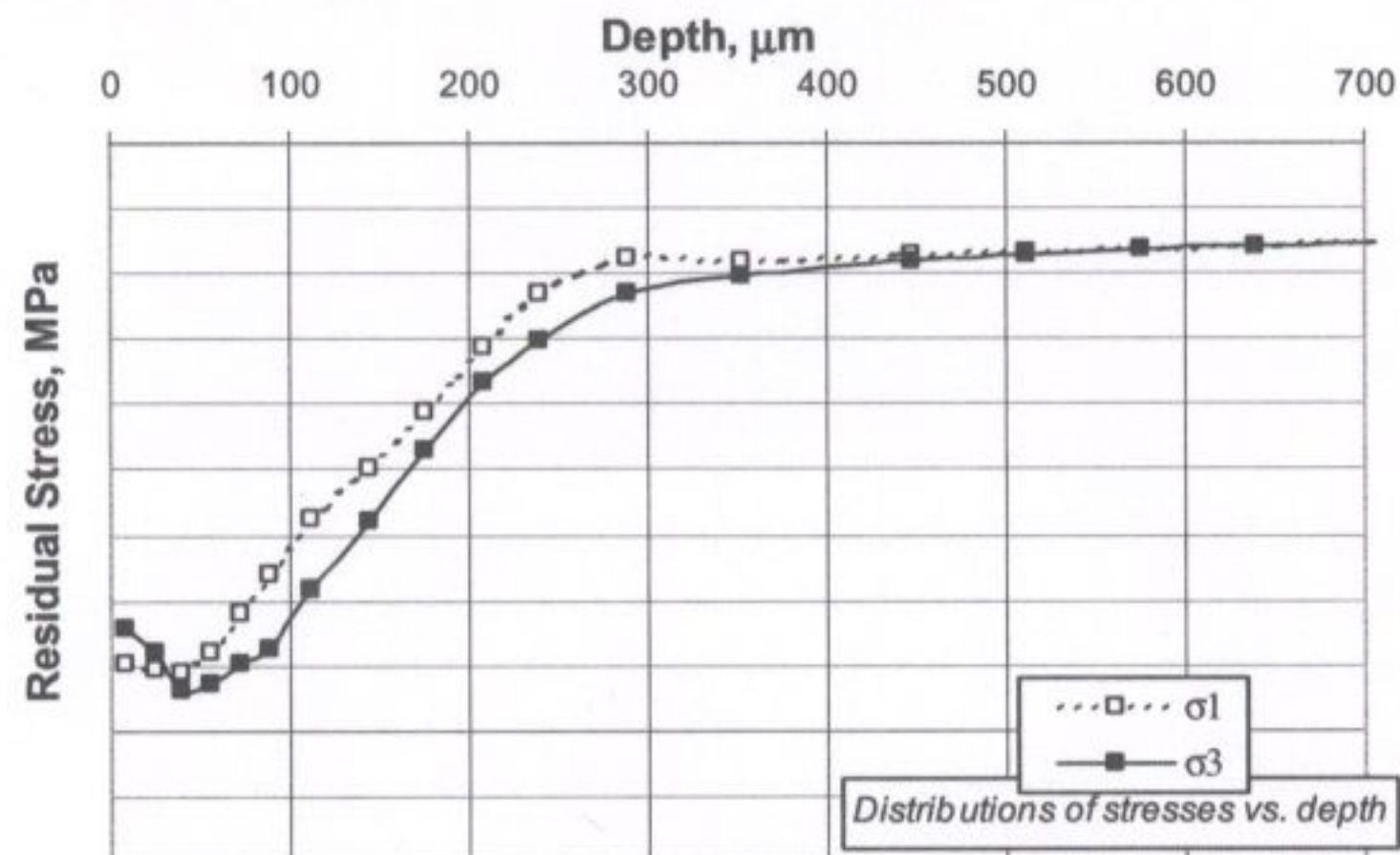
Preparation of Samples Shot-peened



- A key task within the exercise is to produce a profile of the variation of residual stress with depth.
- A representative stress profile for the shot peened specimen RSC81/3 has been generated using the hole drilling technique.
- The hole drilling measurements were carried out using a Stresscraft RS 3-D hole-drilling machine, and were carried out according to the procedure given in the NPL Good Practice Guide No. 53.
- The stress profile will be compared with the profiles returned from the exercise in a subsequent report.
- **As with the XRD data presented above, absolute values of stress are not presented.**

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Preparation of Samples Shot-peened



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Timetable

- Agree participation, test programme and materials (completed)
- Complete preparation of components (Oct 2005 - completed)
- Complete baseline characterisation tests (Nov 2005 - completed)
- Distribute components & start first intercomparison exercise (Dec 2005 - completed)
- Organise meeting to report results (Apr 2006 - completed)

- "Email newsletter" to all participants on progress (April 2006 and July 2006)
- Set up dedicated web pages (May 2006)
- Complete testing (July 2006)
- Meeting at ECRS-7, Berlin (Aug 2006)
- VAMAS report and input to CEN/TC138/WG10 (Aug 2006)
- Agree next phase of testing (Aug 2006)

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