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Tribological Studies on Milling AISI D2 Using Modified Simarouba Oil

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Abstract: *In this paper, experiments are conducted on CNC milling AISI D2 material using minimum quantity lubrication technique under modified Simarouba oil as straight cutting fluid. Cutting force, Surface roughness value (Ra), Tool wear and Temperature is studied for the evaluation. The results under the Simarouba oil are compared with the results milled under conventional mineral oil. The experimental results show that the cutting forces are dropped by about 5% under modified Simarouba oil compared to mineral oil. About 13% drop in Surface roughness value (Ra) are noticed under formulated Simarouba oil. Also 3% drop in Tool wear is noticed under Simarouba oil. Further, a marginal drop in tool temperature is noticed under the modified vegetable oil (Simarouba) mode of lubrication.*

Keywords: *Minimum Quantity Lubrication, Mineral oil, Simarouba, CNC, Milling*

INTRODUCTION

It is reported that approximately 39 million tons of metalworking fluid (MWF) been used in machine tools around the planet and furthermore, an increase of 1.2% is previewed for this decade. Out of this amount, about 85% is of petroleum-based oils (Lee and Choong, 2011). It is well known that MWF is the most frequently changed component in the machining industry. It is need of the hour to extend the metalworking fluid life or to reduce the impact of MWF disposal to the environment (Carlos *et al*., 2014). Alternatively, vegetable oil-based cutting fluids are being explored to replace the conventional fluids. Sana Werda *et. al.* (2016), conducted the experiments on milling using X100CrMoV5 steel alloy material. It is reported that there was a reduction of tip temperature of about 45 % compared to dry machining. Further, cutting force was dropped by 20% and 40% lower mean roughness using synthetic ester and fatty alcohol compared with dry machining (Sana Werda *et. al*. 2016). Geoff Burton *et.al.* (2014), conducted the experiments on Al6061 and Steel 1018 using stable emulsification of vegetable oil (Canola) through ultrasonic atomization without using any surfactant. The emulsified vegetable oil in water is directly used to investigate its effectiveness as MWF in milling operations.

It is reported that cutting forces 22% drop by using canola oil in water compared to dry machining (Geoff Burton *et.al.*, 2014). Alper Uysal et. al. (2015), conducted the experiments on commercial vegetable cutting fluid and 1% wt. of nano MoS_2 (Molybdenum Disulphide) particles reinforced vegetable cutting fluid during milling of AISI 420 It is reported that tool wear reduced by 16.8% and surface roughness decrease by 8.8 % (Alper Uysal *et. al.*, 2015). In the present work, Simarouba oil is modified, to use it as a cutting fluid for milling AISI D2. The milling operation is carried out using minimum quantity lubrication technique. The parameters, cutting force, surface roughness value, Tool wear and Temperature are measured under modified Simarouba oil as cutting fluid. The obtained results are compared with mineral based cutting fluid.

MATERIALS AND METHODS

A. Modification of Vegetable Oil

The raw Simarouba oil is obtained from Simarouba Glauca multipurpose tree which can grow well even in the degraded area and transesterification method is used for 1 liter oil modification with Methanol to obtain Methyl ester of Simarouba oil (MESO). The process is carried out by mixing the Simarouba oil with Methanol in 3:1ratio in a three neck round bottom flask. The mixture is mixed with 2% KoH catalyst. The mixture is heated over an hour with a magnetic stirrer. Further, the solution is poured into the separating funnel for gravity separation where the MESO is separated from Glycerin. It is allowed to settle for about eight hours. The obtained MESO is heated with distilled water to vaporize the alcohol content present in the oil. Obtain MESO is termed as modified Simarouba oil.

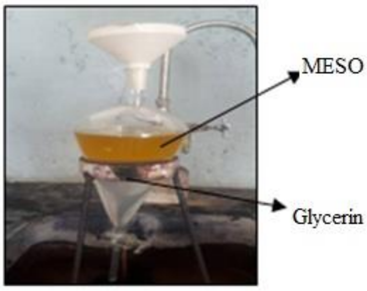

Fig.1 Separation of MESO and Glycerin

B. Material for Milling

The chemical composition of AISI D2 is determined at NABL, Bengaluru. The results are tabulated in table 1.The material has potential applications in the areas of tool and die making, shear blades, punches and dies.

Table-1 Chemical composition of AISI D2

Chemical Composition	
Constituent	% of total weight
C	1.760
Si	0.409
Mn	0.328
S	0.011
P	0.016
Cr	11.530
Mo	0.408
V	0.201

Fig. 2 Experimental system

C. Experiments

Milling experiments on AISI D2 are carried out using vertical machining CNC milling centre under mineral oil (Divyol 52 ST) using minimum quantity lubrication technique in this technique uses a spray of small oil droplets in a compressed air. The experiments are conducted for various Depths of cut, 0.3, 0.5 and 0.7 mm, Feed rates of 60, 80 and 100 mm/rev and Cutting speeds of 1500, 2000 and 2500 rpm. The Cutting force is measured using tool dynamometer. An optical microscope is used to measure Tool wear. The Surface roughness of the milled component is measured using Talysurf. The experiments are repeated under modified Simarouba (MESO) of lubrication and the above parameters are recorded.

RESULTS AND DISCUSSION

A. Cutting Force

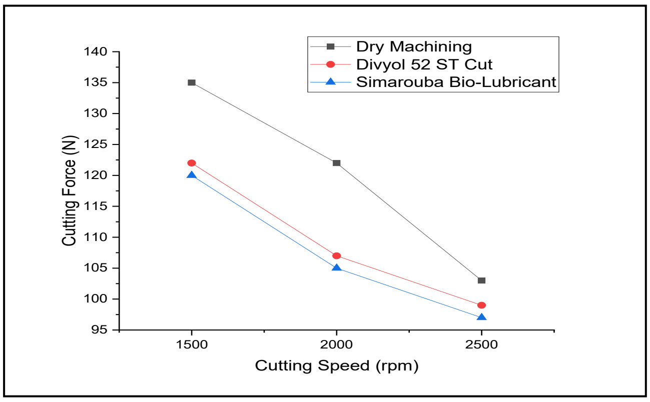

Fig. 3 Variation of Cutting force with Cutting speed

Fig. 3 represents deviation of cutting force with cutting speeds. The argument is for the constant feed rate of 80 mm/rev and depth of cut of 0.5 mm for various cutting speeds. It is noticed that the cutting force linearly decreases as the cutting speed increases. It is seen from the Fig.3 that at low speed operations, the cutting force under mineral oil is dropped by 8% compared to dry machining. However, the use of modified Simarouba oil reduces the cutting force by 13% and 4% compared under dry and mineral oil mode of lubrication respectively.

Small variation in magnitude of cutting forces at 2500 rpm is observed under all lubrication modes. However modified Simarouba oil produces 5% of lower cutting forces compared to mineral oil. Drop in cutting force under vegetable oil is due to high viscosity (4.68 at 40^{0}C) and adhesiveness of oil (Susmitha *et al.*, 2016).

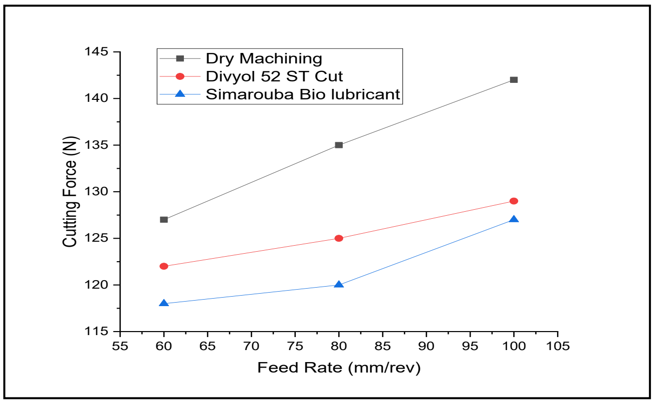

Fig.4 Variation of Cutting force with Feed rate

Fig. 4 shows variation of cutting force with feed rate. The discussion is based on for constant speed of 1500 rpm and depth of cut of 0.5 mm. It is observed that cutting force increases with increase in feed rate. Among the three operations, the force obtained under modified Simarouba oil is the lowest. About 13% and 4% of drop in cutting force under MESO compared to dry and mineral oil respectively.

B. Surface Roughness

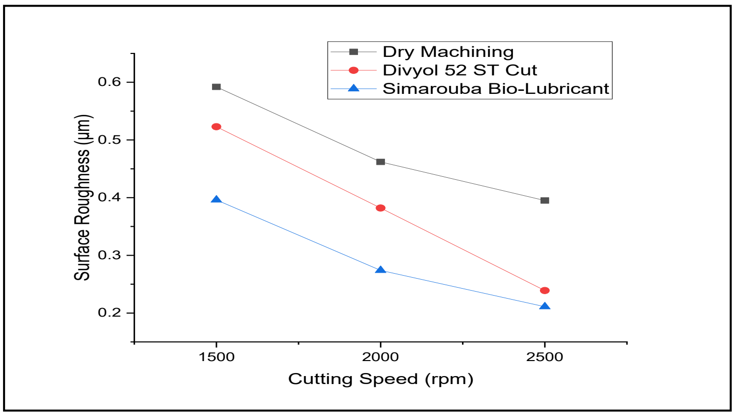

Fig. 5 Variation of Surface roughness with Cutting speeds

Fig.5 depicts the variation of Surface roughness value with cutting speeds. The argument is for the constant depth of cut of 0.5 mm and cutting speed 1500 rpm for various cutting speeds. It is observed that the Surface roughness values linearly drop as the cutting speed increases. It is seen from the Fig. 5 that, the Surface roughness value under mineral oil is decreases by 7 % compared to dry machining. Conversely, the use of esterified Simarouba oil decreases the Surface roughness values by 20 % and 13 % compared under dry machining and conventional oil respectively. Small deviation in magnitude of Surface roughness value at 2500 rpm is noticed under all lubrication modes. However esterified Simarouba oil produces 13 % of lower Surface roughness value compared to mineral oil. Drop in Surface roughness value under vegetable oil is due to the presence of surface active agents such as stearic acid (25.60 %) help to reduce surface energy and increase its wetting power or oiliness (Obi *et al.*, 2013).

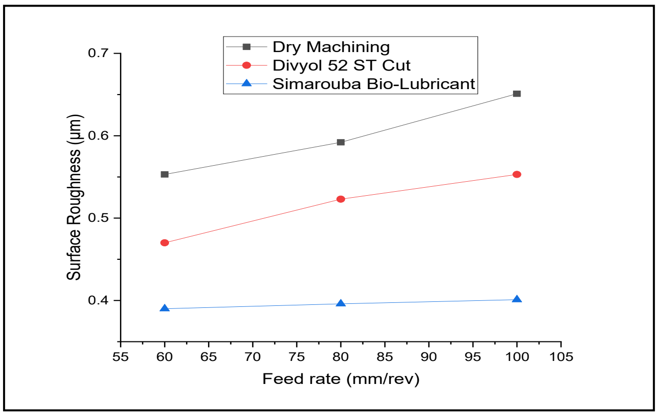

Fig. 6 Variation of Surface roughness with Feed rate

Fig. 6 shows variation of Surface roughness value with feed rate. The conversation is based on for constant speed of 1500 rpm and depth of cut of 0.5 mm. It is noticed that Surface roughness value increases with increase in feed rate. Among the three operations, the Surface roughness value obtained under modified Simarouba oil is the small. About 20 % and 13 % of drop in Surface roughness values under MESO compared to dry and mineral oil respectively.

C. Tool Wear

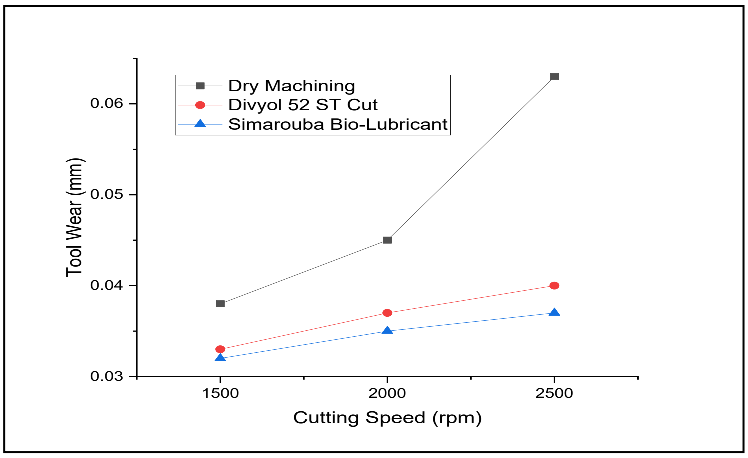

Fig.7 Variation of Tool wear with Cutting speed

Fig. 8 depicts variation of tool wear with cutting speeds. The conversation is for the steady cutting speed 1500 rpm and depth of cut of 0.5 mm for different cutting speeds. It is noticed that the tool wear linearly rises as the cutting speed increases. It is seen from the fig. 8 that the tool wear under mineral oil is drop by 3 % compared to dry machining. However, the use of modified Simarouba oil decreases the tool wear by 5 % and 4 % respectively compared under dry and mineral oil form of lubrication. Little deviation in amount of cutting speed at 2500 rpm is observed under all lubrication modes. Little variation in amount of cutting speed at 2500 rpm is observed under all lubrication modes. However, modified Simarouba oil produces 3 % of lower tool wear compared to mineral oil. Fall in tool wear under Simarouba is due to thermal degradation, high pour point (14.2^{0}C) and oxidation stability result in reduced tool wear during machining (Ajay *et al.,* 2015).

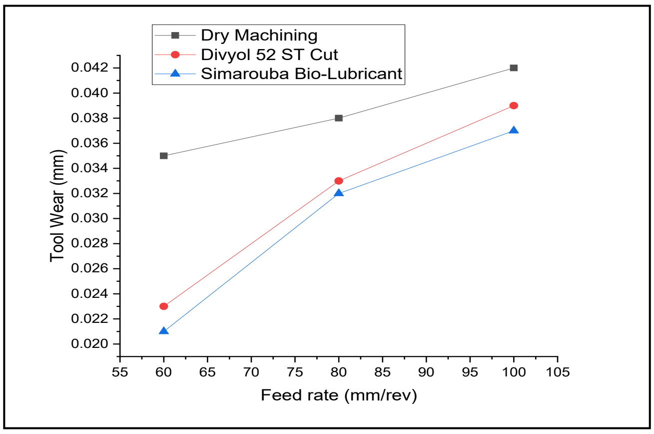

Fig.8 Variation of Tool wear with Feed rate

Fig. 8 shows distinction of tool wear with feed rate. The argument is based on for steady speed of 1500 rpm and depth of cut of 0.5 mm. It is noticed that tool wear increases with rise in feed rate. Among the three operations, the wear obtained under modified Simarouba oil is the lowest. About 5 % and 3 % of decrease in tool wear under MESO compared to dry and mineral oil respectively.

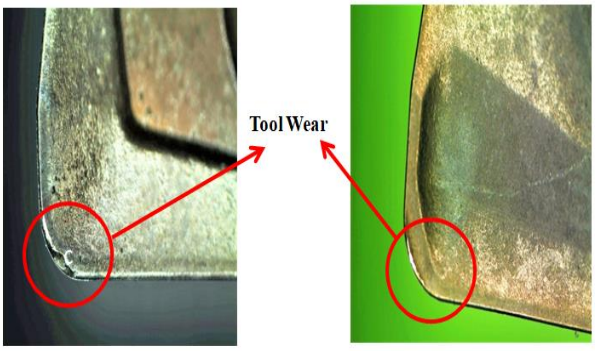

Fig. 9 Optical microscope images of Tool wear during dry machining and modified Simarouba oil

D. Temperature

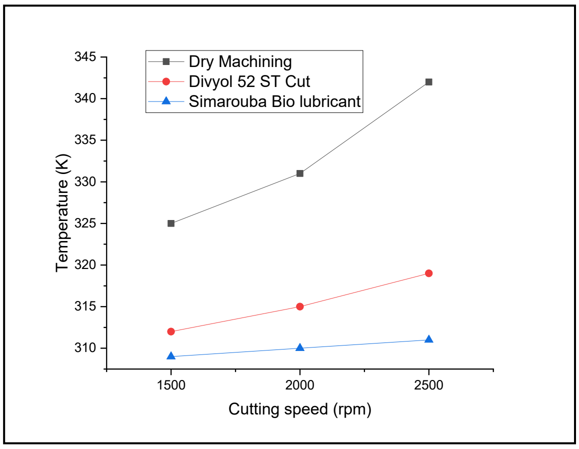

Fig.10 Variation of Temperature with Cutting speed

Fig.10 shows variant of temperature with cutting speeds. The discussion is for the constant cutting speed 1500 rpm and depth of cut of 0.5 mm for different cutting speeds. It is noticed that the temperature linearly rises as the cutting speed increases. It is observed that at low speed operations, the temperature under mineral oil is drop by 7 % compared to dry machining. Conversely, the use of adapted Simarouba oil reduces the temperature by 10 % and 3 % respectively compared under dry and mineral oil mode of lubrication. Small deviation in amount of cutting speed at 2500 rpm is observed under all lubrication modes. However, modified Simarouba oil produces 3 % of lower temperature compared to mineral oil. Drop in temperature under vegetable oil is due to high heat carrying capacity at cutting zone during machining (Obi *et al.*, 2013).

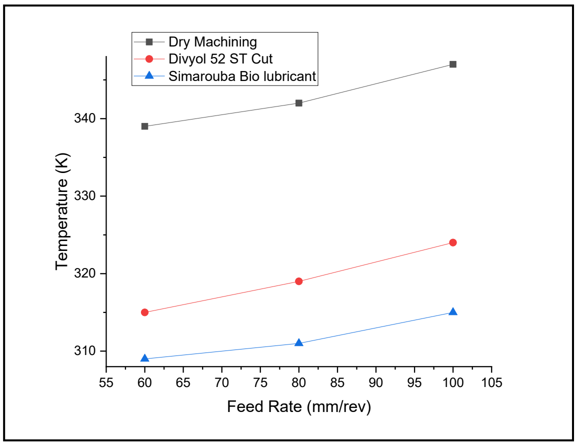

Fig. 11 depicts distinction of temperature with feed rate. The argument is based on for constant speed of 1500 rpm and depth of cut of 0.5 mm. It is observed that temperature rises with increase in feed rate. Between the three operations, the temperature obtained under modified Simarouba oil is the lowest. About 10 % and 3 % of drop in temperature under MESO compared to dry and mineral oil respectively.

CONCLUSION

The experimental results reveal that the Cutting forces are dropped under modified Simarouba oil compared to mineral oil and dry cutting. For the constant feed and depth of cut, about 5% drop in Cutting forces under modified Simarouba oil is noticed. Surface roughness values are reduced by about 13% under the formulated Simarouba oil. A marginal drop in tool wear is observed under modified vegetable oil compared to conventional oil. Further, an insignificant drop in tool temperature is recorded under the vegetable modified oil compared mineral oil.

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