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CONSEQUENCE OF MINIMUM QUANTITY LUBRICATION IN MACHINING: A REVIEW

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ABSTRACT

Cutting fluid plays an important role in the cutting process of metal piece. This cools the metal piece surface and helps to remove excessive part of the metal as per required zone. But, the excessive use of cutting fluid, and the wrong way of applying it on the metal piece affects human health as well as the environment. Cutting fluid costs 16 to 20 % of the total production cost of manufacturing. Among different techniques available for cooling the work piece during the cutting process, the researchers have focused on Minimum Quantity Lubrication (MQL) technique. This scheme minimizes the utilization of coolant material by spraying it on the metal surface. In this paper, a state of art of the recent papers related to MQL approach is presented. The paper also explains the mechanism of MQL technique, observed that this technique finds a feasible solution to the flood lubrication and provides similar performance.

Keywords: Cutting Fluid, Minimum Quantity Lubrication, Machining.

I. INTRODUCTION

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].

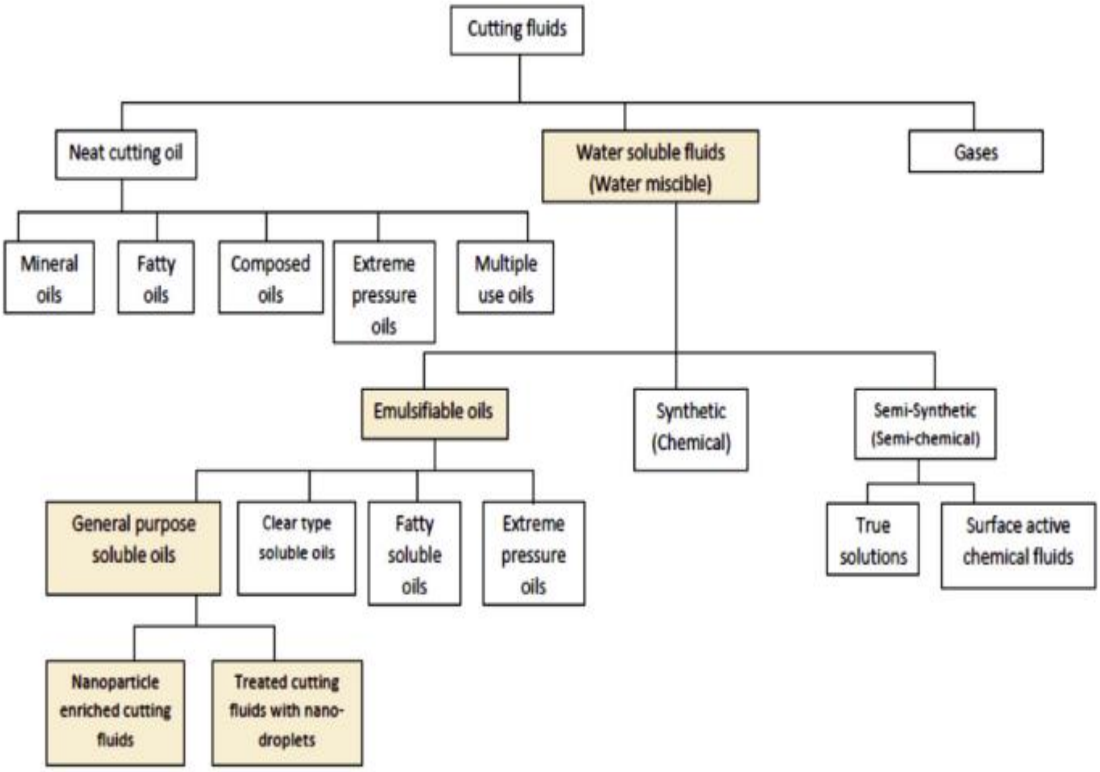

Figure 1: Classification of cutting fluid

This movement of workpiece results in extensive plastic deformation, which need 99% of energy to move the machine tool. Therefore, one can say that during relative movement process about 99 % of energy is converted into heat. Some researchers (Park et al. 2017; Javaroni et al. 2020; Rahim, and Sasahara 2011) have been

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observed that during the cutting process of ferrous material, temperature increases extensively and hence reduce the strength of material, which results in tool failure [2], [3], [4]. For efficient productivity, speed of the cutting tool required to be higher. But as with the increase in speed, it increases the tool temperature. Therefore, a process is needed that controlled the temperature by cooling tools temperature constantly. To overcome this problem, some of the researchers have suggested blunt tools [5]. But these tools require higher power, and finish surface poorly. One of the solutions to increase tools performance is only to decrease the raised temperature, which is performed by cutting fluids. In 1996, Baradie is the research who classified cutting fluids as shown in Figure 1[6]. Later on in 2014, Debnath et al. have presented a research in which he used bio-based cutting fluids (using vegetable oils), and observed that machine has performed better compared to the mineral based cutting fluids [7].

Sharma et al. (2009) have provided a survey of different cooling techniques including Minimum Quality Lubricant (MQL), allied cooling, compressed air/vapor/ gas cooling, high pressure cooling, cryogenic cooling, soil cooling and food cooling as shown in Figure 2 [8].

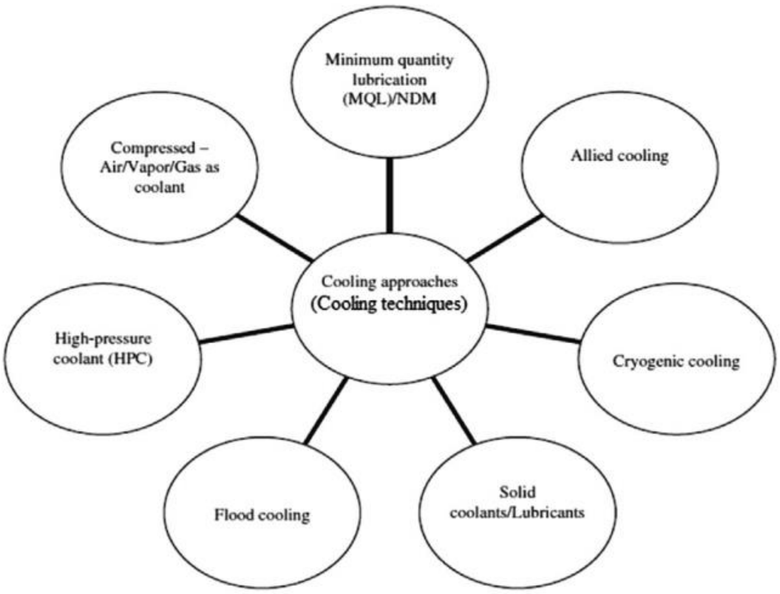

Figure 2: Cooling Techniques

MINIMUM QUANTITY LUBRICATION (MQL)

The use of a minimum amount of lubricant is becoming more common in machining operations due to the rationality and environmental friendliness of this technology, increased productivity and lower costs [9].

Minimum quantity lubrication technology is becoming increasingly important for productivity, economy and environmental friendliness in machining operations. Keeping in mind the growing need to reduce manufacturing costs, testing has demonstrated an important advantage of this technology: the MQL internal feed system can cut the total cost of ownership in half compared to machining with a cutting fluid. As MQL technology develops in collaboration with industry partners, its benefits will be recognized around the world [10].

Types of lubricants are used in MQL

Typically, MQL technology uses two types of lubricants. First, vegetable oil is a synthetic ester. It is considered a good lubricant due to its high flash point, high boiling point, low viscosity, good lubrication and high corrosion resistance. Thus, these types of oils are widely used in refining operations where friction diminution is more important [11].

Other types of lubricants used in MQL technology are fatty alcohols, which are prepared from mineral oils. Oily alcohols are said to be very effective for surface treatment and cooling of the cutting tool, and their lubrication is not as good as synthetic ester oil. For this reason, it is often used for processing operations that require effective heat dissipation rather than friction reduction. Both types of lubricants are known to be environmentally stable, biodegradable and non-toxic [12].

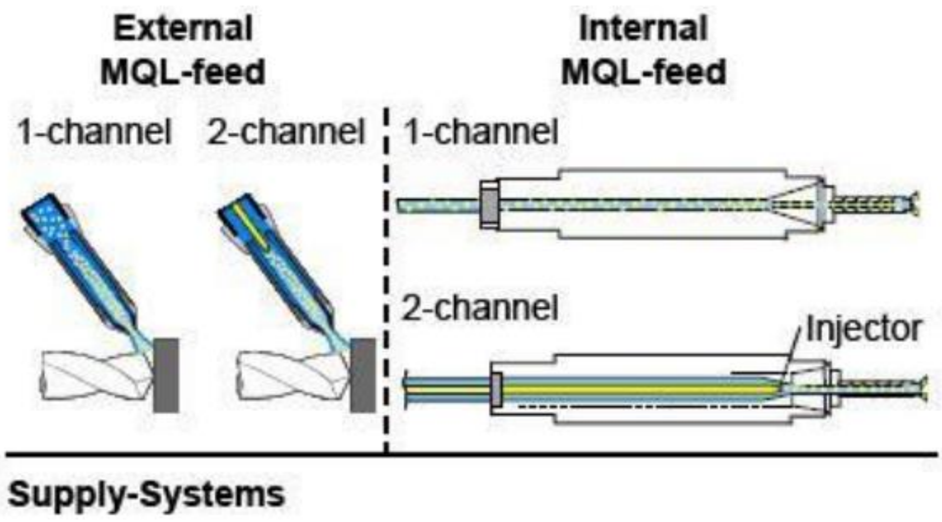

Figure 3: MQL Method [14]

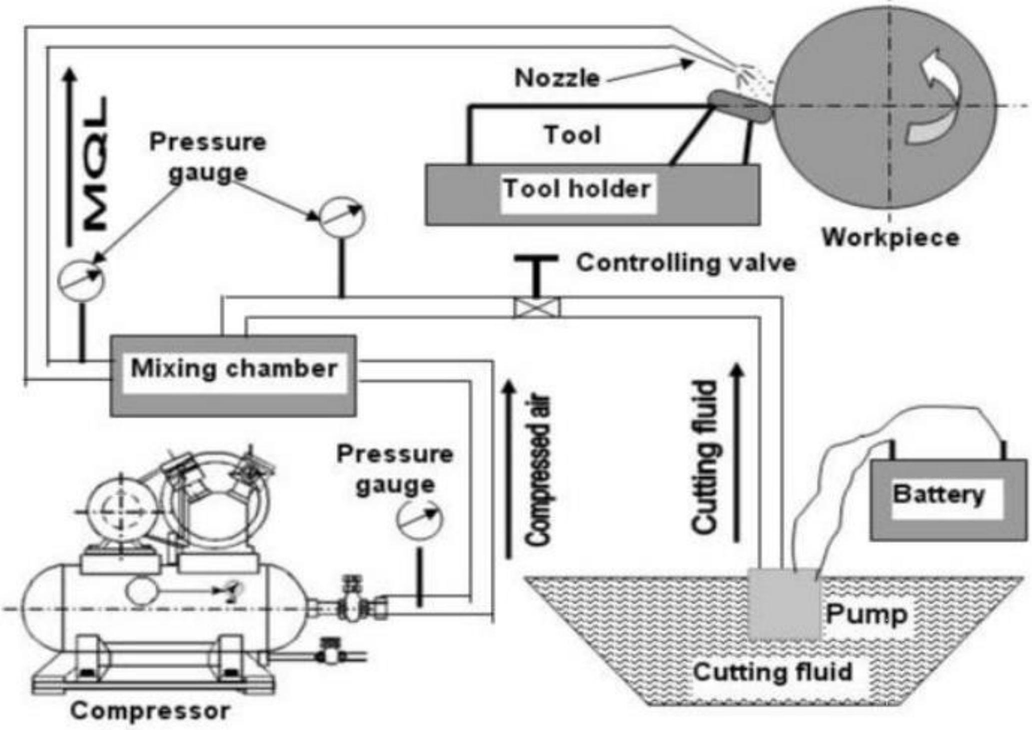

Figure 4: MQL setup [14]

II. RELATED WORK

Thakur et al. (2012) have studied the relationship between the hardening of the tool and its life with respect to different parameters such as speed of cutting, feed cutting depth etc. From experiments it has been shown that the tool life has been improved by treating tungsten carbide tool using cryogenic. In addition to this, cutting parameters not only minimized the hardening properties of cutting parameters but also prolong tools life [15]. **Hua and Liu (2018)** studied the effects of speed of cutting, feeding rate and radius of tool nose on the surface roughness, microhardness and work hardening of Inconel 718. Use three distinct cutting speeds for dry turning tests, three distinct feed rates, and two tools with distinct nose radii. Analysis reveals that the feed speed and the tool nose radius have a significant effect on the surface roughness of the machined surface, but there is no obvious trend between the cutting speed and the surface roughness. It has also been observed that degree of work hardening was directly related to the cutting speed and feed rate. However, when a larger nose radius is used, the degree of work hardening tends to be significantly minimized [16]. **Patel et al. (2019)** have prepared work-piece of two different angle 90°, and 60° respectively. The specimens have been prepared on the rake face and coated with PVD tungsten carbide. The experiments have been performed under cooling MQL condition on AISI 304 SS at different v and f conditions for both specimens. To show improvement in the prepared sample, comparison with un-textured tool under wet cooling and MQL condition has been presented. The results show that designed sample significantly reduced the surface roughness compared to the un-textured tool under wet and MQL condition [17]. **Patel et al. (2019)** have designed a micro grooved specimen and coated with tungsten carbide and examined its performance under dry condition. Micro grooves of dimension width (50 to 100 μm), spacing (15 to 100 μm), and depth of (10to 30 μm) have been prepared on rake face. During experiment cutting depth and speed both were kept constant. From analysis there is a significant tool wear were found on the micro textured specimen on the cutting surface [18]. **Trif, and Popan (2019)** have illustrated the experimental as well as theoretical concept of the roughness and cutting forces on the C45 carbon steel while exposed to external turning process. The study have provided the general idea about te turning, different roughness that were examined during the turning process of C45 carbon steel. This includes how the cutting force and the roughness forces were affected the simulation process of C45 using DEFORM 2D software [19]. **Mikołajczyk et al. (2020)** have examine the effect of cutting in different shapes that includes orthogonal cutting process and oblique cutting at different angles ranges from 0 degree to 60 degree. Experiment results demonstrated that with the increase in the λ_s angle, there is a minor change in the uncut chip thickness has been observed. Also the h_{min} value decreases with the increase in the λ_s angle. It opens up a new direction for cutting tool edges from beveling to finishing, and provides new ideas for the abrasive wear problem that may occur in micro-cutting [20]. **Abidi (2021)** studied ceramic tool life and machining productivity as well as the surface roughness during turning of hardened steel C45, with a focus on selecting the best combination of cutting parameters. The analysis has been performed based on the single factor planning method of cutting speed and feed rate. The results reveal that the hybrid ceramic tool was suitable for turning hardened steel C45 (40 HRC). It has been concluded that under the combination of cutting speed (200 m/min), it performs well in terms of tool life, productivity and surface quality, feed (0.08 mm) /rev) and depth of cut (0.3 mm) [21].

III. CONCLUSION

This research article presented a state of art in the application of cutting fluid such as mineral and vegetable oil. The MQL technique has been discussed for different machine learning processes such as drilling, milling etc. The effect of using MQL technique over the parameters has also been provided in distinct machining processes. Most of the researchers have proven that MQL approach performed better compared to dry and wet machining. MQL is also environmental friendly. Following points have been observed:

- MQL technique decreases the friction coefficient due to the better oil mist present in the contact area. This decreases the tangential force compared to the conventional grinding.
- For hard steel, MQL technique reduces grinding force. Although for soft steel, higher force was observed compared to fluid cooling condition.
- During high speed running of machine MQL milling performed better.
- Tool cutting temperature has been reduced and produced color chips in addition to dimension deviation.
- MQL improved tools life and illustrate about 40 % enhancement in material removal rate in contrast to aqueous flood.

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