Influence of Cutting Fluids on Quality and Productivity of Products in Manufacturing Industries

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Abstract—Cutting fluids have seen extensive use and have commonly been viewed as a required addition to high productivity and high quality machining operations. All machining processes cause high cutting temperature, tool wear and impairing product quality as the effect of friction. Cutting fluids help to overcome adverse effect of temperature. Cutting fluids also provide cooling, lubrication, and chip flushing in machining processes.

This article is a summary of basic cutting fluid characteristics and discusses how it plays a great role in manufacturing industries. The aim of present study to select the optimum cutting fluid that minimize the environmental impact, cost and maximize the quality.

Index Terms—Cutting fluids, Quality, Productivity, Machining.

I. INTRODUCTION

Cutting fluid is designed especially for metal working and machining process. Cutting fluids are very important in manufacturing process. Cutting fluid is a type of coolant and lubricant used to reduce the effort of friction. Cutting fluids are also used to carry away excessive heat in machining operations which can cause damage the microstructure of metals. Proper use of coolants can also help improve part quality and dimensional accuracy.

Machining or metal cutting is most widely used production technique. Material is removed from a less resistant material called work piece with the help of cutting tool in the machining process. The material cutting process results tiny parts or layers of removed material is called chip. The chips are accumulated on the tool face and leave the work piece material. As a result of this process high normal and shear stress can be generated on the tool face which may cause undesirable effects in machining operation. This may cause heat generation in machining operation which affects the machineability. Now days the machining industries are paying attention in improving product quality and productivity at greater cutting velocity and feed rate. It becomes extremely tough to attain both greater cutting velocity and feed rate because they cause very high cutting temperature. As the result of the high cutting temperature premature failure of the cutting tools occurs in the cutting zone. The premature failure of cutting tool causes poor dimensional accuracy. It also degrades the surface integrity of the product by inducing tensile residual stresses and surface and sub-surface micro cracks. Hence, the study shows that it is essential to reduce the temperature in the cutting zone for improving product quality and productivity. Temperature may be reduced by selection of cutting tool, machining environment, cutting fluid and machining parameters [2,3]. Cutting fluid is a substance which is used in machining for cooling & lubrication. The use of cutting fluids in metal cutting was first reported in 1894 by F. Taylor, noticing that cutting speed could be increased up to 33% without reducing tool life by applying large amounts of water in the cutting zone [4-6].

Thus two primary major functions of cutting fluid are cooling and lubricating. Cooling reduces temperature in cutting zone and lubrication decreases friction coefficient & cutting forces between tool and workpiece. Sometimes secondary functions of the CF which may be play greatest practical importance, such as washing away the swarf and protecting the workpiece along with machine components from corrosion [7].

The certain process parameters such as flank wear, surface roughness on the work piece, cutting forces developed and temperature developed at the tool chip interface etc. plays a major role in the evaluation of efficiency of machining process. Some factors such as selection of machining environment, type of cutting fluid used and maintaining cutting fluid parameters such as concentration, pH value and bacterial growth, etc. also affects the optimum use of cutting fluid. Following sections discuss these important considerations.

Machining Environment

According to Cutting Fluids application Machining environment is mainly classified as four types given below:

(a) Dry Machining
(b) Minimum Quantity Lubrication (MQL)
(c) Cryogenic
(d) Wet environment.

(a) Dry Machining – In dry machining cutting fluids is not used so that friction and cutting temperature will be more than that of wet machining. It can reduce the tool life, surface quality. It can also affect thermally induced geometrical deviations in the machined part, hence for obtaining long tool lives, it is not recommended to use the dry machining for high values of depth of cut [1,8].

(b) Minimum Quantity Lubrication (MQL) - Lubrication, cooling, and chip flushing functions of Cutting Fluids makes the performance of machining operations better but its uses also create negative effects on employee health and environmental pollution [10]. MQL or near dry lubrication...
means that the use of Cutting Fluids with a flow rate of 50–500ml/h for only a minute amount [1,10–12]. MQL has limited effectiveness in machining operation because of it is more effective in lubrication than cooling [13].

(c) Cryogenic Machining – The use of compressed and chilled gas for cooling in machining operations is termed as cryogenic machining. In Cryogenic machining, operations are conducted at very low temperatures below than about 120K. In cryogenic machining the cutting zone temperature, tool and workpiece temperature is reduced by directing liquefied gases (a super cold medium) into cutting zone. Carbon dioxide, Nitrogen, Oxygen, Argon etc. gases are used in cryogenic machining [1]. Cryogenic machining can be considered as cleanest procedure of cooling in metal cutting operations.

(d) Wet environment – wet environment or flood cooling condition is most commonly used method in which a large amount of Cutting fluids are continuously applied on cutting tool and work piece interface. In wet environment neat cutting oil or water soluble cutting fluid is used for lubrication of the contact areas between rake face, chips, flank face and machined surface. In wet environment cutting fluids also remove heat induced by friction in cutting zone. These functions of cutting fluids result in improved machinability. The parameters of cutting fluid such as pH value, concentration and bacterial growth etc. plays a very important role in selection of proper cutting fluid. The way of use of cutting fluid with optimum pressure and flow rate is quietly very important in the view of performance of machining operation such as tool life, power consumption, cutting forces, surface integrity and machining accuracy. Some researchers [3,9] indicated that application of pressurized Cutting Fluids shows better performance of machining operations. It helps in increasing tool life, chip breakability and decreases temperatures in the cutting zone and lowers forces. Machinability can be increased by using optimum value of cutting fluid pressure and flow rate, so it is necessary to find out the optimum values of these parameters and also keep attention that the values of these parameters could not be vary throughout the machining process [3,9].

Cutting fluids:
Cutting fluids are normally classified in to three main groups. These are
(a) Gases
(b) Neat cutting oils
(c) Water soluble cutting fluids
(a) Gases - Gas-based Cutting Fluids can be used in the form of gas or in the form of cooled pressure fluid. But these are the substances that generally found in the gaseous form at room temperature. Nitrogen, Argon, Helium and Carbon dioxide are the examples of the Gaseous cutting Fluids. Liquid coolants cannot be used in some machining operations because in such cases there is a risk of corrosion occurrence over workpiece or machine component so gaseous cutting fluids are beneficial in such cases. Gaseous cutting fluids cannot be reused so that it makes the use of gaseous cutting fluid costly & limited.

(b) Neat cutting oil - Neat Oils or Straight oils generally refers to petroleum or mineral-oils. The petroleum or mineral oils are basically used directly without dilution with water but sometimes to improve specific properties they have some specific additives. Generally for light-duty machining of ferrous and nonferrous metals additives are not required. For more severe applications extreme pressure (EP) additives such as sulfur, chlorine, or phosphorus compounds may be used with the straight oils. These additives enhance the oil's wettabillity, lubrication and improve the oil's ability to handle large amounts of metal fines. The high cost, fire risks, inefficient in high cutting speed, low cooling ability, smoke formation and high risk to the human health etc. factors make the use of straight oils limited. (c) Water soluble cutting fluids - The primary function of Cutting Fluid is removal of heat from cutting zone by conduction process, so it is essential for cooling that the used cutting fluid should have high thermal conductivity and specific heat. Specifically, water is the most favorable coolant fluid with low cost accompanied with high thermal conductivity and specific heat. However water has low lubrication effectiveness and also has corrosive nature to ferrous materials which are most commonly used in machining equipments. To overcome these problems different additives have been added to water [19].

Oil is not soluble in water that’s why tiny globules of oil is formed & suspended in water. Emulsifier is used for breaking of oils into tiny particles and made the Emulsion. Thus emulsion is used in metal cutting operation so that oil helps in lubricating and water does cooling [20]. Such water miscible cutting fluids are classified as:

i. Synthetic cutting fluid
ii. Semi- synthetic cutting fluid
iii. Vegetable based cutting fluids
iv. Soluble cutting fluid

i. Synthetic cutting fluids - Synthetic Cutting Fluids contains soluble lubricants, high pressure additives, corrosion inhibitors, biocides, surfactants and deformer. The composition of synthetic cutting fluids does not have mineral oils. They form a solution with water and has lower lubrication effectiveness and suitable for low force application.

ii. Semi- synthetic cutting fluids – Semi- synthetic cutting fluids are better lubricants than synthetic cutting fluids. They are more effective in corrosion or oxidation prevention. Semi-synthetic cutting fluids contain both mineral oils and chemical additives. They can cause serious health problems like cancer, skin diseases, and respiratory diseases due to their toxicity to the person which is constantly working with these cutting fluids. Their untreated disposal is also harmful for air, soil, ground water and subsequently agricultural product.

iii. Vegetable based cutting fluids - Vegetable based cutting fluids refers to the oils basically extracted from trees or vegetables like Sunflower based, coconut oil, Palm oil, Ground nut oil etc. these are environmental friendly cutting fluids results better performance than mineral based cutting fluid and straight oil [1,4,5,24]. The biodegradability, renewability and less toxic property of vegetable based cutting fluids make them as a better substitute for petroleum based Cutting Fluids and synthetic fluids.

iv. Soluble cutting fluids - The soluble oils have lubrication and corrosion prevention characteristics of mineral oils, together with the cooling effect of water. Soluble oils consists
of a mineral oil accompanied with emulsifiers which allow the oil to be dispersed into the water in proportion that varies from 1:10 to 1:100 [18,26]. So that they have characteristics of both mineral oils and water. They contain the lubrication & rust prevention property of mineral oils and cooling effect of water.

Considering on the basis of industrial application aspects of cutting fluids such as cost, reuse, environmental hazards, and disposal etc. make the water soluble cutting fluids most preferable.

Economical issues of cutting fluid

The associated costs with cutting fluids are not only the purchase and preparation cost of the cutting fluid but it also consists of the maintenance and disposal costs. Generally cutting fluids are not naturally biodegradable. So it is essential to treat the cutting fluids before disposal. The expensive treatments of cutting fluid before disposal affects the disposal cost too much which can be up to two or four times their purchase price.

The heat removal for cooling from cutting zone during machining depends on the concentration of water soluble cutting fluid. The manufacturing efficiency and product quality are also directly affected by concentration of water soluble cutting fluid. As cutting oil is costlier along with its hazardous effects, still its use is necessary considering manufacturing aspects so optimum use and proper maintenance of cutting fluid concentration may help in economical issues and increase cutting fluid life to achieve green manufacturing.

Conclusion

Cutting fluid plays a vital role in manufacturing industries. They help to achieve higher productivity and machinability with high quality product. The higher productivity and machinability can be considered in terms of increased tool life, surface finish, and accuracy to size and make chip breaking and chip transport easier. With these add-ons the cutting fluids are also associated with some drawbacks like hazardous effects, environmental and health impacts. Costs associated with their use, maintenance and disposal is also a major drawback of cutting fluids, so optimum use of cutting fluid is essential.

Parameter of water soluble cutting fluid such as concentration, pH value and bacterial growth also has influence on machinability, environment and cutting fluid life, so it is necessary to use properly maintained cutting fluid which is beneficial to both manufacturing and environmental aspects and help to achieving green manufacturing.

REFERENCES

[31] Water soluble cutting fluid catalogue, obtained from Internet, dir.indamart.com/cgi/catprdesk.mp/ss=water+soluble+cutting+oil.