ESRF	**Experiment title:** A Study of Advanced Machining Techniques in Titanium, Nickel and Ferrous Alloys.	**Experiment number**: ME-857
Beamline: ID31	**Date of experiment**: from: 20-02-2004 to: 23-02-2004	**Date of report**: 03-06-2004
Shifts: 9	**Local contact(s)**: Dr. Francois Fauth	*Received at ESRF:*

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Report:

The aim of the experiment was to investigate the residual stress fields resulting from advanced machining techniques in alloys typically employed in the aerospace industry. Advanced machining techniques, involving high cutting speeds, feed rates and depths of cut, whilst reducing the effects of chatter and resulting in improved surface integrity, are of particular interest as they can lead to a significant reduction in both the fabrication and tooling costs and weight of a component. An important aspect of the process is that these external variables and tool wear can be readily controlled and monitored during the the process, with the added possibility of inducing a beneficial residual stress into the surface region. Through combining information of the residual stress field with the surface topography and microstructure, component design should be enhanced through an increase in the crack initiation period.

This experiment required the facilities at the ESRF because of the high flux and high energy x-ray source and established strain scanning facilities of beamline ID31. These allowed a considerable amount of measurements to be undertaken in a relatively short timeframe. In the current experiment over 2000 lattice strain measurements were made during the 9 shifts; this allowed an extensive picture of the near-surface residual stresses to be determined in the radial, axial and circumferential directions of turned Ti-6Al-4V. Unfortunately, comparable experiments attempted on Inconel 718 resulted in complete attenuation of the beam, except for measurements undertaken in the radial direction, and these had to be abandoned. Although results had previously been obtained from nickel alloys of a similar thickness, 5 mm, it was thought that the some of the alloying elements in the 718 alloy, probably niobium and molybdenum, may have been the main contributors to the increased attenuation.

The results from the titanium specimens mean that the effects that the machining parameters, including the rotational speed, feed rate, type and condition of the insert etc. have on the residual stress field is now more fully understood. An accurate determination of the near surface residual stress field means that their influence on crack initiation, and subsequent crack propogation, can be realistically considered. This type of work is of considerable importance to the aerospace and other industries because ensuring structural integrity and reliability in the context of fatigue properties often requires the incorporation of residual stresses.

Due to the guage volume not being fully submerged in the specimen for the near surface measurments an effective gauge centre was calculated[1], this taking into consideration both the effect of the geometric gauge centre and the variation in path lengths where appropriate.

From the graphs shown in Figure 1 it was evident that the circumferential and axial residual stresses were typically compressive, although the maximum compressive region was generally observed to be 10 – 50 microns below the surface. The residual stresses in the radial direction were frequently tensile in nature. The near surface (< 15 μm depth) residual stresses returned a variety of values, ranging from compressive to tensile, with the this being considered to be a consequence of plastic deformation resulting from the cutting process.

Typical variations in the resulting residual stress distribution can be seen between the plots for specimens 1, 3 & 5, from new inserts, and 6 & 8, from worn inserts. The type of insert employed, peripheral ground or direct pressed, was also noted to effect the stress distribution, evident when comparing the results from specimens 1, 3, 5 & 7 with those from specimens 9, 11,13 & 15. The result of increasing the feed rate and cutting speed can be observed through comparison of the results from specimens 1 & 3 and 5 & 7 respectively.

[1] Kang W. P. (1999). Strain Manual. Engineering Science Group Technique Report ESG1/99, Salford University.

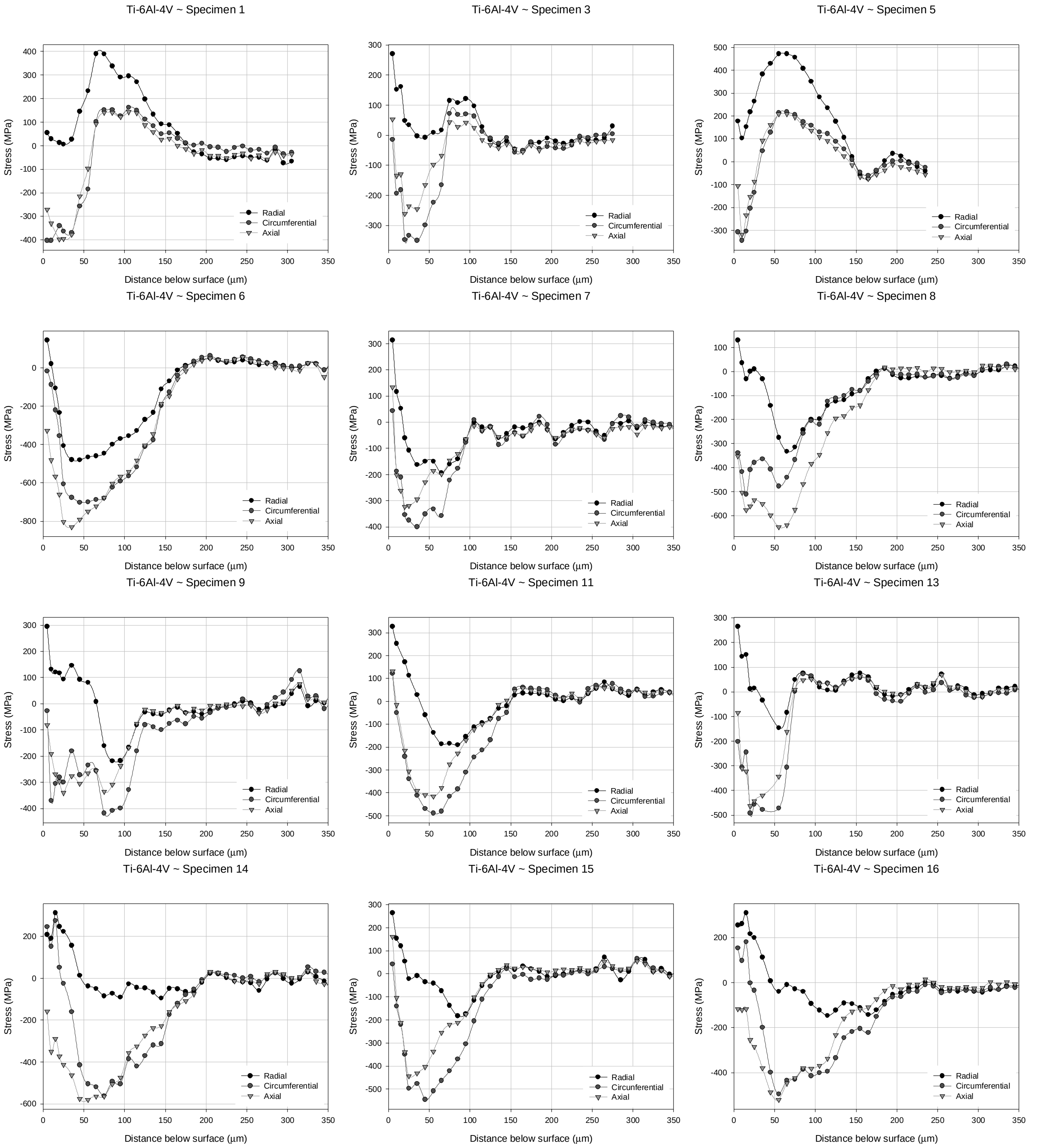

Figure 1: Residual stresses induced through the turning of Ti-6Al-4V in the radial, circumferential (cutting) and axial (feed) directions.