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AN EXPERIMENTAL INVESTIGATION OF VEGETABLE OIL BASED CUTTING FLUID ON DRILLING MEDIUM CARBON STEEL BY HSS DRILL BIT

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ABSTRACT

Drilling is the most prominent machining process, requiring specialized techniques to achieve optimum cutting condition. Drilling can be described as a process where a multi-point tool is used to remove unwanted materials to produce a desired hole. High production machining and drilling with high cutting velocity, feed and depth of cut is inherently associated with generation of large amount of heat and high cutting temperature and power consumption. In Dry condition, such high cutting temperature not only reduces dimensional accuracy and tool life but also impairs the roundness deviation, taper of the hole. Conventional cutting fluid uses for producing cylindrical holes in the work piece can reduce above problems but it pollutes the environment and has high risk of water pollution and soil contamination during disposal. The increasing needs for environmentally friendly production techniques have justified the demand for an alternative to machining process using cutting fluids. Vegetable oil is used as cutting fluid is more effective to reduce temperature and also have good lubrication properties. In this regard the present work has been carried out with a view to study the effects of vegetable oil based cutting fluid on the cutting performance of medium carbon steel, as compared to completely dry and wet in terms of force, torque, chip formation mode and roundness deviation. Compared to the dry and wet, vegetable oil based cutting fluid performed much superior mainly due to reduction in cutting zone temperature, enabling favorable chip formation and improving roundness and taper. It also provides lubrication in the tool tip and work surface interface.

Keywords: Vegetable Oil Based Cutting Fluid, Drilling, Chip, Force, Torque, Roundness Deviation.

1. INTRODUCTION

Hole making had long been recognized as the most prominent machining process, requiring specialized techniques to achieve optimum cutting condition. Drilling can be described as a process where a multi-point tool is used to remove unwanted materials to produce a hole. It broadly covers those methods used for producing cylindrical holes in the work piece. While removal of material in the form of chips new surfaces are cleaved from the work piece accompanied by a large consumption of energy. The mechanical energy necessary for the drilling operation is transformed in to heat leading to conditions of high temperature and severe thermal / frictional conditions at the tool- chip interface [Ezugwu and Lai 1995]. The magnitude of the cutting temperature increases though in different degree with the increase of cutting velocity, feed and depth of cut. At such elevated temperature the cutting tools if not enough hot hard may lose their form stability quickly or wear out rapidly resulting in increased cutting force, dimensional inaccuracy of the product and shorter tool life [Kitagawa et al. 1997]. This problem increases further with the increase in strength and hardness of the work material. During drilling process, the most important factor affecting the cutting tool performance and work piece properties is cutting temperature that emerges between drill bit and chip.[Eyup and Babur 2006]. The cutting temperature directly influences hole characteristics such as diameter, perpendicularity and cylindricity, as well as surface roughness and tool wear [Eyup and Babur 2006]. A major portion of the energy is consumed in the formation and removal of chips. The greater the energy consumption, the greater are the temperature and frictional forces at the tool–chip interface and consequently the higher is the tool wear [Senthil Kumar et al 2002]. Drill wear not only affects the surface roughness of the hole but also influences the life of the drill bit [Panda et al. 2006].

Worn drills produce poor quality holes and in extreme cases, a broken drill can destroy almost all finished parts. A drill begins to wear as soon as it is placed into operation. As it wears, cutting forces increases, the temperature rises and this accelerates the physical and chemical processes associated with drill wear and therefore drill wears faster [Sanjay et al. 2005].

Thrust and torque depend upon drill wear, drill size, feed rate and spindle speed. Research results show that tool breakage, tool wear and work piece deflection are strongly related to cutting force [Sanjay et al. 2005]. The application of cutting fluid during machining operation reduces cutting zone temperature and increases tool life and acts as lubricant as well [Beaubien and Cattaneo 1964]. Also Dhar et al. [2004] state that without cooling and lubrication, the chip sticks to the tool and breaks it in a very short cutting time. It reduces cutting zone temperature either by removing heats as coolant or reducing the heat generation as lubricant. In addition it serves a practical function as chip- handling medium [Cassin and Boothroyed 1965]. On the other hand, the cooling and lubricating effects of cutting fluid influence each other and diminish with increase in cutting velocity [Kitagawa et al. 1997].

Manufacturing by machining constitutes major industrial activities in global perspective. Like other manufacturing activities, machining also leads to environmental pollution [Ding and Hong 1998 and Hong et al. 1999] mainly because of use of cutting fluids. These fluids often contain sulfur (S), phosphorus (P), chlorine (Cl) or other extreme-pressure additives to improve the lubricating performance. These chemicals present health hazards. Furthermore, the cost of treating the waste liquid is high and the treatment itself is a source of air pollution. The major problems that arise due to use of cutting fluids are- [Aronson 1995]

- environmental pollution due to breakdown of the cutting fluids into harmful gases.
- biological hazards to the operators from the bacterial growth in the cutting fluids
- disposal of the spent cutting fluids, which also offer high risk of water pollution and soil contamination.

Since beginning of twentieth century people [Welter 1978; Kennedy 1989 and Thony et al. 1975] were concerned with possible harmful effects of various cutting fluid application. During machining process, a considerable amount of heat is generated for which the cutting fluid may attain a temperature sufficiently higher than the saturation temperature. The vapor is produced at the solid-liquid interface as a result of boiling. Vapor may be generated also at the liquid-air interface when the fluid vapor pressure is less than the saturation pressure, namely as evaporation phenomena. Vapor generated then may condense to form mist. Mists are aerosols comprised of liquid particles (less than 20 μm). [Iowa Waste Reduction Centre 1996] reported that besides potential skin and eye contact, inhalation is also a way to occupational exposure.

From viewpoints of Performance, cost, health, safety and environment, vegetable oils are, therefore, a viable alternative to petroleum-based metalworking cutting fluids [Skerlos and Hayes 2003; Krahenbuhl 2005], because

- The lubricating film layer provided by vegetable oils, being basically strong and lubricious, improves workpiece quality and overall process productivity reducing friction and heat generation.
- A higher flash point yields opportunities for increased rates of metal removal as a result of reduced smoke formation and fire hazard.
- The higher boiling point and greater molecular weight of vegetable oil result in considerably less loss from vaporization and misting.
- Vegetable oils are nontoxic to the environment and biologically inert and do not produce significant organic disease and toxic effect.
- No sign and symptom of acute and chronic exposure to vegetable oil mist have been reported in human [ACGIH 1991].

The purpose of this research is to investigate the effects of vegetable oil based cutting fluid as an alternative to conventional cutting fluid on the drilling performance of medium carbon steel, as compared to completely dry cutting and wet with conventional cutting fluid. During each test cutting forces, roundness deviation, chips formation mode are measured and compared.

2. EXPERIMENTAL PROCEDURE

The photographic view of the experimental set-up is shown in Fig. 1. The coolant used was water soluble cutting oil and vegetable oil based cutting fluid dispensed at a flow rate of 10 l/hour. Drilling metals by high speed steel (HSS) is a major activity in the manufacturing industries. Drilling of steels involves more heat generation for their ductility and production of continuous chips having more intimate and wide chip-tool contact. Again, the cutting temperature increases further with the increase in strength and hardness of the steels for more specific energy requirement. Keeping these facts in view the commonly used steel medium carbon steel has been undertaken for the present investigations.

Fig 1. Photographic veiw of the experimental set-up

The drilling tests have been carried out on a radial drill machine (RM-U9 Radial Drill Machine, Sweden) by HSS drill under dry, and wet by conventional cutting fluid and vegetable oil conditions. The photographic view of the experimental set-up is shown in Fig.1.The experimental conditions of the present experiments are given in Table-1.

Table 1: Experimental conditions

Machine tool	: Radial Drill Machine (Sweden), 1.5 kW
Work material	: Medium carbon steel
Cutting tool	: High speed steel (φ 4.0, 6.0 & 8.0 mm)
Process parameters	
Cutting speed	: 200, 440 and 670 rpm
Feed rate	: 0.16 mm/rev
Length of cut	: 20.0 mm
Cutting fluid	: 10 litter/min
Environment	: • Dry • Wet • Vegetable oil based cutting fluid

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

During machining any ductile materials, heat is generated at the (i) primary deformation zone due to shear and plastic deformation, (ii) chip-tool interface due to secondary deformation and sliding and (iii) work-tool interfaces due to rubbing. All such heat sources produce maximum temperature at the chip-tool interface, which substantially influence the chip formation mode, cutting forces and tool life. Therefore, attempts are made to reduce this detrimental cutting temperature. Conventional cutting fluid application may, to some extent, cool the tool and the job but cannot cool and lubricate effectively as expected at the chip-tool interface where the temperature is maximum because it looses it lubricating properties at high temperature.

3.1 Drilling Force and Torque

Drilling force is an important factor in drilling operation. The force exerted by the rotating drill bit on the surface which is to be drilled, referred as drilling force. Force measuring device is used to measure the drilling force and torque. The effect of conventional cutting fluid and vegetable oil based cutting fluid on drilling force and torque with 8 mm HSS drill bit and various rpm at constant feed rate as shown in Fig. 2, Fig. 3, Fig. 4 and Fig 5 respectively. Here drilling force decreases with increasing the rpm of the spindle because with increases rpm material losses its viscous properties and drilling force increases with increasing the depth of cut. Drilling torque also increases with increasing the depth of cut but it is decreased at higher rpm. Torque and Drilling force increases with hole depth because the drill bit contact surface increases, so friction force is more in higher depth of cut. The investigation shows that the force and torque at dry condition is higher than the wet condition. By using vegetable based cutting oil it is possible to reduce cutting force 6% and torque 6.6 % than using conventional cutting fluid. Fig.6 and Fig.7 show that the drilling forces and torque with the variation of drill diameter. In these Figs. it is cleared that the force and torque increases with increases the drill bit diameter in all environment. Wet with conventional cutting fluid can reduce force and torque than dry condition but with vegetable oil condition force and toque is average 8% more reduced than wet with conventional condition.

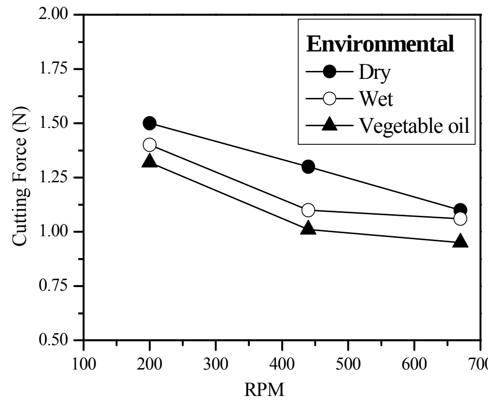


Fig 2. Variation of drilling force with rpm at different environments.

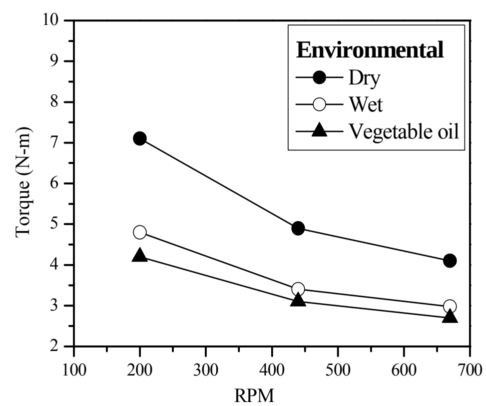


Fig 3. Variation of drilling torque with rpm at different environments.

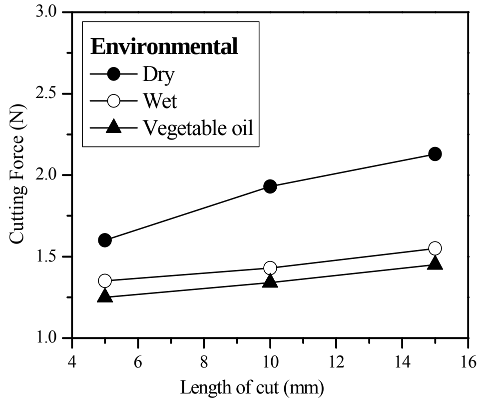


Fig 4. Variation of drilling force with increasing length of cut at different environments.

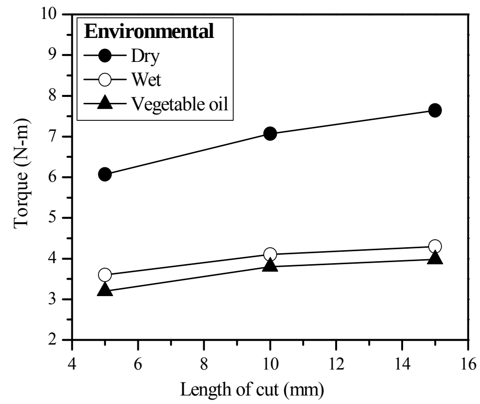


Fig 5. Variation of drilling torque with increasing length of cut at different environments.

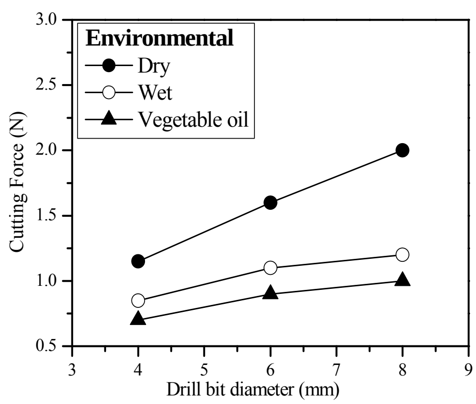


Fig 6. Variation of drilling force with different drill bit size at different environments

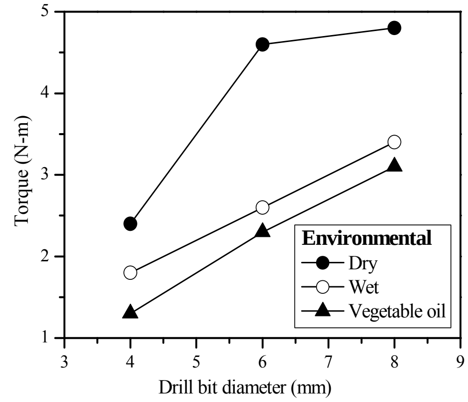


Fig 7. Variation of drilling torque with different drill bit size at different environments

3.2 Roundness Deviation

Before the analysis of the quality parameters of the holes, it is important to note that neither diameter nor any other quality parameter of the hole was influenced by tool wear. Fig. 8 shows that the roundness deviation closed to the beginning of the hole occurs with the number of drilling holes. For dry condition roundness deviation is higher than wet condition with conventional cutting fluid and wet with vegetable oil based cutting fluid. Some points fluctuate from the curves nature in case of dry conditions. But for wet condition, these cases are less. Fig. 9 shows the deviation for maximum, average and minimum values of hole diameter. The fluctuation of the curve occurs due to the irregular drilling force; increment of drilling temperature, variation on feed rate, vibration etc. These causes mainly occurred in dry condition. But in case of wet condition, the drilling operation is comparatively smooth. The curve for wet with vegetable oil condition is approximately straighter than the dry condition.

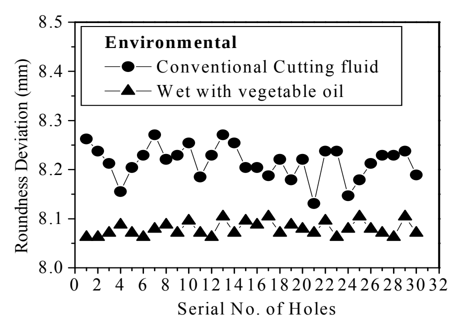


Fig 8. Roundness deviation close to the beginning of holes under dry and wet condition at 440 rpm and 8 mm drill bit.

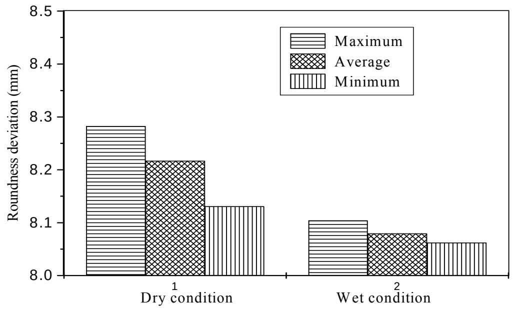


Fig 9. Maximum, average and minimum roundness deviation close to the beginning of holes under different environment at 440 rpm and 8 mm drill bit

3.3 Chip morphology

The shape of the chip is the most important factor for the smoothness of a drilling process and study of drilling chip is required to understand the mechanism of chip formation and those of material removal. The chips produced during drilling medium carbon steel eel at 440 rpm is shown in the Fig.10 under the different environments. Dry drilling at both 8 mm and 6 mm and 4 mm diameter drill bit provided different types of chips such as lamellar, spherical, irregular shaped. In dry condition some chips have burn for higher drilling zone temperature and ductility of steel specimens are expected to yield larger number of spherical chips. Chips produced under wet condition at both 8 mm, 6 mm and 4 mm drill bit provided approximately equal width chips but more straight in shape. For 6 mm drill bit the chips has the build up edges, which are harmful for the operation and operator. The rotational motion causes the spiral chips to have difficulty maintaining their shape as the hole gets deeper. If chips cannot keep up with the rotational motion, they will either break or be forced to move along the flute without spinning, and form string chips. Cutting fluid played very effective role for cooling and provided lubrication between drill bit and chip interface. The shape of the chip produced under dry conditions was spiral but wet condition became lamellar. The color of the chips became metallic from burnt blue due to reduction in drilling temperature by wet condition by vegetable oil.

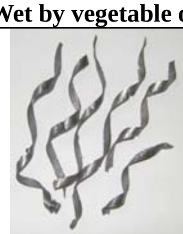
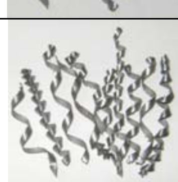
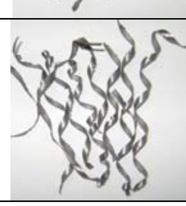
Drill bit Size	Environments	
	Dry	Wet by vegetable oil
8 mm		
6 mm		
4 mm		

Fig 10. Chips produced by HSS drill bit under dry and wet by vegetable oil based cutting fluid conditions.

4. CONCLUSION

The experimentally observed effect of vegetable oil based cutting fluid in drilling medium carbon steel by HSS drill may be summarized as follows:

i. The drilling force and torque is higher in dry condition than the wet conditions. Drilling with vegetable oil based cutting fluid is able to reduce more cutting force and torque 6% and 8% respectively than conventional cutting fluid.
ii. With increasing depth of hole and the drill bit diameter force and torque also increased in all environment but these are relatively low at vegetable oil environment.
iii. Roundness deviation was smaller at both the entrance of the holes under wet condition in compare to dry condition. When high depth of cut used, the drilling with wet condition was difficult because of poor cooling and lubrication action.
iv. The formation of chip under wet condition with vegetable oil based cutting fluid is more favorable in compare to dry condition because of high lubricant capacity. The beneficial effects of cutting fluid may be attributed to effective lubrication action, which prevents the chip sticking on the tool and makes the cut feasible and vegetable oil based cutting fluid is not harmful to the environment.

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7. MAILING ADDRESS

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