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ANALYSIS OF THE EFFECT MECHANISM AND CHEMICAL COMPOSITION OF COOLING LUBRICANTS IN MECHANICAL PROCESSING

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Abstract
This study explores the efficiency of cooling lubricants used in mechanical processing, focusing on their functional mechanisms and chemical compositions. The analysis considers the influence of various factors, including the chemical properties and diversity of lubricant components, cutting conditions, and the material properties of both the workpiece and the cutting tool. The investigation also evaluates the impact of processing conditions on the overall effectiveness of cooling lubricants, providing insights into their optimization for enhanced performance and tool longevity. The findings aim to contribute to the development of more efficient and environmentally sustainable cooling lubricants in industrial applications.

Keywords: efficiency, chemical composition, operational properties, contact zone, lubricating film, washing actions, cutting parameters, lubricating actions, cooling actions, temperature, chemical reactions, processes.

Introduction

In mechanical processing, the role of cooling lubricants (CLs) is critical in ensuring efficiency, precision, and tool longevity. These lubricants not only reduce friction and heat during machining but also influence the surface finish and dimensional accuracy of the processed material. The selection and optimization of CLs depend on a complex interplay of factors, including their chemical composition, cutting conditions, and the properties of both the workpiece and the cutting tool.

Cooling lubricants typically consist of a base fluid combined with additives designed to enhance their thermal, lubricating, and protective properties. The chemical composition and the specific combination of components significantly determine the performance of the lubricant. Additionally, cutting parameters such as speed, feed rate, and depth of cut, as well as the type of machining operation, play a vital role in the effectiveness of CLs. Variations in the material being processed, such as hardness and thermal conductivity, further add to the complexity of lubricant optimization.

Despite the widespread use of cooling lubricants, there is a pressing need to understand their effect mechanisms better to improve their performance under diverse machining conditions. Furthermore, the environmental and health impacts of traditional lubricants have driven research toward developing more sustainable and eco-friendly alternatives.

This paper aims to analyse the mechanisms of action and the impact of chemical composition on the efficiency of cooling lubricants. By examining the relationships between the CLs' properties, processing conditions, and material characteristics, the study seeks to provide a comprehensive understanding that can guide the development of advanced lubricants tailored to specific applications.

Materials and methods

Mechanical engineering production widely uses various types of cooling lubricants in mechanical processing of machine parts. According to modern concepts, cooling lubricants produce lubricating, cooling, dispersing and washing actions during cutting. These actions can manifest themselves simultaneously and separately in different zones of the contact surface of the tool, chips and workpiece. This depends on the characteristics of the operation and cutting parameters, the characteristics of the processed and tool materials.

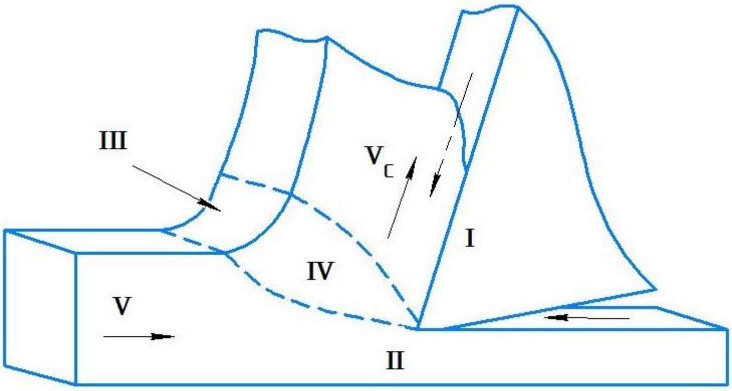

Fig. 1. Zones of action of cooling lubricant when cutting metals

In most cases, the high-performance properties of cooling lubricants are determined by their lubricating and cooling action. In contact areas I and II, the lubricating action of the cooling lubricant is predominantly manifested (Fig. 1). It is due to the ability of the cooling lubricant to enter into physical, chemical, physicochemical interaction with activated surfaces and form physical (adsorption) and chemical lubricating films on them. The final manifestation of the lubricating action is a decrease in the contact length, the work of friction forces, a decrease in the power of heat sources, an increase in the durability of the cutting tool and the quality of the machined surface [1,2,3].

There are many assumptions about the mechanism of penetration of the lubricating medium into the contact zone. According to the hypothesis first presented by prof. A.I. Isaev, penetration of the cooling lubricant into the contact zone is possible due to the vacuum (pump) action created by periodic breakdowns of the build-up. Periodic shedding of build-up particles ensures continuous formation of micro roughness in the contact zone and supply of the rubbing surfaces with lubricant.

Some works note that the penetration of the cooling lubricant into the contact zones occurs through a dynamic network of intersurface capillaries, under the action of a pressure difference at its ends. The sizes of the resulting capillaries, according to various researchers, are in the range of 1-50 microns and ensure a constant supply of cooling lubricant to the contact surfaces. Vibrations accompanying the cutting process, as well as artificially created vibrations of the cutting tool, have a similar effect on the penetration of the cooling lubricant into the contact zone. The method of feeding has a great influence on the penetration of the cooling lubricant into the contact zone. Additional kinetic energy imparted to the liquid when fed by spraying or a pressure jet contributes to better penetration of the medium onto heavily loaded contact surfaces. Depending on the processing conditions, physical and chemical lubricating films can be formed in the contact zone. Adsorption lubricating films are formed at low pressures and low temperatures. Surface-active molecules contained in the cooling lubricant are adsorbed on the contacting metal surfaces, forming a lubricating film. Such a film can withstand high normal stresses, but weakly resists the action of shear stresses. The higher the resistance of the boundary film to the action of normal and the lower the shear stresses, the lower the friction coefficient and the higher the lubricating ability of the medium [1,2,3].

With increasing temperature, physical adsorption turns into chemical adsorption, in which the active components of the cooling lubricant enter into chemical interaction with juvenile surfaces. The formation of chemical lubricating films is facilitated by the presence of oxygen, chlorine, sulfur, iodine or phosphorus containing compounds in the cooling lubricant.

In the contact zone, the molecules of such compounds can interact with each other, with atmospheric oxygen and the emitted electrons of juvenile surfaces, with the formation of atoms and radicals that enter into a chemical reaction with the metal, forming a lubricating layer.

Thus, the process of implementing the lubricating effect consists of the following stages: 1-penetration of the lubricant components into the contact zone, and 2 - adsorption and chemisorption of the components of the cooling lubricant with the formation of a lubricating film. At high cutting speeds, the efficiency of the lubricating action will be determined by the rate of formation of lubricating layers and, consequently, the penetrating properties of the components of the cooling lubricant and the rate of formation of the lubricating layer.

The lubricating action of the components of the cooling lubricant is also manifested in the fact that carbon, oxygen, sulphur, phosphorus and other elements included in their composition, under conditions of high pressures, stresses and temperatures, not only react with the metal surface to form a boundary lubricating film, but also diffuse into the thinnest surface layers of rubbing metal surfaces, forming eutectic alloys (secondary structures) with lower friction coefficients, shear resistance and melting temperatures. As a result, the processes of friction and plastic deformation of the metal are facilitated [1,2,3].

The efficiency of the lubricating action depends on the operation and cutting parameter, the properties of the workpiece and tool materials, the method of feeding the cooling lubricant and is determined mainly by the rates of formation and wear of boundary lubricating films, as well as their composition, structure and properties. During cutting, the main part of the mechanical energy is converted into heat and only a small amount of it is spent on changing the energy of the crystal lattice of the workpiece. With an increase in machine power and productivity, the role of cooling also increases. The cooling effect of the cooling lubricant consists in removing heat from the heated surfaces of the cutting tool, chips and workpiece. As a result of the cooling effect, the average cutting temperature decreases, and the contact length decreases due to an increase in the curvature of the chips due to the difference in temperatures of its inner and outer surfaces. The cooling effect of the cooling lubricant is based on the laws of heat exchange.

The cutting tool, workpiece and chips heated to high temperatures transfer part of the heat to the cooling lubricant by convective heat exchange. In addition, heat removal during cutting can be carried out due to heat transfer by radiation, evaporation of the medium and chemical reactions occurring during the absorption of thermal energy. Heat exchange is most strongly influenced by the viscosity, thermal conductivity, heat capacity, density and wettability of the cooling lubricant, as well as the temperature difference between the cooled surface and the liquid flow [1,2,3].

Analysis of the mechanism of heat transfer from the heated surface to the liquid shows that heat is removed through a thin wall layer with a thickness of 50-150 microns. Therefore, the use of high flow rates of cooling lubricant (more than 1.2-1.5 l/min) is not advisable in terms of increasing the efficiency of the cooling capacity.

In most cases, effective cooling has a positive effect on the durability of the cutting tool, roughness and accuracy. For a number of metal cutting operations, the efficiency of the cooling effect of the cooling lubricant increases when the liquid is supplied in a sprayed state, under pressure or through internal channels in the tool compared to the supply of cooling lubricant by pouring a free-falling stream.

However, cooling can also have negative consequences. For example, when milling with a carbide tool at a high cutting speed, the use of cooling lubricant leads to the occurrence of thermal stresses in the cutting part of the cutter and reduces its durability. In addition, effective cooling can also lead to the occurrence of internal tensile stresses in the metal, which worsens the operational properties of the product [1,2,3].

In sections III and IV (Fig. 1), the dispersing effect of the cooling lubricant is manifested. This action is based on the Rehbinder effect, which is a set of phenomena consisting in a change in the mechanical properties of solids under the influence of surface physicochemical processes that cause a decrease in the surface energy of solids.

The Rehbinder effect is observed to varying degrees for solids of all types and structures. Its manifestation is associated with numerous physicochemical factors: the chemical composition of the solid and the environment, which determines the nature and intensity of interatomic interactions; the real structure of the solid; the conditions of deformation and destruction.

Depending on the combination of all these factors, the Rebinder effect can manifest itself in varying degrees and in various forms, from facilitating plastic deformation to significantly reducing strength, leading to the emergence of brittleness, right up to spontaneous dispersion of the solid into particles of colloidal sizes. When metals are deformed, the adsorption of organic substances causes a decrease in the yield strength and hardening coefficient, accompanied by a decrease in the distance between the active slip lines of dislocations, which in some cases ensures strong plasticization of single crystals and polycrystalline metals. The peculiarity of these processes is that large organic molecules cannot penetrate into the volume of the solid and their action is limited only to its surface [1,2,3].

During metal cutting, chips and sludge are formed, consisting of fine chips, particles of tool wear and rubbing machine parts, scale, dust, dirt, products of thermal-oxidative destruction of components of the cooling lubricant and the vital activity of microorganisms. Solid colloidal particles of sludge penetrate into the microroughness of the workpiece, machine parts and tools, where they are firmly held by electrostatic and mechanical forces. The accumulation of sludge particles leads to a decrease in the tool life and deterioration in the quality of the treated surface. Thus, the washing action of the cooling lubricant consists in washing out solid particles, carbides, small chips, non-metallic inclusions from the cutting zone. Cooling lubricants used for drilling deep holes, for cutting threads in blind holes during grinding must have high washing capacity. In cutting processes, cooling lubricants of oil and water-miscible classes are widely used. Their component composition is determined by the cutting conditions, as well as a set of physical and chemical, operational, sanitary and hygienic, and environmental requirements. Oil cooling lubricants are mineral oils with a viscosity at 50°C (2-40)$\cdot 10^6$ m^2/s without additives or with additives of various functional purposes - antifriction, antiwear, antiseize, antioxidant, detergent, antifoam, antifog, anticorrosive, etc. This class of cooling lubricant has good lubricating properties, ensures a long service life of the cutting tool, protects the workpiece and machine parts from corrosion. The disadvantages of oil cooling lubricants include low cooling capacity, high cost, increased volatility, fire hazard and low thermal stability.

The largest part of modern cooling lubricants are water-miscible cooling lubricants - emulsion, semi-synthetic and synthetic. These cooling lubricants have a number of advantages over oil ones: higher cooling capacity, fire safety and less danger to workers' health, relatively low cost, fire safety and less toxicity. At the same time, they also have a number of disadvantages - the need to solve disposal issues, low efficiency in certain operations and insufficiently high stability of properties over time.

Emulsifying cooling lubricants (emulsols) are mixtures of petroleum oil, emulsifiers, binders, corrosion inhibitors, biocides, antifriction, antiwear, extreme pressure, antifoam and other additives. When mixed with water, they form emulsions. Medium-viscosity petroleum oils are used as the basis for emulsols, the content of which in the emulsol can reach 85%. In cutting processes, emulsols are used in the form of 1-10% emulsions in water, depending on the operating conditions [1,2,3].

The composition of semi-synthetic cooling lubricants is similar to that of emulsols in terms of component composition, but differs significantly in component concentration. The basis of semi-synthetic cooling lubricants is water (up to 50%) and emulsifiers (up to 40%). A low-viscosity (2-10)$\cdot 10^6$ m^2/s at 50°C petroleum oil is an obligatory component. They are used in the form of 1-10% aqueous solutions (transparent or slightly opalescent). Synthetic cooling lubricants are a mixture of water-soluble polymers, surfactants, corrosion inhibitors, biocides, antifriction, antiwear, extreme pressure and other additives. They can be made in the form of powders and are used in the form of 1-20% aqueous solutions depending on cutting conditions. Synthetic and semi-synthetic cooling lubricants have a number of advantages over emulsifying ones in terms of stability, service life, and transparency. However, these cooling lubricants are expensive, and their disposal is associated with a number of difficulties.

Good cooling and lubricating properties of emulsion and semi-synthetic cooling lubricants are ensured by the presence of both water and oil in their compositions. The compatibility of mineral oil with water, and the formation of colloidal solutions, as well as the maintenance of the resulting systems over a long service life, are facilitated by the introduction of emulsifiers, stabilizers, and binders into the cooling lubricant [1,2,3].

The role of antifriction additives is that during the cutting process they form adsorption lubricating films on the contact surfaces and thus reduce friction. Technical vegetable and animal fats, fatty acids, organic acid esters, as well as amines and their derivatives are usually used as antifriction additives. The content of antifriction additives in cooling lubricants is 0.5-20%. Anti-wear additives, due to the presence of chemically active elements - sulfur, chlorine, iodine, fluorine, nitrogen, etc. - are able to prevent seizing and intensive wear of the cutting tool.

The concentration of anti-wear additives in cooling lubricants is usually 0.15-5% depending on the purpose of the cooling lubricant, as well as the presence of other additives. Anti-seize additives are added to cooling lubricants to prevent the cutting tool from seizing with the workpiece and to reduce intensive wear of the cutting tool at high temperatures and mechanical loads. The action of extreme pressure additives consists in the chemical interaction of their decomposition products with contacting metal surfaces. As a result, chemical compounds with metals with lower shear resistance and a lower melting point than the original metal are formed. The chemical lubricating film reduces cutting forces, prevents adhesion and diffusion.

Depending on the cutting conditions, the content of extreme pressure additives can be 0.5-50%. Sulfur and sulfur-containing compounds (sulfurized oils, sulfofresol, Ukrinol-3, Aquol-2, etc.) are widely used as additives due to their high lubricating capacity. The high lubricating capacity of these compounds is due to the fact that the formed films - sulfides, retain their properties at temperatures up to 850 °C [1,2,3].

The high lubricating capacity of chlorinated oils and paraffin, etc. is widely known. The basis for the high efficiency of the lubricating action of chlorine-containing additives is the ability of molecules to release atomic chlorine when in contact with a juvenile surface or under the influence of high temperature. However, the disposal of used cooling lubricant containing chlorine compounds presents certain difficulties, since hydrochloric acid is formed when it is burned. In the practice of cutting metals, especially when cutting difficult-to-machine materials: stainless steels, molybdenum, nickel and titanium alloys, the use of cooling lubricants containing iodine and its compounds is effective.

The basis for the high lubricating action of iodine-containing cooling lubricants is the mechanism of destruction of neutral iodine molecules into radicals and the initiation of chain reactions with the formation of protective films. Oxygen, the main component of the cooling lubricant, plays a huge role in the formation of separating films. It has been established that increasing the concentration of dissolved oxygen to 22% leads to an increase in tool life by 2-4 times. The role of oxygen in increasing tool life is that under the action of activating surfaces, hydrogen peroxide is formed, which plays the role of a lubricant.

Based on this fact, a number of cooling lubricants have been developed that include hydrogen peroxide. Polymers are increasingly used as additives to cooling lubricants. Their use is based on the fact that during their thermal destruction in the cutting zone, complex organic radicals are released that have increased chemical activity with respect to juvenile surfaces of the tool and chips, as well as the ability of polymers to activate the process of surface deformation and dispersion of solids [1,2,3].

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Tribopolymer-forming additives have recently become widespread as components of cooling lubricants. The components of these additives under conditions of high temperature, pressure and chemical activity are capable of entering into polymerization reactions with the formation of friction polymers with high tribological properties.

The role of anticorrosive additives (corrosion inhibitors) is to prevent corrosion on metal parts of equipment and the workpiece. Among the anticorrosive additives in oil cooling lubricant compositions, the most widely used are polymeric unsaturated fatty acids, alkaline earth salts of fatty, naphthenic, alkylsalicylic and sulfonic acids, oxyethylated fatty amines and amides, derivatives of olkenyl succinic acid, oleyl sarcosine, disulfides, aminophosphates and dialkyl dithiophosphates.

Sodium nitrite is widely used as a corrosion inhibitor in water-miscible cooling lubricants. The content of anticorrosive additives is 0.1-1.5%.

Oil cooling lubricants lose their properties as a result of interaction with atmospheric oxygen. Alkylphenols and bisalkylphenols are used to stabilize them against oxidation. The addition of 0.1-0.2% of the specified additives provides the cooling lubricant with high antioxidant properties.

In order to prevent the deposition of sludge and resinous substances on the surfaces of the cutting tool and workpieces, as well as to prevent oxidation, detergents and dispersants are introduced into the cooling lubricant. Depending on the type of cooling lubricant, the type of processing and the workpiece, the content of detergents and dispersants in the cooling lubricant ranges from 0% to 3%.

The introduction of some polymers into the cooling lubricant at a concentration of 1-2% can significantly reduce their tendency to form fog. The introduction of some components may have side effects. For example, emulsifiers increase the foaming ability of the cooling lubricant, which worsens the technological properties of the cooling lubricant. To prevent foam formation and reduce its stability, antifoam additives are added to the cooling lubricant. The role of such additives can be played by alkyl sulfates, calcium lanolin soaps, calcium oleate and polysiloxanes. The concentration of such additives is 0.001-0.01%. Cooling lubricants have one or another smell, which is given to them by the components - the base and additives. Therefore, reodorants are added to the cooling lubricant - substances that suppress unpleasant odor. Pine oils, α-pinene, ester aromatic substances are used as reodorants. Their concentration is 0.1-1.0%. Improving the smell of the cooling lubricant is controlled by the degree of purification of petroleum oil, the concentration of additives. Deodorization of additives used to improve the smell of the cooling lubricant allows to exclude the use of reodorants altogether [1,2,3].

The most important properties of the cooling lubricant can be significantly worsened by bacterial contamination. Bacteria destroy the components of the cooling lubricant that ensure its durability and high-performance properties, reduce the pH value, worsen the anti-corrosion properties, cause the appearance of an unpleasant odor and lead to the need to replace the cooling lubricant.

Conclusions

To protect the cooling lubricant from microbiological damage, biocides are introduced into them: bactericides are used against aerobes and anaerobes, fungicides against fungi; biocides with bactericidal-fungicidal action are also known. Triazines, oxazolines, thiazolines, products of interaction of heterocycles with aldehydes, etc. have found wide application as biocides to cooling lubricants.

Thus, the analysis of the mechanism of action and component composition of cooling lubricants shows that:

- the efficiency of manifestation of functional actions of cooling lubricants depends on the chemical composition of the cooling lubricant, the material being processed and the material of the cutting tool and the processing conditions.
- taking into account all these factors will lead to complication of the composition of the cooling lubricant, the technology of its preparation, maintenance measures, and ultimately to an increase in the cost of mechanical processing;
- the efficiency of the lubricating and dispersing action is determined by the monomolecular layer, and the cooling action is also determined by a thin layer of about 50-150 microns.
- modern cooling lubricants are complex, multi-component, polydisperse mixtures of substances of different chemical nature and functional purpose;
- the component composition of the cooling lubricant and the concentration of components depend on the cutting conditions;
- of all the variety of components, only a part is intended to perform the main functional properties of the cooling lubricant - lubricating, cooling and dispersing.
- the need for other components is obviously due to the peculiarities of the technology of using the cooling lubricant.

References

1. Латышев В.Н. Повышение эффективности смазочно-охлаждающие жидкости / В.Н.Латышев. – Москва: Машиностроение, 1975. -89 с.
2. Виноградов Д.В. Применение смазочно-охлаждающих технологических средств при резании металлов: учебное пособие по курсу «Инструментообеспечение машиностроительных предприятий» / Д.В. Виноградов. - Ч.1: Функциональные действия. –М.: Изд-во МГТУ им. Н.Э.Баумана, 2013. -90 с.
3. Худобин Л.В. Смазочно-охлаждающие технологические средства и их применение при обработке резанием: справочник / Л.В.Худобин.- Москва: Машиностроение, 2006.-544 с.