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Effects of Air Jet-assisted Little Quantity Lubrication on Surface Finish and Tool Wear in Face Milling Process of Aluminium 7050-T7451

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Abstract. In this paper, a new method of air jet-assisted little quantity lubrication (AJLQL) is proposed to obtain a good balance of cooling capacity, lubrication ability and application cost, and workpiece surface finish and tool wear are researched based on milling experiment of aluminium alloy 7050-T7451 on the platform of established AJLQL system. The results show that: (1) AJLQL can decrease workpiece surface roughness effectively, the degree of influence on surface roughness ranges from large to small is feed per tooth(f_z), cutting fluid flowrate(Q), axial cutting depth(a_p), air pressure(P) and spindle speed(n); (2) under the same other process conditions, tool flank wear of dry cutting is bigger than that of AJLQL, and the flank wear becomes less with the increase of cutting fluid flowrate, which shows the excellent lubrication effect of AJLQL.

1. Introduction

Green manufacturing is important for the sustainability of manufacturing, and green cutting is its key technology. The green cutting methods commonly used in the field of metal cutting are dry cutting, minimum quantity lubrication (MQL) cutting, cryogenic cutting and green wet cutting[1-4]. The existing green cutting methods have problems such as insufficient cooling or lubricating ability and high application cost. In recent years, many experts and scholars have improved on the basis of the existing green cutting method or proposed new green cutting method. In order to improve the shortage of cooling capacity in MQL grinding, Stachurski proposed a MQL-CCA method which combines MQL with low temperature compressed air and used in grinding process[5]. In order to improve the lubrication and cooling capacity of MQL, two improvement schemes for adding solid lubricants is proposed respectively[6], the former is by adding Polytetrafluoroethylene in vegetable oil, and the latter is by adding different proportions of graphite in aqueous solution. In order to improve the cooling performance of MQL, Bagherzadeh presented a CMQL methods by combining MQL and low temperature CO2, and Ti6Al4V and Inconel 718 turning experiments were carried out[7]. Li carried out the grinding test by using nanoparticle jet MQL[8], the results showed the effectiveness of the nanoparticle jet on improving the cooling capacity and processing quality of MQL.

In this paper, a new method of air jet-assisted little quantity lubrication (AJLQL) is proposed to obtain a good balance of cooling capacity, lubrication ability and application cost, which is an improvement of little quantity lubrication (LQL) presented in 2010[9]. In this research, workpiece surface finish and tool wear are researched based on machining experiment.

2. Mechanisms of AJLQL

AJLQL is conducted by an atomized device, which can output uniform mixture of compressed air and a little amount of cutting fluid. By this device, the air and the atomized cutting fluid of AJMQL can be accurately injected into the cutting zone at high speed in gas-liquid two-phase state, thereby achieving the purpose of improving the cooling and lubricating effect. Compared with MQL, AJLQL has two distinct features: (1) because the cutting fluid flow rate is greater than MQL, the fog particle concentration of gas-liquid two-phase cooling lubricating medium is significantly greater than MQL; (2) types of cutting fluids can be selected according to different machining conditions. When the main purpose is to improve the cooling capacity, the water-based cutting fluid can be selected, and the oil-based cutting fluid can be selected when the main purpose is improving the lubricating ability, thereby expanding the selection range of the cutting fluid.

Since the cutting fluid flow rate of AJLQL is larger than that of MQL, the cooling and lubricating effect is better than MQL. In the meanwhile, AJLQL also retains the advantage of better lubrication effect of MQL because of the high-speed injection into the cutting zone and extends the excellent cooling and lubrication effect of conventional flood lubrication at low and medium speed cutting to high speed cutting. Compared with cryogenic cutting, since the cooling lubricating medium is at room temperature, the spalling tendency of the rake face of the tool and the quenching tendency of the workpiece surface finish can be alleviated due to the decrease of thermal stress, and the problem of insufficient lubrication ability of the cryogenic cutting can be avoided.

3. Experimental Setup

The experimental setup is shown in Fig.1. The experimental work is performed on a TK855 vertical machining center. The workpiece material is aluminium alloy 7450-T7451 with size of 150 × 43 × 38, shown in Fig.2. Cutting style is end milling. The tool path is along positive direction of x-axis. The cutter is a carbide two-tooth end mill with a diameter of 10 mm. Milling width ae is fixed to 10 mm. Cutting fluid is emulsion with 10% mass percentage.

Figure 1 Experimental setup

Figure 2 Workpiece

In the present work, Taguchi Methods is employed to research the effects of AJLQL on workpiece surface finish. Effect factors on workpiece surface finish are selected, which are cutting fluid flowrate Q (A), cutting speed n(B), feed per tooth f_z (C), axial cutting depth a_p (D), and air pressure P(E), four levels are selected for each factor. Experimental design of $L_{16}(4^5)$ is shown in Table 1. In order to obtain reliable data, each experiment is repeated 3 times, and 3 test areas are selected at equal intervals on the cutting surface obtained in each experiment. The surface roughness is measured using a portable surface roughness meter TR300.

Experiment is performed in order to research the effects of AJLQL on tool durability. The process parameters are shown below. n=6000rpm, f_z=0.02mm/z, a_p=5mm, P=0.6MPa. The cutting fluid flowrates are 0mL/min, 100mL/min and 200mL/min, respectively.

Table 1 Experimental Design

Factor	Level			
	1	2	3	4
Flowrate /*Q*（mL/min）	300	200	100	0
Cutting Speed/*n*（rpm）	2000	4000	6000	8000
Feed per tooth/f_z（mm/z）	0.01	0.02	0.03	0.04
Axial depth/a_p（mm）	2	3	4	5
Air pressure/*P*（MPa）	0.6	0.45	0.3	0.15

4. Results and Analysis

4.1. Effects of AJLQL on workpiece surface roughness

Experimental results are shown in Table 2.

Table 2 Experimental results

Test No.	Factor (level)					Experimental results
	A	B	C	D	E	Surface roughness *Ra* (μm)
1	1	1	1	1	1	0.0907
2	1	2	2	2	2	0.140
3	1	3	3	3	3	0.172
4	1	4	4	4	4	0.283
5	2	1	2	3	4	0.180
6	2	2	1	4	3	0.141
7	2	3	4	1	2	0.243
8	2	4	3	2	1	0.273
9	3	1	3	4	2	0.309
10	3	2	4	3	1	0.264
11	3	3	1	2	4	0.206
12	3	4	2	1	3	0.201
13	4	1	4	2	3	0.302
14	4	2	3	1	4	0.252
15	4	3	2	4	1	0.183
16	4	4	1	3	2	0.150

Results of intuitionistic analysis are shown in Table 3. K_i indicates the sum of all the corresponding experimental results when any column level is *i*. $k_i = K_i/4$. *R* is the range of K_i. As can be seen from Fig.3 that the degree of influence on surface roughness ranges from large to small is f_z, *Q*, a_p, *P* and *n*. It's common sense that f_z has significant effect on surface roughness. The second significant factor for surface roughness is cutting fluid flowrate. The reason may be explained that the lubrication effect becomes better with increase of cutting fluid flowrate. According to the analysis in Table 3, the optimal scheme is A_1-B_2-C_1-D_3-E_1.

Table 3 Results of intuitionistic analysis

	Factor				
	A	B	C	D	E
K_1	0.6857	0.8817	0.5877	0.7867	0.8107

K_2	0.8370	0.7970	0.7040	0.9210	0.8420
K_3	0.9800	0.8040	1.0060	0.7660	0.8160
K_4	0.8870	0.9070	1.0920	0.9160	0.9210
k_1	0.1714	0.2204	0.1469	0.1967	0.2043
k_2	0.2093	0.1993	0.1760	0.2303	0.2105
k_3	0.2450	0.2010	0.2515	0.1915	0.2040
k_4	0.2218	0.2227	0.2730	0.2290	0.2303
R	0.2943	0.1100	0.5043	0.1550	0.1103

4.2. Effects of AJLQL on tool flank wear
Fig.3 shows the effects of AJLQL on tool wear in aluminium alloy 7450-T7451 milling process. Tool flank wear VB is measured under an optical microscope. From Fig.3, it can be seen that tool flank wear of dry cutting is bigger than that of AJLQL, and the VB value of milling under condition of AJLQL with 200mL/min is less than that of AJLQL with 100mL/min. This can be explained that the comprehensive effect of cooling and lubrication becomes better with the injection of high speed atomized cutting fluid.

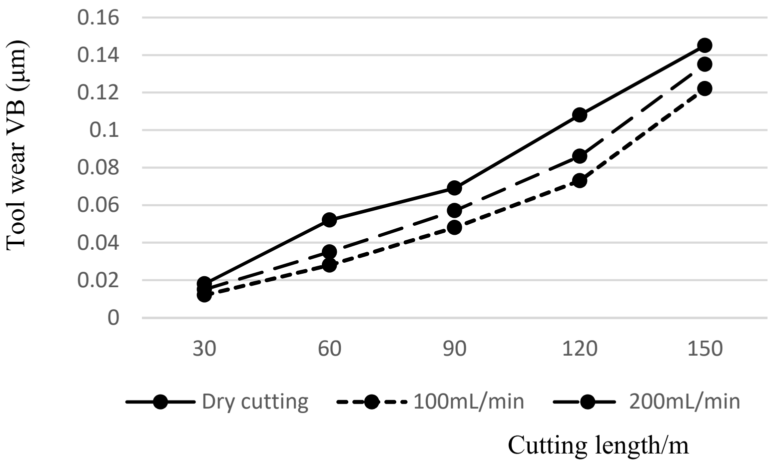

Figure 3 Tool wear curve

5. Conclusions
Milling experiment of aluminium alloy 7050-T7451 is conducted in order to research the effects of AJLQL on surface finish and tool flank wear. The conclusions can be made as the following.

(1) AJLQL can decrease workpiece surface roughness effectively, and the degree of influence on surface roughness ranges from large to small is feed per tooth(f_z), cutting fluid flowrate(Q), axial cutting depth(a_p), air pressure(P) and spindle speed(n), which shows that cutting fluid flowrate of AJLQL has a great influence on surface roughness;

(2) Under the same other process conditions, tool flank wear of dry cutting is bigger than that of AJLQL, and the flank wear becomes less with the increase of cutting fluid flowrate, which shows the excellent lubrication effect of AJLQL.

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