AN INVESTIGATION ON EFFECTS OF MACHINING PARAMETERS IN TURNING WITH THE USE OF MINIMUM QUANTITY LUBRICATION AND SOLID LUBRICANTS

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ABSTRACT

To control the high heat generated during machining process, large amount of cutting fluid is applied to machining area. Application of cutting fluid may increase total production cost and also causes threat to worker's health and environmental damage. With this view, alternatives are required to avoid the application of cutting fluid. The use of minimum quantity lubrication and solid lubricants is one such response to reduce the consumption of cutting fluid. In this direction, the objective of the proposed work is develop a setup to apply solid lubricant with minimum quantity to machining area. The solid lubricants are mixed with oil to analyze the effects on output parameters such as surface roughness, tool wear and cutting force. The mixture containing solid lubricant and oil performed effectively as compared to fluid cooling during machining. Hence proposed approach of lubrication can be considered as cost effective and environmentally friendly technique in place of fluid cooling.

1. INTRODUCTION

The ever increasing trend towards increasing productivity has demanded the development of reliable machining processes. Heat generated during machining is an important issue to be focused as it is further affecting surface integrity and tool life. Heat generated in primary machining zone is due to plastic deformation of work material. Secondary heat zone is due to the friction between tool and chip interface. Also some amount of heat is generated between flank face and tool. In order to carry away the heat generated in machining zone, conventional cutting fluid is utilized in high pressure and volume. However the use of cutting fluid results in environmental pollution and also affects workers health. By considering this an effort is made in present work to evaluate the feasibility of minimum quantity lubrication and solid lubricants in machining.

2. BACKGROUND AND REVIEW

Researcher has applied a novel concept called minimum quantity lubrication as an alternative to fluid cooling. It involves the usage of minimal quantity of cutting fluid with a typical flow rate of 50-500 ml/h which is directly applied to the cutting zone thereby avoiding the need of fluid disposal as it happens in flood cooling. Since MQL involves significantly lesser amount of cutting fluid, this phenomenon is popularly referred to as 'near dry machining' or 'micro lubrication' or 'spatter lubrication' (Klocke and Eisenblatter 1997).

It states to the supply of small quantities of fluid via an aerosol to the machining area. The mixture of air and oil can be prepared in a tank or on the nozzle tip (Klocke et al. 2000) The amount of fluid quantity required can be found based on the width of wheel. It is suggested as

1 L/min of fluid per 1 mm of wheel width (Barczak et al., 2010). The effects of 2 ml/hr oil in a flow high pressure air at 2 Mpa, while hard turning AISI4340 steel was investigated by Varodarajan et al. (2002). The effort may be considered as near to dry machining. The results obtained in the experiments revealed the better performance of process in case of parameter measured like temperature, cutting forces, tool life and surface roughness than dry and wet machining. Hadad and Sadeghi (2013) conducted the experiments during machining of AISI 4140 steel to analyse the performance of dry, wet and MQL techniques. It was reported that the least value of cutting force was found in case of minimum quantity lubrication and in wet condition.

Li and Liang (2007) assessed the effects on process parameters by applying the MQL method for lubrication. It is concluded that the reduced machining speeds, the tangential cutting force was also reduced up to certain limit. Investigations has been reported in face milling operation with dry, wet and MQL lubrication on aluminium alloy A356 at different cutting speeds up to 5225 m/min. The cutting force value reported highest in dry condition and lowest during machining with flood cooling (Kishawy et al., 2005). Attanasio et al. (2006) tried to identify the advantages of the application of minimum quantity lubrication with respect to improvement in tool life while machining of normalized 100Cr6 steel. The effects of grinding parameters on ABNT 4340 steel using minimum quantity lubrication method explored by Silva et al. (2007). It is also observed that the Ra values were significantly reduced in MQL method, maybe due to very good property of lubricity. The effect of dry and MQL machining on surface roughness during turning of AISI D2 steel was analysed by Sharma and Sadhu (2014). The vegetable oil was selected as cutting fluid in order to reduce the environmental effects. Solid lubricant assisted machining is one attempt to avoid the use of cutting fluids (Rao and Vamsi Krishna, 2008).

Investigators used the graphite as a solid lubricant in grinding process which resulted the decrease in heat generation (Venu Gopal and Rao, 2004). During the machining of hardened AIS I52100 steel with ceramic inserts, it was found that solid lubricants are more effective at higher cutting speeds (Dilbag Singh and Rao, 2008) The variation in cutting forces with flow rate were studied by applying graphite and MoS2 lubricants. It was observed that the cutting force decreases with increase in lubricant flow rate. Reddy and Rao (2006) investigated the role of solid lubricant assisted end milling machining with graphite and molybdenum disulphide lubricants on surface quality, cutting forces and specific energy while machining AISI 1045 steel using cutting tools of different tool geometry. Based on available literature it can be concluded that if MQL and solid lubricants applied efficiently to machining, the process performance can be increased.

3. EXPERIMENTAL PROCEDURE

The turning experiments were performed on Kirloskar Turnmaster 35 lathe machine with 3 H.P power and the spindle rotation ranges from 45 rpm to 1120 rpm. The workpiece material used in turning test was Inconel 718 in form of cylindrical rod. The dimensions of workpiece is 50 mm in diameter and 100 mm in length. The minimum quantity lubrication setup was mounted on lathe machine as shown in fig. 1. In contains nozzle, control valves, reservoir for fluid and air compressor. The purpose of the air compressor is to take solid lubricant mixed with fluid to nozzle.

Figure. 1 Minimum quantity solid lubrication set up mounted on lathe machine

The solid lubricant flow can be regulated by controlling the air flow in the system. The cutting inserts used in the experimentation were cemented carbide inserts from Sandvik with ISO designation SNMG120408-SM with WIDAX tool holder PCLNR1616H12 I7D. During the experiments the value of cutting speed, feed and depth of cut were kept constant as 130 m/min, 0.35 mm/rev and 1 mm respectively. Two different solid lubricants boric acid and calcium fluoride mixed in SAE 40 cutting oil were used for minimum quantity solid lubrication. Based on literature review conducted, the concentration of solid lubricant was 15% by weight. The air pressure was kept as 2 bar during the experiments.

During the machining the force components were measured by lathe tool dynamometer mounted on machine. . The strain gauge with tungsten carbide tool was attached to the tool post of the lathe machine. The surface roughness was measured on a surface roughness tester (Mitutoyo). The surface roughness was taken perpendicular to the turning direction and measured at three locations around work-piece circumference. The value of the surface roughness is the average of three points taken for each measurement. Tool wear was studied with the use of scanning electron microscopy after machining tests.

4. RESULTS AND DISCUSSION

The values of output parameters measured during experiments is shown in Table 1.

Table 1 Values of measured output parameters

	Surface Roughness Ra (µm)	Cutting Force (N)
Dry	2.860	460
Wet	2.340	440
MQL	2.710	450
15% Boric acid+ SAE 40 oil	2.410	420
15 % CaF_2+ SAE 40 oil	2.640	410

The surface roughness was measured at 130 m/min, 0.35 mm/rev and 1 mm. The comparison of surface roughness produced in all machining condition is presented in Fig. 2. In order to conclude about the performance of lubricating condition it should be considered with the value of cutting force and tool wear mechanism also. The Ra values was significantly affected however the machining with wet and 15% boric acid presented average Ra value as 2.410 µm. The highest value of Ra was observed in case of dry machining followed by MQL condition.

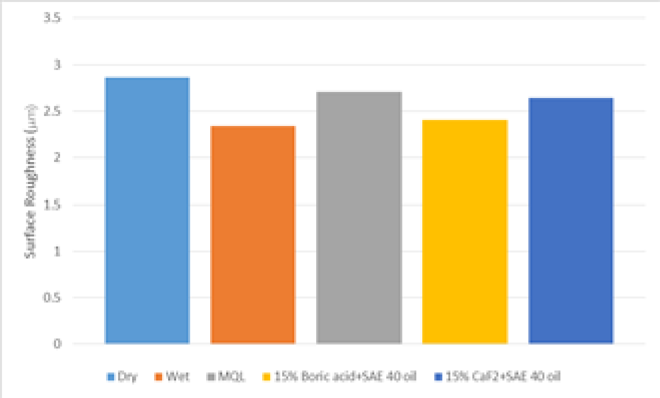


Figure 2 Variation in Surface Roughness Ra for different lubricating condition

The efficiency of lubricant to be stacked in the interface is mainly depends on viscosity and other frictional factors.10% boric acid mixed with SAE 40 oil has performed better due to its viscosity and ability to create a lubricating film between tool work interface during machining.

At selected cutting conditions the solid lubricant assisted machining surpassed others in terms of cutting force and lowest tool wear but surface roughness was slightly on higher side with the use of CaF_2. One reason of this can be roughness is mainly associated with the condition of the edge. In this case the cutting edge distortions can be reflected on the finished surface. The cutting forces were found in close difference to each other for solid lubricants.

Fig. 3 shows the comparison of cutting force developed during machining with different environments.

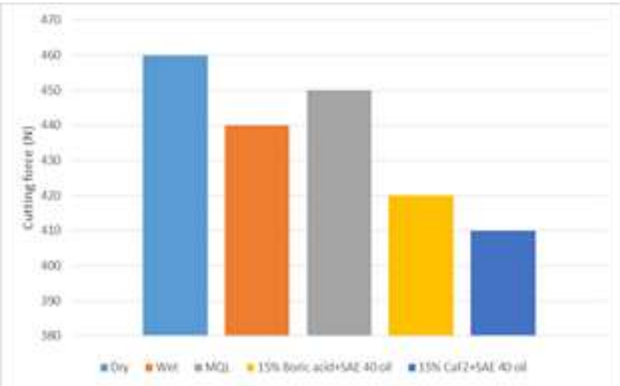
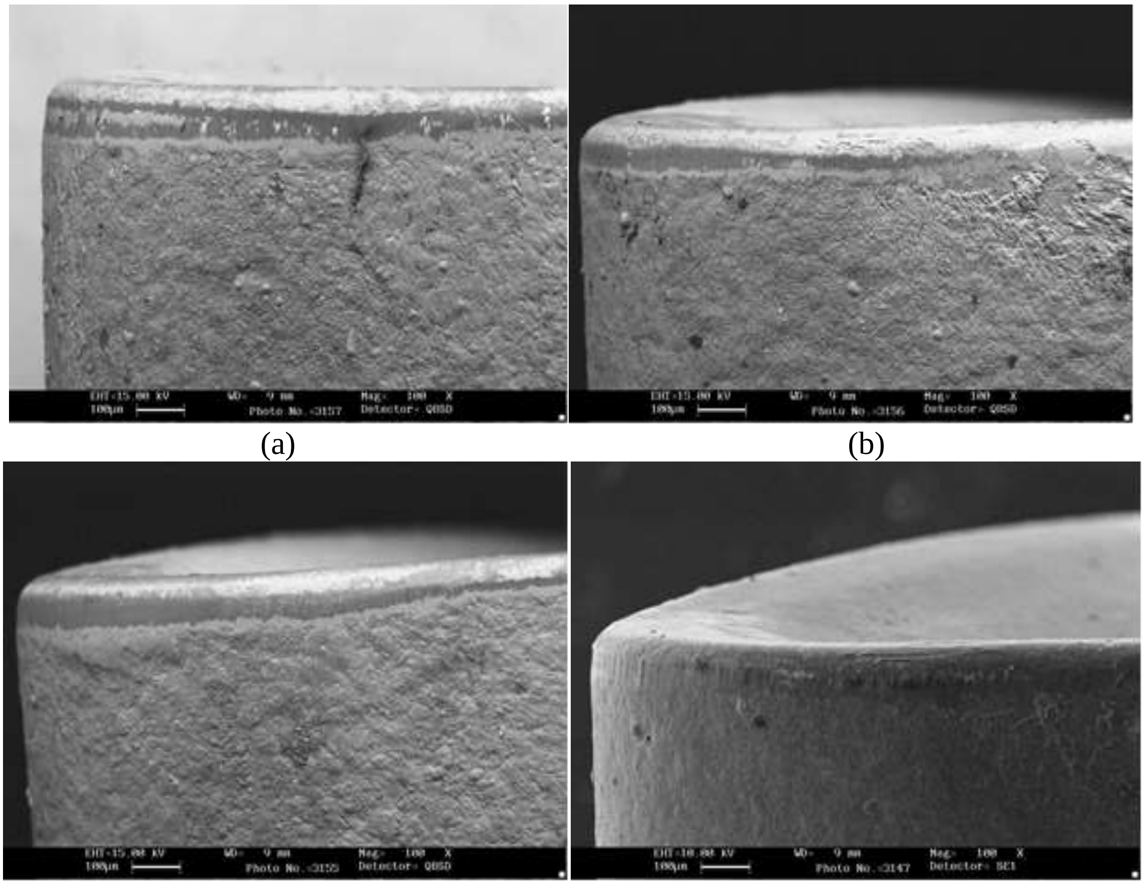


Figure 3 Variation in cutting force for different lubricating condition

The lowest cutting force was observed in case of CaF_2 and highest value with dry machining. It may be because of better lubricating properties of CaF_2. It can be noted here that MQL and dry machining performed almost similar by giving similar cutting forces, higher roughness and similar tool wear which can be a sign of presence of build-up edge due to the presence of high temperature in the cutting zone.

Fig. 4 shows the mechanism of tool wear in case of all machining conditions. It can be observed from Fig. 4 (a) that highest amount of flank wear was observed in case of dry machining. Abrasion and BUE was also observed as tool wear mechanisms.



(a) (b) (c) (d)

Figure 4 SEM images of the tool wear (a) Dry (b) Wet (c) MQL (d) Solid lubricant assisted machining

In case of wet machining, abrasion and adhesion were found as leading wear mechanisms as shown in Fig. 4 (b). In MQL machining, chipping at the cutting edge and abrasion were found as major wear mechanisms. However, adhesion was also found at a small scale as shown in Fig. 4 (c). Fig. 4 (d) shows the tool wear mechanism with the use of solid lubricants. The minor amount of flank wear was observed in case of solid lubricant assisted machining. Which is also evidenced from the lower value of surface roughness reported in this case.

5. CONCLUSIONS

The turning experiments was conducted on newly prepared setup of minimum quantity solid lubrication. The effectiveness of MQL and solid lubricants can be evidenced from the experimental results. Significant reduction in surface roughness and cutting forces was observed with the use of solid lubricant assisted machining. The tool wear observed was also minimum in case of the use of solid lubricants due to better lubricity and layered structure which slides easily during application. The overall machining performance has improved with minimum quantity solid lubrication.

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