Effect of Minimum Quantity Lubrication (MQL) on Surface Roughness of Mild Steel of 15HRC on Universal Milling Machine

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Abstract

In this research work, the effects of three parameters, namely, cutting speed, feed and depth of cut were studied upon Surface Finish during milling operation. The end milling was performed under the Minimum Quantity Lubrication condition (900ml/hr) using end mill cutter and compared with conventional flooded lubrication (2liter/min). The comparative effectiveness was investigated in terms of surface finish. The surface finish was found to be improved by 27%. The findings of this study show that MQL may be considered to be an economical and environmentally compatible lubrication technique.

Keywords: MQL; Surface Finish; End Milling; flooded

1. Introduction

High production machining of inherently generates high cutting zone temperature. Such high temperature causes dimensional deviation and premature failure of cutting tools (by N. R. Dhara et al. (2007)). In high speed machining, conventional cutting fluid application fails to penetrate the chip-tool interface and thus cannot remove heat effectively. Addition of extreme pressure additives in the cutting fluids does not ensure penetration of coolant at the chip-tool interface.

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Interface to provide lubrication and cooling. However, high-pressure jet of soluble oil, when applied at the chip-tool interface, could reduce cutting temperature and improve tool life and surface finish to some extent (by N. R. Dhara et al. (2007)). Application of flood coolant to HSM has not been very promising. Majority of the coolants, especially the water based ones, have negative effect upon tool life. MQL is the name given to the process in which very small amount of oil is pulverized into the flow of compressed air. MQL helps in reducing cutting temperature and also averts thermal shocks, experienced by flood coolant (by Liao and Lin (2007)). Considering the high cost associated with the use of cutting fluids and when the stricter environmental laws are enforced, the choice of MQL seems obvious (by N. R. Dhara et al. (2007); Khan and Dhar (2006)).

2. Development of set up:

In this study lubricant and air is mixed by MQL set up which is based on spray gun concept. The two separate hollow pipes carry lubricant and air which mixed in mixing chamber just before the tip of the nozzle. The lubricant flow is controlled by flow control valve. In order to have contentious mist, constant pressure is assured by the pressure gauge reading because change in pressure may vary quantity of the lubricant coming out of the nozzle. Outer diameter of nozzle is 3mm. Experiments are carried with the following parameter viz. Coolant pressure, spot distance, coolant flow rate are 5bar, 20mm, 900ml/hr.

![Fig. 1: (a) MQL set up; (b) Photographic view of surface roughness measurement](image)

3. Experiment design:

The experimental set-up consists of a sunrise universal milling machine (Table size -1143*254, Speed -52-600rpm, motor 2 KW). The extremely small amount of cutting fluids for the requirements of Minimum Quantity Lubrication was supplied by the MQL system during the experiment at 5 bars. Pressure. The MQL system is a superfine particle oil mist generator capable of supplying superfine particles of oil–air mixture from a ejecting nozzle, while discharging cutting oil at a level of 900-1000ml/hr. The work piece (100*110*25) material was Bright Mild Steel of hardness 15 HRc. 5 mm diameter, 4 flutes end mill was used. Uncoated HSS end mill (axial rake angle 5°, helix angle 30 degree, nose radius of the insert r = 0.80) were selected. A fully synthetic water soluble coolant was used as the coolant in a volumetric concentration of 1:10. The MQL system generates the oil mist based on the principle of Minimum Quantity Lubrication, oil mist generator.

The experiment was carried out at three cutting speeds: 160,225,300 RPM, at constant feed rate and three DOCS: 0.1, 0.2, and 0.3 mm. The experiments were designed by using Taguchi L9 rectangular array with minitab15 software. Surface roughness was analyzed for comparison. In the figures the flooded and MQL represent flood cooling, and MQL results respectively.
4. Results:

Table 1: comparison of Flooded and MQL Experiment on Mild Steel of 15HRC on Universal Milling Machine

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Speed (rpm)</th>
<th>Depth of cut (mm)</th>
<th>Surface Roughness (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flooded</td>
</tr>
<tr>
<td>1</td>
<td>160</td>
<td>0.1</td>
<td>1.27</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>0.2</td>
<td>2.48</td>
</tr>
<tr>
<td>3</td>
<td>160</td>
<td>0.3</td>
<td>1.91</td>
</tr>
<tr>
<td>4</td>
<td>225</td>
<td>0.1</td>
<td>3.08</td>
</tr>
<tr>
<td>5</td>
<td>225</td>
<td>0.2</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>225</td>
<td>0.3</td>
<td>2.73</td>
</tr>
<tr>
<td>7</td>
<td>300</td>
<td>0.1</td>
<td>1.81</td>
</tr>
<tr>
<td>8</td>
<td>300</td>
<td>0.2</td>
<td>2.61</td>
</tr>
<tr>
<td>9</td>
<td>300</td>
<td>0.3</td>
<td>2.54</td>
</tr>
</tbody>
</table>

Fig. 2: Depth of cut v/s Ra for speed 160 rpm

Fig. 3 (a) Depth of cut v/s Ra for speed 300 rpm; (b) Depth of cut Vs Ra for speed SS 225 rpm
To compare flooded lubrication with MQL, the graphs are plotted for surface roughness vs. depth of cut at various speed combinations. Fig. 2 Shows graph for flooded lubrication with the speed of 160 rpm. It clearly shows that as the depth of cut increases, surface roughness also increases and then decreases. Fig. 3(b) shows combination with cutting speed of 225 rpm. This combination is the most optimum combination among the all combinations. With the increasing depth of cut, surface roughness decreases drastically then gradually increases. Fig. 3(a) shows graph plotted at the speed combination of 300 rpm. This graph depicts that surface roughness increases with increasing depth of cut and at a certain point it becomes constant. Fig. 2 shows graph for mql with cutting speed of 160 rpm. If we comparing this graph with flooded lubrication then it clearly shows that surface roughness value for mql is less than flooded lubrication.  

MQL shows better result at slow cutting speed and low depth of cut. Fig. 3(b) depicts the most optimum result with the minimum surface roughness value of 0.95μm which is far less than flooded lubrication. As per as MQL is concerned Surface roughness value is almost constant with little variations. Surface finish of MQL is better with medium cutting speed.

The machining temperature at the cutting zone is an important index of machinability and needs to be controlled as far as possible. MQL is expected to provide some favourable effects mainly through reduction in cutting temperature. When the chip-tool contact is partially elastic, where the chip leaves the tool, MQL is dragged in that elastic contact zone in small quantity by capillary effect and is likely to enable more effective cooling (by Lajis M.A. et al. (2008)). With the increase in cutting speed (Vc.) the chip makes fully plastic or bulk contact with the tool rake surface and prevents any fluid from entering into the hot chip-tool interface (by N. R. Dhara et al. (2007)). The last graph is drawn at the speed of 300rpm. It explains that at the minimum depth of cut MQL is adventitious but with increasing depth of cut flooded MQL and flooded lubrication shows same effect. It is quite evident that the effect of flood cooling and also of minimal quantities of lubricant diminishes with increasing federate and Depth of cut. As most of the mechanisms are temperatures dependent. At higher Depth of cuts more heat is generated because of the higher amount of metal removal, consequently increasing the temperature at the chip–tool interface (by Tsai M.K. et al. (2007)). It was found that the cooling ability of water in terms of temperature drop decreases with an increase in both temperature and depth of cuts. So, this might be the reason for flood cooling having no effect at higher depth of cuts, while the effect for MQL might be due to inadequate lubrication.

Conclusion:

An attempt has been made to evaluate the performance of MQL with a view to investigating it as an alternative to the traditional flood cooling method. Considering the drastic reduction of in lubricant consumption it can be easily deduced that the MQL (900ml/hr) technique can be adopted as a replacement for dry machining and it may also be regarded as an alternative economic approach for flood cooling (21it/min), especially when the ecology and the operator’s physiology is of major concern. The following conclusions can be deduced from the experiments performed. The ecological aspects of cutting fluid, minimum quantity of lubrication and environment friendly oil are used to minimize the negative aspects of cutting fluid while achieve the same function such as friction reduction, cooling, flushing away chips. The cutting performance of MQL machining is better than that of conventional machining with flood cutting fluid supply because MQL provides the benefits mainly by reducing the cutting temperature, which improves cooling effect and results in better surface finish.

References


