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Studies on Process Parameters in End Milling Operations of Aluminium Alloy

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Abstract

Aluminum is one of the most widely used metals in the construction of aero planes, truck wheels, screw machine products and turbine manufacturing industries. Accurate prediction of process parameters is important in controlling the dimensional accuracy of thin walled aeroplane components. The effects of various process parameters such as pressure and friction acting on the cutter - chip interface, cutter geometry on chip flow and specific cutting energy are studied. Pressure and friction acting on the cutter - chip interface decrease with the increase of feed rate. Chip flow angle increases with the increase of feed rate. Effect of cutting speed on the pressure and friction parameters for aluminium has a negligible effect on the process parameters. Specific cutting energy decreases with an increase in feed rate

1. Introduction

The milling process is a highly non-linear plastic deformation process with many independent and dependent variables process parameters change as functions of the feed rate, tool rotation angle and the position angle of a point along the cutting edge. As a result of using constant process parameters, the measured force components are underestimated during the engagement and disengagement periods. The average chip thickness is a function of the feed rate and the radial immersion, to determine the average parametric relationships many tests with different combinations of feed rate, and radial and axial immersions must be performed (3). Therefore, computing the variation of the parameters as a function of the tool rotation angle for slot cutting tests at different cutting conditions would be enough to establish parametric relationships for the forces. The purpose of this work is to demonstrate the feasibility of obtaining process parameters as functions of the tool rotation angle, feed rate and cutting speed from a few milling cutting tests. A study of process parameters in machining of aluminum (2024) is presented in this paper.

2.Experimental work

A 3 axis CNC milling machine was used in the experiments. The work piece was clamped on the measuring platform. The force-measuring platform consisted of piezoelectric transducers capable of measuring the three Cartesian force components. A digitizing oscilloscope was coupled with a magnetic pick up coil to precisely determine the spindle sped. A series of slot cutting experiments was conducted using single fluted titanium nitride coated HSS sharp milling cutters with radius of 12.5 mm, helix angle of 30^0 and rake angle of 13^0. Cutting action was chatter free for all of the cutting tests and the collected chips were uniformly curved into spirals with smaller sizes and appearance. No cutting fluid was used. Table 1 shows the testing conditions for the slotting tests conducted in cutting 2024 free machining aluminum. While cutting aluminum some indication of built up edge formation was observed where a very thin film of aluminum stuck to the cutting edges practically served as another layer of coating on the cutter surface. The depth of this layer was found to be negligible on comparison to chip thickness.

Table 1. Cutting Conditions

Workpiece material	Cutting speed (rpm)	Feed rate (mm/min)	Values of cutting speed and feed rate
2024 aluminum	n_1, n_2, n_3	f_1, f_2, f_3	n_1=1600, n_2=2000, n_3=2500 f_1= 0.025, f_2=0.127, f_3=-0.203

Work material: 2024 aluminum, young's modulus = 70 GPa, Poisson ratio=0.345, tensile strength =900 MPa, hardness=120 HB; HSS cutter: helix angle = 30^0, diameter = 25 mm, rake angle = 13^0

3. Results and Discussion

3.1 The Effect Of Feed Rate

The feed rates were varied from 0.025 mm/rev to 0.203 mm/rev while keeping rake angle =13^0

Pressure parameter as a function of spindle rotation angles at various feed rates is plotted in Fig 1.

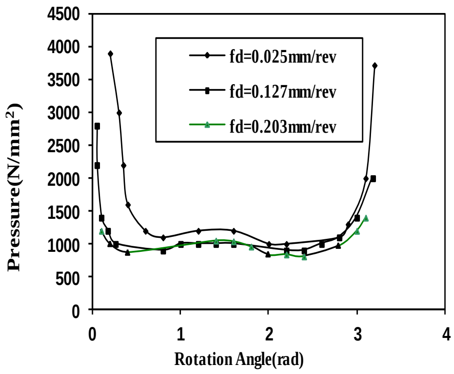

Fig.1 *Measured pressure parameter at various feed rates: rpm 1600, R_a = 2.54 mm; R_d = 12.7 mm*

It can be seen that pressure parameter (K_n) decreases as feed rate increases. The decaying rate of pressure parameter is higher around smaller feed rate values, which is an expected behavior. Fig 2. shows the friction parameter, K_f, as a function of feed rate. It can be seen that the friction parameter K_f, also decreases with increasing feed rate.

This behavior is analogous to the decreasing friction coefficient with increasing feed rate in oblique cutting operations.Fig.3 shows the chip orientation angle (direction of friction force) as a function of the tool rotation angle and feed rate. The direction of the friction force is closely related to the direction of the chip flow angle. Although for some materials, the direction of the chip flow may be the same direction of friction force due to the lateral effects perpendicular to the chip motion in general, there may be some differences between those two directions. It has been found that chip flow angle generally increases with the increase of feed rate. A close relationship between the friction parameter and the chip flow angle was observed. Chip flow angle was also found to decrease with increasing friction. The friction parameter rose to a maximum value during the tool entry into the work piece. This maximum value was found to increase with the decrease of feed rate.

3.2The effect of cutting speed

The cutting speeds were varied from 400 rpm to 1000 rpm while keeping feed rate f_d = 0.203 mm/ rev. Fig 4. shows the effect of cutting speed on the pressure parameter for 2024 aluminum work piece.

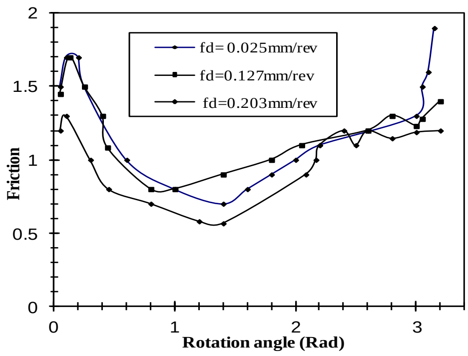

Fig.2 *Measured friction parameter at various feed rates: rpm 1600, R_a = 2.54 mm; R_d = 12.7 mm*

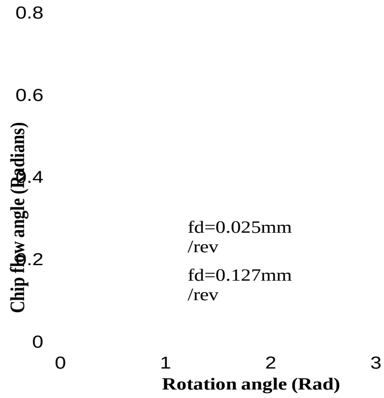

Fig.3: *Measured chip rotation angle at various feed rates: rpm = 1600, R_a = 2.54 mm; R_d = 12.7 mm*

It can be seen that the cutting speed has a negligible effect on the process parameters in the tested range.

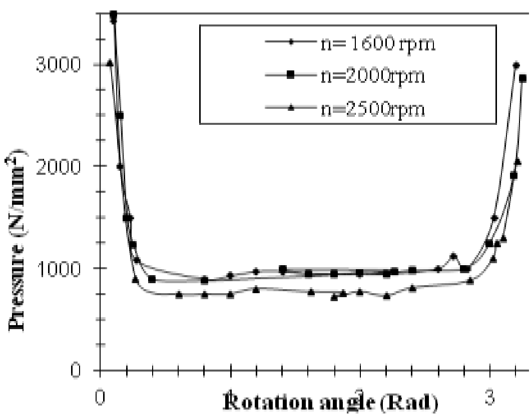

Fig.4: *Pressure parameter at different cutting speeds. f_d = 0.203 mm/rev; R_a = 2.54 mm; R_d = 12.7 mm*

Fig.5 shows the effect of the cutting speed on the friction parameter in the tested range of cutting speed. A negligible effect of the cutting sped on the friction parameter in the range of cutting speed used during the tests. Therefore, the effect of the cutting speed in the testing range can be neglected.

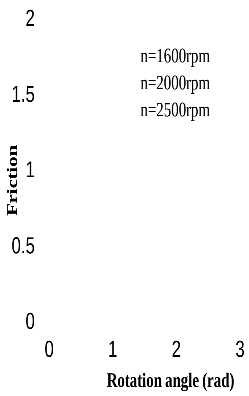

Fig.5 *Friction parameter at different cutting speeds; f_d = 0.203 mm/rev; R_a = 2.54 mm; R_d = 12.7 mm*

3.3. Effect Of Feed Rate As A Function Of Specific Cutting Energy

The feed rates were varied from 0.025mm/rev to 0.203 mm/rev while keeping cutting speed = 2500 rpm. Effect of feed rate on specific cutting energy for the 2024 aluminum is plotted in fig.6. Specific cutting energy follows a similar trend with the pressure and friction parameters and it decreases with an increase in feed rate, which is in close qualitative with the reported specific cutting energy results obtained through oblique cutting by Boothroyd .

4. Conclusions

In the present work, the important conclusions made, which are as follows:

- Pressure parameter (K_n) decreases marginally with an increase in feed rate
- Friction parameter (K_f) decreases with an increasing feed rate with the cutting speed of 700 rpm.
- The chip rotation angle generally increases with the increase in feed rate
- Negligible effect of the cutting speed on the friction parameter as well as pressure parameter.
- Specific cutting energy decreases with an increase in feed rate.

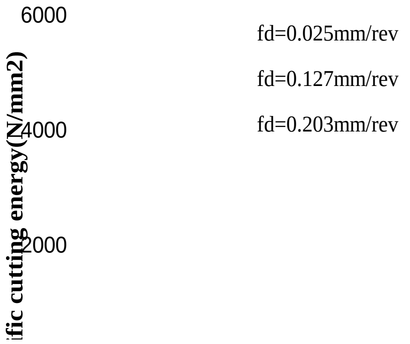

Fig.6 *Specific cutting energy Vs rotation angle; rpm = 2500; R_a = 2.54 mm; R_d = 12.7 mm*

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