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Microlubrication effects in milling AISI 1018 steel:An approach towards Green Manufacturing

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Microlubrication effects in milling AISI 1018 steel: An approach towards Green Manufacturing

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Abstract

Flood cooling is primarily used to cool and lubricate the cutting tool and workpiece interface during machining process. The adverse health effects caused by the use of coolants and the potential economic advantages of greener machining methods are drawing manufacturer's attention to adapt and develop new methods of using lubricants. Microlubrication serves as an alternative to flood cooling by reducing the volume of cutting fluid used in the machining process. An outline for how to conduct a laboratory experiment using microlubrication and the subject are discussed.

Keywords: Microlubrication, Minimum Quantity Lubrication, Milling, Tool wear, Steel, Design of experiments.

1. Introduction

Metal working fluids (MWFs) are used to cool and lubricate the tool/workpiece interface during machining. The MWFs perform several important functions including reducing the friction-heat generation and dissipating generated heat at tool-workpiece interface which results in the reduction of tool wear. MWFs flush the chips away from the tool and clean the workpiece causing less built-up edge (BUE). Therefore, MWFs cannot be completely avoided; however, their exposure to machine operators is a cause of growing occupational health hazards. U.S. National Institute for Occupational Safety and Health (NIOSH) recommends that occupational permissible exposure limits to MWF aerosols be limited to 0.4 mg/m3 of thoracic particulate mass which corresponds to approximately 0.5 mg/m3 total particulate mass as a TWA concentration for up to 10-hrs per day during a 40-hrs work week [1]. However, the oil mist level in the U.S. automotive parts manufacturing facilities has been estimated to be 20-90 mg/m3 with the use of conventional lubrication by flood coolant [2]. The exposure to such amounts of metal working fluid may contribute to adverse health effects and safety issues, including toxicity, dermatitis, respiratory disorders and cancer [3]. Also, the costs related to the use of MWFs range from 7-17% of the total costs of the manufactured work piece [4] as compared to the tool cost which is only about 2-4% [5]. Microlubrication is also known as 'Minimum quantity lubrication' (MQL) and 'Near-Dry Machining'. In microlubrication, a small amount of cutting fluid, around 10 ml/hr, in the form of aerosol is delivered to the cutting tool/workpiece interface and does not recirculate through the lubrication system. It is almost all evaporated at the point of application. Hence no recirculation is required. It is important however to ensure an efficient extraction of aerosol from the machine. In a flood application, the same coolant is recirculated through the system, filtered and used again [6]. The lubrication is obtained via the lubricant, and the cooling is achieved by the pressurized air that reaches the cutting surface in a microlubrication application. Further, microlubrication reduces induced thermal shock and helps to increase the workpiece surface integrity in situations of high tool pressure [7]. The efficiency of a machining process depends on the tribological conditions which lowers the tool wear rate obtained by the cooling and lubricating effectiveness of the cutting fluid. The main objective of this work is to highlight the experimental laboratory approach to investigate the effects of microlubrication. In this example end milling AISI 1018 steel is conducted with a solid carbide cutter under varying cutting speed and feed rate levels and a constant depth of cut. A full factorial experiment is described.

2. Experimental Methods

End milling experiments were carried out on a Mori Seiki computer numerical control (CNC) Dura vertical 5060 milling machine with a spindle power of 15 HP and a maximum spindle speed of 10,000 RPM. AISI 1018 steel was used as workpiece material. The alloy can be easily formed, machined, welded and fabricated. The alloy is a free machining grade that is often employed in high volume screw machine parts applications and is commonly employed in shafts, spindles, pins, rods, sprocket assemblies and a wide variety of component parts. A Kuroda Ecosaver KEP3 microlubrication unit was installed on the milling machine to provide a constant aerosol flow rate of 12 ml/hr through external nozzle. Acculube LB-2000 was used as minimum quantity lubricant manufactured by ITW Rocol North America. An exhaust pump was used to collect the mist generated during machining to replicate the exact factory production environment. End milling was carried out with cutting speeds of 24, 30 and 36 m/min and feed rates of 0.15 and 0.25 mm/rev. The cutting parameters were decided based on the recommendation in the ASM metal handbook for machining [8]. The axial depth of cut was 3.175 mm and the radial depth of cut was 6.35 mm. The cutting tool used in the experiment was 25.4 mm diameter solid carbide end mill having square ends and two flutes with bright oxide finish manufactured by Guhring Inc. The helix angle of the flute was 30º and the flute length was 38.1 mm. Figure 1 shows the end mill used in this experiment with clearly marked side 1 and 2. The end mill was mounted on a tapered shank tool holder before being inserted into the tool magazine. A particulate monitor DataRam4 manufactured by Thermo Scientific was used to collect the data for aerosol mean diameter particle size and aerosol concentration. Flank wear on both the flanks was measured at regular interval by Mitutoyo Toolmakers microscope. The tool was declared failed if the flank wear of any one of the two flanks went above 0.5mm[8].

Figure 1: Solid carbide end mill.

3. Design of Experiments

The study was conducted using a randomized factorial design. Table 1 shows the factorial experiment with six cutting speed and feed rate combinations. The experiment was fully randomized.

Table 1: Factorial experiment layout of cutting speed and feed rate combination.

Solid Carbide End Mill		**Cutting Speeds (m/min)**		
		24	**30**	**36**
Feed Rates (mm/rev)	**0.15**	24, 0.15	30, 0.15	36, 0.15
	0.25	24, 0.25	30, 0.25	36, 0.25

An analysis of variance (ANOVA) was carried out for flank wear and F-ratios were calculated.

4. Conclusion

The cutting performance under microlubrication was found to be five times better in terms of tool life and two times better in terms of MRV under low cutting speed and feed rate combination (i.e. 24 m/min and 0.15 mm/rev) as compared to high cutting speed and feed rate combination (i.e. 36m/min and 0.25 mm/rev) for AISI 1018 steel using a vegetable based cutting fluid. Gradual two-body abrasion was the dominant wear mechanism except for treatment 24 m/min and 0.25 mm/rev where the tool underwent catastrophic failure due to massive chipping. The ANOVA clearly indicated that both the cutting speed and feed rate are statistically significant factors based on a 95% confidence level for both the flank wear sides.

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