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Enhancing metal processing efficiency based on using a lubricating-cooling agent with ultradispersed diamond powder

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Enhancing metal processing efficiency based on using a lubricating-cooling agent with ultradispersed diamond powder

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Abstract. The present study describes a new technological environment based on ultradispersed diamond graphite powder. The task is to further study effects of lubricating and cooling agent containing diamond nanopowder. The agent is fed into the zone of refinement or polishing of the part while affecting wear and durability of carbide tooling. The impact of the agent on the quality of the surface layer in the processing of heat-resistant steels and alloys is investigated. It also identifies the optimal agent composition when polishing a particular material. Experimental studies established a positive effect of the agent on the treated surface quality and other parameters of clean finishing and polishing of various metals.

1. Introduction

The use of lubricating-cooling process agents (LCPA) contributes to greater accuracy of parts and increases cleanliness and quality of treated surfaces [1]. LCPA is a well-recognized means of making mechanical processing operations more cost-effective [2].

The process agents introduced into the material processing zone are selective in their polishing and refinement processes [3]. This action depends on the properties of tool material and part, processing rate, method of the agent supplying, etc. [4]. And most importantly - it depends on the lubricant and supply system.

Let us consider some types of existing LCPA.

It is known that solid lubricants applied to the working surfaces of the tools give an increase in their durability [5, 6]. But the widespread use of these lubricants was not found because of their laborious application processing and disposability.

Thickened lubricants have not been widely used in the processing of materials due to the difficulty of their involvement in the processing zone [7].

Gaseous lubricants play a positive role in the materials processing [8, 9]. But owing to the cumbersomeness of the plants manufacturing them and the complexity of their supplying into the cutting zone, they found only limited use.

Diamond pastes and suspensions have become widespread in the inventive finishing lapping processing operations. The compositions of the pastes and suspensions are in most cases multi-component. The range of the compounds used as part of the base is extremely high. This is due to the specificity of the diamond pastes and suspensions in the process of refining and polishing depending on the material being processed and processing requirements. At the same time the trend of creating the universal pastes suitable for processing different materials can be observed [10].

This paper aims to analyze the impact of LCPA containing diamond-graphite nanopowder on the main indicators of the refinement process and surfaces polishing. This topic is not completely ambiguous and requires a comprehensive study for various steels and alloys [11].

It can be assumed that the use of the ultradispersed diamond powder with a grain structure of 2-8 nm will provide high quality indicators of metals and alloys processed surface.

2. Methods and Materials

At all stages of the development and selection of such mass consumption products like LCPA, a large set of tests for their technological properties in relation to various metal processing operations is usually required and conducted.

At all stages of the development and selection of such mass consumption products like LCPA, a large set of tests for their technological properties in relation to various metal processing operations is usually required and conducted.

When processing materials with new LCPA the challenge is to characterize the properties that need to be determined before the liquid goes into volume production. This data can be derived from the bench-scale testing of agents in laboratory conditions.

But the estimated figures related to the technological properties of LCPA coincide with the technological properties indicators of the metals being processed. The LCPA evaluation procedure is ultimately the procedure for assessing processing of metals by cutting.

The main benchmarks for evaluating can be: surface roughness, its luster and the removal of metal. The metal removal can be determined by weighing the processed sample before and after testing using the analytical balance. The surface roughness can be measured using a microscope and a microinterferometer. The presence of luster is defined visually.

The organic component of the pastes and suspensions must meet the following requirements:

- to hold the diamond particles in a suspended state;
- to reduce friction between the diamond particles and the surface processed;
- to prevent adhesive processes in the contact materials system;
- to form a linkage between the lap and the surface processed;
- chemically affect the material processed.

The pastes and suspensions in terms of these requirements and studied in this paper are given in Table 1.

Table 1. Compositions of testing pastes and suspensions

Component	Content, %			
	Reference		Experimental	
	I	II	III	IV
Chrome oxide	45.0	3.0	10.0	20.0
Diamond-graphite nanopowder	-	2.0	5.0	10.0
Stearin acid	12.0	-	-	-
Wax	1.0	-	-	-
Trietanolamine	4.0	-	-	-
Trietanolamine oleate	-	65.0	55.0	40.0
Sodium salts	-	5.4	6.4	8.3
Water	38.0	24.6	23.6	21.7

The essence of the method for evaluating diamond pastes and suspensions from submicropowders consists in determining the material removal rate and the surface roughness parameter of treated pastes and suspensions

The materials developed were tested for operational properties on a polishing and finishing machine. A schematic representation of the finishing process (refinement process) is shown in Figure 1.

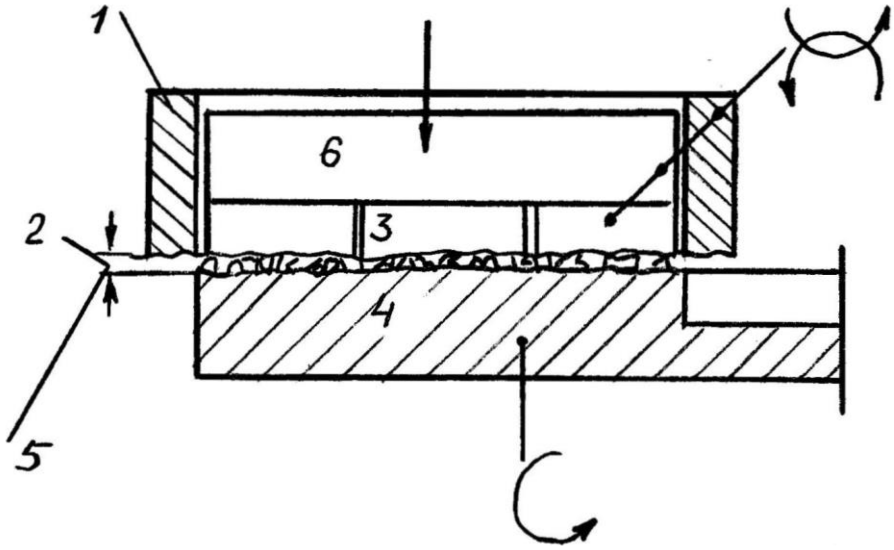

Figure 1. Diagrammatic representation of the finishing process (refinement process): 1 – ring for straightening; 2 – refinement / polishing; 3 – processed parts; 4 – lapping plate; 5 – pasta or suspension; 6 – pressing.

The refinement of the lap 4 is given as a rotational motion because for straightening 1 - reciprocal. The ring for straightening 1 serves to hold parts during the refinement as well as for the straightening of the lap in the process. The treated parts 3 are pressed with constant force to the lapping plate 4.

Cylindrical samples 18-20 mm in diameter, 20-25 mm in height were used for testing. Grinding was carried out on a sisal wheel for 2 minutes, polishing - on a cotton wheel for 1-3 minutes depending on the processed material.

The application of the pastes and suspensions was carried out during the treatment every 10 seconds in an amount of 1 gram by weighing the pastes for each operation on the analytical balance. The test was repeated 10 times.

The force of sample pressing to the lapping during grinding operation is 9.8-29.4 kPa. Polishing operation: initial period - 0.15-0.20 MPa, final period - 24.5-98 kPa. The average relative movement speed of the sample is 20 m/min.

3. Results

The first series of experiments examined the processing of rapid-cutting steel 1.3343 (UNS-T11302), stainless steel X12CrNiTi18-9 (AISI 321), carbon steel DIN-C105W1 (AISI 5132) and doped steel X165CrMoV12. For comparative evaluation, samples of din-C45 steel (AISI 1044) were polished.

With the increased concentration of diamond-graphite nanopowder in the developed finishing pastes, the performance of the material removal increases. The same conclusion can be drawn from the quality of the treated surfaces. As the powder concentration in the paste increases, the surface roughness decreases.

With increasing concentration of the ultradispersed diamond-graphite powder the height of micro-level surface decreases. On some materials, the performance of the time of refinement and lapping increases about 2-3 times compared to the reference paste I.

The best results in determining the rate of material removal from the surface boundary were obtained by processing materials such as X12CrNiTi18-9 (AISI 321), X165CrMoV12, DIN-C105W1 (AISI 5132), DIN-C45 (AISI 1044). In the processing of colored alloys as well as rapid-cutting steel 1.3343 (UNS-T11302) with an increase in the abrasive component in experimental polishing-finishing pastes, there was a slight increase in the material removal rate. However, this parameter is much higher compared to that of the reference paste.

As a result of experimental studies it was found that when refining the reference paste the surface of the sample is matte, there is a large number of scratch marks. When polishing the samples with this paste there was a good shine, bright image, but not clear because of unobliterated scratch marks. Treatment with experimental pastes generally showed a bright sample surface, a small number of scratch marks and a clear image.

In the second series of experiments the diamond consumption was determined to remove one micron of the let from one square centimeter of the surface. The original surface roughness of the blank was produced by grinding and corresponded to $R_a = 0.63$ µm.

Samples 20 mm in diameter, 25 mm in height from steels DIN-C105W1 (AISI 5132) and 1.3343 (UNS-T11302) as well as hard alloy HG30 were treated. In order to compare the results obtained, these samples were also processed by commercial pastes ASM 1/0 and ASM 3/2. The results of the studies are shown in Table 2.

Table 2. Diamond consumption for removal of one micron allowance with 1 cm^2 of surface

Process material	Consumption				
	Reference		Experimental		
	ASM 1/0	ASM 3/2	II	III	IV
DIN-C105W1	0.020	0.021	0.020	0.018	0.015
1.3343	0.026	0.028	0.028	0.026	0.024
HG30	0.024	0.025	0.024	0.022	0.021

The consumption of diamonds in experimental pastes is generally lower than that in commercially produced pastes. It can be concluded that it is cost-effective to use these experimental pastes.

4. Conclusion

It has been found that after treatment with the presented experimental pastes for one minute only the deepest scratch marks remain on the surface of the samples. After 2-3 minutes of treatment the traces of abrasive interaction disappear almost completely. The surface of the sample is bright, has good gloss, the image is clear.

The polishing-finishing pastes and suspensions studied herein may be recommended for finishing-tacking operations. When the surfaces are finished, the roughness of 0.02 µm can be achieved. The efficiency of the finishing process compared to commercially available abrasive pastes is 1.5-2 times higher.

When finishing and polishing stainless steels it is recommended to use paste III; when polishing hard alloys - paste II; when polishing fast-cutting steels - paste IV.

References

[1] M'Saoubi R et al 2015 *CIRP Annals – Manuf. Tech.* **64(2)** 557–80
[2] Sharma V S, Dogra M and Suri N 2009 *Int. J. Mach. Tools Manuf.* **49(6)** 435–53
[3] Kishawy H et al 2005 *Int. J. Mach. Tools Manuf.* **45(2)** 219–27
[4] Adler D P et al 2006 *Mach. Sci. Technol.* **10(1)** 23–58
[5] Sterle L, Kalin M and Pušavec F 2018 *Procedia CIRP* **77** 401–4
[6] Krishna P V and Rao D N 2008 *Int. J. Mach. Tools Manuf.* **48(10)** 1131–7
[7] S G Dokshanin et al 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **560** 012192
[8] Elshwain A E I, Redzuan N and Yusof N M 2013 *IJRET* **2** 690–702
[9] Patil S et al 2016 *Key Eng. Mater.* **705** 233–9
[10] Rawat S S and Harsha A P 2019 Current and future trends in grease lubrication *Automotive Tribology* eds J K Katiyar et al (Springer) pp 147–82

[11] Ivanov M et al 2014 *Nanosyst. Phys. Chem. Math.* **5** 160–6