The Influence of the Metalworking Fluid on Tool Wear in Milling Inconel 718

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The understanding of tool wear mechanisms is fundamental for developing more productive metalworking fluids. Therefore, the influence of different fluids on tool wear is studied when milling Inconel 718 using a rotating dynamometer, a stationary dynamometer and a 3D microscope. A force model explains the relation between tribological conditions, tool wear and process forces. By fitting the model to the data, it is found that the metalworking fluid and the process parameters not only influence the wear rate globally, but also lead to different wear mechanisms. The 3D data of worn cutting edges confirms the different wear mechanisms.

Keywords: tool wear, cutting force, metalworking fluid, Inconel, milling

1. Introduction

Tool life is often limiting productivity in milling of super alloys, such as Inconel 718. Metalworking fluids have a high impact on the tool life in milling. They are able to modify the tribosystem in favor of the tool material.
In a production environment, the tool's condition is hard to observe. Big data approaches, such as in Natarjan et al. [1] are getting more popular; however, they do not provide an insight into the wear mechanism. Therefore, in this case, a mechanistic approach is chosen to derive the tool's condition from the cutting force data.

2. Methods

Inconel 718 is milled using different metalworking fluids (emulsions or cutting oils) and different parameter sets, as shown in Table 1.

Table 1: process parameters

Tool Diameter [mm]	20
Cutting Speed [m/min]	20 – 60
Feed per Tooth [mm]	0.05 – 0.1
ap [mm]	2 – 3
ae [mm]	0.5

The cutting forces are measured using a rotating cutting force dynamometer, exemplary data is shown in Figure 1. This data is complemented with data from a stationary piezo-dynamometer.
A model based on the Altintas-Model [2] is developed. Different terms to account for the chip deformation force and the friction in different regions around the cutting edge are included. By introducing the same nonlinearities introduced in the measurement data evaluation as well, the modelled cutting forces match the measured ones, as shown in Figure 1. The model parameters obtained in the fitting process are further used to describe the tribological situation at the cutting edge.
At regular intervals during milling, pictures of the cutting edge are taken to measure the flank wear land width v_B, as shown in Figure 2A, the most common wear indicator. Additionally, the 3D shape of the cutting edge is measured with a confocal microscope, as shown in Figure 2B. After milling, the cutting edge is etched to remove the adhering Inconel and the 3D shape is measured again.

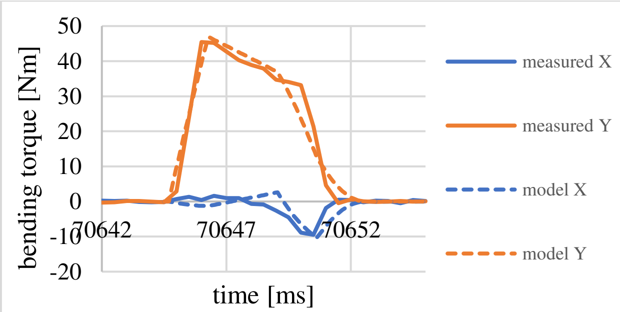

Figure 1: Measured and modelled forces in the tool's coordinates X and Y

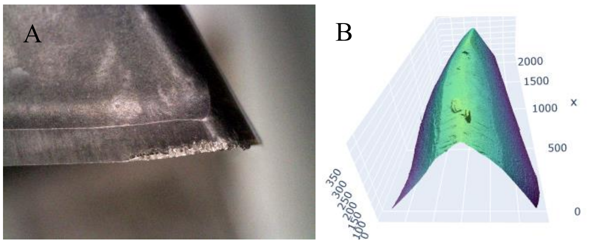

Figure 2: A: Worn tool after a total milling distance of 5 m. B: 3D measurement of a cutting edge after a total milling distance of 11 m.

3. Discussion

At least two of the model parameters are linearly independent which leads to the conclusion that two independent wear mechanisms exist. Using the 3D information of the worn cutting edges, these can be attributed to cutting edge nose and flank wear. Both the process parameters and the metalworking fluid have an effect on the different extent of each wear mechanism.

4. References

[1] Natarjan, U et al., "Application of particle swarm optimisation in artificial neural network for the prediction of tool life", Int J Adv Manuf Technol, 31, 2007, 871-876.

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