IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 3, May 2026

Impact Factor: 8.2

Performance Evaluation of Lubrication System in Machine Tools

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Abstract: *In order to enhance machine tool performance, efficiency, and life expectancy, lubrication is vital. Good lubrication reduces wear, reduces friction, maintains temperatures, and ensures that all moving components function effectively. Taking into consideration various issues such as friction reduction, temperature control, tool wear, and finish quality of the surface, the following research provides a comprehensive performance analysis of machine tool lubrication systems. Various types of lubrication processes, including dry machining, flood lubrication, and Minimum Quantity Lubrication (MQL), are critically analyzed. Results from experiments indicate that efficient lubrication significantly enhances machining performance, reduces tool wear, and increases efficiency.*

Keywords: Lubrication System, Machine Tools, Tool Wear, Friction, MQL, Surface Finish, Machining Performance

I. INTRODUCTION

With regards to the modern-day manufacturing process, machine tools are indispensable due to the need for precision, productivity, and reliability in producing superior parts. Heat and friction arise from plastic deformation and sliding contact, which occurs in operations such as turning, drilling, and milling because of plastic deformation and sliding contact between the machine tool and workpiece. The lack of control of these processes can result in bad surface finish, dimensional inaccuracies, faster tool wear, and reduced lifetime of the machine. Hence, through reduction of friction, minimizing wear, distributing heat, and ensuring efficient chip removal, the use of lubrication is necessary to improve performance [1],[2]. Despite the effectiveness of flood cooling in cooling and lubrication purposes, the disadvantages of flood cooling include fluid consumption and cost, among others [3]. As a result of this, new techniques of lubrication, such as MQL and dry machining, have gained significant attention. While dry machining does not involve cutting fluids and therefore has reduced environmental impact, it is restricted in usage due to higher temperatures and more tool wear [4]. On the contrary, the use of MQL provides an efficient compromise between lubrication efficiency and environmental friendliness, improving tool life and providing better surface finish due to small amounts of lubricant that are supplied directly to the cutting area in aerosol form [5], [6].

Tribologically speaking, processes such as adhesion, abrasion, and diffusion wear become part of the process in which the cutting tool, workpiece, and lubricant interact. The ability of the lubricant system to be able to produce a steady layer of lubricants at high pressures and temperatures is crucial to reduce the coefficient of friction as well as increasing the life span of the tools [9]. Besides, due to the fact that overheating near the cutting region is capable of degrading the quality of the tools used and hence wear out the tool sooner, thermal control becomes another important part of the lubrication system. Various complex techniques, such as cryogenic cooling and high-pressure coolant systems, have been used to address these challenges especially in the high speed and difficult cutting processes [10]. The effectiveness of lubrication systems not only depends on the nature of the material, but also on the machine parameters and geometry used. In recent years, the role of sustainable lubrication techniques has gained greater importance because of both economic and environmental reasons. Apart from the high cost of maintenance and waste disposal, most of the traditional cutting fluids are also highly hazardous, posing risks to human health and

DOI: 10.48175/IJARSCT-34925

the environment [12]. Thus, with a greater focus on environmentally sustainable lubrication techniques that use minimal amounts of lubricants but ensure effective machining, the development of such lubrication processes is gaining increasing attention in modern manufacturing operations. Also, with the development of Industry 4.0, there is an increase in the automation of lubrication systems through integrated control and sensing mechanisms, making it possible to monitor parameters like temperature, vibrations, and cutting forces. It is necessary to evaluate the lubrication system performance in machine tools for identifying the optimal lubrication procedures that enhance productivity, ensure sustainability, and meet the evolving demands of modern manufacturing industries.

Methodology and Experimental Setup

The performances of different lubricants used in machine tools are evaluated in this study by employing a systematic experimental procedure. The process involves comparing the performances of different lubrication methods through critical parameters such as tool wear, cutting temperature, surface finish, and material removal rate, among others, under flood lubrication, dry machining, and MQL. The experiment is conducted in a controlled machining environment in conventional or computerized lathes. Due to the wide range of applications in industries, an engineering material, for instance, medium carbon steel, such as EN8 or AISI 1045, is selected as the workpiece material. To make sure that there is uniformity in the process of cutting, a specific carbide insert tool design is adopted. Prior to undertaking the experiment, machine calibration must be done and all the relevant process parameters set at predetermined levels to ensure consistency in the whole testing process.In order to make a proper comparison, the machining parameters will be chosen by employing standard machining procedures and remaining constant throughout the various lubricating conditions. Examples of these are cutting speed, feed, and depth of cut. The depth of cut must range from 0.5 to 1 mm, feed rate must range from 0.1 to 0.3 mm/rev, and the cutting speed from 80 to 120 m/min. Three types of lubrication regimes will be employed during the experiments. The first one is the dry cutting regime, where there will be no application of cutting fluids. Flood cutting employs the use of a pump system that feeds cutting fluid into the cut region constantly. The MQL technique uses air compression to provide a very small quantity (50-100 ml/hr) of fluid as a mist spray to the work-tool contact area. Since it involves less fluid, the MQL technique assures precise and controlled lubrication.The following measurements can be taken in milling through the use of appropriate measuring equipment. Cutting temperature measurement can be carried out using an infrared thermometer or thermocouple placed near the cutting zone. Tool wear measurement is done mainly by considering flank wear using a toolmakers microscope. In addition, a surface roughness tester (profilometer) is utilized in the analysis of the surface roughness of the machined workpiece and will produce results such as Ra. For the calculation of productivity and MRR, machining time is also determined.To ensure the reliability and consistency of results, multiple tests are carried out in each case. Then, the data is analyzed and compared based on the three lubrication cases. This process will make use of statistics and graphics analysis, with particular emphasis on how lubrication affects the efficiency of machining.It is possible to identify the best and most sustainable lubrication system for machining tools through this systematic method, ensuring that the evaluation of its efficiency is reliable and unbiased.

Table 1: Machine Tool and Workpiece Details

Parameter	Specification
Machine Tool	CNC/Conventional Lathe
Workpiece Material	EN8 / AISI 1045 Steel
Workpiece Diameter	25–50 mm
Workpiece Length	100–150 mm
Cutting Tool	Carbide Insert (ISO standard)
Tool Geometry	Rake angle, clearance angle as per standard

DOI: 10.48175/IJARSCT-34925

Table 2: Machining Parameters

Parameter	Value	Unit
Cutting Speed	80–120	m/min
Feed Rate	0.1–0.3	mm/rev
Depth of Cut	0.5–1.0	mm
Cutting Environment	Dry / Flood / MQL	—

Table 3: Lubrication Conditions

Lubrication Type	Description	Flow Rate	Key Feature
Dry Machining	No lubricant used	0	Eco-friendly but high heat
Flood Lubrication	Continuous fluid supply	5–10 L/min	Good cooling
MQL	Mist lubrication with air	50–100 ml/hr	Low consumption, high efficiency

Table 4: Measurement Instruments

Parameter Measured	Instrument Used	Accuracy
Cutting Temperature	Infrared Thermometer / Thermocouple	±1–2°C
Tool Wear	Toolmaker’s Microscope	±0.01 mm
Surface Roughness (Ra)	Surface Tester (Profilometer)	±0.01 µm
Machining Time	Stopwatch / Digital Timer	±0.1 sec

Table 5: Experimental Plan

Experiment No.	Lubrication Type	Speed (m/min)	Feed (mm/rev)	Depth of Cut (mm)
1	Dry	100	0.2	0.5
2	Flood	100	0.2	0.5
3	MQL	100	0.2	0.5
4	Dry	120	0.25	1.0
5	Flood	120	0.25	1.0
6	MQL	120	0.25	1.0

Table 6: Performance Evaluation Parameters

Parameter	Symbol	Unit	Description
Tool Wear	Vb	mm	Flank wear measurement
Surface Roughness	Ra	µm	Surface quality indicator
Cutting Temperature	T	°C	Heat at cutting zone
Material Removal Rate	MRR	mm³/min	Productivity measure

Table 7: MQL System Specifications

Component	Specification
Lubricant Type	Vegetable oil / Synthetic oil
Air Pressure	4–6 bar
Flow Rate	50–100 ml/hr
Nozzle Position	Directed at tool–chip interface
Delivery System	Pneumatic spray

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II. RESULTS & DISCUSSION

Dry machining, flood lubrication, and Minimum Quantity Lubrication (MQL) were studied under similar machining conditions in order to test the efficiency of lubrication methods. Some of the parameters that were considered include tool wear, cutting temperature, surface finish, and material removal rate (MRR). Through comparison, we get clear information regarding the efficiency of each of the three lubrication methods. From the experiments, it is clear that the state of lubrication is one of the most significant factors that affect tool wear. In the case of dry machining, where no lubrication is present, there is metal to metal contact between the cutting tool and work piece. Flood lubrication provides cooling and lubrication efficiently; hence, it minimizes tool wear; however, MQL causes the minimum tool wear among all conditions. This is because MQL minimizes friction and provides adequate cooling with the formation of lubricating film at the point of contact between tool and chip. Longer tool life and lower tool cost have a strong relationship with minimized tool wear. Dry machining experiences the highest temperature since there is no cooling fluid used. Flood lubrication minimizes temperature by providing an efficient flow of fluid to the cutting zone. Similarly, MQL minimizes temperature greatly compared to dry machining due to efficient heat removal through the air-oil mist even with minimal use of lubricant. Even though it remains reasonably within limits, the cooling capacity is slightly less compared to that of flood lubrication.Based on the results obtained, dry machining results in the poorest surface quality in relation to Ra due to high friction and unstable cutting process. The cooling effect from flood lubrication reduces friction and helps in chip removal, hence improving the surface quality. Out of the three scenarios, MQL provides the best surface quality due to the lack of excessive fluid interference and consistent lubrication of the cutting process. As the machining parameters such as cutting speed, feed rate, and depth of cut were kept constant, MRR is relatively consistent for all forms of lubrication. Nevertheless, due to low wear rate and improved machining stability, which lowers downtime and tool change time, productivity is relatively higher in MQL and flood lubrication.

The following table summarizes the results of the study:

Parameter	**Dry Machining**	**Flood Lubrication**	**MQL**
Tool Wear	High	Moderate	Low
Cutting Temperature	Very High	Low	Moderate
Surface Roughness	Poor	Good	Very Good
Tool Life	Low	Medium	High
Lubricant Consumption	None	High	Very Low

It is clearly seen in the discussion that while flood lubrication provides good cooling, it uses excessive amounts of fluid and causes environmental problems. Dry machining, even though it is environmentally friendly, is not appropriate for processes that need accuracy and high tool longevity. Due to reduced effects on the environment, better finish quality, and reduced tool wear, MQL stands out as the optimal approach.In summary, it becomes clear that lubrication plays a crucial role in the efficiency of machining processes and that by employing advanced lubrication techniques such as MQL, output levels could be raised significantly, and costs reduced.

III. CONCLUSION

The above study on performance evaluation of machine tools lubrication system emphasizes the significance of lubrication in achieving better-quality products, durability of the tooling equipment, and higher productivity. The comparison of dry machining, flood lubrication, and minimum quantity lubrication illustrates the fact that although all three methods have their merits and demerits, there is a significant difference between their efficacies when considering performance characteristics. Although dry machining seems cost-effective and environmentally friendly because of the absence of fluids used for lubrication, it is not as effective as others in applications that require precision machining owing to high cutting temperatures, quick tool wear, and rough surfaces obtained during

DOI: 10.48175/IJARSCT-34925

machining. Conversely, flood lubrication has cooling and reduced tool wear benefits but has drawbacks such as excessive fluid consumption, higher cost of operations, and problems associated with handling and disposal of the However, based on their effectiveness and environmental impacts, the best lubricant among those discussed above is minimum quantity lubrication (MQL). This technique decreases friction, minimizes wear of the tools, and increases surface finish because there is enough lubrication between the tool and chip contact without using much fluid. While its cooling performance is slightly below that of flood lubrication, it is sufficient for most machining activities while significantly reducing costs and minimizing environmental impact.

The paper finds out that selection of the appropriate lubricant system plays an important role in enhancing machining efficiency. MQL combines both sustainability and high efficiency, making it suitable for modern manufacturing facilities. Moreover, utilizing advanced lubrication techniques together with smart monitoring systems would increase the efficiency of machining operations further and contribute to the transition towards Industry 4.0 and green manufacturing processes.Taking everything into account, proper design and optimization of lubrication systems would lead to higher productivity, increased tool life, improved surface finish, and reduced environmental footprint, all of which would contribute to efficient and sustainable manufacturing operations.

REFERENCES

[1] M. P. Groover, *Fundamentals of Modern Manufacturing*, 6th ed., Hoboken, NJ, USA: Wiley, 2020.

[2] S. Kalpakjian and S. R. Schmid, *Manufacturing Engineering and Technology*, 7th ed., Upper Saddle River, NJ, USA: Pearson, 2014.

[3] E. Brinksmeier, C. Heinzel, and M. Wittmann, “Friction, cooling and lubrication in grinding,” *CIRP Annals*, vol. 48, no. 2, pp. 647–672, 1999.

[4] J. P. Davim, *Machining: Fundamentals and Recent Advances*, London, U.K.: Springer, 2008.

[5] T. Obikawa, Y. Kamata, and J. Shinozuka, “High-speed machining using minimal quantity lubrication,” *International Journal of Machine Tools and Manufacture*, vol. 46, pp. 121–128, 2006.

[6] A. S. Kumar and A. K. Suresh, “Performance evaluation of minimum quantity lubrication in machining,” *Journal of Cleaner Production*, vol. 87, pp. 87–98, 2015.

[7] D. Dornfeld, *Green Manufacturing: Fundamentals and Applications*, New York, NY, USA: Springer, 2013.

[8] H. Klocke, *Manufacturing Processes 1: Cutting*, Berlin, Germany: Springer, 2011.

[9] B. Bhushan, *Introduction to Tribology*, 2nd ed., Hoboken, NJ, USA: Wiley, 2013.

[10] E. Brinksmeier, O. Riemer, and J. T. Evans, “Coolant strategies for high-performance machining,” *CIRP Annals*, vol. 59, no. 2, pp. 723–742, 2010.

[11] M. Sharma, S. K. Gupta, and A. K. Singh, “Performance evaluation of nano-fluid based MQL in machining,” *Journal of Manufacturing Processes*, vol. 32, pp. 415–425, 2018.

[12] D. Dornfeld and B. Linke, “Green manufacturing: Environmental considerations and sustainability,” *CIRP Annals*, vol. 61, no. 2, pp. 635–655, 2012.

[13] Y. Altintas, *Manufacturing Automation: Metal Cutting Mechanics, Machine Tool Vibrations, and CNC Design*, 2nd ed., Cambridge, U.K.: Cambridge University Press, 2012.

DOI: 10.48175/IJARSCT-34925