	Experiment title: Evaluation by Synchrotron Radiation of Shape Factor Effects on Residual Stress in Nitrided Layers	**Experiment number:** ME 1032
Beamline: ID15A	**Date of experiment:** from: July 17th, 2005 to: July 21th, 2005	**Date of report:** August 29th, 2005 *Received at ESRF:*
Shifts: 9	**Local contact(s):** Dr. Guillaume Geandier	

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Report:

Problem. Nitriding is a thermo-chemical treatment to improve fatigue life of steel parts what are exposed to high abrasive forces at the surface like gears, spline shaft transmissions, and shafts. During the nitrogen diffusion the precipitation of nitrides generate residual stresses increasing the superficial hardness. These residual stress profiles are a function of the nitriding process (time, temperature, nitrogen activity,...), the steel composition but also critically depend on the geometry of the steel components [2]. If the surface curvature is very small, for example near notches or fillet between two teeth of gear, and comparable to the nitriding depth the knowledge of the local residual stress is important in order to determine macroscopic stresses in the material. In fact the true stress depends on the applied stress as a function of the component shape factor.

In such conditions the determination of in-depth stress gradients by classical X-ray diffraction has limitations because i) the spatial resolution is not sufficient since the irradiated area has the same dimension as the surface curvature of the component, ii) it is very difficult to take into account the removal of matter which is required to determine in-depth stress profiles, iii) the stress gradient for a curvilinear geometry is not the same than for a plane geometry. From our earlier neutron diffraction measurements [1, 6, 7, 8] we concluded that i) we need to reduce the gauge volume size to improve the accuracy of the residual stress values (specially close to the surface), ii) we need to determine the normal component of the stress tensor (σ_{33}) because the geometry of the sample induces a complex stress state and the material is as well multi phased.

Synchrotron diffraction. The synchrotron diffraction technique is a well-adapted method to determine such stress gradients in strongly absorbing materials due to the penetration power of high energy X-rays. The removal of matter is not required and

it is possible to determine an in-depth map of the stress tensor near notches.

Experimental method. Sample is taken from a nitrided gear what is used in a gear-box. Gear material is a quenched and tempered french steel grade 32CrMoV13 as base material. This steel is treated by gas nitriding to obtain a nitriding depth of about 0.8 mm. Measurement are performed on the fillet between two teeth using ID15A beam-line. Residual stresses are determine using $\sin^2\psi$ method. ψ angles have been taken using eulerian cradle with the goniometer in ψ configuration. Stress profiles were determined by in-depth scanning following axial and circumferential directions with 7 ψ angles. Volume gauge is approximatively $0.05\times0.05\times1\text{mm}^3$ with diffracting angle equal to 10° to operate in energy dispersive mode. Several peaks were used simultaneous in order to determine, with a greatest accuracy compatible with acquisition time (10 min by spectrum), stresses using iron phase. Stress profiles were determined without taken into account absorption attenuation of radiation and correction of surface effects (difference between barycenter of gauge volume and diffracting volume). The determination of σ_{33} component was made using free stress iron lattice parameter (a_0) determined in the core of sample (average of several measurements). Shear stresses were supposed equal to none.

Results. Stress profiles were presented on figure 1. Compressive residual stresses were found close to the surface. Tensile stresses appear from 0.6-0.8 mm in-depth to the surface (approximatively the nitriding depth). The σ_{33} component is not equal to none, this important result seems to show the geometrical effect on stress state near non plane surface. But to confirm this hypothesis we have i) to realise more experiments in order to determine a_0 gradient in a plane specimen, ii) to take into account volume gauge correction.

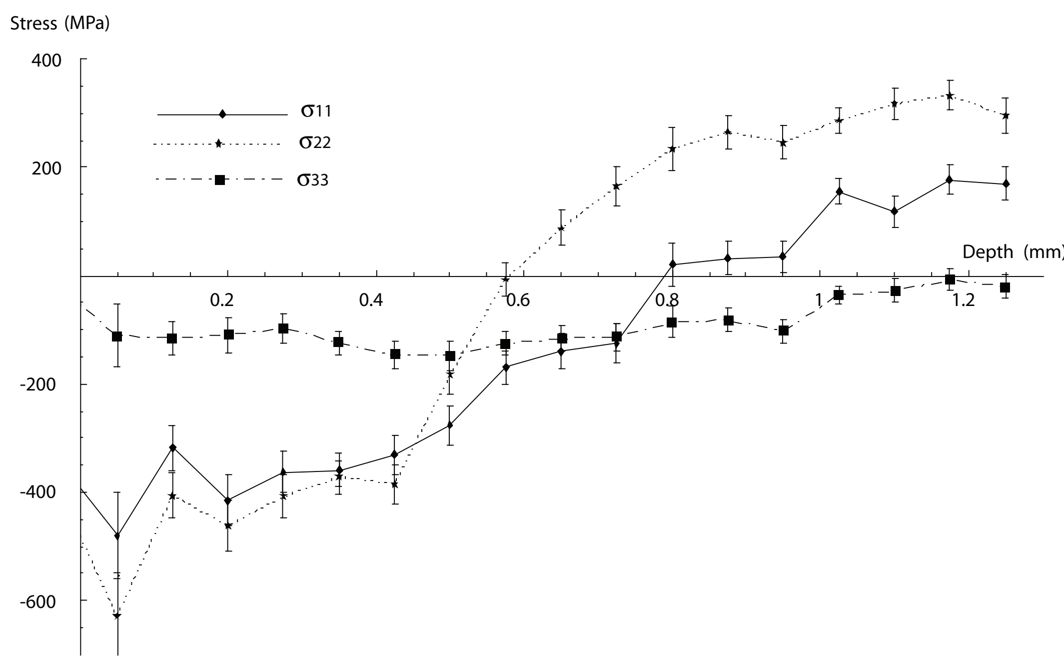

Fig. 1: *Stress profile of nitrided specimen near non plane surface.*