Experimental Study on Effect of Emulsifier Concentration on Workpiece Surface Temperature and Tool Wear in Turning Mild Steel

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Abstract : Oil in water emulsions are used in high-speed machining operations such as turning, milling, grinding etc. The purpose of using these emulsions is to keep the temperature rise in control. During machining a lot of heat is generated which has to be controlled. Commonly used method of reducing temperature is use of cutting fluids. The cutting fluids are stable colloids of oil dispersed in water with the help of a surface active agent. Temperature rise is related to the machining quality as well as the machining economics. High temperature degrades the surfaced integrity as well as reduces the life of the cutting tool. The tool wear depends on the temperature rise during machining. In this part study, the effect of varying the emulsifier content in non edible base oil on surface temperature before and after machining has been studied and the results reported.

***IndexTerms* - Surface temperature, emulsifier, base oil, machining quality**

I. INTRODUCTION

Metal cutting operations involve removal of material from the parent material by the action of cutting tool. Very high temperatures are reached during metal removal because the material removal occurs by shearing of material in the form of chips. This high temperature has detrimental effects on all the machining components viz workpiece, cutting tool as well as on the machining quality such as surface integrity, surface roughness, possible deformity of workpiece. Researchers have also reported that the chip formation mechanism depends on the temperature [1]. The crystal structure of any material depends largely on the temperature. As the temperature rises the crystal structure begins to experience some change. Usually there is some softening of the material as the temperature rises. This is beneficial to a limit that it reduces the cutting effort required for metal removal as less energy is required for shearing [1]. It has also been shown that temperature rise causes shift in the position of the workpiece shear zone [2]. All input work done by the cutting tool gets converted into heat [3]. There are three different zones which have been identified as the zones of heat generation in metal removal operation – Primary zone, secondary zone and the tertiary zone. The highest amount of heat is generated in the primary zone followed by secondary zone and finally least amount of heat in the tertiary zone. It is well known that shearing occurs before chip formation [4,16]. This is the plastic deformation condition. Due to this plastic deformation and shearing the material is removed from the workpiece. This is, thus, the highest heat generation and the highest temperature zone. In the secondary deformation zone the chips generated rub over the face of the cutting tool. This regular flow of chips on the cutting tool face causes rise in temperature due to friction. The third zone, also known as tertiary zone is the zone or the interface of the cutting tool flank and the workpiece surface. The different zones of heat generation are shown in Fig.1

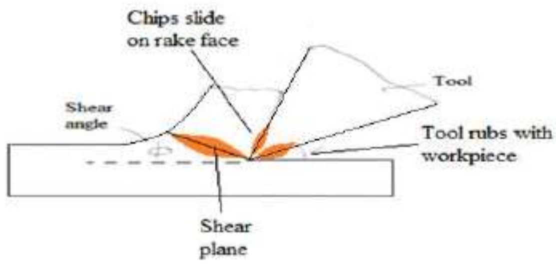

Figure 1: Zones of heat generation in metal machining.

Cutting fluid plays an important role in machining operation. In high speed machining operations where the cutting speed is very high, water based cutting fluids are used. There are different methods of applying cutting fluids such as flood method, jet method and MQL. Each method has its own advantage as well as disadvantage. Temperature measurements during machining are done by using thermocouples by embedding them into the tool holder. There are several shortcomings of temperature measurement by this method [5]. The latest technique is the use of infrared thermometers [6]. Many researchers have successfully used the infrared technique for temperature measurement to study the temperatures in machining [5- 10]. In this study the same technique i.e. measurement by infrared thermometer has been employed for measuring temperature of surface. Measurement of surface temperature after machining is important parameter because it is a direct indicator of the heat generated in the machining process and also gives a qualitative indication about the effectiveness of cutting fluid. Obviously, lower the temperature of surface after machining better is the effectiveness of cutting fluid in terms of heat carrying capacity. The cutting fluid constituent has an impact on the tool wear also. Many researchers have reported increased tool life by using additives in cutting fluids such as EP additives. However there is not much literature available on the effect of the constituent of cutting fluid on tool wear accept a few research articles [11-14]. In this study the average tool wear was also studied with varying the concentration of the surfactant in the cutting fluid.

II. Materials and Methods

In this study, biodegradable cutting fluids were developed from neem oil using a biodegradable surfactant. The concentration of the surfactant was taken 5%, 10% and 15%. Only a single base oil was chosen for keeping the thermal conductivity effect of the oil same for all the cutting fluid formulations. The cutting fluids were formulated by mixing the oil and emulsifier using a mixer running at 2500 rpm for 5 minutes each. The mixing time was limited due to temperature rise in the mixture during mixing due to the high speed of the mixer. Cutting fluids were prepared in three batches of 500 ml each and then mixing all the batches together and then diluted to 10 times by mixing with water in a plastic container. Each cutting fluid sample was prepared in similar way. High speed of mixing and the mixing time ensured proper mixing of surfactant in the oil and a homogenous mixture/concentrate was obtained. During machining a submersible pump was used for maintaining a constant flow rate of 1 liter per minute. The cutting conditions were same for all the samples in order to maintain constant heat generation during machining. Temperature of cutting fluid before each pass and after each machining pass was noted. Also, the temperature of workpiece before and immediately after each pass of machining was noted. The comparison was made between the differences in temperature observed.

III. Result and Discussion

Figure 2 shows the effect of 5% surfactant on cutting fluid temperature carrying effectiveness and also on the surface temperature of the workpiece. As seen from figure 2 for temperature with 5% surfactant, the temperature of cutting fluid in the sump increases as the machining time increases. This is due to the fact that the cutting fluid absorbs heat from the cutting zone and also some heat is generated due to friction occurring due to fluid flow through various channels inside the sump and picks up heat from the surrounding and also from the mechanical action of the submersible pump. As is clear from the results in figure 2, the cutting fluid temperature immediately after carrying heat from the cutting zone is higher. This is because the cutting fluid absorbs heat generated at the cutting zone.Temperature rises with machining time the workpiece surface temperature. The temperature of workpiece before machining is less than that after machining after every cutting pass. This is due to the fact that the heat generated gets absorbed in the workpiece and not all heat is carried away by the chips and the cutting fluid. The magnitude of temperature is always higher than that before the machining after every 2 minutes. The increase in the magnitude of surface temperature at the end of each pass of machining is due to decrease in the diameter of the workpiece [15].

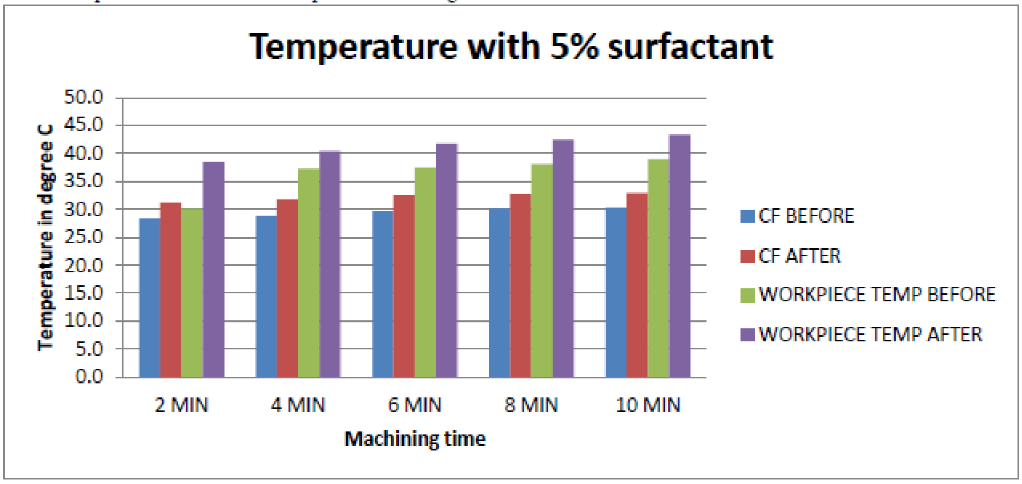

Fig 2: Effect of 5% surfactant

Fig 3 for surfactant concentration 10% and Fig 4 for surfactant concentration 15% show similar result. The cutting fluid temperature increases immediately after passing through the machining zone because it absorbs the heat generated during metal removal and gets hot. Similar trend is observed with increase in the concentration of surfactant in the cutting fluid. However the average increase in the surface temperature is about two percent which could be attributed to decrease in thermal conductivity by the addition of more emulsifier in the cutting fluid.

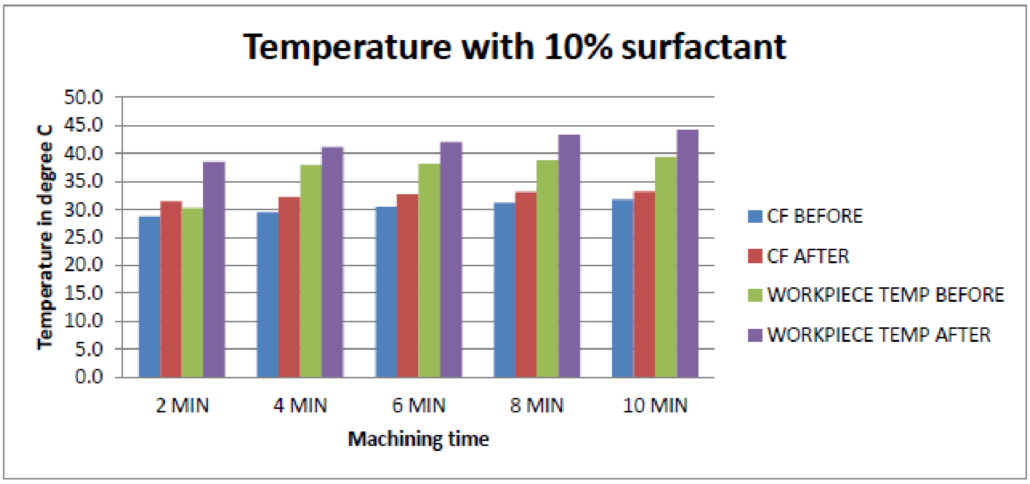

Fig 3: Effect of 10% surfactant

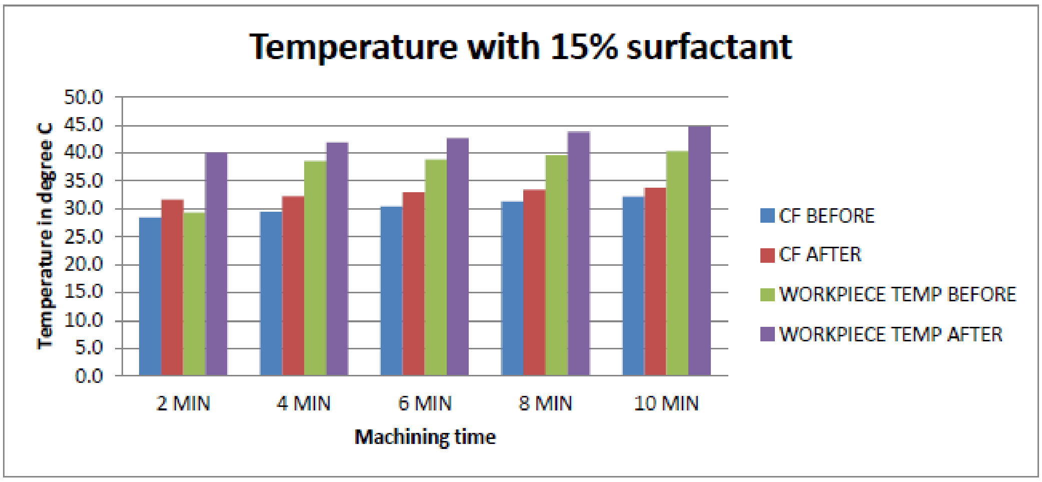

Fig 4: Effect of 15% surfactant

Figure 5 shows comparison between the surface temperatures of workpiece before starting the machining run with each surfactant concentration in the cutting fluid. The initial temperature of the workpiece serves as the base point for establishing the temperature rise after machining has been done. Figure 6 shows the average workpiece surface temperature recorded immediately after machining after every 2 minutes. From figure 6 it is observed that the workpiece temperature is highest for 15% surfactant concentration after every 2 minute of machining. It is therefore a clear indication that the surface temperature rise is directly proportional to the amount of surfactant concentration in the cutting fluid which in turn depends on the thermal conductivity. Addition of surfactant causes a drop in the thermal conductivity of the cutting fluid.

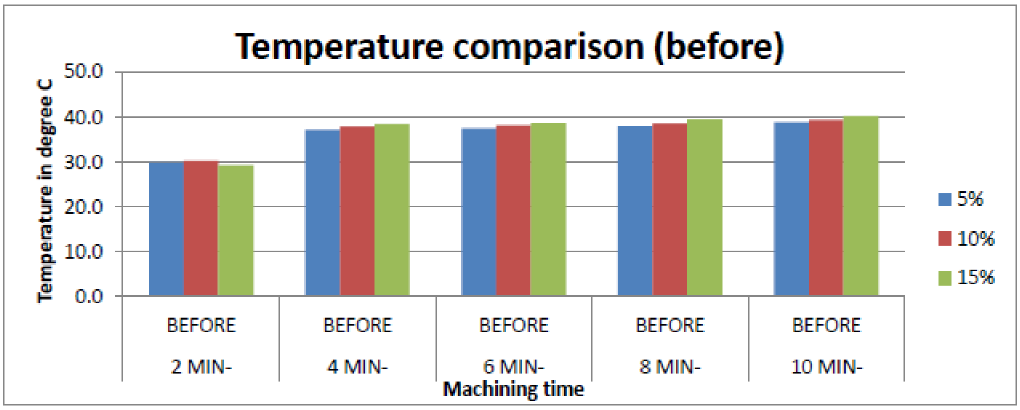

Fig 5: Temperature of workpiece surface before machining

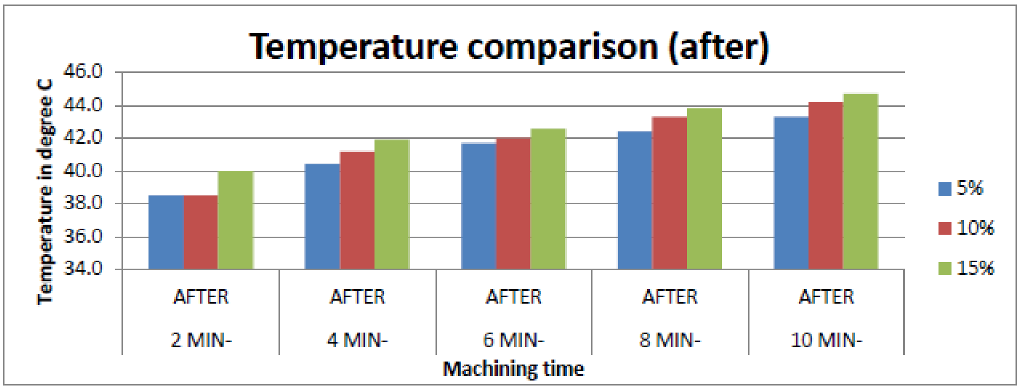

Fig 6: Temperature of workpiece surface after machining

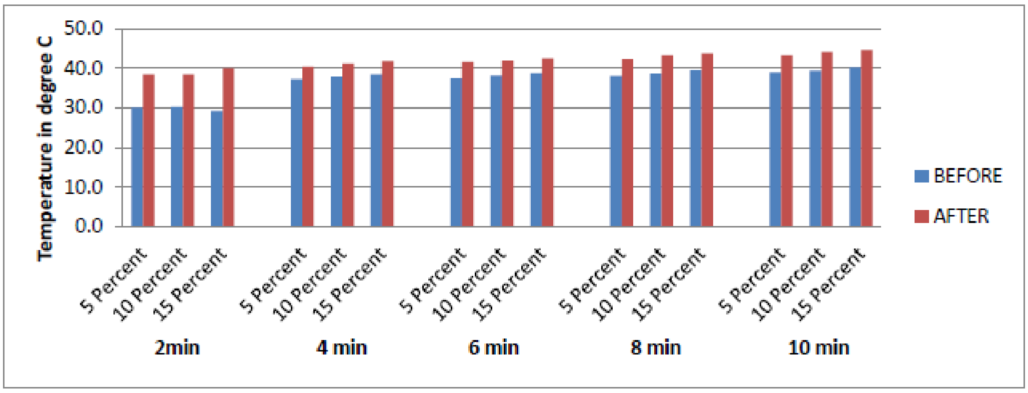

Fig 7: Temperature comparison (before and after) all cutting fluids with time

Figure 7 shows the temperature comparison before and after for all cutting fluids used in this study. From the results it is clear that 5% surfactant gives the least rise in temperature of the workpiece surface

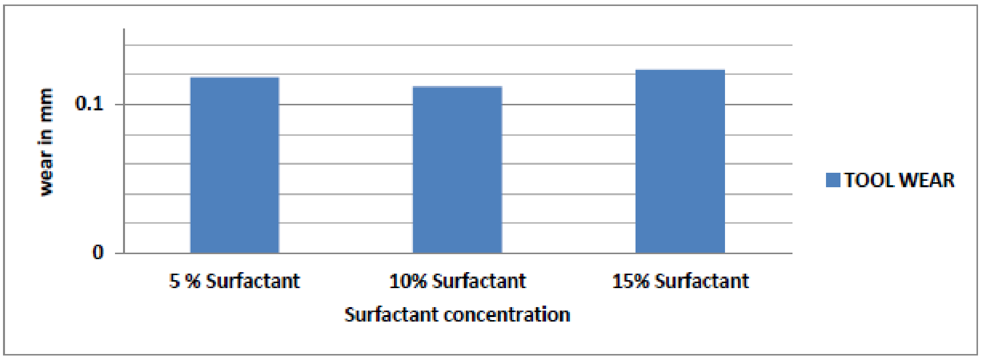

Fig 8: Tool wear comparison with different surfactant concentration

After machining was over, tool wear was measured and a comparison is showed in figure 8. As seen from the results, 10% surfactant gives the minimum tool wear which implies an increase in the life of the cutting tool. This could be attributed to better lubrication property of cutting fluid with 10% surfactant than the other cutting fluids.

IV. Conclusioon

In this study following points were found:

1. Surfactant concentration does have a role in the temperature rise during machining
2. Increasing the surfactant concentration reduces the thermal conductivity of the cutting fluid although the effect is not very large
3. Surfactant plays a role in tool wear also.
4. 5% surfactant concentration gives best results for minimum temperature
5. 10% surfactant gives best results for minimum tool wear

V. FUTURE

Studies can be done on optimizing the concentration of surfactant for getting a balance between surface temperature and tool wear

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