ENVIRONMENTAL ACTUALITY, TECHNOLOGICAL COMPETITIVE ENVIRONMENT AND PREDICTION OF THE PROSPECTS OF ANHYDROUS DIAMOND-SPARK GRINDING USING SOLID LUBRICANTS

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Abstract: The use of solid lubricants in anhydrous grinding technologies is consistent in reducing the use of water to serve industrial needs, which is one of the leading global environmental dominants. It is proposed to carry out development and research of ecological anhydrous processes of abrasive finishing forming of difficult-to-process materials by the method of diamond-spark grinding, which is the founder of NTU "KPI" and which has proved its high innovative flexibility and efficiency by wide scientific and industrial practice. The technologically competitive environment and some hypotheses and bases for the development of a complex of patentable technical solutions, as well as scientific and practical recommendations on the choice and technological instructions for the implementation of solid lubricants in diamond-spark grinding operations are presented. The article announces the implementation of the project ID: 62437 (3002-5695) with international cooperation under the auspices of the Ministry of Science and Education of Ukraine.

Keywords: difficult-to-process materials, finishing, water saving, technological productivity, functional quality, ecological cleanliness of technologies.

Ecological relevance

Parts with high functionality due to the increased hardness and durability of manufacturing materials, that is hard-to-process materials, are widely used in industries that determine the technological and technological competitiveness of developed countries. Simultaneously ensuring technological productivity, functional quality and environmental cleanliness of technologies in the manufacture of parts from such materials is a major complex problem.

Generally accepted technological methods for accurate finishing grinding of difficult-to-work parts consist in use of jet irrigation with lubricating-cooling technological means (LCTM) on water or oil liquid basis [1].

In the industrialized countries of the world, a large number of liquid LCTM are used, for example in Germany and the USA up to 110 and 250 million liters per year, respectively. But the intercontinental scale of the problem of the provision of clean fresh water of vast territories in the Asian, African, Australian, American regions is globally stimulating the reduction of water consumption for industrial purposes as a permanent trend in the scientific and technological development of our civilization [2], including with regard to

LCTM during machining – from minimizing the flow, for example in the form of partial microdoses, and to complete rejection [3].

The LCTM is a source of relatively high production costs associated with its preparation, transportation, operation of feed systems to the treatment area, regeneration, recovery and disposal. According to the Swiss firm Mikron SA Aqno [4], the cost of LCTM per machine is an average of $ 50 to $ 300 per day, taking into account the full cost of the LCTM filing systems in the treatment area, maintaining its normal condition.

The work being announced is a response to the environmental challenge, also taking into account economic considerations, through the refusal to use water resources in LCTM compositions and the proposal of innovative anhydrous processes of diamond-spark grinding (DSG) of difficult-to-process materials materials using solid lubricants (SLs).

Technically competitive environment

An analysis of the activity of firms and research centers shows that there is an intense search in the world for efficient technological methods of transition to low and waterless machining technologies in line with the global environmental challenge of drinking water. The problem of cooling systems in the process of grinding materials is updated by the modern European technology platform Industry 4.0 (M. Winter, Germany [1]) and is considered in the unity of technical, economic and environmental development (E. Benedicto (Spain), D. Carou (Ireland) and M. Rubio (Portugal) [3]).

In China and the USA, ideas about the thermodynamic mechanism of grinding processes are formed under conditions of minimal cooling and lubrication (M. Yang and others [5]). Heat removal from the cutting zone using minimal liquid lubrication alternative to conventional approaches is investigating by finite element models (M. Hadad and A. Sharbati, Iran [6]). Unconventional inclusion of the grinding wheel in the flow of cooling agents in the processing of difficult-to-process materials is developing (S. Toyokawa and others, Japan [7]). Various solid alternatives to liquid remedies that are grease-cooling and clean the grinding wheel surface down to hard water (dry ice) are considered (Yu. Ohta and others, Japan [8]).

New opportunities for comprehensive optimization of grinding operations in countries with fresh water problems are associated with the improvement of air cooling (B. Boswell and others, Australia and Indonesia [9]). Air flow as a cooling medium when cutting materials is proposed to be pre-activated by ionization (M. Sh. Migranov and others, Russia [10]). Regional cultures of clean water savings and the global nature of the problem also stimulate international scientific and technical cooperation in the development and research of minimal lubrication techniques as a viable alternative to conventional irrigation (B. Sen and others [11], India, Bangladesh, Poland and the United Kingdom).

Perspective approaches to the development of environmentally-friendly productive diamond grinding processes for difficult-to-process materials include the use of anhydrous SL processing and minimal liquid cooling (M. Winter, Germany [1]), but known information on relevant research practices in the leading economically advanced research schools (USA , The United Kingdom, Germany, China, Japan) and others are, first and foremost, fragmented and not sufficient to develop technological instructions and industry recommendations. Secondly, it is possible to claim that there are no such studies regarding the most advanced electrophysical methods of diamond-abrasive processing, except for some experience of DSG at the NTU "KPI" with the study of microgeometric heredity of the process on hard alloys (A. K. Agu and M. D. Uzunyan [12], Nigeria and Ukraine).

The main idea of the work

The central idea of the work is to use the advantages of diamond grinding with the developed cutting surface of the working surface of the wheel from the standpoint of the thermal load of the cutting zone and therefore less dependence on the intensive use of LCTM, in the usual practice – jet irrigation; the possibility of transition through the application of SLs to the global trend of reducing water consumption in the industry due anhydrous diamond-abrasive processing technologies; solution on this basis of a complex problem of technological productivity, function the quality and ecological purity of diamond grinding of difficult-to-process materials.

Working hypotheses and bases

Previous studies by the authors on the processes of diamond grinding with the initiation of electric discharges (DSG) and without electric current in the treatment zone [13, 14] allow to assume the less significant thermo-physical consequences of the engineering of the treated surface than the more developed and stabled a cutting relief of the wheel working surface during grinding.

The consequence of this hypothesis is the expectation of a much smaller dependence of the productivity and quality of diamond grinding processes with developed wheel cutting relief from the LCTM.

From the point of view of the cleaning of the wheel working surface from the products of chip formation during processing, the important working hypothesis is the electro-physical by nature, to a large extent, the equivalence of anhydrous DSG processes to the processes of diamond grinding with the function of jet cleaning and washing of the wheel working surface from the chip products.

From the standpoint of reducing heat intensity in the treatment area, an important working hypothesis is largely tribological in nature, the equivalence of anhydrous diamond-spark grinding processes using SL to processes of diamond grinding with jet irrigation.

Among other working hypotheses, the following are more significant:

- SLs of the work surface of a diamond grinding wheel can be considered as a coating with a high wear rate, which is renewed according to a certain technological regulation, that is, in the function of a certain protective barrier between the bond of the wheel and the treatment surface, as a variant – dielectric barrier;
- use of SLs in the barrier consideration between the wheel bond and the surface of the treatment creates prerequisites for the selective, in the areas of contact sampling of lubricants, and therefore more functionally efficient electro-discharge auto-forming of cutting relief, increases the mode combinatorial capabilities in the management of the cutting relief in DSG process;
- use of SLs in diamond grinding slows the loss of cutting grain sharpness, and at the same time, with the consequent increase in the life of diamond wheels, contributes to a more pronounced surface roughness;
- use of SLs in diamond grinding significantly extends the possibilities of controlling the engineering of the surface layer under treatment due to the variation in the composition, intensity and structure of the cycle of SL feed, and at DSG – also in conjunction with the control of the flow of electricity into the cutting zone.

Determining the structure of research

The structure of the research is built in motion from virtual computer finite element modeling and analysis of the thermo-physical state of the cutting surface and surface in the processes of diamond-abrasive cutting of difficult-to-process materials using known SLs to a coherently constructed chain of full-scale experiments, in advance, from the very beginning of the project, provided by the original, patent-protected development of a method and device for SL feeding on the cutting surface

of the grinding wheel according schemes for continuous and controlled intermittent sliding contact.

The chain of full-scale experiments is based on the tests of known SLs in diamond grinding with thermometric studies in conditions and without electric current in the cutting zone, obtaining and generalization of experimental databases on surface layer X-ray, micrometry and surface microscopy after anhydrous DSG processes, in this case with the use of SLs, everything is done by grinding of hard-to-process materials from a series of hard-alloy and super-hard tools.

Further, as determined from the results of the studies of the physic-technical challenges for improving the SL compositions of diamond grinding of hard-to-process materials, new SL compositions are developed and experimentally tested, with the patenting of selected ones based on the results of tests for practical application.

Completes the block of experimental research on the project, based on the opportunities provided by the use of SLs, search for new management solutions, first, the development of cutting relief in the DSG processes; secondly, the engineering of the surface layer under diamond-abrasive treatment due to variation in the composition, intensity and structure of the SL feed cycle, and in the case of DSG – also compatible with the control of electrical modes in the cutting zone.

The peculiarities of the individual components of the research are largely determined by the specificity of electro-physical phenomena in the DSG zone in the presence of SL which is considered as a coating with a high wear rate and is renewed according to certain technological regulations.

Predictions for results and prospects

Work out a system of technical solutions for the method and device for feeding solid lubricants, SL compositions, control of the efficiency of anhydrous diamond grinding processes; scientific and practical guidelines for selection and technological instructions for application of SL as well as management of roughness of the machined surface under anhydrous diamond grinding with SL will be useful results of practical experience, first acquired through scientific research as well as validated, refined, developed.

Waiting for confirmation by thermometric studies – virtual (on finite-element models) and full-scale (instrument visualization by infrared thermal imager) – for the working hypothesis of a considerable degree of thermal analogy, and possibly the advantage with a lower level of thermal stress of anhydrous DSG processes with SLs compared to the use of conventional grinding with the irrigation scheme for the submission of LCTM is based on the knowledge of tribology and thermal physics of the pronounced discrete (developed, free of shavings relief) and almost continuous (relief in shavings) intense mechanical contacts.

The expectation of the confirmation of microscopic studies of the working hypothesis of the equivalence of anhydrous DSG processes to the processes of diamond grinding with the function of jet cleaning of the wheel working surface and its washing from chips by implementation of the jet scheme of the LCTM submission based on the such known phenomena in the area of cutting at DSG as evaporation of micro-thin chip of sliding contacts in channels of electric micro-discharges between diamond wheel metal bond and surface of machining.

The results of the research on the project with the prospectus provided here, technical solutions, scientific-practical and technological recommendations and instructions will significantly develop the theory and practice of grinding.

Conclusions

Thus, further progress in solving the complex problem of technological, qualitative and ecological functionality of the finishing forming for the difficult-to-

process materials is associated with using the DSG method with application of SL simultaneously initiating electro-discharge physical effects in the cutting zone in addition to mechanical removal of the allowance.

The technical ideology of the work is based on modern scientific and practical ideas in the fields of engineering, cutting materials and materials science. Scientific novelty follows from the presence of analogues only far from solving the issues of this project.

The advantage of the expected results is that their use does not require significant financial costs, but on the contrary will save considerable money with obtaining a significant environmental effect without reducing the technological productivity and functional quality of diamond grinding of difficult-to-process materials.

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