Research On MQL Flow Rate Based on CNC Milling of Aircraft Structural Parts

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Abstract. Micro lubrication technology (MQL) has been widely applied globally, mainly focusing on the design of lubrication mechanisms. There is a lack of research on the flow rate under actual processing conditions. The size of cooling capacity affects manufacturing costs, environmental governance, workpiece quality, and other factors. This article conducts research on the MQL flow rate of oil gas mixed lubrication, and experimentally obtains MQL flow parameters suitable for aircraft structural component processing.

Keywords: MQL*; Flow*; Aviation structural components; milling.

1. Introduction

Mechanical cutting generates frictional heat. In high-speed cutting, the ratio of heat absorbed by the tool increases with the increase of speed. In order to optimize performance, it is necessary to fully cool the tool. Proper coolant flow can extend the service life of cutting tools and improve effective cutting speed. If not properly cooled, the blade will quickly heat up. This way, the workpiece material will stick to the cutting edge, creating built-up debris (BUE), which will shorten the tool life and affect the surface finish. Based on economic and environmental considerations, people's call for "green cutting" is increasing. The newly developed micro lubrication (MQL) technology is increasingly favored by people as a cost saving and environmentally friendly green processing technology [2-5]. MQL cutting technology usually involves mixing compressed air with a small amount of lubricating oil for atomization, and then delivering it to the cutting area between the tool and the workpiece for centralized cooling and lubrication. This texture can exercise a decisive influence on the application and performance of the machined component [6].

MQL combines the advantages of both dry cutting and traditional wet cutting. On the one hand, reducing the amount of cutting fluid to a very small amount (usually MQL is only 0.03-0.2L/h, while traditional wet cutting uses 20-100L/min) not only significantly reduces the cost of cutting fluid use, but also uses synthetic esters with good natural degradation as lubricants, Minimizing the harm of cutting fluid to the environment and human body; On the other hand, compared with dry cutting, MQL introduces cooling and lubricating media, which greatly improves the cooling and lubricating conditions during the cutting process, and significantly reduces the friction and wear between tools, workpiece and cutting, which helps to reduce the cutting force, cutting temperature and tool wear

2. The relationship between the amount of cutting fluid and the cold hole in the tool

There are several factors that affect the amount of cutting fluid, including the diameter of the cold hole in the tool, the pressure of mixing gas, the viscosity of cutting fluid, cutting materials, etc. Through a lot of tests and use experience, take the cutting fluid with mixing pressure of 10bar and viscosity of 30 as an example, which basically meets the range of jet oil in Table 1. Because of the high biodegradability of vegetable oil, fatty alcohol, polyethylene glycol, etc., MQL cutting fluid is also often selected. The selection of specific media depends on the supply method, materials involved, processing technology, and subsequent treatments required for the workpiece (such as annealing, surface treatment, or coating treatment)

Table 1 Application range of cutting fluid for tool internal cooling diameter.

Oil and gas mix ratio	Hole diameter	Flow MIN. (ml/h)	Flow MAX. (ml/h)
Auto	1mm	5	7
Auto	1.5mm	10	15
Auto	2mm	20	35
Auto	2.5mm	40	45
Auto	3mm	45	50
Auto	3.5mm	55	60
Auto	4mm	70	100
Auto	5mm	120	200

The diameter holes of the cutting tools vary when designed by the manufacturer, and the cooling effect of the tools distributed on the bottom and side teeth also varies greatly. When determining the injection amount based on the internal cooling holes of the cutting tools, the position of the internal cooling holes should also be considered. Under high-speed rotation, the sprayed cooling oil becomes divergent. If the position of the inner cooling hole is too far from the tool tip, it will lead to insufficient cooling. However, when using micro lubrication cooling for metal cutting, it is necessary to reasonably select the target distance and spray flow rate in order to maximize its characteristics, save resources, and improve production efficiency.

In addition, cutting fluid has high pressure and is finally ejected from the inside of the motorized spindle by the tool. Regularly check whether the internal cooling tool is blocked, or serious equipment accidents will be caused. The temperature of cutting fluid will have a certain impact on the thermal elongation of the spindle, which is also a problem that needs attention in the design.

3. The relationship between cutting parameters and oil consumption

In MQL cutting experiments with different processes, it was found that there was a saturation phenomenon in the amount of lubricating oil used during the machining process. When the lubricating oil dosage reaches saturation, the tool durability and machined surface quality no longer continue to improve with the increase of lubricating oil dosage, but will also decrease to varying degrees. This may be because the increasing cooling effect will produce greater thermal shock on the tool and cause fatigue of the tool with the increase of the amount of lubricating oil. Therefore, in order to maximize the application performance of MQL, it is necessary to quantitatively optimize the amount of lubricating oil used

Taking aluminum alloy cutting as an example, taking vegetable oil with viscosity of 30 as the cutting oil, Table-2 shows the injection amount of cutting fluid set for different cutting depths.spindle speed is 20000, The injection amount at or above this set value will not cause tool sticking and part failure. There are separate settings in the deep cutting program

Table 2 Setting of different cutting depths and cooling oil injection rates

Cutting depth	Cutting	Feed	Hole diameter	Flow ml/h
3mm	Side	F9000	3mm	45
3 mm	full	F9000	3 mm	45
5 mm	Side	F9000	3 mm	45
5 mm	full	F9000	5 mm	120
10 mm	Side	F9000	5 mm	180
10 mm	full	F9000	5 mm	200

Setting of cooling oil injection amount under different processing parameters.as a same hole diameter5mm, Due to the varying diameters of internal cooling holes from tool manufacturers, it is necessary to first understand the diameter of the internal cooling hole in the tool when selecting the spraying value. If the tool has multiple internal cooling holes, the diameter is obtained by adding the diameters of the multiple internal cooling holes.

Table 3 Setting of Different Cutting Parameters and Cooling Oil Spray Quantity

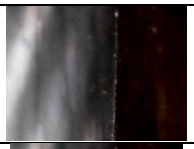
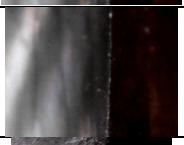
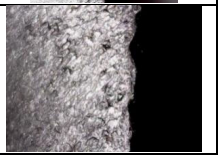
Cutting depth	Spindle speed	Cutting	FEED	Flow ml/h
5 mm	20000	Side	F6000	100
5 mm	28000	Side	F9000	120
5 mm	28000	full	F10000	150
10 mm	20000	Side	F6000	180
10 mm	28000	Side	F9000	200
10 mm	28000	full	F6000	200

Using the same milling parameter S20000F6000, the milling stroke is 5000mm, and the degree of tool wear is monitored based on different flow settings. It can be seen that the larger the flow rate is, the smaller the damage degree of the tool is, see Table-4. When the flow rate is exceeded, the tool wear reaches balance.

4. Emissions and residual parts on the surface

In MQL machining, under the action of air flow under a certain pressure, the small droplet like cutting fluid shoots into the cutting area at a high speed and kinetic energy, and its permeability is greatly enhanced. Its permeability is related to various factors such as specific cutting parameters (cutting speed, feed rate and cutting depth), droplet density, droplet speed, droplet size, spray direction, and so on.

Table 4 Tool damage under the same cutting parameters

Flow ml/h	describe	photograph
120	Slightly white blade	
100	Slightly white blade	
90	Red sparks, boundary	
80	Red sparks, boundary	
70	Red sparks, boundary; sticking; burn marks, broken	

In engineering practice, it is found that after a large amount of cutting fluid jet cutting, aluminum alloy will cause some oil residues, which cannot be removed after fluorescence treatment, and the stroke dark spots. After cleaning with ultrasonic cleaning equipment, such problems can be solved.

As the amount of lubricating oil increases, the peak volume distribution of oil mist particles first increases and then decreases, The floating of mist. Although the cutting fluid used in semi dry machining is a mixed liquid based on vegetable oils with minimal impact on the human body and is rarely used, long-term inhalation by operators is not a good strategy. Medical research has shown that oil vapor and large particle droplets pose relatively little harm to the human lungs. Even if the concentration of oil mist is only 0.4l-0.55mg/m, long-term exposure of workers to this oil mist can still lead to chronic bronchitis, chest discomfort, and airway irritation.

In the discharge and treatment of oil mist, it is necessary to strictly follow the emission signs for design. The entire machine tool needs to be sealed and filtered through capillary flue, paper bag, and static paper bag to ultimately meet the emission standards. In engineering practice, the filtering device should be regularly replaced to maintain green emissions.

5. Summary

In this paper, the MQL micro lubrication system has been deeply discussed, and the relationship between the amount of cutting fluid and various parameters has been summarized through daily engineering practice.

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