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STATISTICAL ANALYSIS OF THE EFECT OF MACHINING PARAMETERS ON FATIGUE LIFE OF AEROSPACE GRADE ALUMINUM ALLOY (AL 6082T6)

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ABSTRACT

In this research work, aerospace grade aluminium alloy (Al 6082-T6) was analysed for the effect of cutting parameters on the fatigue life of the machined samples and optimization of cutting parameters for response factor. Different combinations of machining parameters were selected according to the ISO 3685 for sample preparation. Fatigue life of the samples was the response variable under investigation. Specimens for the rotating bending fatigue test were prepared according to the BS ISO 1143:2010 standards. The cutting inserts were selected from Sandvik Coromant catalogue recommended for machining of Al 6082-T6 alloy. A Designed of Experiment (DoE) with full factorial design was employed and a total of 81 experiments were performed for combination of cutting parameters. Fatigue life of the samples was observed to decreases with increasing feed rate, which is attributed to the compressive residual stresses at the surface of the samples. However, fatigue life increased with higher cutting speed and Depth of Cut (DoC).

Keywords: Machining parameters; Aluminium alloy; Fatigue life.

1 INTRODUCTION

Machining is the principal manufacturing process in the world with some 10-15% of the value of all goods being attributed either directly or indirectly to machining (Wyatt et al. 2006). Aluminium based alloys are known for their poor fatigue performance. Fatigue damage occurred in three stages i.e.

crack initiation, crack propagation and finally fracture of component (Lee et al. 2005; Suraratchi et al. 2008; Zhao et al. 2008). The surface and subsurface modifications affect the functional performance such as dimensional accuracy of the machined component (Jawahir et al. 2011). Machining played a significant role in producing the high surface integrity of the machined components. Surface integrity affected the crack initiation and propagation stage in the fatigue failure stages. Hence the functional performance of the machined components was improved by improving the surface integrity (Haron 2001; Haron et al. 2005; Ezugwu et al. 2007; Ghanem et al. 2003; Ginting et al. 2009). Surface integrity indicated the surface characteristics such as residual stresses which depend on cutting parameters such as cutting speed, feed rate and depth of cut (Ataollah Javidi et al. 2008). Residual stresses have a significant impact on fatigue life whether it is compressive or tensile (Sharman et al. 2001). Tensile residual stresses which are produced on the surface of the components after machining operation guide to early failure of components (Lin et al. 1991; Elkhabeery et al. 1989; Huafuh et al. 1995; Thiele et al. 2000). Furthermore, high surface quality enhanced and low surface quality decreased the fatigue life of the structures. (Toda et al. 2011). According to research the fatigue life was enhanced by introducing the compressive residual stresses on the surface of the machined component through machining parameters (EI-Axir 2002). The parameters such as cutting speed, feed rate and tool nose radius had a large impact on surface quality (Dahlman et al 2004; Arola et al. 2002; Sasahara 2005). This research work focuses on the analysis of effect of turning parameters on the fatigue life of Al 6082 T6 alloy. Samples were machined using different combination of cutting speed, feed rate and depth of cut, including the manufacturer's recommended machining values. Machined samples were then subjected to rotating bending fatigue test and statistical analysis performed for the effect of each parameter on the fatigue performance of the samples.

2 MATERIAL AND EQUIPMENT

Aluminium 6082-T6 alloy was used for fatigue testing in this research work. Specifications of the specimen were prepared by following the rotating bending fatigue test standard BS ISO 1143:2010. The equipment used for fatigue testing experimentation was pure rotating bending fatigue testing machine (Model PQ-6) as show in figure 1. The parallel specimen four points loading was selected from the standard. Dimensions of the specimen are shown in figure 2.

Figure 1: Rotating fatigue testing machine

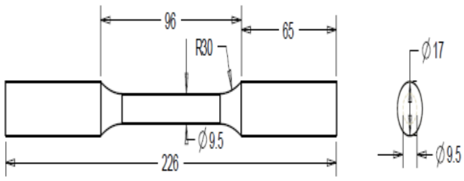


Figure 2: Specimen for fatigue testing.

The inserts (VCGX 16 04 04-AL H10) were selected from the Sandvik Coromant Catalogue 2011 which was recommended for the machining of Al 6082-T6. Each input factor has three levels according to the 3^3 full factorial design of experiment.

3 DESIGN OF EXPERIMENTS

A total of 81 experiments were performed by using different machining conditions with replication of 3. The selected cutting conditions were applied only to the final cut of the specimens. The values for the machining input parameters are shown in Table 1.

Table 1: The values for the machining parameters

S/NO	Parameter	Values
1	Feed Rate (mm/rev)	0.15, 0.2, 0.25
2	Cutting Speed(m/min)	1500, 2000, 2500

3	Depth of Cut (mm)	1.25, 1.5, 1.75

The response factor selected for these experiments was fatigue life of the machined samples and full factorial experiments carried out and analysed.

4 RESULTS AND DISCUSSION

Figures 3 and 4 show the effect of machining conditions on the fatigue life. In Fig. 3, the value used for depth of cut (DOC) is 1.25mm for the machining of testing area of the fatigue testing specimen.

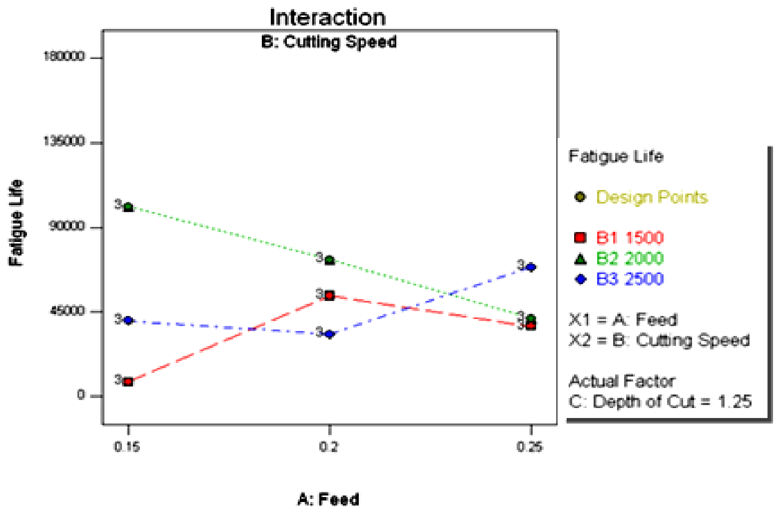
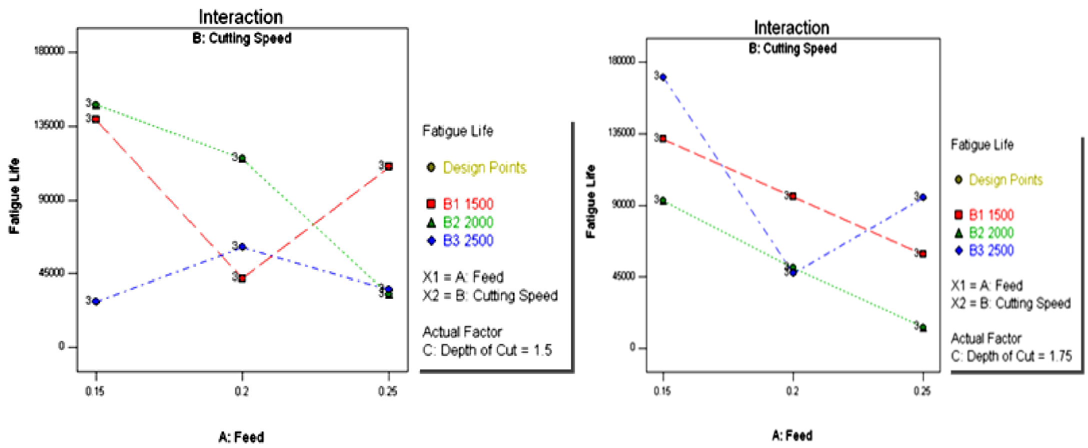


Figure 3: Effect of machining conditions on fatigue life with DOC=1.25mm

It is clear from the figure that fatigue life is more at low feed rate and medium (2000m/min) cutting speed shown by green line. The high fatigue life at the low feed rate could be due to the presence of compressive residual stresses produced at the surface of the machined component. These results resemblance the previous research where it was also found that low feed rate enhanced the fatigue life (Sasahara 2005). At the speed of 2500m/min, the fatigue life is more at the higher feed rate(1.75mm/rev) as compared to lower feed rate(1.25mm/rev) shown by blue line. At the cutting speed of 1500m/min, the fatigue life is lower at smaller feed rate (0.25mm/rev) as compared to higher feed rate (0.25mm/rev). So, the fatigue life in case of cutting speed 1500m/min is lower as compared to cutting speed 2500m/min shown in Fig. 3a. At the optimum cutting conditions values (i.e. V_c 2000m/min & f=0.2mm/rev), fatigue life is more with optimum cutting speed and feed. At the cutting speed of 1500m/min, fatigue life is reduced at lower feed rate (0.15mm/rev) as compared to higher feed rate (0.25mm/rev) shown by redline. During the machining of Al6082-T6 alloy, the surface of the machined specimen is improved by applying the higher cutting speed. In the case of cutting speed 1500m/min, the surface quality of the machined component decreases. Such specimens show lower fatigue life as compared to the specimens machined at higher cutting speed. Similar results were also reported by Jeong-Du Kim and Youn-Hee Kang (Kim et al. 1997). At the cutting speed of 2000m/min, fatigue life is more at lower feed rate (0.15mm/rev) as compared to higher (0.25mm/rev) feed rate. At cutting speed 2500m/min, fatigue life is more at higher (0.25mm/rev) feed rate as compared to lower (0.15) feed rate for depth of cut (DOC) 1.25mm.

In Fig. 4a, the response of the fatigue life with DOC=1.5mm in the machining of fatigue testing specimen is shown. The value of depth of cut (DOC) 1.5mm is used for the final cut of the testing area of the specimens. At the cutting speed 1500m/min, the fatigue life is greater at lower feed rate (0.15mm/rev) as compared to higher feed rate (0.25mm/rev) shown by the red line. At the cutting speed 2000m/min, the fatigue life is more at lower feed rate (0.15mm/rev) as compared to higher feed rate (0.25mm/rev). At the cutting speed 2500m/min, the fatigue life is more at the optimum value of feed rate (0.2mm/rev) as compared to lower and higher feed rate shown by blue line. In Fig. 3c, the response of fatigue life with the machining conditions is shown with DOC=1.75mm in the machining of fatigue testing specimen. At the cutting speed 1500m/min, the fatigue life is higher at lower feed rate (0.15mm/rev) as compared to higher feed rate (0.25mm/rev) and there is gradual decrease in fatigue life along the feed rate shown by the red line. At the cutting speed 2000m/min, the fatigue life is more at lower feed rate (0.15mm/rev) as compared to higher feed rate (0.25mm/rev) and there is gradual decrease in fatigue life shown by the green line. At the cutting speed 2500m/min, the fatigue life is less at the optimum value of feed rate (0.2mm/rev) as compared to lower and higher feed rate.



(a) (b)

Figure 4: Effect of machining conditions on fatigue life with (b) DOC 1.5mm (c) DOC 1.75mm

As the depth of cut increases from 1.25mm to 1.75mm as shown in Fig.4c, the fatigue life also increases at the same lower feed rate 0.15mm/rev. Due to increases of depth of cut, the compressive residual stresses at the machined surface increases. So, the fatigue life is more in case of more depth of cut 1.75mm as compared to depth of cut 1.25mm. Surface roughness is also more in case of smaller depth of cut 1.25mm as compared to the more depth of cut 1.75mm. Fatigue life decreases as surface roughness increases. So, the longer fatigue life is obtained in case of higher depth of cut 1.75mm as compared to lower depth of cut 1.25mm as shown in the Fig. 3.

5 CONCLUSIONS

- Fatigue life decreases as feed rate increases. Fatigue life is more at low feed rate (0.15mm/rev) as compared to high feed rate (0.25mm/rev).
- Fatigue life increases as depth of cut increases. Fatigue life is more at maximum depth of cut (1.75mm) as compared to minimum depth of cut (1.25mm).
- Fatigue life is more with low feed rate, higher cutting speed and max depth of cut for the values of f=0.15mm/rev, V_c=2500m/min and a_p=1.75mm.
- There are number of the cutting conditions combinations obtained from the experimental results. According to the desirability of max fatigue life, optimized design variable are cutting feed = 0.15mm/rev, cutting speed = 2500m/min and depth of cut = 1.75mm.

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