International Journal of Research in Advent Technology, Special Issue, ICATESM 2019
E-ISSN: 2321-9637
Available online at www.ijrat.org

To analyze the use of vegetable oil as a cutting fluid in turning of AISI 1040 by high speed steel

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Abstract- Machining is associated with the generation of heat and high cutting temperature at the cutting zone. This high temperature generated at the cutting zone may impair the dimensional accuracy of the work-piece and reduce the functional tool-life of the cutting tool. Hence, keeping cutting temperature within limits is very necessary. This is done by using cutting fluids like mineral oils, synthetic oils etc. But using mineral and synthetic oils does have adverse effects both on the operator and the environment. Also it costs the company heavily. Taking into account all the harmful effects of cutting fluids used regularly in industries, Vegetable oil has been considered as an alternative in the experimental investigation conducted. A physical set-up based on Tool-Work Thermocouple Technique has been fabricated for measuring cutting temperature. Work material selected is AISI 1040 (200 BHN) and Tool material selected is High Speed Steel (HSS S400 grade). Experimental investigations were conducted at three different cutting velocities keeping feed rate constant. It was observed that for turning AISI 1040, HSS performs better at cutting velocities below 75m/min. At higher cutting velocities (85m/min and above) HSS tends to fail after a mere 10 seconds of machining. Also a comparative study was done among vegetable oil, castor oil and water as cutting fluids.
Keywords- AISI 1040; Cutting Fluid; Cutting Temperature; Plain Turning; Vegetable Oil

1. INTRODUCTION

Machining is inherently associated with the generation of heat and high cutting temperature at the cutting zone. The high cutting temperature impairs the dimensional accuracy of the workpiece and deteriorates the surface integrity of the machined surfaces, damages the cutting tool and reduces its functional life. The high cutting temperature also causes deterioration in the surface integrity of the machined surfaces by oxidation and corrosion. It is therefore indispensable to control the cutting temperature and its consequences to a possible extent without sacrificing productivity. Applying cutting fluid helps control cutting temperature and its detrimental effects. It reduces cutting temperature directly by taking away heat from the cutting zone and indirectly by reducing cutting forces. Generally, cutting fluids are employed in liquid form but occasionally also employed in gaseous form. [1]

Cutting fluids used in industries are usually soluble oil, mineral oils, synthetic oils and chemical fluids. These fluids often prove hazardous to the worker as well as the environment. These are difficult to dispose off also as pollution can be one major effect. Also these cost the company harder on its pocket as these cutting fluids are very expensive. Also fluid handling might cost higher than the actual cost of the cutting fluid. Hence, using a not-much-expensive organic cutting fluid is very necessary considering the effects it has on men, economics and environment. Anil Raj et al [2] evaluated the performance of Vegetable oil based cutting fluid during hard turning of AISI 4340. He observed a considerable decrease in cutting temperature with soyabean oil when compared to other categories.

R. Padmini et al. [3] studied the effectiveness of vegetable oil based nanofluids as potential cutting fluids in turning AISI 1040 steel. Awadhesh Pal et al. [4] carried out experimental investigation to assess the machinability of hardened AISI 1040 steel during hard turning (55 HRc) and soft turning (35 and 45 HRc) using TiC mixed alumina ceramic tools.

Selecting an appropriate job-tool combination is most necessary for limiting cutting temperature, better machined surface and a longer tool life. However, using carbide inserts and ceramic tools might always not be feasible owing to the high cost and less availability. S. Vanangamudi and M Pradeep Kumar [5] conducted an experimental study of HSS double-point tool on chip-tool interface temperature during turning of Mild steel for different cutting conditions. It was found that the HSS double point tool obeys with its single counter-part. The cutting temperature increases with increase in cutting speed.

Several temperature measurement techniques like chip-tool thermocouple, embedded thermocouple, moving thermocouple, radiation techniques like infra-red thermometry and calorimetric methods etc. had been developed so far to evaluate the chip-tool interface temperature generated in the cutting zone during machining. Naohiko Sugita et al [6] described a technique of measuring cutting temperature by a micro- sensor array integrated to the rake face of the cutting tool. The micro thermocouple sensor had been composed of the cutting tool itself and the work-piece material. Pedro-J.Arrazola et al. [7] performed metal cutting experiments for improved determination of chip tool contact temperature by Infrared Thermography. S.B.Hosseini et al. [8] studied the estimation of the temperature and the heat flux at the chip–tool interface using the inverse heat conduction problem technique. However, tool-work thermocouple tech-nique is widely used during metal cutting due to its ease of implementation and lower cost as compared to other techniques. A thermocouple is a device used extensively for measuring temperature and is based on the Seebeck effect which states that when two different or unlike metals are joined together at two junctions, an electromotive force (emf) is generated due to a heat gradient produced at those two junctions.

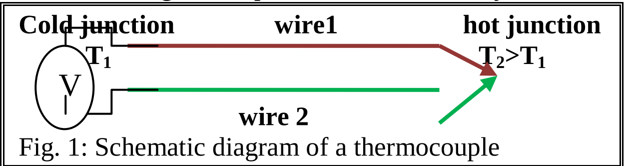

Fig. 1: Schematic diagram of a thermocouple

In this study, HSS tool has been used to machine AISI 1040 in dry as well as wet condition i.e. in presence of vegetable oil, castor oil and water. Cutting temperature has been measured by Tool-work thermocouple technique.

2. EXPERIMENTAL SET-UP AND PROCEDURE

2.1. *Machining Operation: Tool and Job Material*

In this experimental study, High Speed Steel (HSS) cutting tool had been used for turning of AISI 1040 steel. Because of better strength, toughness and hardness in the heat treated condition, AISI 1040 is used in couplings, crankshafts and cold headed parts. Considering the economics associated with the machining procedure and availability of the tool, High Speed Steel cutting tool had been used for this procedure.

HSS cutting tool of S400 grade manufactured by Miranda Tools (a part of Ashok Piramal Group) had been used for the operations. High speed steels are high performance steels offering high hot hardness i.e. at temperatures upto 500°C and high wear resistance. These are superior to the older high carbon steel tools in that these can withstand higher temperatures without losing their hardness. With the introduction of advanced cutting tool materials, HSS might have lost on its usage in the industry but its ease of availability and comparatively lower cost still make it a commonly used tool in conventional cutting.

The turning operation has been conducted on an Engine Lathe at both dry and wet conditions. A round bar of length 350 mm and diameter 40 mm of AISI 1040 steel has undergone plain turning.

2.2. *Experimental Set-up*

The experimental set-up has been presented here in Table 1.

Table 1: General description of the experiment

Operation:	Plain Turning
Machine Tool	Engine Lathe
Job Material	AISI 1040 of 223 BHN
Job Length Job diameter	350 mm 40 mm
Effective Cutting Length	200 mm
Tool Type	High Speed Steel (HSS)
Cutting Velocity Feed Depth of Cut	65, 69, 70, 74 m/min 0.2 mm/rev 0.3, 0.5, 0.75 mm
Cutting condition	Dry, Wet(Vegetable oil, castor oil, water)

2.3. *Temperature Measurement*

In this study, plain turning had been carried out on an engine lathe at cutting velocities 65 m/min, 69 m/min, 70 m/min and 74 m/min with High Speed Steel tool. A set-up similar to that used by Satish Chinchanikar and S.K Choudhary [9] had been used. A schematic representation of the set-up used has been shown in Figure 2.

A wire screwed to the cutting tool and another connected to the rear end of the workpiece were connected to the multimeter. A digital multimeter (model mas830L, EEE-Tech make) had been used to measure the electro-motive force across the junctions. A carbon brush was used to connect the rear end (chuck end) of the rotating workpiece, which acted as the cold junction, to join it with the multi-meter. The tool-work interface acted as the hot junction. An emf was generated when the tool and work came in contact during the turning operation. This emf was then measured by the multimeter. A pre-calibrated standard K-type thermocouple chart (NIST, USA) had been used for the emf-temperature conversion.

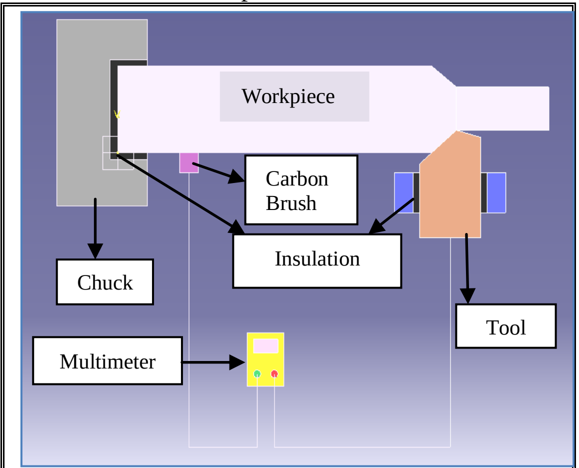

Fig. 2. Schematic representation of tool-work Thermocouple technique used for measuring the cutting temperature during the experiment.

A total of 9 runs of experiment had been conducted for the wet condition i.e. in presence of cutting fluid. 3 each runs for vegetable oil, castor oil and water had been conducted. 1 run was conducted for the dry condition at the beginning.

Each run was carried out for a duration of 60 seconds.

3. RESULT AND DISCUSSION

The objectives of this study was to develop a tool-work thermocouple set-up, determine the cutting temperature at dry condition, compare the cutting temperatures during dry machining and wet machining (vegetable oil, castor oil and water) and then justify the use of vegetable oil as an effective cutting fluid.
The results obtained during the experiment have been enumerated in Table no. 2.

Table 2: Result obtained during the experiment

Working Condition	Feed mm/rev	Diameter mm	Depth of cut mm	Cutting Velocity m/min	Temperature °C
Dry	0.2	37	0.5	69	189
Vegetable Oil	0.2	35 37 37	0.3 0.5 0.75	65 69 69	108 128 184
Castor Oil	0.2	40 40 35	0.3 0.5 0.75	75 75 65	92 108 142
Water	0.2	35 32 38	0.1 0.3 0.5	65 59 70	94 135 149

In dry machining, cutting temperature produced was around 190°C at cutting velocity 69 m/min and a depth of cut of 0.5 mm. On application of Vegetable oil at the same cutting velocity and depth of cut, temperature obtained was 128 °C. With castor oil at the same machining parameters, temperature produced was 108°C. For water, temperature produced was 135 °C.

It was observed that at cutting velocity and depth of cut greater than that of dry machining, the temperature produced is still lesser when vegetable oil, castor oil and water are applied.

Also, at 1 mm depth of cut and dry machining, the tool failed after machining for 15 seconds only.

4. CONCLUSION

Cutting temperature reduced remarkably in presence of vegetable oil when compared to dry machining. Also there was no effect on the machined surface when exposed to air after applying vegetable oil. Vegetable oils are operator friendly, biodegradable, easily available and are affordable. Also, although cutting temperature was reduced to a greater extent while using castor oil, yet vegetable oil being cheaper than castor oil is suggested to be used as an effective cutting fluid. During machining AISI 1040 at 85 m/min, the cutting fluid was water. Although temperature decreased by a good number, yet the machined surface was found to get corroded when exposed to air. Hence, water should not be used because of its oxidising nature. The investigation needs to be continued to study the effect of vegetable oil with other combinations of machining parameters and with fluids like coconut oil. Expectedly, vegetable oil works best in the investigated range of machining parameters.

Acknowledgments
The support extended by the technical staff of Department of Mechanical Engineering of Techno India, Salt Lake, Kolkata is highly acknowledged.

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