Journal of Advances in Manufacturing Engineering
Web page info: https://jame.yildiz.edu.tr
DOI: 10.14744/ytu.jame.2025.00001

Original Article

The effect of activation of oil coolants with ionized air on increasing the resistance of high-speed cutting tools

Eshreb DZHEMILOV*[1], Shoir KARIMOV[2]

[1]*Department of Mechanical Engineering, Crimean Engineering and Pedagogical University, Simferopol, Republic of Crimea*
[2]*Faculty of Mechanics, Tashkent State Technical University, Tashkent, Uzbekistan*

ARTICLE INFO

Article history
Received: 16 December 2024
Revised: 31 January 2025
Accepted: 28 February 2025

Key words:
Durability, high-speed cutting tool, ionized air, lubricating and cooling process environment.

ABSTRACT

The durability of the cutting tool significantly affects the productivity of metalworking. Increasing the durability of the cutting tool is the main task of lubricating and cooling technological means. Along with reducing the negative impact of lubricating and cooling liquids, the technology of minimum lubrication has become widespread. The disadvantage of this technology is the low cooling capacity of the working area. To solve this problem, this study proposes the combined effect of lubricating and cooling media supplied by the MQL together with ionized air. Ionized air acts as a dry lubricant, accelerating the formation of oxide films on rubbing surfaces. The temperature of the supplied air is reduced without additional equipment, which improves the quality of cooling without additional costs.

Cite this article as: Dzhemilov, E, & Karimov, S. (2025). The effect of activation of oil coolants with ionized air on increasing the resistance of high-speed cutting tools. *J Adv Manuf Eng*, 6(1), 00–00.

INTRODUCTION

Metalworking is one of the most common methods of obtaining a finished product, and plays a leading role in mechanical engineering. An integral part of a metal working operation are cutting tools, which have various design and geometric parameters. The quality of the parts obtained and the cost of their manufacture directly depend on the choice of tool material, geometry, and tool productivity methods [1].

The most common method of increasing productivity and quality of processing is the use of lubricating and cooling process media (LCPM) of various compositions, which have cooling, lubricating, cutting and plasticizing, cleaning, protective and strengthening properties [2–5]. Mineral oils and LCPM based on them are widely used in machine-building enterprises, however, the profitability of using such oils is significantly reduced due to the increase in auxiliary costs associated with transportation, storage, regeneration and disposal, in turn, widely used industrial oils and emulsions based on them negatively affect the health of production personnel, and are also one of the main pollutants of the environment [5–7].

Taking into account all of the above, in the world practice of metalworking, ways have been determined to reduce the negative impact of the applied cutting fluids, such as: a complete rejection of them and a transition to "dry" cutting, processing with a metered supply of a minimum amount of the process medium, and the creation of new, environmentally friendly compositions [6]. Today, a complete rejection of the use of cutting fluids is not possible. The metered supply of the process medium is not suitable for all process operations and does not completely resolve the issue of environmental safety. Therefore, the third option is more rational. Western manufacturers Blaser Swisslube (Switzer-

***Corresponding author.**
*E-mail address: eshrebdzhemilov@gmail.com

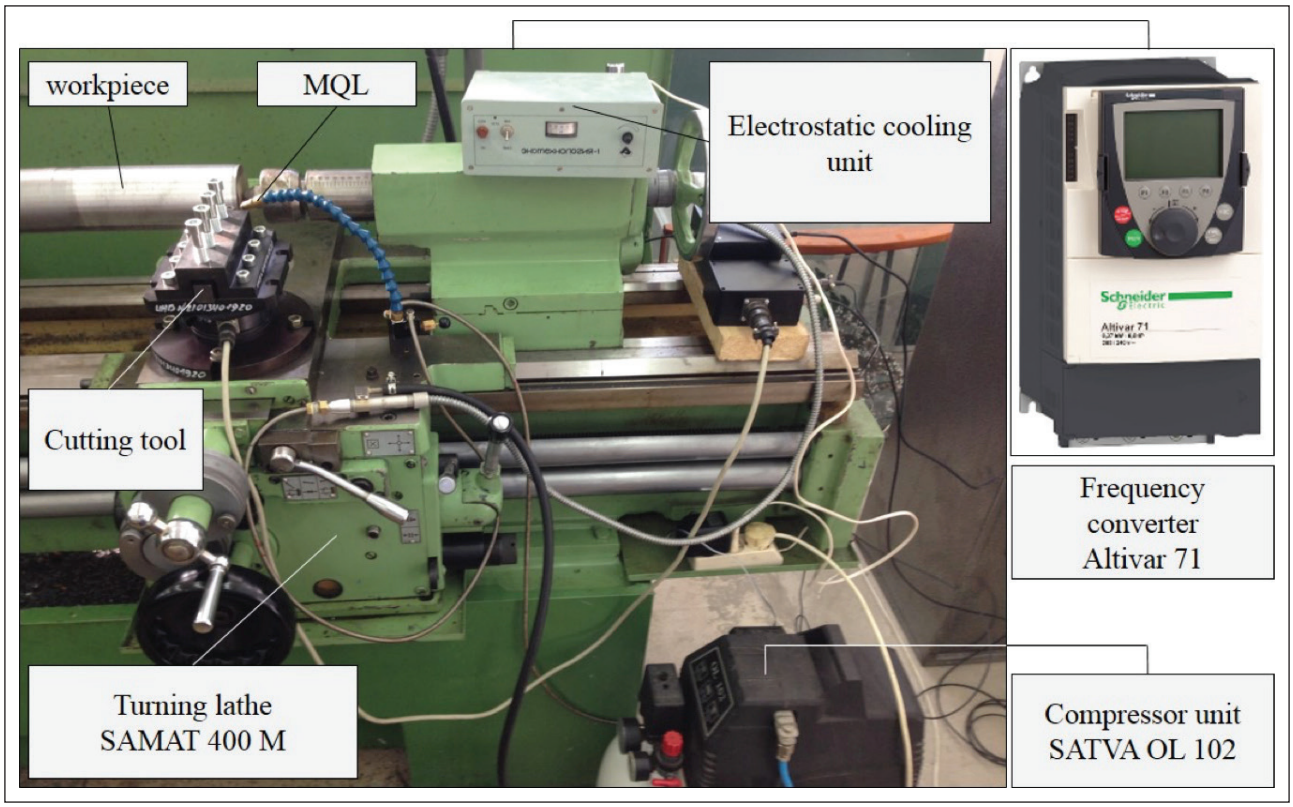

Figure 1. Experimental stand.

land) and Houghton (USA) have extensive experience and proven technologies for creating such compositions. These companies are engaged in the development and production of compositions that do not contain chlorine and sulfur compounds, while the tribological properties are preserved, and in some cases they increase, due to the introduction of esters of carboxylic saturated acids that do not have aromatic bonds. These acids are contained in large quantities in vegetable oils, taking this into account, it is possible to select for a specific type of processing.

Nowadays, machine-building enterprises often use oil coolants and emulsions based on them, the composition of which contains antifriction, extreme pressure and anti-fog additives, corrosion inhibitors, which in turn are organic compounds of nitrogen, chlorine, sulfur and phosphorus. When cutting metals, changes occur in these additives, especially during their evaporation and combustion, with the subsequent formation of hazardous compounds (CO, SO_2, HCI and others), negatively affecting the environment and the health of workers [7–10].

The rising prices and limited resources of petroleum products and mineral products and their impact on environmental pollution make it necessary to explore alternative and environmentally friendly process media for industrial purposes. In recent years, it has been shown that the use of vegetable oils as cutting fluids has undoubtedly improved the performance of mechanical processing due to the adsorption and chemisorption phenomena. In fact, these oils significantly improve the environmental performance of the cutting process compared with mineral cutting fluids [5–8].

The combined use of a metered minimum supply of sprayed cooling lubricants using special minimum quantity lubrication (MQL) devices affects the chip formation process in the cutting zone more effectively than traditional (flooding) supply. Using MQL technology to supply lubricant with a minimum consumption of process fluid, the lubricating effect of the medium becomes predominant, which directly affects the contact stresses in the working area of the tool, as well as the specific friction work, the load on the cutting system, plastic deformation, surface quality and wear rate of the cutting tool.

Most machining operations involve heating of tools, workpieces, chips and the environment. Cooling of the contact zone by the tool with the chips is relevant. In the context of the application of MQL technology and the decisive measure of this, ionized air will be used to form an air-droplet mixture. The efficiency of cooling the processing zone by supplying air passed through a corona discharge, in the works [9–11]. The penetrating effect of ionized agents is higher due to the directed movement of ions under the influence of electromagnetic fields as a result of exposure. Formed when an air flow occurs through a corona discharge, is a very popular method of joining and a strong oxidative transition to the formation of oxide films on the surface of the cutting tool, which, in turn, prevent wear.

Theory

During laboratory studies on measuring the content of ionized air in combination with oils (rapeseed and mineral I-20) on a SAMAT 400M screw-cutting lathe, increased accuracy was achieved, and an Altivar 71 frequency converter

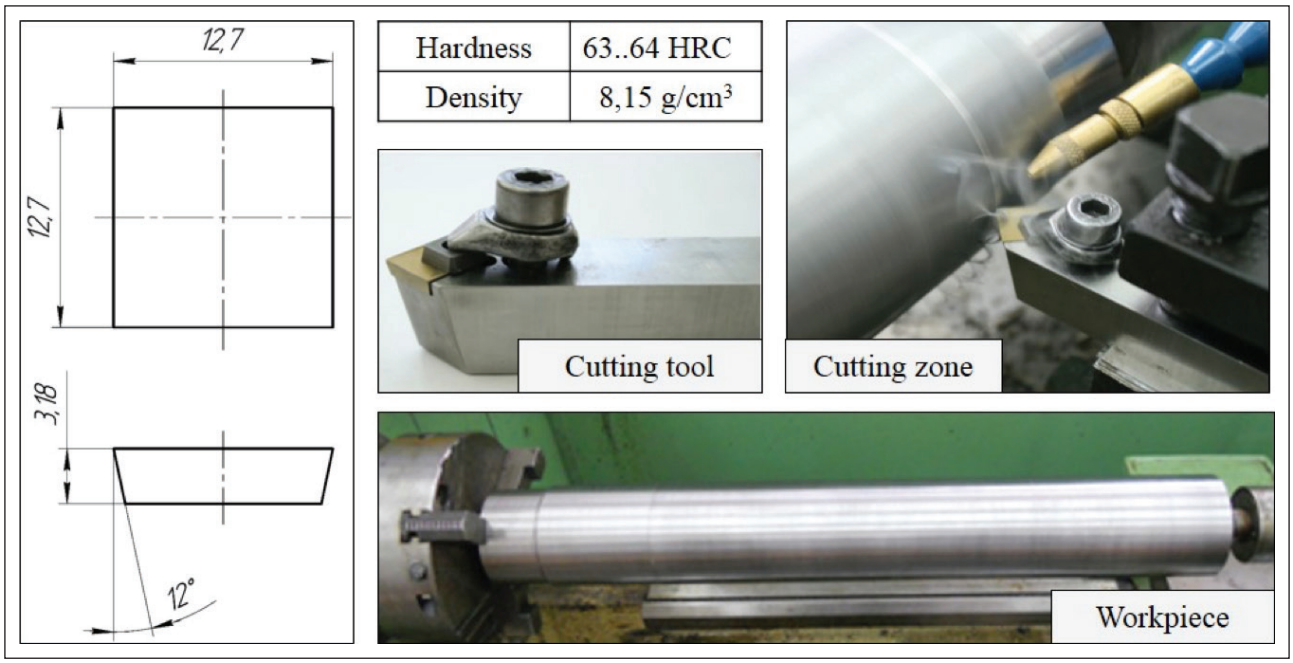

Figure 2. Workpiece and cutting tool.

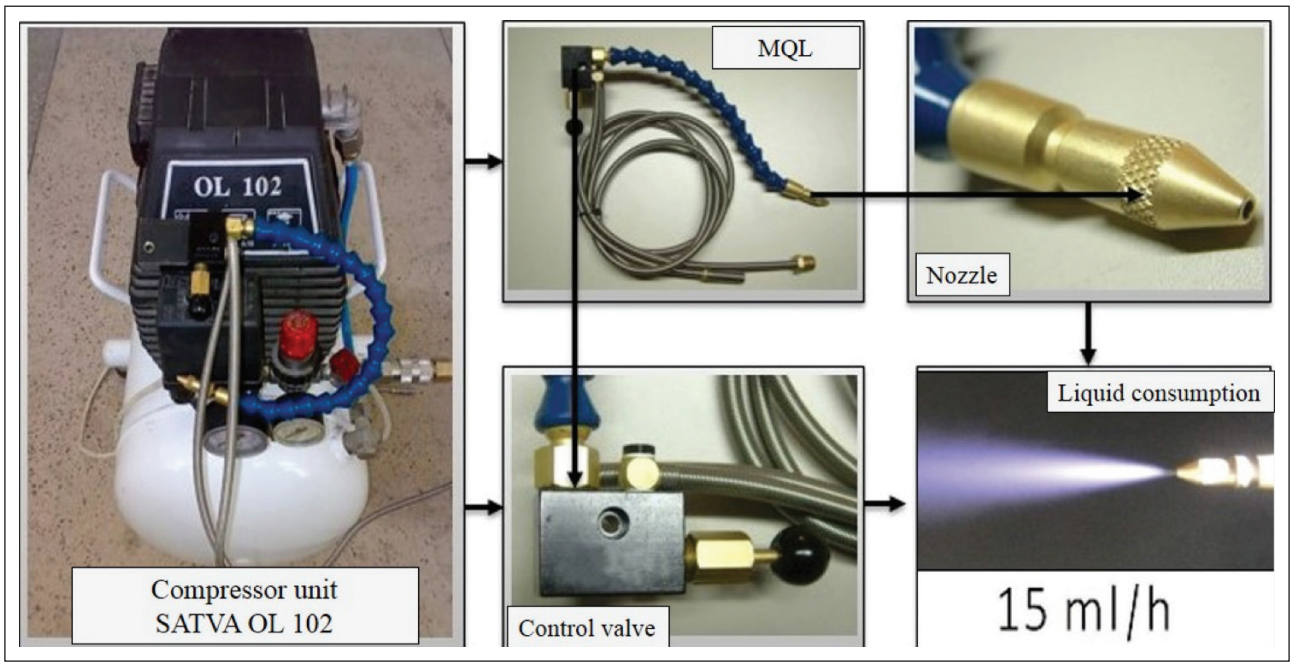

Figure 3. General view of the MQL and the SATVA OL 102 compressor unit.

was installed on the machine, allowing for a constant peripheral measurement speed. The general appearance of the stand for conducting experimental studies is shown in Figure 1.

The research was conducted on the following materials: steel 45 and stainless steel grade 12X18N10T. Multifaceted replaceable cutting plates ISO SPUN120308 made of high-speed steel grade HSSCo5 were used as the cutting tool (Fig. 2).

The supply of the cooling liquid was carried out in the form of an aerosol (containing a lubricant and ionized air) using a special dosing device. The general appearance of the device is shown in Figure 3.

The experiments were carried out at a constant cutting depth of t = 0.5 mm and feed rate S = 0.2 mm/rev. The cutting speed was V=55 m/min when processing 45 steel, and V=27 m/min for AISI321 stainless steel. The wear values were measured on the rear surface using an ИМЦЛ 150x75(2)Б instrumental measuring microscope. The wear criterion for the cutting plate was h_z = 0.35 mm in the normal wear zone on the rear surface of the tool (Fig. 4).

Air ionization was carried out using the "Экотехнология-1" electrostatic cooling unit (Fig. 5). Air ionization was carried out using the "Ecotechnology-1" electrostatic cooling unit (Fig. 5).

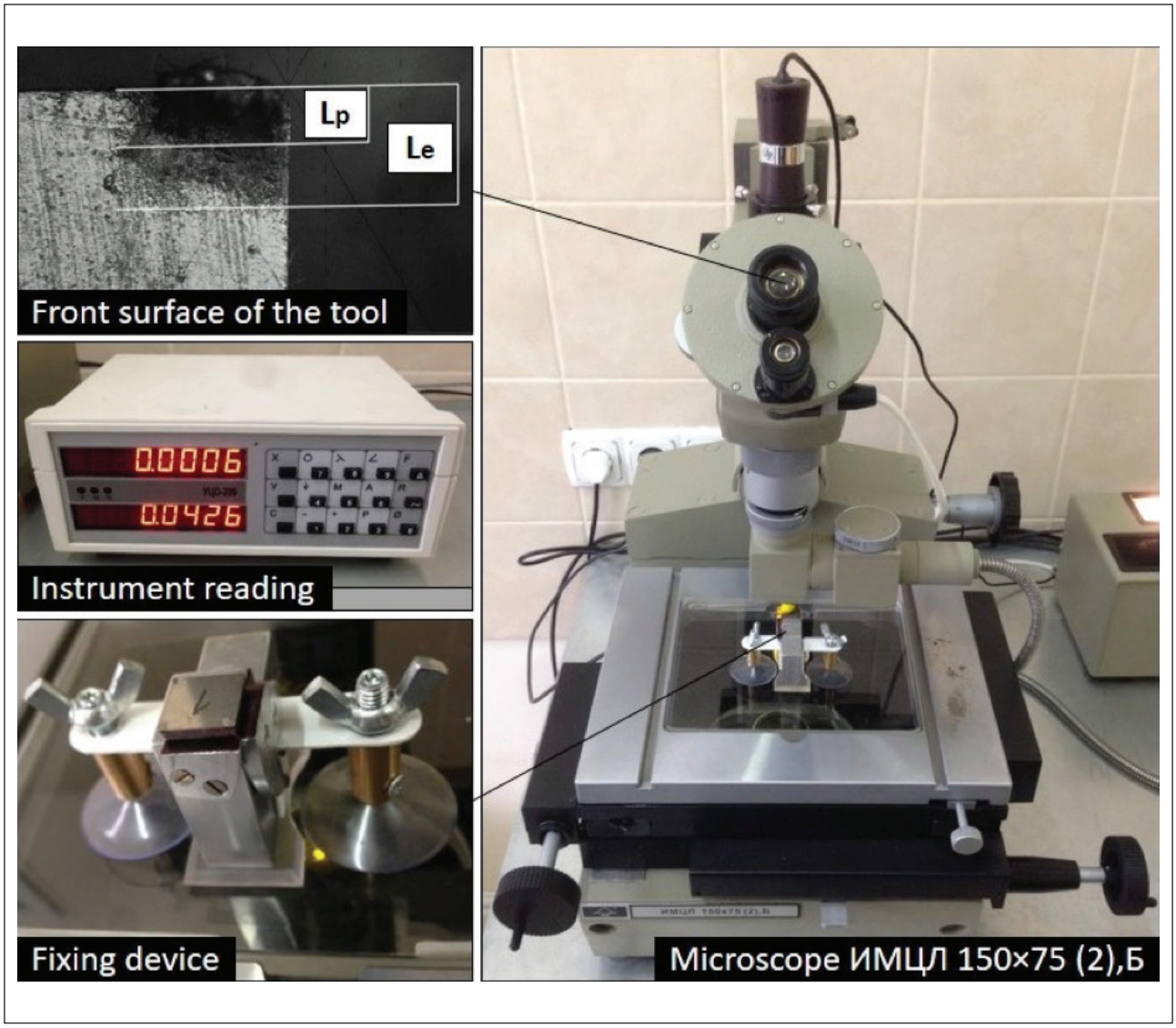

Figure 4. Wear measurement.

RESULTS AND DISCUSSION

The use of LCPM from the standpoint of reducing tool wear is primarily associated with a reduction in friction and temperature, which tend to preserve the original properties of the tool material and the conditions of contact interaction. Figures 6 and 7 show graphs of the effect of ionized air in combination with oil cooling lubricants on the durability of the cutting tool, from which it follows that ionized air in combination with vegetable (rapeseed) oil significantly exceeds the results of dry cutting and cutting in an ionized air environment in terms of durability.

The obtained experimental data can be explained by the fact that ionized gases and ionized-oil mixtures significantly affect the contact interaction, reducing the occurrence of adhesive phenomena and the friction coefficient, which is due to a 1.5-2.0-fold decrease in the volume of inhibited layers and build-ups, as well as the length of contact of the cutting tool with the chips, compared to the action of mineral-based cooling fluids. It was found that electrostatic air cooling promotes the formation of oxide and nitride films on the contact surface of the cutting tool, while reducing the contact area of the coming chips along the front surface. When using a combined method of feeding the cooling fluid to the cutting zone, a significant increase in the durability of the cutting tool is observed compared to dry cutting (Fig. 6, 7).

The obtained experimental data show the presence of rather complex parallel physical and chemical processes both in the external environment itself and in the contact zone of the tool with the chips. Modified oil cooling lubricants with ionized gas create condensation centers and contribute to an increase in the entropy of the process. From which it follows that the ionized air-oil flow contributes to an increase in the durability of the cutting tool made of high-speed steel.

In further research, it is planned to evaluate the combined influence of process fluids and activated gases when processing difficult-to-cut materials and for various technological operations.

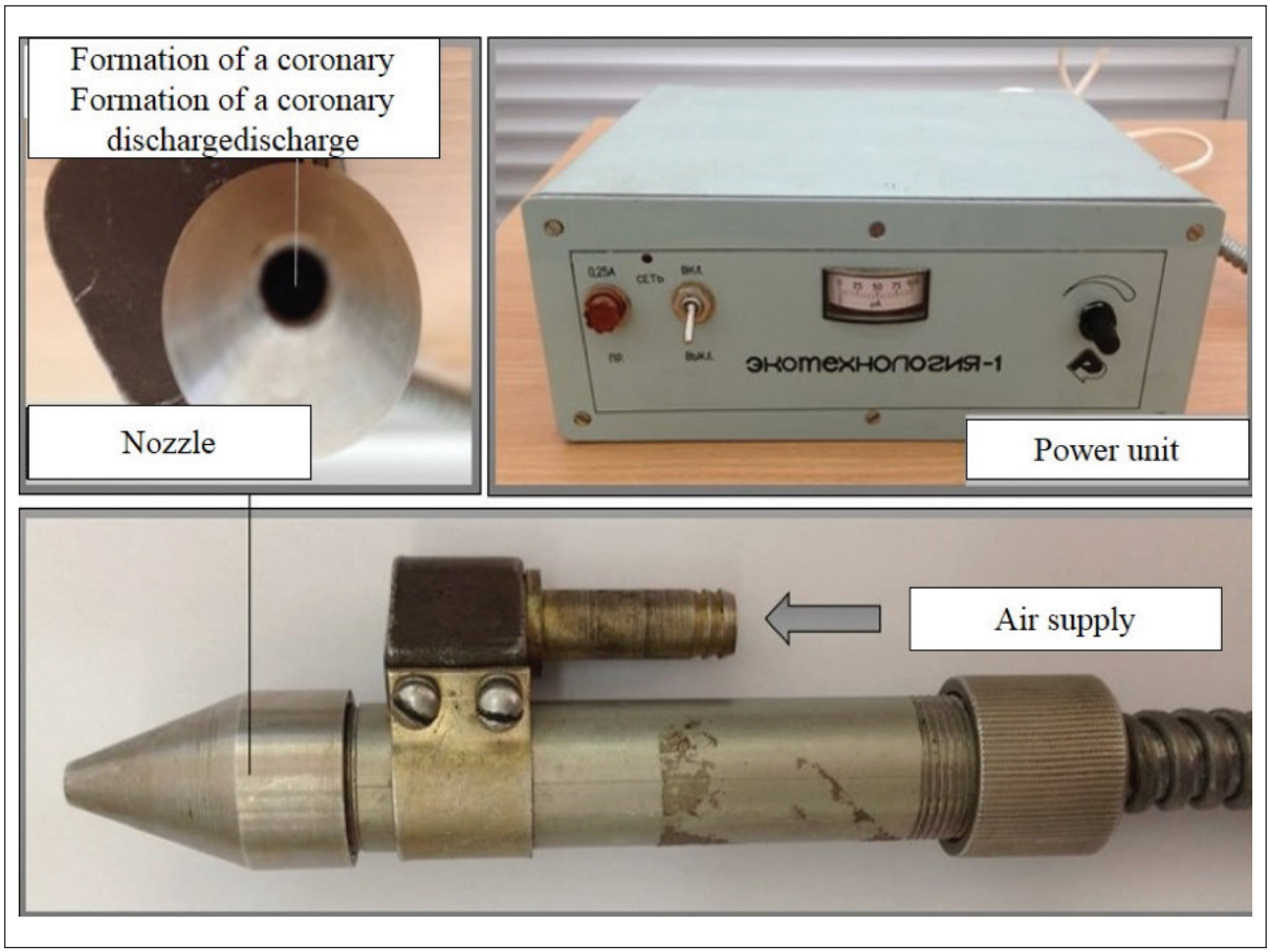

Figure 5. Electrostatic cooling unit "Экотехнология-1".

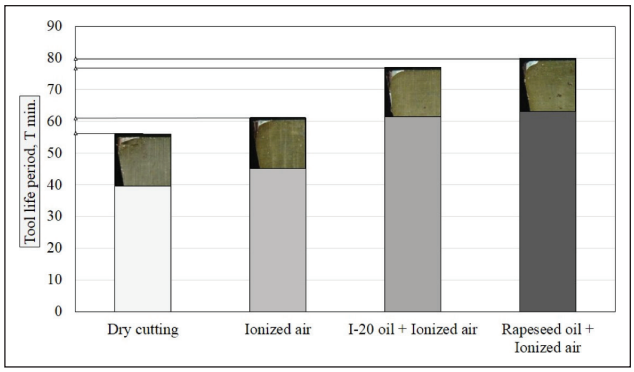

Figure 6. Wear of the cutter when turning C45 steel in various environments.

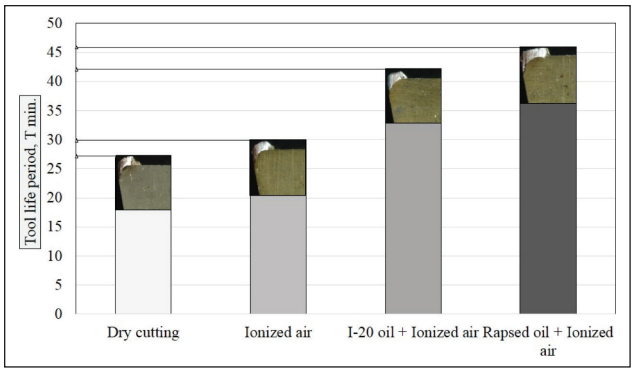

Figure 7. Wear of the cutter when turning AISI321 steel in various environments.

CONCLUSION

Based on experimental data, it has been established that the mechanism of action of the ionized air-oil mixture on the cutting process consists in changing the friction conditions in the contact zone of the tool and the workpiece. It has been shown that the process of air ionization in combination with the technology of minimum lubrication MQL, create the necessary conditions for increasing the durability and, accordingly, reducing the wear of the cutting tool, facilitating the process of plastic deformation during the cutting process.

Considering that the turning process takes place with the release of a large amount of heat, the influence of clean ionized air increases durability by up to 15% due to the formation of passivating films on the surfaces of the cutting tool. The formation of these films also reduces adhesive wear of the cutting tool.

With the combined influence of ionized air and process fluids, an increase in the durability of cutting tools is observed up to 27% when processing structural steel and up to 43% when cutting stainless steel.

Data Availability Statement

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

Author's Contributions

Eshreb Dzhemilov: Design, supervision, materials, data collection and processing.

Shoir Karimov: Conception, analysis and interpretation, literature review.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Use of AI for Writing Assistance

Not declared.

Ethics

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] Mali, R. A., Aiswaresh, R., & Gupta, T. V. K. (2020). The influence of tool-path strategies and cutting parameters on cutting forces, tool wear and surface quality in finish milling of Aluminium 7075 curved surface. *International Journal of Advanced Manufacturing Technology, 108*, 589-601. [CrossRef]

[2] Yakubov, C., Skakun, V., & Dzhemalyadinov, R. (2021). *The increase of cutting tool life with wear-resistant coating by a LCPM directional operation in a starting phase of metalworking*. Materials today: Proceedings. 2020 International Conference on Modern Trends in Manufacturing Technologies and Equipment, ICMTMTE 2020, pp. 1617-1621, 2020. [CrossRef]

[3] Yin, Q. A., Liu, Z. Q., & Wang, B. (2023). Prediction of temperature field in machined workpiece surface during the cutting of Inconel 718 coated with surface-active media. *Advances in Manufacturing, 11*, 378-389. [CrossRef]

[4] Dennison, M. S., Jebabalan, S. K., & Barik, D. (2024). Applicability of nano-cutting fluids for enhanced cooling, low tool wear, and high tribological performance during machining-a review. *Discover Applied Sciences, 6*, Article 663. [CrossRef]

[5] Pang S, Zhao W, Qiu T, Liu W, Yan P, Jiao L, & Wang X. (2023). Effect of cutting fluid on milled surface quality and tool life of aluminum alloy. *Materials, 16*(6), Article 2198. [CrossRef]

[6] Gunjal, S., & Sanap, S. (2024). Experimental investigation of tool life and chip thickness using vegetable oils as cutting fluids under MQL. *Journal of Mines, Metals and Fuels, 72*(2), 581-587. [CrossRef]

[7] He, L., Shi, J., Ni, J., & Feng, K. (2022). Investigation on cutting force reduction of eco-friendly cutting fluids with castor oil and additives in broaching. *International Journal of Precision Engineering and Manufacturing-Green Technology, 9*, 369-381. [CrossRef]

[8] Wang, H., Han, R. D., Tang, Y. L., & Wang, Y. (2010). Experimental investigation on green cutting GH4169 with ionized air cooling and lubricating. *Key Engineering Materials*, 426-427, 279-283. [CrossRef]

[9] Kurnosov, N. E., Lebedinskiy, K. V., Tarnopolskiy, A. V., Asoskov, A. S., & Perelygin, Y. P. (2017). Turning of structural steel while supplying cooled ionized air to the cutting zone. *Australian Journal of Mechanical Engineering, 16*(1), 58-64. [CrossRef]

[10] Ma, F., Tang, L., Zhang, J., Hu, Y., Li, B., & Sun, Y. (2023) The friction mechanics model within chip-tool-workpiece dual interfaces for cutting nickel-based superalloy at the cooling and lubrication conditions of the three forms oil-on-water mist in wide temperature range. *The International Journal of Advanced Manufacturing Technology, 125*(3-4), 1135-1159. [CrossRef]

[11] Esov, V. B., Klimochkin, K. O., Muratov, K. R., & Khurmatullin, O. G. (2011). Applying cooled ionized air for high speed milling. *Proceedings of the Samara Scientific Center of the Russian Academy of Sciences, 13*(4), 957-959.