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Effect of Cutting fluids in Machining Operations

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ABSTRACT: Cutting fluids provide cooling at the cutting tool and on the surface of work piece, lubricate the tool workpiece interface and evacuate chips from the cutting zone in the machining processes. The primary reason for using cutting fluid is to reduce the temperature at cutting zone and friction wear either through cooling or lubrication. To maximize the efficiency of cutting fluids in machining processes the knowledge of machining conditions and cutting fluid types are critically important. However, misemploy of the cutting fluid and non-efficient method of disposal can raise health issues and environmental impact. In this paper, an attempt has been made to provide overview of cutting fluids type, cooling techniques and main alternatives as dry machining, cryogenic cooling, minimum quantity lubrication and hybrid cooling minimizing use of cutting fluids.

KEY WORDS: Cutting fluids, Machining, Properties

I.INTRODUCTION

Machining is a process designed to change the size, shape, and surface of a material through removal of materials that could be achieved by straining the material to fracture or by thermal evaporation. Machining offers important benefits such as- Excellent dimensional tolerances, sharp corners, grooves, fillets, various geometry. One of the prime factors in any industry is manufacturing. At present, machining plays an important role in the processing industry. It is conceivably the most flexible manufacturing process in which any shape, size, and surface finish can be obtained by removing extra material from the surface of workpiece. A device that removes unwanted material by direct mechanical contact is named as a “cutting tool”, and a machine which is responsible to move workpiece so that excess material can be removed properly is known as “machine” [1].

Cutting fluids are widely used in machining processes. The main functions of cutting fluid are cooling, lubrication, removing the chips and protecting the workpiece [2]. The cutting fluids is essential in a machining operation in order to enhance the productivity in terms of performances [3]. The use of cutting fluid in machining processes increases the tool life, dimensional accuracy, and surface integrity [4]. The utility of cutting fluids has linked with some drawbacks such as their cost, environmental impact, and health hazards. The use of Cutting Fluids (CFs) in machining operations is being enquired for environmental and economic reasons. The cutting fluid (Mineral-based) needs physical or chemical treatment by an environmental protection agency to remove the hazardous and toxic components before its disposal. The total cost of cutting fluids, including its disposal cost is approximately 17 % of the total machining costs of a product. In recent years, new cutting fluid and cutting fluid application methods have been developed to overcome the main drawbacks of cutting fluids [5, 6]. The main alternatives cutting fluid application methods are dry machining, minimum quantity lubrication (MQL), high pressure cooling (HPC) and cryogenic cooling. However, there is need to understand the technical, economic, and environmental aspects of cutting fluid and its application methods in various machining processes.

II. FUNCTIONS OF CUTTING FLUIDS

The basic functions of cutting fluids include the following four considerations: cooling, lubrication, corrosion protection and chip removal. In cooling, the energy generated in metal cutting operation both through deformation and the sliding friction appears to be thermal energy or heat. This high temperature can usually shorten the fool life, cause an undesirable surface finish, and bring down the cycle time due to the reduction of cutting speed. This cutting fluid

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acts as coolant and reduces the heat generated. It is believed that due to high pressure and relatively high temperature in most cutting operations, liquid film cannot be sustained along tool/work piece interface for all the time. Thus, the conditions in a typical cutting process are believed to approach boundary lubrication. This can be achieved by cutting fluids. A good cutting fluid protects the work piece from corrosion damage. The fourth major function of cutting fluid in machining process is to remove chips from the cutting zone. And the fluid will also prevent the machined surface from being scratched by chips.

The primary functions of a cutting coolant are cooling and lubricating the workpiece in a machining process [7]. Lubrication property in cutting coolant reduces the abrasion and adhesion at low cutting speeds as well as greases the contact areas between chips and tool rake face [8]. Today vast variety of cutting fluids are available and effectiveness of cutting fluid depends upon various factors such as cutting parameters, strategies for cutting fluid application and types of machining.

Cutting fluid, as a component of machining industry, has been introduced and applied over 100 years. Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing work piece and thermal deformation, improving surface finish, and flushing away chips from the cutting zone.

Cutting fluids are classified into four categories: straight oils, soluble oils, semi synthetic fluids, and synthetic fluids. Baradie is the research who classified cutting fluids as shown in Fig. 1[9].

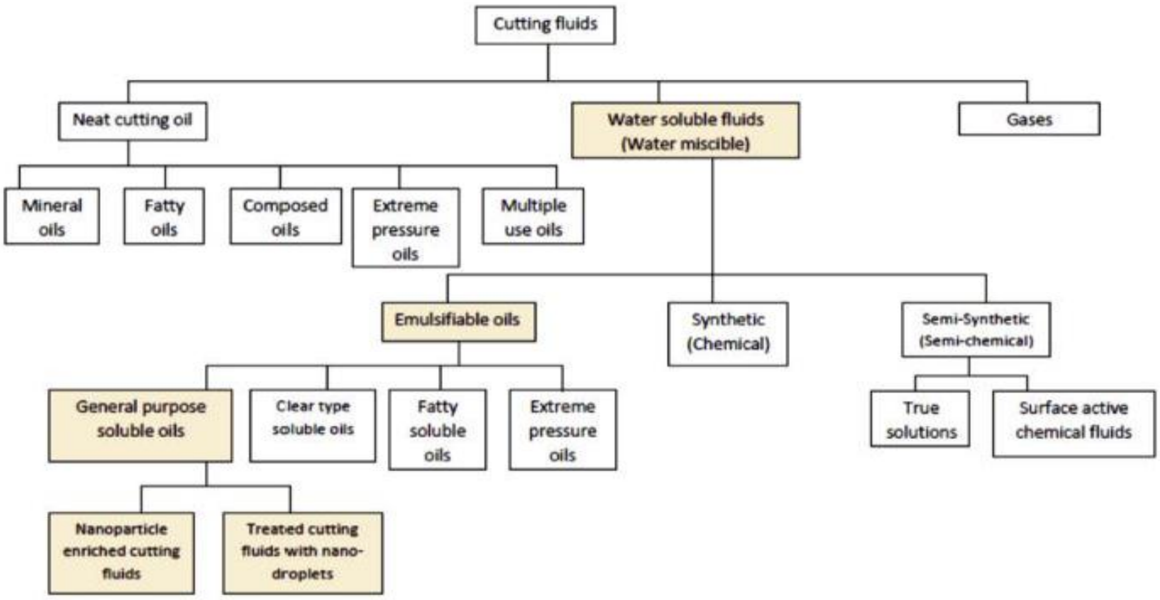

Fig.1. Classification of cutting fluid

The cutting fluids are mainly categorized as straight cutting oils and water-soluble oils. These cutting oils are not diluted and improve the wetting and lubricating properties, corrosion resistance and under extreme pressure conditions addition of sulphur, chlorine compounds improve surface finish and enhance tool life.

Straight oils are used for low-speed applications, where temperature is not significant [10]. The reduction in smoke formation and fire hazard can be achieved by vegetable oils due to higher viscosity [11]. Vegetable oils are preferred than mineral oils in reducing surface roughness and tool wear. Generally, vegetable oils are appealing substitutes for oils got from petroleum having minimal social, economic, and environmental effects attracting industries to attain sustainability [12, 13].

Emulsifable oils (also referred as soluble oils) are mineral based oil include emulsifiers, EP and other additives. Soluble oils are low cost; provide good cooling capability at higher speeds. Soluble oils have better cooling capacity than straight oils and provide rust protection. The main problems related with soluble oils are toxic mist, bacterial attack, susceptible to hard water. Soluble oils show less mean tool-chip interface temperature than dry cutting conditions but higher than synthetic and semi-synthetic fluids during machining of AISI 8640 steel. The tool life was

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extended with the semi-synthetic fluid based on flank wear parameter. The tool was observed diminishing with increase in cutting speed at same cooling/lubricating conditions [16].

Soluble oil was used by employing MQL technique in turning of stainless steel as reported by Sohrabpoor et al (2014). The low surface roughness and tool wear was observed under MQL as compared to dry, cool air and wet strategies [17]. The flank wear was reduced by 24% by employing soluble oil in machining of Al-MN alloy. Neem seed oil was found more effective than soluble oil as a cutting fluid. The surface roughness was reduced by using neem oil as compared to soluble oil and dry machining. The least surface roughness was obtained with neem seed oil at spindle speed of 250 rpm. The highest reduction in flank wear was observed with neem oil at spindle speed of 250 rpm during machining Al-MN alloy [18].

III. MACHINING PARAMETERS IN PERFORMANCE

The properties of cutting fluids should not change within a range of pressure, temperature and time having same stable chemical composition. For instance, cutting liquids must prevent corrosion between workpiece material and cutting tool as well as lubricating oil of slides and machine bearing [9]. According to the principle of metal cutting, heat generation occurs in three deformation zones during metal removal process namely as primary deformation zone, secondary deformation zone and tertiary deformation zone as shown in fig.2.

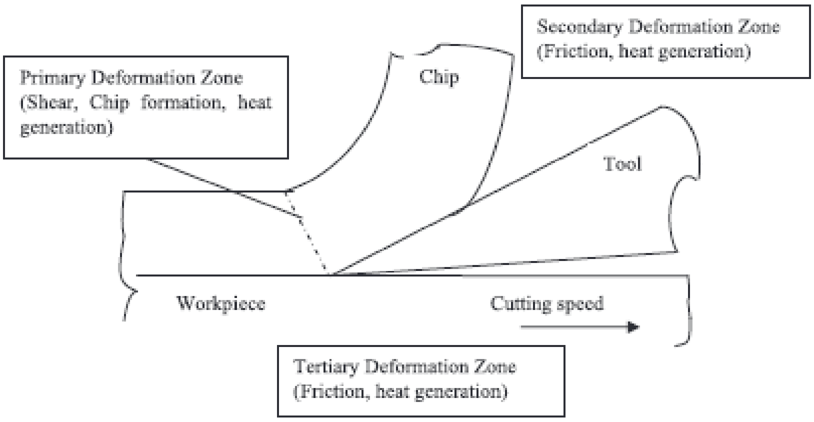

Fig.2. Sources of heat generation in metal cutting

The formation of chips occurs in all machining processes; this occurs due to deformation of work material on the surface of job with aid of cutting tool. Chips are produced in different sizes and shapes depending on work material, cutting conditions and tool geometry. The main aim of machining operations is to improve quality and productivity by reducing machining costs. The parameters affecting the machining performance are shown in fishbone (cause & effect) diagram fig.3.

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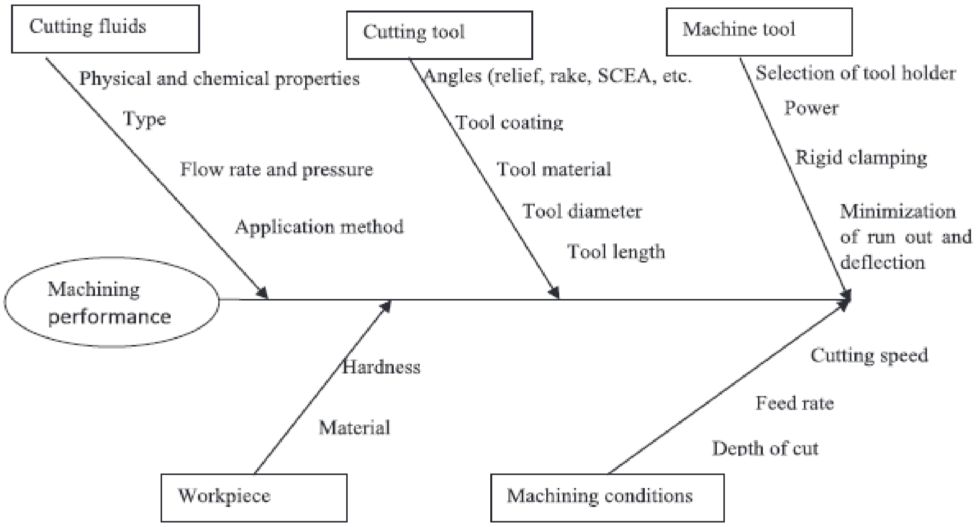

Fig 3. Effect of machining parameters in performance

Cutting fluids are generally applied in machining operations as milling, drilling, and turning. A cutting fluid should have excellent lubricating and cooling properties. Cutting fluids decrease the friction, improve surface finish, prevent the formation of built-up edge (BUE), evacuate chips from the cutting zone and protect work from corrosion. Today the interest is developing in manufacturing industry for good quality product, low cost, and high profitability. High productivity is essentially associated with high cutting speed, depth of cut and feed rate resulting high temperature in the cutting zone. Consequently, the quality of a product, dimensional accuracy and tool life are deteriorated. If the feed rate and cutting speed are reduced just for smoothness of surface, it is just wastage of resources without significant gains in productivity. Therefore, to produce a quality product the efficiency of cutting fluids and optimization of parameters should be well determined.

IV. SELECTION OF CUTTING FLUIDS

Cutting fluids used, should provide easy machining operation in all materials. Ferrous metals are brittle in nature and hence during machining they break into small size chips. The friction between cutting tool and chip is less due to small size chip formation. It was proposed that using emulsion cutting fluids increases surface finish quality and prevents dust formation during machining. During machining operation of, generally the high pressure containing, and additive cutting fluids are used. In stainless steel machining, high pressure cutting oils should be selected. Work-hardening properties in some steels would cause some problems during machining operation. For machining of heat resistant and difficult-to-cut steel alloys, water based cutting fluids are preferred, because temperature becomes higher in cutting area.

The other influential parameter for selection of cutting fluid in machining processes is the cutting tool material. Different cutting tool materials are commercially available for carrying out different machining operation. High speed steel cutting tools can be used with all type of cutting fluids. However waterless cutting fluids are preferred when difficult-to-cut materials are machined. In case of the tungsten carbide (WC) cutting tools application, more cooling characteristics from cutting fluids are required. This is because of high generated heat in the interface of cutting tool and workpiece material. The negative effect of generated heat during machining with WC cutting tools causes rapid tool wear. Hence toll life will be shorter and surface finish quality falls. The selection of cutting fluid depends upon the factors as shown in fig.4.

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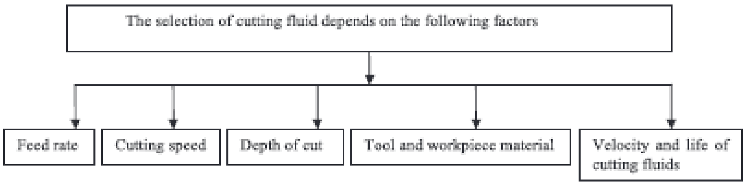

Fig.4.Selection of cutting fluids

V. APPLICATION OF CUTTING FLUIDS

In dry machining, the cutting fluids is not used during the machining process. Dry machining method is used to avoid the problems related with the use of cutting fluid such as environmental pollution, health hazard and safety consequences. The special coated carbide cutting tools are developed for the use in dry machining. Dry machining is carried out at lower cutting speeds to increase the tool life, which in turn increases the production rate [20]. The heat generation at tool chip interface in dry machining leads to overheating the tool. The friction between the tool and workpiece during dry machining considerably increases the temperature in higher level of abrasion, diffusion, and oxidation. Also, the heat generation between tool and workpiece due to friction causes the dimensional deviation and metallurgical changes in the workpiece [21]. The chip formation, which could cause deterioration on the machined surface is unable to wash away. Thus, the cutting fluid cannot be completely eliminated in machining process [22].

Minimum quantity lubrication (MQL) applications are introduced beneficial method [23]. This MQL cutting fluid application method is also known as near dry lubrication. MQL machining is one of the practical ways to the cleaner production in the context of the sustainable manufacturing [24]. In this MQL method, very small amount of mist of air-cutting fluid mixture is applied to the cutting zone. The pressure applied and the flow rates of mist in MQL application method is 6 bar and 50 ml/h - 2 l/h respectively, also the nozzle diameter is 1 mm. The quantity of cutting fluid used in MQL is one ten-thousandth that of the in wet cooling [20]. The cutting fluid is used in such small quantities that it is practically consumed in the process, eliminating the fluid disposal problems. In addition, chips produced are nearly clean from cutting fluid, which are easily recyclable [25]. Some MQL advantages against other lubrication/cooling systems are: reduction of cutting fluid consumption, cost and tool wear; improvement of surface roughness, diminution decrease of the environmental and worker health hazards and improve lubrication than that of the of conventional lubrication/cooling system [26, 27, 28, 29]. MQL is used focusing on the lubricant properties rather than coolant properties, heat removal is achieved mainly by the compressed air [30].

Cryogenic machining is new technique such in which nitrogen and helium gas are used as a coolant. Nitrogen is an inert gas and lighter than air. Cryogenic machining is environmentally friendly and safe alternative technique to the conventional flood cooling. In this technique the nitrogen in a liquid form and at temperature around -200 °C is injected through a nozzle of small diameter into the cutting area. The heat generated during machining process is absorbed by liquid nitrogen and its vapor forms a cushion at tool-chip interface and acts as a lubricant [20]. Additionally, the chips produced by this technique have no residual of oil attached to them and therefore can be recycled as scrap metal. In cryogenic machining volumetric flow rate and pressure of liquid nitrogen are significant parameters for machining performance. Due to the ability of cryogenic fluid of reducing the coefficient of friction at the tool-chip interface, the cutting forces required in cryogenic turning are less than in dry machining. The magnitude of cutting force increases due to overcooling of workpiece and results into the embrittlement of the workpiece, In cryogenic machining the cooling ability decreases at higher cutting speed as tool-chip contact fully plastic and as cryogenic coolant could not penetrate at interfaces. By proper application liquid nitrogen and controlling its jet parameters, the tool life can be improve significantly [19].

VI. CONCLUSION

Cutting fluids play an important role during machining but they use have some drawbacks such as their negative effects over the environment and workers health as by costs associated such as the equipment, fluids purchase and waste fluid treatment. All of these plus governmental regulations are encouraging companies to implement lubrication/cooling systems more efficient and sustainable. The alternative techniques such as dry machining, MQL, High Pressure Cooling (HPC) Cryogenic cooling have been implemented in some machining processes, even may become more

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efficient than conventional lubrication/cooling. However, there are still applications where cutting fluids cannot be removed.

1. The dry machining is the best method since it eliminates the contamination of cutting fluids in turn health and environment related issues. The high amount of heat is generation and its effects on machining responses has put the limitation on use of this method. To use this method, it is necessary to select appropriate cutting parameters and cutting tool.

2. MQL is an efficient method of cutting fluid application to reduce the negative effects of use of cutting fluid in machining processes such as operator's health and environmental issues. MQL system reduces the fluids use and is a more viable alternative considering not only the economic and environmental impact but also the performance. MQL method is applied when dry machining cannot be used, or applicable and wet cooling is not desirable.

3. Cryogenic fluid considerably reduces the coefficient of friction at the tool-chip interface; hence it requires less cutting force than in dry machining. Cryogenic cooling can increase the tool life, especially in difficult-to-machine materials. Its environmental impact is lower than other cutting fluids and cutting fluid methods, but its initial cost is high.

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