ESRF	**Experiment title: Residual stress evolution in the wide chord fan blade**	**Experiment number**: ME780
Beamline: ID15 A	**Date of experiment**: from: 08/04/2004 to: 12/04/2004	**Date of report**: 01/09/2004
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Report:

Residual strain measurements were made in Rolls-Royce Trent-700 Wide Chord Fan Blades (WCFBs), as used on the Airbus A330. The aim of the experiment was to study the changes in residual stress state that occur in the WCFB during service. Foreign object damage (FOD) is an important service issue. Serious damage may occur if debris is ingested by the engine, particularly during take-off.

Three fan blades were studied; one in the as-manufactured condition, one which had experienced long service life and a small FOD event, and third blade which had suffered a severe bird strike impact. Measurements were made comparing the two used blades with the new blade.

The blades are large (~900×350×50mm), with a complicated twisted aerofoil profile. This shape required an additional manual rotation stage to align the blades for measurement in addition to the translators and rotation stage on the instrument. The combined weight of a blade and this rotation stage was ~30Kg. The complex shape and large weight meant that special experimental techniques were required.

Before the experiment, the parts of the blade that were to be studied were digitised using a Mitutoyo coordinate measurement machine (CMM) with a Metris scanning laser probe. This measures the sample to a high degree of accuracy (~10μm) in three-dimensions, generating a cloud of points describing the surface. Reference markers attached to the blades were also measured using the CMM. The markers used were pieces of copper sheet drilled with 2mm holes. These holes can be accurately located in the CMM point cloud, and also located on the beamline by scanning across the hole and measuring the diffracted intensity. Thus it was possible to relate the CMM data to the coordinate system of the instrument translators. A *Matlab* routine was used to automatically generate macros to map strain at a series of points within each fan blade. These Matlab routines have been made available for other users though the FaME38 group.

To support the large weight of a blade and the rotation stage a counter-weight system was set up using the crane available on the beamline. It was possible to measure a sample of this size only because of the large space available for samples on this beamline.

Strain was measured in two directions simultaneously using two detectors. In the fan blades these were the radial and axial directions. This two detector set-up used at ID15a is described in the experimental report for ME773, part of the same series of experiments as this beamtime allocation. Using two detectors greatly simplified measuring these complex samples by reducing both set-up and measurement time by half. Measuring two strain components allowed the calculation of residual stresses in the thin blade section, where plane stress could be assumed.

Figure 1 shows the point cloud data measured at the distorted leading edge of the fan blade which had experience a bird strike impact. The measurement points, automatically generated and written into the measurement macro, are shown as larger points at the mid-thickness of the blade. Residual strains were measured at the points shown, and stresses calculated. Figure 2 shows the measured stresses displayed as a colour map, projected on to the distorted component geometry. It can be seen that the impact which has deformed the leading edge has introduced compressive stresses (blue) at the leading edge, and a significant area of tensile stress (red) behind the leading edge. Tensile residual stresses can reduce the fatigue life of the component.

Figure 3 is a contour plot showing the residual stress state aroud a much smaller impact at the leading edge of the blade which had experienced more typical service. Note that the size scale of the impact is much smaller than the birdstrike impact in shown in figures 1 and 2. The pattern of stresses around this impact is different. Compresssive stress is again seen at the leading edge, but in contrast to the larger impact almost no tensile stresses are observed. This indicates that small FOD impacts may have a less deblitating effect than would be expected for their size.

Further work characterising the stress concentration effect of such impact sites under an applied load is required in addition to these residual stress results to fully understand the consequences of FOD on blades in service.