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Modeling of heat transfer conditions in cooling lubricant emulsions with low-boiling continuous media in narrow gaps

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ABSTRACT

The article analyzes the behavior of the cooling lubricant emulsions of oil-in-water type in a limited volume of narrow gaps. Vapor phase which has been generated by heating the emulsion to a temperature that exceeds the boiling point of water, modifies substantially the conditions of interaction between the dispersed droplets of oil with friction surfaces. Nucleation and growth of vapor bubbles stimulates heat transfer due to the pulsating character of motion of the emulsion and associated with it breakup of the oil droplets. A model of "hot" turbulence has been proposed in the double emulsion of the dispersed phase (oil and steam), initiated by the growth of vapor bubbles. In order to assess the effectiveness of the cooling lubricant emulsion, the mechanisms of hydrodynamic fragmentation of droplets of lubricating oil under conditions of narrow gaps were taken into account. The model was used to estimate the empirical constants in the dependence of the critical temperature from volumetric concentration of oil for AA 5182 aluminum cooling lubricant emulsion E1 (Januszkiewicz et al., 2004), separating the lubrication regime from the "dry" slip regime. It was shown that the model estimates are in good agreement with the experimental data. Therefore, the obtained results indicate that the model representations of this work do not contradict the physical nature of the complex process of heat transfer.

1. Introduction

Manufacturing processes in various industries use large amounts of expensive working and process fluids. The fluids in the form of compositions of the oils, emulsions, aerosols play a significant role in almost all branches of engineering. In particular, they are used for cooling of the working surfaces of workpiece and tool during the machining of metals, lubrication of tools and machines. The removal of heat, modification of the working area with surface-active additives contributes to the quality of treatment, increases the equipment life and improves the working conditions of production staff. The effectiveness of many metals treatment technologies is associated with the use of a variety of cooling and lubricating fluids in the form of heterogeneous dispersed systems. Therefore, the study of their hydrodynamic and thermal characteristics in a specific industrial environment is one of the vital technical and scientific problems.

For the solution of these problems technology of minimum cooling and lubrication (MQCL) [1–3], environmentally friendly machining [4], providing a better quality of surfaces in the industrial machining environment [5] are aimed. The authors performed complex investigations which have shown the significance of the conditions of emulsion mist formation, as well as the detailed contact of single droplets with the object surface. Quantitative and qualitative results of the analysis of the initial indices of the emulsion mist generation in the process of machining under the conditions of the MQCL method contribute to the understanding of the role of various factors in the formation of the complex heat transfer processes. These include the size and distribution of droplets, surface wettability, air pressure, nozzle distance and flow velocity [1]. It should be noted that the emulsion mist represents an important class of dispersed systems, since the dispersion medium (air) in contrast to the liquid emulsion allows you to observe the real state of the processes. Therefore, they serve as a source of visual physical representations that can be used in specifications under similar conditions models of more complex heat transfer processes during evaporation of emulsions.

Heat transfer processes in liquid emulsions with the phase transformations differ in their content and character. They consist of a large number of combinations of elementary physical phenomena, the content of which depends on physico-chemical, thermohydrodynamics and geometric parameters. The number of elementary phenomena and their interactions determine physical content and complexity of the heat transfer modeling. The heat transfer

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