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Surface defects created by the forging process and their effects on the fatigue performance of a 6082 Al-alloy

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Abstract. The increasing use of forged Al-alloy components in automotive vehicles has generated a large quantity of data which shows that a retained forged surface can have a significantly detrimental effect on fatigue performance. Extensive SEM studies of the fatigue crack initiation sites on four point bend S-N samples and the as-forged surface appearance of these and actual components have been undertaken. The results from these studies have shown common features across all the samples examined. These features, rather than the surface roughness, can be associated with multiple fatigue crack initiation sites and explain the observed reduction in fatigue properties.

Introduction

It has long been known that surface finish can have a strong influence on the fatigue performance of metals and alloys. As part of the Jaguar Land Rover fatigue characterisation process, this effect is quantified from Four Point Bending (FPB) S-N tests and the results thus obtained used to modify the strain-life (LCF) damage curve. The increasing use of forged and cast-forged Al-alloy components in vehicles has generated a large quantity of such data, which shows that a retained forged surface finish can have a significantly detrimental effect on fatigue performance. The current work examines the surface effect on the fatigue behaviour of a 6082-T6 forged aluminium alloy.

Material and test procedures

Fatigue tests were carried out under Four Point Bend (FPB) loading on rectangular specimens ($100 \times 20 \times 6$ mm) taken from 6082-T6 forged aluminium components. Three sets of samples were prepared with different surface conditions: polished, fully-machined (ground) and as-forged. The surface roughness was very similar for the machined and forged surfaces. They were tested at room temperature on a DARTEC servo-hydraulic test machine under load control at 10 Hz and at a stress ratio $R = 0.1$. Fatigue life was defined as separation fracture with 5×10^6 cycles as the run out criterion. The fracture surfaces of tested specimens were examined on an SEM.

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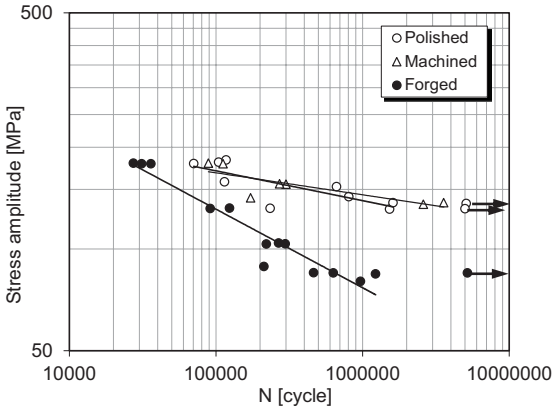

Figure 1. Fatigue test results.

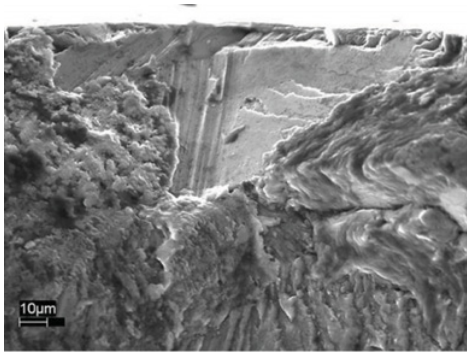

Figure 2. Crack initiated from as-forged surface.

Results and discussions

The fatigue test results are displayed in Fig. 1. A significant reduction in fatigue properties was found for the specimens with as-forged surfaces compared with samples having either polished or machined surfaces. Little difference was found between polished and machined samples. In other words, the degradation was caused by surface condition rather than surface roughness.

SEM examination revealed that fatigue cracks always initiated from macro forging defects (Fig. 2) on the specimens with the forged surfaces and from micro metallurgical defects on the samples with polished or machined surfaces (Fig. 3). It was clear that crack initiation was much easier from the macro forging defects than from micro metallurgical defects.

The total fatigue life can be divided into two phases: crack initiation and crack propagation. For the situation where the macro defects are absent, the crack initiation phase can be as high as 70% of the total fatigue life. The significant reduction in fatigue performance for the specimens with a forged surface was believed to be due to the existence of macro forging defects, which acted as stress raisers and allowed crack initiation easily. The FPB test results were used to define a surface effect factor that was applied to the strain-life fatigue curve to account for the effects of a retained as-forged surface. It is the strain-life curves which are widely used in automotive fatigue analysis; especially in the chassis and body departments. If the surface effect is ignored, significant errors in CAE results are inevitable.

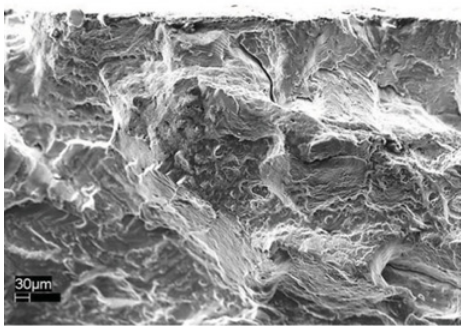

Figure 3. Crack initiated from machined surface.

Summary

Fatigue life can be significantly reduced due to the existence of a forged surface. This effect must be considered when materials are characterised using fully machined specimens otherwise errors in CAE fatigue analyses are inevitable. It is the forged surface defects, rather than the surface roughness, that are responsible for the reduction in fatigue properties.