SURVEY ON NANO CUTTING FLUIDS IN METAL CUTTING APPLICATION

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ABSTRACT *Nano cutting fluids are the mixtures of conventional cutting fluid and nanoparticles. Addition of the nanoparticles can alter lubricating properties, and convective heat transfer coefficient (cooling properties) of nano-cutting fluids. In the present work, nano-cutting fluid is made by adding 1% nanoparticles (eg: Al_2O_3) to conventional cutting fluid. Comparative study of tool wear, cutting force, workpiece surface roughness and thermal conductivity among dry machining, machining with conventional cutting fluid as well as nano-cutting fluid has been undertaken. This study clearly reveals that the cutting force, workpiece surface roughness, tool wear, and temperature of the job are reduced by the using nano-cutting fluid compared to dry machining and machining with conventional cutting fluid.*

Keywords Force; Morphology; Roughness; Wear; Thermal conductivity.

1. INTRODUCTION:

The most important properties of cutting fluids are cooling (superior convective and conductive heat transfer coefficient), lubrication, and evacuation of chips from machining zone. Cooling is one of the most important challenges in the machining process faced by most of the industries such as automobiles, electronics, and manufacturing [1-5]. New technological developments leads to increasing thermal loads that require faster cooling. The conventional techniques of enhancing the cooling rate are already stretched to their limits. Hence, there is need for new and innovative cutting fluids to achieve the high performance cooling[11-12].

Nano-cutting fluid is one of the novel concepts, where in nanoparticles are suspended in conventional cutting fluid, which are being developed to meet more demanding cooling and lubricating challenges in machining.

Friction is the main root cause of energy loss in many machining operations such as turning operations. It decreases the tools life and machinability. In order to reduce friction several lubricants should have been found out for various operations. Researchers have developed various methods to improvise the properties of lubricant oils by adding various chemicals to improve the physical, chemical and mechanical properties. Recent work on mixing Nanoparticles with oil proves to be a great method as it significantly reduces frictional co efficient. Nano based lubricants have been used to reduced friction more when compared to vegetable-based oils and normal oils. Recent research involves mixing of Nano particles such as Al_2O_3 have been used. These particles when mixed with lubricant oils enhance the lubrication properties as well as reduces the coefficient of friction

The present work aims at demonstrating the possibility of enhancing the important properties of a cutting fluid by adding suitable nanoparticles and forming stable nano-cutting fluids. Recent studies states that suspended nanoparticles can alter the thermophysical and transport properties of the conventional cutting fluids. A small amount of copper nanoparticles (less than 1% vol. fraction) or carbon nanotubes dissolved in ethylene glycol can increase the poor thermal conductivity of ethylene glycol by 40% to 150%. The thermal conductivity of Nano fluids increases nonlinearly with the temperature.

Kim and Bang show that addition of nanoparticles improves the wettability of the base fluids

Thus, the emergence of nano-cutting fluids has opened up the new possibility of enhancing the thermophysical properties of the base fluids in a desired manner. In tune with emerging trends, the present study reports the successful application of Al2O3 based on nano-cutting fluids for machining operation.

In the present study, a special type of nano-cutting fluid is prepared by mixing self-synthesized Al_2O_3 nano particles into the conventional cutting fluid. The wettability of water, conventional cutting fluid, and nano-cutting fluids is to be measured using macroscopic contact angle method. The comparative wettability study is to demonstrate that the better wettability characteristics of nano-cutting fluids compared to other two fluids. Later, cutting performance is compared with dry machining, machining with conventional cutting fluid, and machining with nano-cutting fluid in terms of tool wear (crater wear and flank wear), cutting force, average surface roughness, and thermal conductivity.

1.1MINIMUM QUANTITY LUBRICATION

In industries large amount of lubricant oils are used it accounts for 15 - 25% of the overall cost of manufacturing in the production industry. Among various methods available in the industry for the application of the coolant, Minimum Quantity Lubrication (MQL) is the best effective method used in coolant agent it can used only when a minimum quantity of cutting fluid required as it minimizes the use of coolant by spraying the mixture of compressed air and cutting fluid in an desired manner instead of normal cooling so it used only minimum for cooling purpose. The MQL technique has provided to be the suitable method because it reduces the cost of the machining process and ECO- friendly with both environment and working labor

However a minimum quantity lubrication method involves normal lubricating oil is mixed with Nano particle. Now a days several Nano lubricants have been foundout by the advanced technology because it has high thermal coefficient. Nano particle plays an important role in the cutting fluid. Nano particle main role is to reduce the friction between surface of the work piece and cutting tool and to increases the lubricant property of the fluid.

2. EXPERIMENTAL PROCEDURE

2.1 DESIGN OF EXPERIMENT

In throughout the experiment work piece used here is mild steel blocks. The Rockwell hardness of the mild steel block is around 70. Where cutting tool used here is high speed steel. Then the properties of the work piece material are shown in Table 1.All gear lathe are used to throughout the experiment for monitoring the process involving the different sets of speed (RPM) and depth of cut value. Thermocouples are used to measure the temperature of the cutting fluid, work piece and cutting tool. In this experiment a constant feed rate are given as 0.1 mm/rev. The coolant are continuously circulated in a drop wise manner, coolant and water are mixed in the ratio 20:1. In this experiment a normal coolant oil is used to measure the temperature of cutting fluid, work piece and cutting tool. Then after a nano particle i.e. (Nano particle is prepared with the help of ball milling) is mixed with correct ratio of normal coolant oil to measure the temperature of cutting fluid, work piece and cutting tool.

Fig.1. Experimental set up

Table1. Physical properties of work piece material

TENSILE STRENGTH	ELONGATION AT BREAK	MELTING POINT	BOILING POINT	MODULUS OF ELASTICITY	SHEAR MODULUS
370Mpa	15%	1427 Celsius	1350 Celsius	204Gpa	80Gpa

2.2 PREPARATION OF LUBRICANT USING BALL MILLING

In order to reduce the size of Nano particle we use ball milling apparatus. It is the best method to reduce the size of the Nano particle. This process was discovered by Benjamin and his surrounding friend at the international nickel company in the late 1960.The ball mill system consists of one turn disc it rotated at 150 rpm and 9 ball were used. The turn disc rotated in one direction and the bowl rotated in opposite direction because of centrifugal force. The centrifugal force is created, by the rotation of the bowl around its own axis together with the rotation of turn disc rotated in the opposite direction. Usually a jar is made up of stainless steel and coated with aluminium. At the initial stage of ball milling, the powder particles are spread along the jar and set the value of RPM as 150. At the intermediate stage of the ball milling size of the Nano particle is in significant change compare to the initial stage of rotation. At the final stage of ball milling process considerable refinement and reduction

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 11 | Nov -2017 www.irjet.net p-ISSN: 2395-0072

of particle size were obtained. Normally the process is carrying out for more than 7 hours to achieve the fine Nano particle size. After the end of the process we should dispose the Nanoparticle from the jar with the help of glass plate and spoon.

Fig.2. high energy ball miller

2.3 ULTRASONIC CLEANER

Ultrasonic cleaner is the rapid and complete removal of contaminants from the object by immersing mixing of Nano particle and oil mixed in the correct ratio in the tank of liquid, flooded with a high frequency of sound wave. These non-audible sound waves creates a scrubbing action within the fluid. They process carried out involved in a beaker is immersed in a water then a high frequency of electrical energy is converted into transducer and into high frequency sound wave-ultrasonic energy. A high frequency sound wave is passed through a beaker solution then this ultrasonic wave are passed in every corner of this set up so it is mixed with correct ratio of oil and Nano particle in the tank. In every 15 minutes cleans up the ultrasonic cleaner because temperature of the fluid is varied.

There are many variables consider during a ultrasonic cleaning process like Heat, power, frequency and mixing time all the phenomenon are included in this process.

Fig.3.ultrasonic cleaner

3. RESULTS AND DISCUSSION

3.1 Tool Wear

In the current study, tool wear refers to the morphology of crater and flank wears. The temperature generated in the primary and secondary shear zone affects the wear of the tool materials. The existence of the high cutting temperature and stress at the cutting edge, coupled with the brittleness of the tool material, accelerates the chipping, cracking, and fracture of the tool edge. This is mostly seen in dry machining process due to the absence of cutting fluid. Therefore, crater wear will be high in dry machining. Due to continuous rubbing of the machined work surface on the thermally softened flank face and absence of cutting fluid leads to the severe flank wear. Conventional cutting fluids provides lubrication and partially reduce the generation of heat in machining zone compared to dry machining conditions. But due to dominant adhesive wear, crater wear is observed near to the tool cutting edge. Adhesive wear mechanism depends upon the adhesive affinity of the tool and workpiece, the hot strength of the tool material at the adhesive junction, and the frequency of interruptions at the adhesive contact.. The adhered workpiece surface layer is often remains attached to the cutting tool edge. Thus the crater wear is observed at the seizure zone of machining. Continuous rubbing of workpiece with the flank face helps to chip-off tool flank surface layers. But, because of the conventional cutting fluid lubrication capability, the tool retains its hardness and thus flank wear partially reduces compared to dry machining process. Compare to conventional cutting fluids, Nano cutting fluids have good conduction, convection and wettability, both tool wears (crater and flank wear) decreases in cutting edge region only. Due to the better cooling and lubrication properties of Nano cutting fluid, the tool retains its original hardness for a longer times. Thus the flank wear is minimum compared to the dry and conventional machining processes

3.2 Cutting Force

As the machining starts, in the initial stage the cutting forces are less as the tool will be sharp and machining will be smooth. As machining time increases, the cutting edge wear increases gradually (sharpness decreases) either by deformation or by chipping. Thus, the cutting force also increases when the machining time increases. Figure 4 shows the variation of the cutting force with respect to machining time. As the machining time increases, the cutting edge gradually wears out, irrespective of the presence or absence of the cutting fluid. Due to the absence of cutting fluid in dry machining, the cutting tool edge wears out soon because of the quick thermal softening of the cutting tool material in the machining zone. This leads to rapid increase in cutting force which is clearly seen around 120s. The presence of conventional cutting fluid enhance the life of cutting edge by providing cooling and lubrication (through conduction and convection process). So, tool hardness is retained for more time and rapid increase in the cutting force is observed around 210s of the machining time. But in case of the nano-cutting fluid, rapid increase in cutting force is not observed because of improved cooling and lubrication system. Though there is a continuous increase in the cutting force from starting of machining, while machining with Nano cutting fluids, cutting force magnitude is smaller as compared to other two methods.

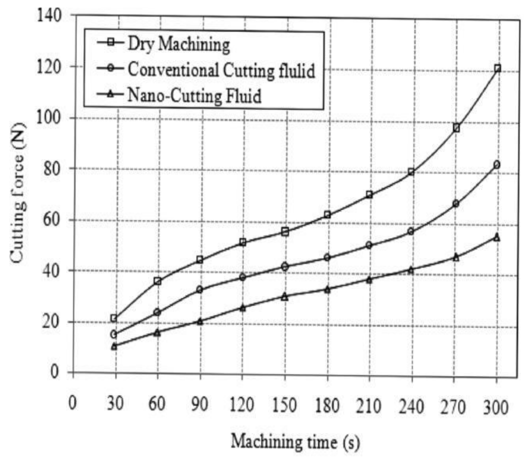

Fig 4.—Variation of cutting force with machining time for dry machining and machining with conventional and nano-cutting fluids

3.3 Surface Roughness

In the dry machining process, the cutting edge wear occurs rapidly, because of the absence of cutting fluid. So the machining process is no more smooth and the surface roughness Ra generated on the workpiece surface is high. When machining with conventional cutting fluid, the cutting fluid presence protects the edge of the cutting tool partially due to its cooling and lubrication properties. So, the machining process is partially smooth and thus the Ra generated is little better when compared to dry machining, (i.e., surface roughness reduces partially). But nano-cutting fluid improves greatly the wetting lubricating properties of rake and flank regions. The net effect leads to the better heat dissipation, so the machining process is smoother and causes retaining of hardness of cutting tool edge. Hence the surface roughness achieved during machining with nano-cutting fluid is minimum compared to the other two machining conditions.

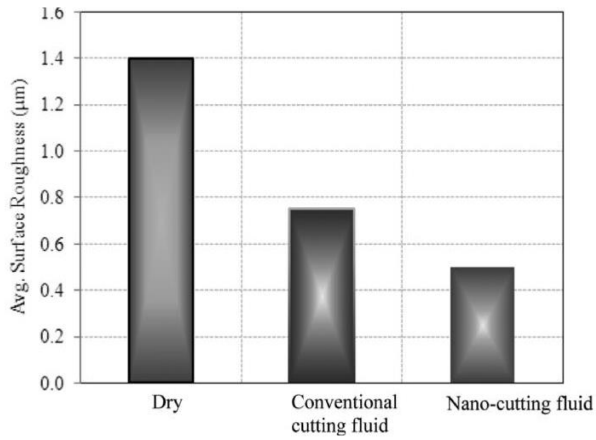

Fig 5.—Variation of average surface roughness while dry machining and machining with conventional and nano-cutting fluid.

4. SUMMARY AND CONCLUSIONS

In the present article, a comparative study of the performance during dry machining, machining with conventional fluids and nano-cutting fluids is reported. The following conclusions can be drawn based on the present work:

a. It is found that adding 1% Al_2O_3 nanoparticles (by volume) to the conventional cutting fluid improves greatly its wettability characteristics compared to pure water and conventional cutting fluid.

b. The great reduction of crater and flank wear is occurred to enhanced thermal properties, improvement in wettability, and lubricating characteristics of the nano-cutting fluid.

c. There is a reduction of ~50% and ~30% cutting force while machining with nano-cutting fluids compared with dry machining and machining with conventional cutting fluid, respectively.

d. There is 54.5% and 28.5% reduction in the Ra value of the machined surface when nano-cutting fluid is used when compared to dry machining and machining with conventional cutting fluid, respectively.

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