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Prediction of Cutting Force in End Milling of Inconel 718

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Abstract

Inconel is prominently known as a hard material to be machined. Due to stability during extreme temperature, it is widely used in aerospace components especially turbine blade (Kitagawa et al. , 1997, Ulutan and Ozel, 2011). Some processes require ball end type due to intricate and complex shape. This curve cutting tip tool reduces stress concentration. However, the complex shape of round nose geometry exhibit tool wear mode that different than flat end milling tool (Aspinwall et al. , 2007). Studies from previous researchers found that the interrupted cutting process causes flaking especially during machining high tensile strength (Figure 1) (Kasim et al. , 2013). This paper presents the effect of cutting speed, feed rate, and depth of cut on the cutting force when machining Inconel 718 under minimum quantity lubrication. The response surface methodology (RSM) was used in the experiment, and a Box–Behnken design was used to determine the cause and effect of the relationship between the four cutting parameters and cutting force. The investigation milling parameters were cutting speed (100, 120, and 140 m/min), feed rate (0.1, 0.15, and 0.2 mm/tooth), axial depth of cut (0.5, 0.75, and 1.0 mm) and radial depth of cut (0.2, 1, and 1.8 mm). The result shows that the radial depth of cut was the dominating factor controlling cutting force, it was followed by axial depth of cut and feed rate. The relationship between cutting force of various factors was expressed in a three-dimensional response graph (Figure 2). The second order prediction cutting force equation (1) was developed with a 95% confidence level. The optimum condition required for minimum cutting force include cutting speed of 110 m/min, feed rate of 0.1 mm/rev, axial depth of cut of 0.5 mm, and radial depth of cut of 0.25 mm. The error between the predictive model and the actual of cutting force was less than 3%. With this optimum condition, a cutting force of 144N was obtained.

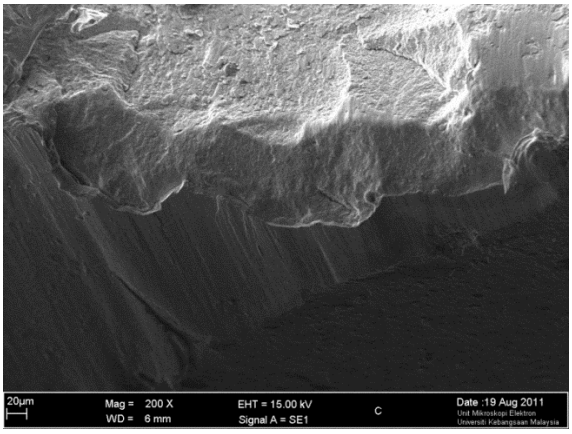

Figure 1: Major failure mode during end milling of Inconel 718 due to interrupted cutting force

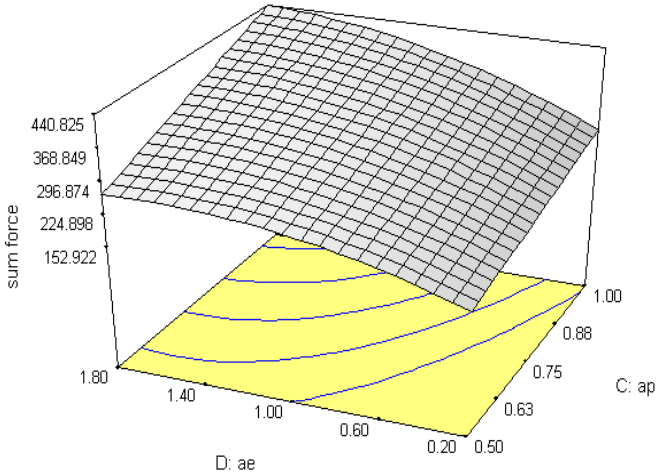

Figure 2: Interaction effect between radial and axial depth of cut on cutting force

$$F_r = 106.4 - 546\,fz - 26\,ap + 37.6\,ae - 60.2\,ae^2 + 1401.13\,fz.ap + 750.26\,Fz\,.ae + 87.24\,ap.ae \quad (1)$$

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