

Determination of the Residual Stress Fields around Scratches in Al alloys

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The use of high-strength and low-weight aluminium alloy parts is widespread in aerospace structural applications. Aluminium alloy parts help to reduce overall weight and, thus, to reduced energy consumption. During service and maintenance, small defects like scratches can occur, which can act as initiation sites for fatigue damage. The local residual stress field around the scratch will be a key factor in determining how much it influences fatigue life. The overall aim of the present study is to study residual stresses around scratches in aerospace Al materials.

Scratches of different depths and root radius were produced, in Al2024-T351 with and without a clad pure-Al layer, with repeated sliding of an automated sharp tool. During the scratching process there will be local hardening of the material owing to the passage of the tool, and residual stress generation. Synchrotron X-ray diffraction has been used to determine the residual strains around the tip of the scratches. Measurements were made in 2024 aluminium, and also in fine-grained 5091 aluminium to improve the spatial resolution with which the strain data could be obtained. The results show high (~100 MPa) tensile stress at the tip of the scribed notch, and that the stresses generated are dependent upon the tool used to make the scribe mark. There is a correlation between the stress at the notch time and the observed fatigue lives. Nanoindentation can be used to determine hardness and residual stresses local to the scratch tip from careful analysis of the nanoindentation load displacement curve. Additionally, the effect of residual stresses on the nanoindentation data can be modelled using Finite Element Analysis.

Here we present results from nanoindentation experiments and Finite Element modelling using ABAQUS. Stresses were introduced in material as an initial condition before indentation. The results of the simulation agree well with the observed trends in the nanoindentation response around the notch. The results from nanoindentation and FE modelling are finally compared to the results from the Synchrotron X-ray diffraction and show a good correlation.