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Effect of vegetable based cutting fluids on chip formation and surface roughness during turning operation of Mild steel

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Abstract

During Machining process, heat is generated between work piece-cutting tool and cutting tool-chip interfaces due to friction. The effect of this generated heat, decreases tool life, increases surface roughness and decreases the dimensional sensitiveness of work material. This problem can be overcome by using Cutting fluids. Vegetable oils like Coconut oil, Mahua oil and Rice bran oil with and without addition of 1% graphite powder is used as cutting fluids during turning operation of Mild steel work piece. Long length silvery colored continuous chip were formed when coconut oil and rice bran oil were used as cutting fluids, indicating that temperature is less at machining zone. The chip thickness ratio is higher for Rice bran oil indicating better cutting action. Surface roughness measured is less for coconut oil followed by Rice Bran Oil. Addition of 1% graphite has not varied the results.

Key words: *Chip formation; Chip thickness ratio ; Coconut oil ; Graphite powder; Mild steel; Mahua oil ; Rice bran oil ; Surface roughness ; Turning; Vegetable based cutting fluids*

1. Introduction:

During metal cutting process, extensive heat is generated due to friction between the chip- tool– work piece interfaces. The excessive heat thus generated can reduce the life of cutting tool and efficiency of the machining. In order to reduce the effects of friction or heat generated, cutting fluids are used [1].Proper selection of cutting fluids can reduce manufacturing cost and improve productivity. Regarding the environmental impacts and health hazards by cutting fluids, recycling and disposal of cutting fluid are also of great importance. Improper disposal actions can cause severe health and environmental problems. These problems gave provision for the introduction of mineral, vegetable and animal oils. Many have investigated the performance of various vegetable oils as cutting fluids for machining operation like drilling, milling turning and results proved that vegetable based cutting fluids are better than petroleum based cutting fluids[2-6]. To enhance the performance of vegetable oil as cutting fluid many researchers have added nano powders of graphite, carbon and so on. Saravana Kumar investigated the performance of multi-walled carbon nanotubes dispensed in coconut oil as Nano fluid while machining Martensitic stainless steel 420 grade. Results concluded that, carbon nanotubes dispensed in coconut oil yields better surface finish and reduced cutting temperature as against conventional cutting fluids or dry condition [7]. Prasad carried out turning using HSS and cemented carbide tools. The cutting fluid was added with nano particles in varying proportions i.e. 0%, 0.1%, 0.3% and 0.5% by weight to form nano cutting fluid. The application of cutting fluids was by Minimum Quantity Lubrication (MQL). The experiment was carried out along flood coolant machining and dry machining with varying flow rates of nano cutting fluid under constant cutting conditions. It was concluded that upon increasing the addition of nano particles by weight percentage, there was an improvement in the performance of cutting fluids in their properties such as surface finish, tool life, cutting temperature and cutting forces [8].Padmini evaluated the performance of vegetable oil based nano fluids during turning of AISI 1040 steel through Minimum Quantity Lubrication (MQL). Nano molybdenum disulphide (nMoS2) was dispersed in coconut oil, sesame oil, canola oil at varying Nano-particle inclusions and properties were analyzed and compared for different machining parameters. From the experiment, 0.5% coconut oil + nMoS2 exhibited superior machining performance. Cutting force reduced by 37%, temperature dropped by 21%, tool wear decreased by 44% and surface roughness was seen to have reduced by 39% when compared to dry machining [9].

2. Experimental Details

The use of vegetable oils allows high performance in machining combined with good environment compatibility. Compared to mineral oil, vegetable oil can even enhance the cutting performance, extend tool life and improve the surface finish. Although, they have many environmental benefits, vegetable oils are more susceptible to degradation by oxidation or hydrolytic reactions.

In the present work Coconut oil, Mahua oil and Rice bran oil with and without addition of 1% graphite powder is used as cutting fluids during turning operation of mild steel work piece. The turning operation was carried out on medium duty lathe with the work piece being firmly held in a 3-jaw chuck with cutting speed, depth of the cut and feed maintained constant with the values as 300 rpm 2mm and 2 mm/rev respectively. Work piece turned is AISI 1014 mild steel having diameter of 25mm with 150 mm length. HSS single point cutting tool with 10% cobalt having Nose radius as 2mm and with Side, end relief angle as 6 degrees is used for turning. But before turning, centering was done for all the work pieces using center drill. The turning operation is carried using Rice bran oil, Mahua oil, Coconut oil, with and without addition of 1% graphite powder, petroleum based oils as cutting fluids and also in dry condition with constant machining parameters. The method of MQL (Minimum quantity lubrication) is used for supplying the cutting fluid.

The surface roughness is measured using profile meter, shown in the figure 1 .The surface roughness of the work piece depends on the temperature of machining zone. As the temperature increases, the work surface becomes brittle and the force needed to cut the material increases leading to increased roughness. Micrometre was used to measure Chip thickness.

Fig. 1 Surface roughness tester

3. Results and Discussion

3.1 Study of chips

The type of the chip produced during metal cutting is an important index of machining process because it indicates:

- Type of the work material
- Amount of energy required to remove unit volume of work material during machining
- Friction at chip-tool interfaces
- Geometry of the cutting tool
- Cutting parameters i.e. feed, speed and depth of cut
- Cutting fluid that affects temperature and friction at the chip-tool and work-tool Interfaces

In the present work, all the elements like work material, tool geometry, cutting parameters are kept constant and only the cutting fluids used are different. The type of chip produced now depends on different cutting fluids used. The work piece material is mild steel which is ductile, so when turned, the chip formed should be continuous type. Types of chips produced using different cutting fluid are as shown in the figure 2. For dry cutting, discontinuous chip are produced, this may be due to high temperature resulted from friction between tool and work piece as no cutting fluid is used; heat due to friction will be transferred to tool and work piece due to which the surface of the work piece will become brittle resulting in dark brown discontinuous chips. Same discontinuous chip are also produced for petroleum based cutting fluid as the temperature at the machining zone is less than dry cutting and higher than other oils used as cutting fluids, this is because of its low viscosity. The SAE20W40 just flows over the machined surface without absorbing max heat from the machining zone. Long length silvery colored continuous chip were formed when coconut oil and rice bran oil are used as cutting fluids, indicating that temperature is less at machining zone as these oils absorb more heat, keeping the work surface ductile in nature. While turning using Mahua oil as cutting fluid, discontinuous dark brown chip were produced due to maximum temperature at the machining zone. Smoke was observed when Mahua oil was used as cutting fluid; this may be due to chemical composition. With 1% graphite addition to these oils, the types of chip produced were same but only the length of the chip got reduced. This may be due to formation of brittle layer by the graphite powder at the cutting temperature.

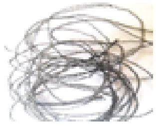
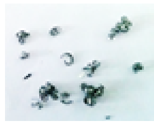
	
Coconut oil	Coconut oil with 1% graphite
	
Rice bran oil	Rice Bran oil with 1% Graphite
	
Mahua oil	Mahua oil with 1%Graphite
	
SAE20W40 (Petroleum based oil)	Dry

Fig. 2 Chips formed using different cutting fluids and at Dry condition

3.2 Chip Thickness Ratio

The value of chip thickness ratio gives information about rate of plastic deformation in the chip formation zone. During cutting process, the tool shear the work surface, hence the outward flow of metal causes chip to be thicker after separation from the base metal. Mild steel work piece is turned at constant speed, feed and depth of cut using HSS tool. Chips produced using different cutting fluids were collected to closely examine the shape, color and chip thickness. The thickness of the chips was measured using a precision profile projector with accuracy of ±0.001 mm and values are tabulated in the Table 1. Using the measured value of chip thickness, cutting ratio of the cutting process can be calculated as in below

$$\text{Chip thickness} = r = \frac{t1}{t2} = \frac{\text{uncut chip thickness}}{\text{chip thickness}}$$

Table 1: chip ratio(r) measured using different cutting Fluids

Sl. No	Cutting fluids used	t_1 (mm)	t_2 (mm)	$r=\frac{t1}{t2}$
1	Coconut oil	0.5	0.64	0.78
2	Coconut oil with 1% Graphite	0.5	0.66	0.76
3	Rice Bran Oil	0.5	0.61	0.82
4	Rice Bran oil with 1% Graphite	0.5	0.62	0.81
5	Mahua oil	0.5	0.7	0.71
6	Mahua oil with1% Graphite	0.5	0.73	0.68
7	SAE20W40 (Petroleum Based oil)	0.5	0.62	0.81
8	Dry	0.5	0.67	0.75

The thickness ratio is always less than one, but if nearer to one then it indicates that machinability is good. The higher the value of chip thickness ratio, the better will be the cutting action. From the figure 3, it can be observed that rice bran oil gives better cutting action followed by coconut oil, SAE20W40 compared to Mahua oil and dry cutting. With 1% graphite addition chip thickness ratio is reduced. This may be because graphite acts as good lubricant but not as coolant, due to which temperature will be high resulting in thicker chips.

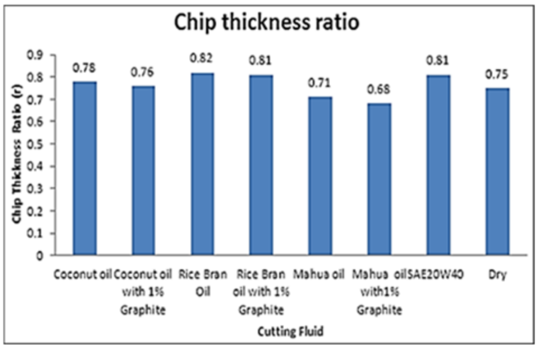


Fig. 3 Graph showing chip thickness ratio (r) measured

3.3 Surface Roughness Of Machined Surface

The surface obtained after turning using Coconut oil ,Coconut oil with 1% Graphite, Rice Bran Oil, Rice Bran oil with 1% Graphite, Mahua oil, Mahua oil with 1% Graphite, SAE20W40 as cutting fluids and also for dry cutting condition are shown in the figure 4. Surface finish usually depends on machining parameters like speed, depth of cut & feed. It also depends on type of material being machined, type of cutting fluid used and type of tool material. In the present work all the elements are kept constant but only cutting fluid used have been varied. Figure 5 shows the effect of pure oils and addition of 1% graphite Nano powder to these oils as cutting fluid on the work surface and shows the surface roughness measured. It can be seen that roughness of work surface using coconut oil as cutting fluid is less compared to other oils used, followed by rice bran oil, SAE20W40 and Mahua oil. Maximum roughness is measured for dry condition, this is mainly because of higher temperature resulted due to high friction between tool and work piece. When coconut oil and rice bran oil is used as cutting fluid the heat absorbed from machining zone is high due to which, the work surface will not be affected, resulting in smooth shearing action i.e. resistance by work surface against will be less.

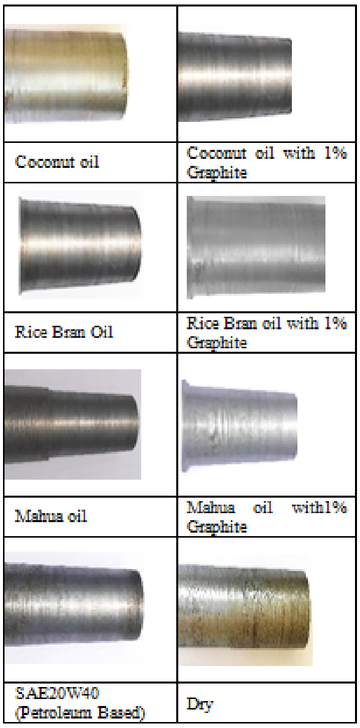


Fig. 4 Surface roughness of machined surface using different cutting fluids and at dry condition

Addition of graphite powder has not improved the surface finish even though it is soft and is been used as solid lubricant, but instead the surface roughness increases as compared to surface obtained using pure oil. This may be due to formation of brittle layer by the graphite powder at the cutting temperature.

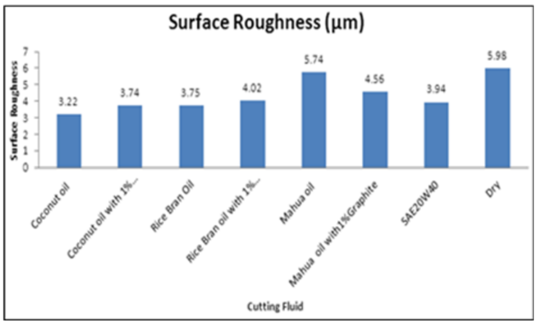


Fig. 5 Surface roughness measured on machined surface for different cutting fluids and at dry condition

4. Conclusion

Experimental results during turning of mild steel work piece using Coconut oil, Coconut oil with 1% Graphite, Rice Bran Oil, Rice Bran oil with 1% Graphite, Mahua oil, Mahua oil with 1% Graphite, SAE20W40 as cutting fluids and at dry cutting conditions are follows

Chip formation: For dry cutting conditions and when cutting fluid used is Mahua oil, dark brown discontinuous chip are produced due less amount of heat absorption from machining zone. Long length silvery colored continuous chip were formed when coconut oil and rice bran oil are used as cutting fluids, indicating that temperature is less at machining zone as these oils absorb more heat keeping the work surface ductile in nature. With 1% graphite addition to these oils, the types of chip produced were same but only the length of the chip got reduced.

Chip thickness ratio: The chip thickness ratio is higher for Rice bran oil with value as 0.82, indicating better cutting action followed by coconut oil, SAE20W40 compared to Mahua oil and dry cutting. With 1% graphite addition chip thickness ratio is reduced.

Surface roughness: Surface roughness measured is less for coconut oil with value as 3.22 µm, followed by Rice Bran Oil with value as 3.75 µm when compared to the surface roughness measured for SAE20W40 and Mahua oil. Maximum roughness is measured for dry cutting. Addition of graphite powder has not improved the surface finish.

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