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DIFFERENT COOLING AND LUBRICATING TECHNIQUE WITH ITS ENVIRONMENTAL IMPACT AND HAZARD: A REVIEW

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Abstract

Cooling and lubrication are very important in machining process. In this paper lubricating and cooling technique during machine operation as well as the application of nanofluids in machining are presented. These cutting fluids are the source of many environmental and biological problems. Sustainable machining technique is important to eliminate the ill effects associated with the cutting fluids. The use of vegetable oil, compressed air, liquid nitrogen, or minimum quantity lubrication (MQL) as a cooling lubrication medium are some example of sustainable way for machining technique.

1. INTRODUCTION:

The innovation and research through ages has led to the development of new substitutes which have been crucial in elimination of the drawbacks of cutting fluids like solid lubrication, minimum quantity lubrication (MQL), dry machining, sustainable cutting fluids, cryogenic cooling, gaseous cooling, and nanofluids. Though, the need for further endeavors in the analysis of these alternatives for environment as well as the economic aspect is clearly evident. The growing competitive market and availability of limited resources are main factors in making Sustainable manufacturing a recent trend in today's industrial setup. Further development in this field will not only reap financial benefits but will also help in putting check to environmental degradation. [1,2,3]. The necessity of shifting towards sustainable manufacturing is due to multi-dimensional factors like increase of occupational diseases amongst the workers working on the shop floor, strict environmental policies of the governments, and to reduce the manufacturing cost, etc. [2,3,4].

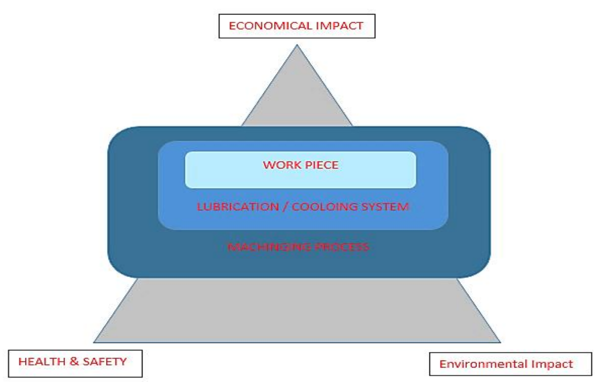

Table 1: Impact on sustainable manufacturing [46]

2. CONVENTIONAL LUBRICATION/COOLING SYSTEMS:

Cutting fluids are most commonly used as coolants and lubricants. Cutting fluids plays a major role in protecting the work piece and the machine tools from corrosion and even helps in reducing power consumption [5, 6, 11]. It reduces the temperature of the work piece and the tool, cleans the cutting area, and also washes away the air contaminants and debris in liquid, which if untreated, leads to various occupational diseases and air pollution. Viscosity and surface tension are the main characteristics of the cutting

Properties	**Straight oils**	**Emulsions**	**Semi-synthetic**	**Synthetic**
Aspect	**Oily**	**Milky**	**Translucent**	**Transparent**
Lubricity	***	**	**	*
Cooling	*	**	**	***
Corrosion Control	***	*	**	**
Microbial control	***	*	**	***
Fire	Hazard	Non flammable	Non flammable	Non-flammable
Disadvantages	Limited to low speed operation create mist	evaporation losses foam tendencies	Hard water influences foam tendencies	Easily contaminated by other processing fluids
Excellent-***; Good-**; Poor-*				

Table 2: Cutting Fluid Properties [46]

fluids as evacuation of chips of different type of work pieces depends on it. [7, 8, 12]. These factors increase the tool life, the cutting speed, improving the surface quality and meeting with the dimensional specifications, reducing the work piece damage. Thus, cutting fluids increases the productivity, improves the efficiency of the cutting tool by reducing the number of defects, which ensures the safety of the process and enhances the machining quality. Thus, the Cutting fluids play a significant role in machining as well as the efforts of addressing health and environmental concerns.[27]. In the processes of low speed machining, lubrication property of the cutting fluid is more useful than its cooling property. Cutting fluids minimizes the friction, due to which a lubrication film is created whose properties depends on the properties of the lubricant [9, 13, 14]. The reduced friction leads to low heat is generation, minimizing all types of wear and tear of the tool piece. When the cutting speed is increased, the heat generation also increases but wear due to built-up-edge (BUE) is reduced and the cutting forces are also lower.

3. ALTERNATIVE TO CONVENTIONAL CUTTING FLUID

Dry machining:

Cutting fluid is not considered in dry machining process. This has some negative impact on tool. While machining, the temperature of tool & workpiece increases because of decrease in heat removal process [15,16,17]. In this process tool wear is main concern which decreases tool life. So, selection of proper tool material for all type of machining process is necessary and which helps in improving wear resistance [21,23].

In this process for section of material various properties of tool should be consider like high toughness, resistance to temperature and pressure, high chemical stability, high hardness & high thermal fatigue [24,25].

In the machining operation where it involves lower cutting speed & does not require the workpiece to be precise, accuracy in dimension and also temperature dependent then we can consider dry machining operation [15]. This has some major advantages due to lack of or no interaction of water and atmosphere during machining process. This results in any chemical reaction while machining. During Machine operation we should ensure to draw hot chips efficiently and quickly, in this process it is observed that in workpiece and chip there is no fluid present as residues [10,11]. It helps in increasing productivity by decreasing energy cost, time by controlling or avoiding cleaning process and proper management in waste fluid treatment. It has some concern as disadvantages like excessive generation of heat, increase in friction between workpiece and tool poor removal of chip and adhesion of material on cutting tool. It is successfully implemented in aluminum machining process but still faces some challenges and hurdles in titanium machining process [22,23,25].

Minimum Quantity Lubrication:

Minimum Quantity Lubrication atomize small quantity of oil with the compressed air which forms a mixture. This mixture is sprayed as droplets on the cutting zone. The flow rate of oil in conventional lubrication is between 0.01-2 l/h. Earlier this flow rate was 50-1000 l/h. Synthetic esters which are chemically treated vegetable oil and fatty alcohols are the common products for machining in MQL system. The cooling effect in MQL system are carried out by fatty alcohols.

Cost reduction, reduce consumption of cutting fluid, less tool wear, improvement in surface finish and decrease in health hazards for workers are some of the advantages of minimum quantity lubrication. Fluid disposal is reduced during machining process combining with MQL because minimum cutting fluids are used in the process. With the help of MQL system recyclable clean chips are extracted.

Sharma et al. [20] signified that there is various alternative technique to use cutting fluids and MQL system is one of that technique. With the help of compressed air, heat is being removed in the process. It mainly focuses on Lubricant properties. When MQL technique is combined with cooled air during machining steel then it has been observed in improvement of cooling and lubricating technique. The mist formation during MQL is considered to be worst from environmental and workers point of view. So, we can use vegetable oil as an alternative to avoid harmful mist formation [18,19].

Solid lubrication:

Thoughts on minimizing the use of fluid coolants for manufacturing has been given due to multiple factors like expensiveness, human safety risk and environmental hazards. For this reason, the use of solid lubricant for operation for surface grinding has been studied. To lower the heat produced at the grinding zone graphite was used as lubricant [41].

In another experiment, cutting variables like cutting force, specific energy and surface finish has been experimentally investigated for machining AISI 1045 steel, cutting tool of different radial rake angle and nose radii with graphite-assisted and molybdenum disulphide lubricants were employed. The friction reduction to the solid lubricant has been concluded [42].

The property of high thermal conductivity and heat dissipation makes it more effective in comparison to cutting fluids in machining processes. At extreme pressure and temperatures, they are highly stable [45]. In an oxidizing media they can be used to 350°C and in non-oxidizing media the temperature can be even greater. Their layered structure with weak Van der Waals bonds is the reason behind its lubricity [43]. Their properties of wear resistance and low friction is due to the lavers which are capable of sliding on each other with small force. Their main applications are in aerospace and automobile industries, to lubricate inaccessible areas, were prolonged storage is required [44].

Cryogenic Cooling:

Carbon dioxide (CO2) at -78°C and liquid nitrogen (LN) at -196°C are main components in cryogenic cooling system. This requires high initial cost due to high equipment cost and require high skilled labor to implement this technique in industrial application. Crater wear on carbide tools can be reduced efficiently and effectively using CO2 liquid during the machining the alloys of titanium and austenite nickel based super alloys [12]. To achieve the temperature of -78°C and -196°C for CO2 and LN2 respectively [41], very special equipment are required and these special equipment are very expensive. In this process basic products are CO2 and LN2.

In this cryogenic cooling system, it has some very good advantages on the environment. During machining process LN2 is absorbed due to heating. It is being evaporated in the environment which does not cause any harmful effect and this is because 79% air on earth is comprised of N2 gas comparing to all of other gas present in environment [5]. During machining heat is being absorbed by liquid nitrogen and it is evaporated. When this liquid nitrogen is evaporated, a thick gaseous layer is formed which acts as a lubricant between tool face and chip [19].

Gaseous Cooling:

In this type of cooling system, the air present abundantly in environment is used as gaseous cooling. The gaseous coolants are being used those which are in gaseous state at room temperature. Air which is used as gaseous coolant has low cooling capacity can be increased by cooling the air remaining in same gaseous state. Helium, Nitrogen and argons are other gases uses as cooling system because it prevents tool and workpiece oxidation [42]. These are not used for common application due to high in cost, to increase the productivity and to reduce the cost of manufacturing [43]. When cutting fluid is combined with these compressed airs then fluid consumption is reduced. In super alloys machining the heat transfer is ameliorated [44].

To reduce temperature and cutting force and to achieve high feed rates and cutting speed, mixture of spray of vegetable cutting fluid, compressed air & liquified nitrogen is inserted in cutting zone [45].

Nanofluids:

Nano-fluids are Nano sized particles suspended into fluids. The current advancements in the field of Nano-technology has provided us Nano-fluids which can act as an alternative to the conventional cutting fluids and can be used in machining with MQL technique [28]. The tri-biological and enhanced heat transfer properties of these fluids will make the machining process more viable. They exhibit anti-friction and ant-wear properties to the base fluid and also has larger surface to weight ratio [32]. Due to their properties, Nano-particles made from materials like carbon, zinc, molybdenum, silver, diamond have been tested for machining operations [34,35]. The higher thermal conductivity due to the inclusion of solid particles makes it applicable as coolant. The cutting fluids used in the industries show poor heat transfer properties, when compared to solids. Since the thermal conductivity of solids are significantly greater than that of heat transfer fluids, thus, a suspension of colloidal solid particles with fluid was taken into consideration [30]. The thermal conductivity of the colloidal suspension was much greater than the conventional heat transfer fluids [29]. The penetration of Nano-fluids into deep unreached surfaces increases its heat transfer capacity significantly. The advantages of Nano-fluids as lubricants in machining is that lubricity over a wide range of temperatures can be achieved. The wear resistance of mixture of water and oxide graphene Nano-sheets is much better than pure water [31,39]. The stability of Nano-particles lubrication can be improved by mixing SiO2 and MoS2 or colloidal solution of silver with alumina. Nano-fluids with MQL system has been studied as an alternative cooling/lubrication system. For instance, better surface performance and reduced tool wear in MQL milling and grinding has been observed when mixture of Nano-particles and vegetable oil is used as lubricant.

E. Benedicto et al. [46] reviewed his work on use of Nano-fluids in industries is hindered due to the viscosity factor. The viscosity and thermal conductivity of the base fluid is increased when Nano-particles are added to it. Low clustering of particles or uniform and stable suspension is the required condition for Nano-fluids.

4. CONCLUSION

In both conventional and alternative lubrication/cooling system the mist is formed. However, mist can be controlled in an alternative lubrication/cooling system. Which help in controlling harmful impact on the environment & reduces the health hazardous of industrial worker. It will also help in reducing cutting force and temperature. The alternative lubrication system also helps in increasing the productivity of organization by optimize use of cutting fluid and helps maintaining the safety standard of organization. In this paper different machine techniques are discussed which include Minimum quality lubrication, cryogenic cooling, solid lubrication, gaseous cooling and Nano fluids

5. FUTURE SCOPE

1. Use of mist control system in MQL
2. Use of bio degradable oil like different type of vegetable oil
3. Optimizing the flow rate of lubrication to increase the productivity

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