Proceeding International Conference on Religion, Science and Education (2022) **1**, 627-632

A review on environmental friendly cutting fluids and coolant delivery techniques in grinding

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Abstract: Grinding is a very high-speed machining process, specifically, it is complex and often fails to achieve the accuracy, coolants are necessary for grinding to achieve the desired production rates. Coolant disposal is a serious issue since it poses a risk to the environment and land pollution. To reduce the friction and of frictional heating during grinding, suitable coolants and lubrication systems should be used, therefore, many approaches to eco-friendly coolant delivery techniques are been illustrated. Continuous long-term scientific research is needed toward green machining. "Go green, think green, and act green" statement should be followed in the industry during production and manufacturing. This literature survey was needed because it highlights previous and present research work on eco-friendly fluid delivery techniques, also the study explained how important this method will play in considering the future environment and workers' health.

Keywords: Grinding; Machining; Coolant; Lubrication; Environment.

Introduction

Coolant and lubricant contain different types of chemicals, to reduce the grinding temperature and chances of burning on the ground surface. Different types of coolants are used for machinings like water-based coolant, oil-based, synthetic or semisynthetic fluid, solid coolant or lubricant, and gaseous coolant. Natural vegetable-oil coolant is a newly developed coolant that is under the process of improvement. If all the machining and grinding processes can be carried out relying on vegetable oil as coolant then-new horizons will be opened towards green technology.

This paper has presented a review of research activities carried out in the application of different types of cutting fluid and coolant delivery techniques during grinding as well as machining. A brief description and mechanism of the cutting fluid delivery technique and systematically discussing its effect on performance in the grinding process are also presented. There is enough literature that reveals which cutting fluid is eco-friendly and which delivery technique provides better performance for grinding considering the environmental condition.

Different Types of Cutting Fluid and Coolant

Oil-based Cutting Fluids

Mineral, animal, vegetable, and synthetic oils are used to make neat oils, which are oil-based lubricants. Mineral oils are similar to petroleum-based oils. Sulfur, chlorine, and phosphorous are always added to neat oil lubricants to generate a thin solid salt film on hot, clean metal surfaces (Groover).

Xavior et al. determined (Xavior et. al.) the influence of oil-based cutting fluids on tool wear and surface roughness during turning of AISI 304 austenitic stainless steel with a cemented carbide tool. The feedrate contributed 61.54 percent to surface roughness, whereas cutting speed contributed ~46.49 percent to tool wear, according to the results of an ANOVA. Furthermore, they discovered that cutting fluid had a significant impact on both surface roughness and tool wear.

ISSN 2829-3355 | EISSN 2828-8467

Cutting fluid was used to efficiently reduce tool wear and, as a result, improve the surface finish.

Gas-based Coolant & Lubricants

Gas-based coolant-lubricants are air, nitrogen, argon, neon, helium, or carbon dioxide. The downside of cryogenic cooling is that when the temperature difference becomes too large, the accuracy of the machining processes suffers (Babic D.) Condensation and fractional evaporation of ambient air produce LN_2. Pure nitrogen has a melting point of 210 °C, which is maintained by LN_2 during post-slow boiling, despite the boiling point of 198 °C (Manivaran G.) The use of LN2 enables not only cooling but also lubrication of the grinding zone as together with LN_2 a mist is formed which surrounds the liquid stream and acts as a lubricating buffer layer in the grinding zone (Ahmed LS, Dhar NR).

Bag et al. applied (Bag S. et. al.) the Analytic hierarchy process as MCDM technique to find out desired grinding quality by choosing proper grinding parameters and they found under cryogenic environment using liquid nitrogen gas as coolant shows good grinding performance than other experimental conditions, but sometimes formation of a quenched layer on the ground surface reduces the surface quality of the workpiece.

Chiffre et al. investigated (Chiffre D. L) the performance of cryogenic CO_2 as cutting fluid in parting or grooving austenite steel. The best performance was obtained when adding a small quantity of lubricant vegetable oil to the gas. Liu et al. studied the application of water vapor as a new type of environmentally friendly coolant and lubricant. In this study, the friction test was carried out by using the water vapor as a lubricant.

Cordes et al. presented (Cordes S. et. al.) the findings of his research on the grinding and milling of high-strength stainless steel under liquid CO_2 delivery circumstances. When compared to dry grinding and milling results, there was a better machining efficiency and less tool wear.

Nano-fluid Coolant

Nanofluids are a new-fangled class of fluids created (K. Sudhakar et. al.) by distributing nanometer-sized solid particles into base fluids like water and lubricating oils to enhance their qualities. The coefficient of friction can be lowered by adapting to Nano lubricants at the tool chip interface. Nanoparticles are thought to deposit on the friction surface and compensate for mass loss, a phenomenon known as the 'mending effect.' The cooling and lubricating fluid contain carbon nanotubes, Al_2O_3, MoS_2, graphene, or diamond nanoparticles. Nanoparticles are used in cutting fluid because of their high thermal conductivity and exceptional tribological properties (Rabiei F et. al., Ravuri et. al., Zhang Y et. al.). Nano lubricant causes nanoparticles to roll at the tool chip interface, reducing friction and thermal deformation of the workpiece while also reducing lubricant consumption. Hisakado et al. investigated (Hisakdo et. al.) the frictional characteristics of paraffin by adding copper and nickel nanoparticles. It was discovered that the coefficient of friction has decreased by 18%.

Solid Lubricants

Graphite is often used as a solid lubricant because of its weakly-bonded hexagonal plate structure (Callister et. al.). Recently Molybdenum disulfide (MoS_2) has been used by Salmon (Salmon C et. al., Rishad A et. al.) as a ‘hard lubricant’ and Titanium Aluminium Nitride (TiAlN) has been used to resist wear on CBN wheels. This new coating of solid lubricant does not need to run in oil.

Methods

Newly Developed Vegetable-based Cutting Fluids

Growing demand for biodegradable cutting fluids has opened an avenue for the development of vegetable oils as an alternative to mineral-based cutting fluids (John J. et. al.). To endure the high temperatures encountered during machining, cutting fluids should have a higher flashpoint. Vegetable oils, on the other hand, have low thermal stability, oxidative stability, high freezing temperatures, and poor corrosion resistance. Because natural vegetable oils are made up of fatty acids with a long carbon chain, they have both cooling and lubricating properties (Y. M et. al.). Vegetable oils minimize friction and wear by providing a high-strength lubricant coating that interacts aggressively with metallic surfaces. This is due to the polarities of fatty acids, which make oriented molecular films available, resulting in oiliness and anti-wear qualities. Because it is resistant to temperature changes, the strong intermolecular connection gives a stable or increased viscosity coefficient (Lawal S et. al.).

Kuram et al. carried out (Kuram E. et. al) experiments to determine the effect of vegetable-based cutting fluids on thrust force and surface roughness during drilling of AISI 304 austenitic stainless steel with high-speed steel tool. The outcomes of cutting fluids made from vegetables were compared to those of commercial cutting fluids. When they used crude-sunflower oil as cutting fluids required less thrust force at a spindle.

Bellucci et al. evaluated (Bellecuo et. al.) the performance of vegetable-based oils in drilling austenitic stainless steel. Five vegetable-based cutting fluids at different levels of additive were tested. They observed that all vegetable-based oils produced better results than mineral oil in terms of tool life and thrust force. The best performance of vegetable-based oil was a 117 % improvement in tool life and a 7 % reduction in thrust force compared to mineral oil.

Lavanya et al. discussed (Lavanya TD et. al.) the possibility of using anti-bacterial additives to develop eco-friendly coolants based on water. The grinding ratio depends on the coolant. Grinding ratios are 0.63 & 1.24 for clay mixture & water respectively. When using Synthetic coolant the Grinding ratio is 1.79.

Discussion

Different Types of Coolant Delivery Techniques

Flood cooling

Flood cooling allows a large amount of cutting fluid to discharge through a nozzle or pipe. As a result, the fluid discharge rate or flow rate is very high. It may absorb more heat from the machine's entire body and machining zone. Overflow of coolant passes through grinding wheel and workpiece. Here is the chance of wastage of coolant. The volume flow rate of cutting fluid is 0.5 – 10 L/min (weblink). The cutting fluid is delivered without mixing with air. Flood cooling can cause the machine tool to corrode more quickly, thus effective insulation on the relevant sections is essential.

Figure 1. Flood coolant delivery technique.

MQL

In the Minimum Quantity Lubricant cooling delivery technique, a very less amount of cutting fluid is allowed to come out through the nozzle. So, the fluid discharge rate or flow rate is very low. It is capable of absorbing heat from the heat-sourced zone. Little amount of coolant passes through the contact zone of the grinding wheel and workpiece. Here is the less chance of wastage of coolant. The volume flow rate of cutting fluid is 0.05 – 0.5 L/hr (weblink). Less volume of cutting fluid is required.

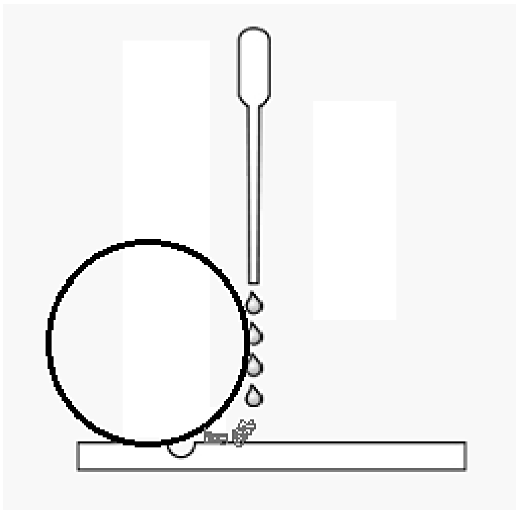

Figure 2. MQL coolant delivery technique.

Jet type coolant delivery technique

The nozzle of different sizes and shapes were used for jet-type coolant delivery technique. The nozzle helps to increase the pressure and reduce the velocity of the coolant. Due to jet formation, coolant can enter a particular grinding zone.

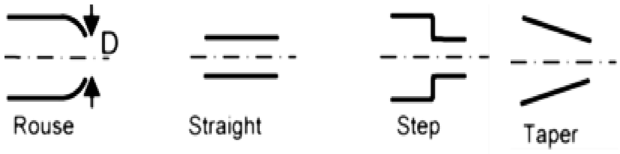

Figure 3. Different types of nozzle for Jet formation coolant delivery technique (Morgan MN et. al.).

Mist formation coolant delivery technique

Oil is passed through (Ahmed N et. al.) a special type of nozzle. The oil is delivered with very high compression air. Compressor device plays an important role. The coolant delivers as fog formation.

Figure 4. Mist formation coolant delivery technique.

Z-Z coolant delivery technique

Z-Z method is in which fluid is passed through the axial hole of the wheel, which passes through the pores and comes out from all over the wheel-periphery under centrifugal force. This process is very much effective and helps to improve grind ability.

Xu et al. carried out (Xu et. al.) research with this radial cooling technique. Although the construction of the wheels and coolant delivery system is more complex than conventional coolant application, they were able to increase the critical heat flux, improve the cooling effectiveness in the contact zone, and increase the overall efficiency of the grinding process. With radial jets, the temperature of the workpiece surface in the grinding zone was consistently kept below the film boiling temperature of 100°C–120°C for water-based coolants.

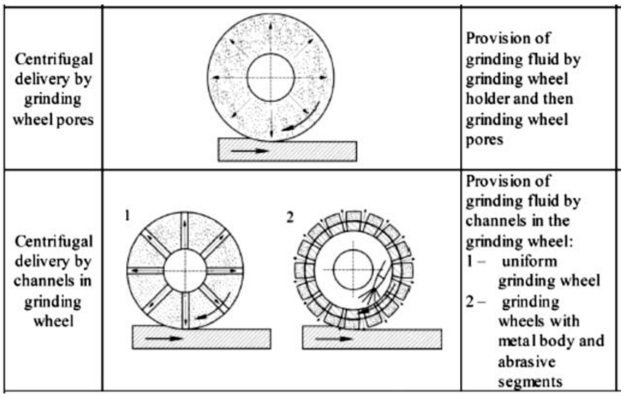

Figure 5. Two types of Z-Z coolant delivery techniques (Wittmann M et. al., Zhang LC et. al.).

Limitations of Commercial Cutting Fluid and Coolant

1) The toxic chemical contaminants present in the coolant will pollute the land and water when disposed of. The emissions from the coolant will also cause adverse effects to the machine operator (Salete M.A et. al.).
2) Mist, fumes, s,moke and odors generated by cutting fluids especially with chemical additives such as sulfur, chlorine, phosphorus, hydrocarbons, and biocides can cause skin reactions and respiratory problems as well (Belluco W. et. al.).
3) If due to negligence of worker, during grinding operation huge amount of CO2 entered ththe rough respiratory system then the level of oxygen in the blood will decrease and there is a chance of fainting.
4) If coolant mix with air and tentersnter on the respiratory system, it can cause cardiovascular disease, lungs infection, nervous imbalance mouth or nose ulcer, eye irritation (Gaurav MG et. al.).

Conclusions

If the uses amount of coolant offer quite good results during grinding and the environment is healthy, then huge coolant should not be used unnecessarily. Using the Mist cooling process the coolant can spread as fog formation in the atmospheric air. In the MQC method a very small amount of coolant comes in contact with grinding-zone with very high temperature, so it is likely to evaporate and may mix with air. Considering the environmental condition, Flood cooling, Mist cooling and Minimum Quantity Cooling processes can be used rarely. Many times there is a possibility of rot in the vegetable oil, so it is necessary to make the right preservation technology for maintenance. Considering all the aspects, from this literature survey it can be concluded that the Z-Z process of coolant delivery technique with pure vegetable oil as cutting fluid is fairly desirable for grinding.

Conflict of Interest: The authodeclaresre that there are no conflicts of interest concerning the publication of this article.

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