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Selection and Preparation of Nano Cutting Fluids for Machining of Hard Steel Materials Under Minimum Quantity Lubrication Technique

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***Abstract*: Machining is one of the most critical processes in the manufacturing industries which involve a controlled removal of material from the substrate by using a cutting tool. Machining covers several processes like turning, milling, grinding and non-traditional machining. The different factors that are considered during machining are Cutting speed, feed, depth of cut, tool material, Work-piece material, type of coolant, machining environment (dry machining, machining with conventional cutting fluid, machining with Nano cutting fluid with Minimum Quantity Lubrication). During the last decade witnessed rapid increase in development of advanced materials for high performance applications. While these materials solve a great deal of technological issue, they also pose considerable challenge in machining due to poor machinability characteristics.**

There are several materials such as EN-32, EN-31, EN-24, hard stainless steels, austenitic steels and duplex steels having high strengths and makes the machining very difficult. The machining of these materials is around 10-20% slower than for other alloys because of its Low thermal conductivity and heat concentrating at the cutting edges. This means coolants and lubricants are necessary and must be used in large quantities. Many alternatives were developed to minimize the quantity of cutting fluid used. The effectiveness and expense of cutting fluid application significantly depends also on how it is applied in respect of flow rate and direction of application. The performance of MQL technique can be enhanced by the use of specialized cutting fluids having superior properties, for which nanofluids give a promising solution. Nanofluids are prepared by mixing a specific amount of nano-particles (having size of the order of few nano-meters) into the cutting fluid. Nanofluids have been found to possess enhanced thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water. In this paper explained how the selection and preparation of nano cutting fluids for hard steel materials during machining and minimum quantity lubrication technique to application of the cutting fluid.

Keywords: MQL, Nanofluids, hard steel materials

I. INTRODUCTION

Machining is characterized by high cutting forces and temperatures that drastically influence the product quality. To deal with the problem, cutting fluids have been the conventional choices. However, several problems posed by the cutting fluids, including the health hazards like dermatitis to the exposed workers, have demanded for alternative cooling methods. [1, 6]

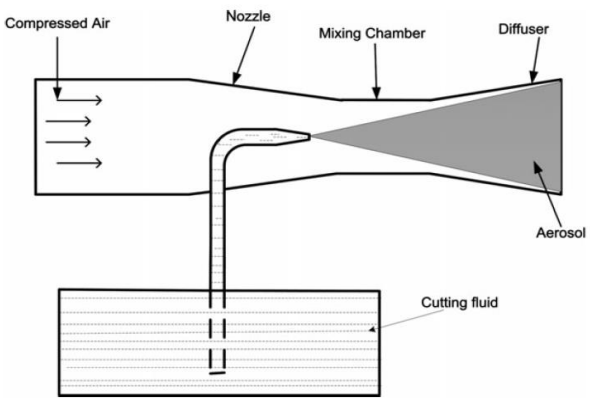
Mist generation is another problem prevalent with the cutting fluids. The aerosol gets accumulated in the respiratory system of the worker and can cause severe problems.

Environmental liability is also a major concern with waste disposal. Many companies are now paying for environmental cleanups or have been fined by regulatory agencies as the result of poor waste disposal practices. Further, addition of additives is also restricted due to their effect on the environment during disposal. [3]

With several limitations of cutting fluids, the search for substitutes is underway. This has given rise to Minimum Quantity Lubrication (MQL) where a bare minimum quantity of the fluid is employed. Since high cooling is to be achieved with minimum quantity of the fluid, the coolant needs to be of high thermal conductivity. [3, 4]

Nanofluids have emerged as a promising solution to this problem. Nanofluids are engineered colloidal suspensions of nanoparticles (1-100 nm) in a base fluid. The applicability of the fluids as coolants is mainly due to the enhanced thermal conductivity of the fluids due to the solid particle inclusion. [1, 4]

Minimum quantity lubrication technique: Minimum quantity lubrication technique is an attractive alternative in which very less amount of cutting fluid is applied directly to the machining area through the nozzle. [2]MQL is the application of mist lubrication, in which a mixture of air and cutting fluid called aerosol is produced and supplied in the cutting zone with a high pressure. Work has been done by many researchers on MQL techniques and most of them reported it to be efficient than conventional flood cooling. [2]



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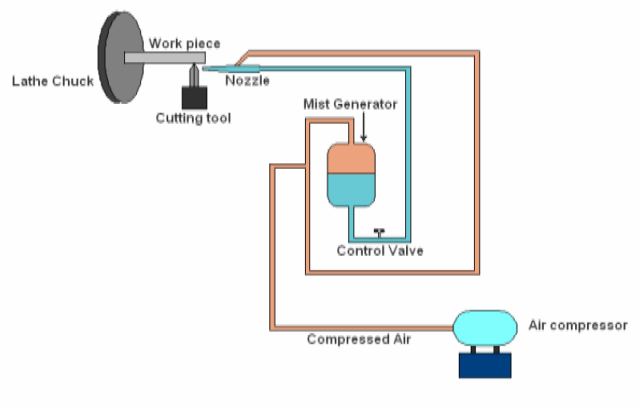

Figure1: Minimum Quantity Lubrication Technique

The effectiveness and expense of cutting fluid application significantly depends also on how it is applied in respect of flow rate and direction of application. The performance of MQL technique can be enhanced by the use of specialized cutting fluids having superior properties, for which nanofluids give a promising solution. [3]

II. SELECTION OF NANO PARTICLES

Nanoparticles can be made of a wide range of materials the most common being metal Oxide, Nitrides, Carbides Ceramics, Silicates and non-oxide ceramics. Even though nanoparticles of other materials exist, those based on polymer materials or compound semiconductors, the former categories count for the most part of current applications. Nanoparticles are generally designed and manufactured with physical properties tailored to meet the needs of the specific application they are going to be used for. [1]

During the machining process selection of suitable nanoparticles are very important. Several nano particles are available in the market produced by chemical process or herbal process nano particles. They are Aluminium oxide (Al_2O_3), Copper oxide (CuO), Molybdenum disulfide (MgO_2), Nano boric acid, Graphene, silicon oxide, titanium oxide (TiO_2) Silicon carbide (SiC) and several compound and hybrid nano particles. [12] While selection of nano particles during machining of hard steel materials we have to considered several properties as mentioned below

- Size and purity of the nano particles
- It should be easily available and should be economical.
- Should not react with workpiece and toll material and should not produce any harmful effect for human worker.
- Good wear resistance and with stand with very high temperature melting point. [1]
- Good in heat carrying capacity and also High thermal conductivity, high stability and high purity.
- Small thermal expansion co-efficient and resistant to oxidation at high temperatures.
- High physical and chemical stability of metal oxide nanoparticles[1]
- Low friction combined with exceptional durability and toughness and ductility
- Should not react with base fluid and surfactants while preparation of nano fluids

III. PREPARTION OF NANO CUTTING FLUIDS

- Cutting fluids play a significant role in machining operations and impact shop productivity, tool life and quality of work
- Selecting the suitable nano particles based on their required properties and base fluids which are required to mix the nano particles.
- The various base fluids are available in the market like natural oils, vegetable oils, neat cut oils, emulsified oils, Deionized water, coconut oils and other oils which is suitable for machining. [1,4,5,6]
- Using % Volume concentration formulae the weight required of nano particles are going to be calculated.
- The preparation of nano cutting fluid using two step method and it is carried in the ultrasonic sonicator, for the distribution of the nano particles along with the cutting fluid.
- The nanofluids were sonicated with ultrasonic vibrator 60-90 minutes. [1,4]
- The nano cutting fluids which is prepared consisting various % of volume concentration of varying nano particles with base fluids. [10]
- During preparation of nano cutting fluid adding surfactant called SDBS (Sodium dodecyl benzene sulfonic acid sodium salt) or SDS (sodium dodecyl sulfate) to improve the dispersion and stability of nano particles in the base fluid. [1,4,6,12]
- During preparation of nano cutting fluids the magnetic stirrer required to stir the fluids every half hour after sonication.
- After preparation of nano cutting fluid to check the thermal conductivity, viscosity flash and fire point of the various proportions.
- High thermal conductivity and low viscosity fluid proportion fluids are selected for machining operation.

Figure2: Ultrasonic sonicator

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Figure3: Magnetic stirrer

VI. CONCLUSION

This paper addressed that selection and preparation of nano cutting fluids for machining of hard steel materials using minimum quantity lubrication technique. The MQL technique is very good technique among other cutting fluid application with minimum amount of cutting fluids is reburied to effectively machining of hard materials. While selection of nano particle many properties are to be considered important is thermal conductivity and wear and friction resistance and heat carrying capacity. Many base fluids are available and selection suitable base fluids required based on their properties and workpiece materials preparation of nano cutting fluids using two-step method with help of sonicator and magnetic stirrer. Machining of any hard steel materials nano cutting fluids under MQL technique gives the best results with less cutting force and surface roughness, toll wear rate and temperature and increases the machinability of the materials during any machining process.

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