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Improving the performance of vibratory treatment based on polymeric composite binder

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Abstract

The advanced technology still requires a good surface finish at a low cost. This scenario asks the industries and the scientific community to develop new finishing processes. Currently, there are many techniques and the most promising of them is the abrasive vibratory treatment (AVT). The performance of the AVT depends on the operating mode (Amplitude, oscillation frequency of the work chamber, thermal and energy parameters), devices design features and other factors, among which the central place is occupied by the functional properties of the granules, generally, based on the composites, predetermining the important role and the main task of the vibratory treatment. However, the analysis of the works in this domain shows that AVT gives good results with the right selection of granules that is the shape, the size and the composition of them, which are determined by the configuration and material of the treated parts thus shows that the functional properties of granules are not completely used. Therefore, the purpose and task of the relevant work is the intensification of the AVT process by improving functional properties and performance of abrasive granules based on a polymeric binder (PB).

Keywords: vibratory treatment, abrasive granules, functional properties, polymeric binder, performance;

1. Introduction

The development prospects of modern industry are largely due to the introduction of new materials and technologies. Some of these materials are polymeric composite materials (PCM). The PCM uses extensively in the automotive industry, aerospace, naval construction, oil and gas industries. We examine in our work a new field application of polymers: their use in the AVT, which is based on the capacity of the polymers, which mechanically activate the surface deformation and the dispersion of the solid bodies.

At the current stage of development of metal processing technology, the questions of improving environmental performance are increasingly relevant. The modern mechanical production represents a complex set of processes using different types relating to the energy influence, a wide range of basic and auxiliary materials in solid, liquid or gaseous, solutions, granules and electrolytes of various compositions and concentrations. To achieve the quality and the required performance is often used toxic materials and granules. In this regard, the significant interest is presented by the development of new granules of treatment, excluding the application of such materials and substances, the introduction of ecologically rational and appropriate technologies so the exploitation of the waste of diverse productions [1]. The industrial production of various abrasive granules (AG) allows extended using the methods of AVT [2]. The important significance to guarantee the cutting properties of these granules belongs to the binder of AG. The binder must solidly retain the abrasive grains and constantly be triturated for the denudation of new cutting edges. It represents an important component, influencing considerably on the performance of granule [3]. The AG is generally manufactured containing a polymeric, metallic and ceramic binder. However, the most widespread is polymeric [4].

Currently the volume of the production of diamond tools with a polymeric binder (PB) represents approximately 70 % of all abrasive production [5, 6]. That is expressed by the positive influence of PB on the treatment processes. PB promotes the reception performance of the treated surface; ensure a low coefficient of friction, consequently, a low temperature, and a capacity of auto-sharpening, which increases granules cutting performance and intensification of AVT production [7, 8]. Generally, AG with elastic and rigid PB are largely used in the industry, as elastic PB is uses compositions, inserting rubber, polyvinyl chloride and phenol-formaldehyde novolac resin [9]. However, it is advisable to note that the major part of the AG is industrialized with the rigid PB [10]. The basis of these agglomerating is composites filled with polymer. The international market, offers a very wide nomenclature granule of different characteristics and particularly containing polyamide and poly benzene resins. But more and more PB based on resins of epoxy, polyurethane and fluoride found an increasing use [4,10].

The analysis of the granules applied in processes of the vibratory treatment, makes it possible to classify them according to various characteristics, in particular, nature of origin, structure, type and shape of granules. Depending on the nature of origin, all granules are divided into two principal groups [11]: inorganic (natural, synthetic) and organic granules according to Figure 1.

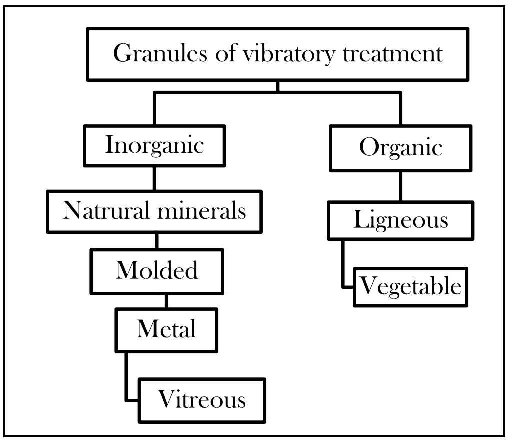


Figure 1. Classification of vibratory treatment granules based on its nature

In recent years, many companies have considerably activated the research of production and sale of AG with defined geometric shape. These works are completed, particularly, in Germany (by Rösler and Walther Trowal companies) according to Figure 2, in the Russian Federation by abrasive factory of Moscow, in USA by Finishing Systems and others companies.

Figure 2. Some granules produced by RÖSLER

The primary reason for such extensive use of AG based on PB is higher cutting capacity, which is due to the release of a large number of macro radicals during the attrition of this binder [12].

The longevity of free radicals under normal conditions is very short, because as reactivity, they can interact with compounds, atoms and molecules that act as locators of unpaired electrons (acceptor). Since generated radicals interact with atoms or molecules of the compounds, their recombination in these conditions is impossible (at least limited). Thus, polymeric granules and compounds used in conjunction during AVT, allow producing even more reactionary radicals, which must more intensify the treatment.

Currently, abrasive fillers are based on traditional materials such as black and green silicon carbide, white and normal electro-corundum and other materials [13]. Natural corundum is a rare material, artificial is expensive. In this context, it is interesting to use non-conventional abrasive materials, including wastes from various industries. In particular, it is known in the field of metallurgical production that slag possesses high abrasive properties and is not deficient and costly. The manufacturing process of abrasive tools is well-known [14], in which the abrasive is mixed with polymer and hardener then the mixture is placed in an appropriate mold, the mold is heated to a temperature of 70° [4].

2. Experimental study

The objective of our study is the production of the AG and the lowering of their cost prices, by replacing one or more expensive components for others less expensive, while preserving the physical and mechanical properties in order to improve the ecological security of this production, thus to solve the task of improving the wear resistance [15], the absence of the clogging and good wettability of AG surfaces. The result which can be achieved in the implementation of this method consists in using:

1) As the abrasive - normal electro-corundum (NE) with a particle size at 06 to 10 μm, granulated slag of blast furnace, slag crushed for the road works and sand.

2) As a polymer – Poly methyl methacrylate (PMMA).

3) As the monomer - methyl methacrylate (MMA) in liquid.

4) As the hardener – dimethyl aniline

2.1. Technological equipment

Experimental studies of the process are conducted with vibratory equipment 4×10 according to Figure 3. The machine has a base 9, welded iron of U-shape, on the basis is assembled metallic square structure 8 for the fixing of the electric motor 5, and the intermediate support 7 with shaft 6 transmitting the rotation of the electric motor by two elastic couplings 4 to vibrator shaft 3, fixed under the vibrating table 1. The vibrating table is installed on four screws springs, relying on the base. On which at the same time fixed the work chambers 2 volumes of 1 up to 10 dm^3. The presentation of the liquid system consists of a pump, pipes and tank 10. The technical characteristics of this equipment are given in Table 1. The advantage of the equipment is the simplicity of conception, easiness of use, and the universality that is reflected by the use of this machine in the laboratories of research as well as in industrial enterprises.

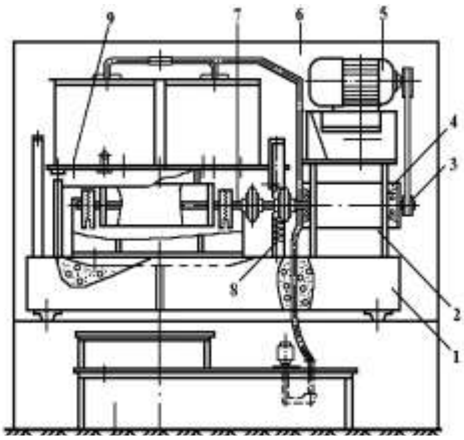


Figure 3vibratory equipment 4×10

The experiments were accomplished with free loading of parts in the work chamber. The consumable loading volume (granules, solutions) and parts, it's about 80 % of the work chamber volume, the entire experience was conducted with continuous solutions.

Table 1. Technical characteristics of vibratory equipment 4×10

Designation	Measuring units	Equipment 4×10
Volume of work chamber	dm^3	10
Number of work chamber	unit	4
Driving device	-	Eccentric weight
Disposition of vibrator	-	Horizontal
Engine power	Kw	1.1
Vibration amplitude	mm	0.5-2.5
Oscillation frequency	Hz	16, 26, 33, 40
Dimensions	m	1.3×0.95×1.37
Weight	Kg	820
Volume of settler	dm^3	200

2.2. Studied granules

To study the influence of granule characteristics of AVT performance and in treating surface finish, as well as the determination of granules functional characteristics, we used:

- Abrasive granules in triangle prisms shape with dimensions of 20×20 mm (TP 20×20).
- Granules epoxy 520, cone-shaped with dimensions of 20 mm and granulometry M40 from 28 to 40 µm.
- Newabrasive materials cone-shaped with dimension of 25 mm, based on polymeric binder + PMMA + MMA + hardener + abrasive grains granulometry M40 and dimension from 28 to 40 µm.
- Normal electro-corundum (NE-10) of 10 µm with an abrasive concentration from 45 to 70%, and the introduction of non-standard agent of load instead of the abrasive, particularly the metallurgical production waste.
- Also, slags of fusion in grains and crushed roadwork granulometryM50 from 40 to 50 µm and M10 from 7 to 10 µm, and sand M6 from 3 to 6 µm.

Noting that before preceding to the experimental studies all the granules must past a prior treatment for 30 minutes.

2.3. Solution and treated materials

In order to study the AVT process when using AG based on a polymer composite, we use an aqueous solution 5% of Na_2CO_3. Studies are conducted on parts of different materials and the most used in the industry: steel 45, copper Cu-B, aluminum 2024A and CuZn40Y40. Exploiting the vibratory equipment 4×10, the operating mode of treatment is the following: amplitude varying from 2 to 2.5 mm, oscillation frequency from 16.7 to 26.7 Hz.

2.4. Technological characteristics (functional)

To perform comparative tests of technological characteristics of new granules compositions, we use the method [4], which takes into account the functional properties and the main parameters of abrasive granules exploitation and which is calculated as follows:

- Concentration of abrasive grains:

$$C_g = \frac{v_a}{v_c} \cdot 100\ \% \qquad (1)$$

Where v_a– Volume of abrasive grains, %; v_c– binder layer volume containing abrasive grains.

- Cutting capacity of abrasive grains:

$$R_{CC} = \frac{Q}{t * S_p}; \quad \frac{g}{h * cm^2} \quad (2)$$

$$R_{CC} = (r_0 + k_a \cdot V_a) \cdot 10^{-4}$$

Where Q – metal removal of the part surface; t – processing time; S_p– surface area of the part; r_0, k_a - empirical coefficients.

- Consumption of the abrasive granules in mass:

$$P_m = \frac{I_m}{t} \;; \; \frac{g}{h} \quad (3)$$

- Consumption of the abrasive granules in volume:

$$P_v = \frac{I_v}{t} \quad ; \quad \frac{dm^3}{h} \quad (4)$$

Where I_m,I_v– Mass and volume of consumed granules layer.

- Treatment coefficient (specific metal removal):

$$k_0 = \frac{Q}{I_m S_p} \;; \quad \frac{1}{cm^2} \qquad (5)$$

$$K_0 = (b_a - c_a \cdot V_a + q_a \cdot V_a^2) \times 10^{-5}$$

Where b_a, c_a , q_a - empirical coefficients.

- Wear resistance of abrasive granules:

$$U = \frac{I_m}{M}; \; \frac{\%}{h} \quad (6)$$

$$U = u_0 + k_a \cdot V_a$$

Where M– one hour of the total initial weight of abrasive granules; u_0 , k_a - empirical coefficients.

- established roughness under normal processing conditions (minimum value R_a of treated parts is achieved at the fixed operating mode of treatment).

3. Results and discussions

The comparative tests of MMA+ PMMA and epoxy resin according table 2 are showed that:
- The cutting capacity in Graph 1 and the wear resistance of the granules in Graph 2 are high compared to granules based on epoxy resin.
- The treatment coefficient in Graph 3 is almost three times higher than for the granules containing epoxy resins.
- The established roughness in Graph 4 is higher than for epoxy resins.

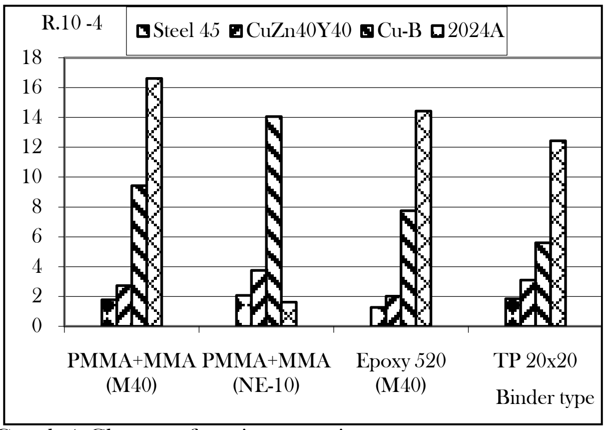
By comparing the experimental results on parts of different materials when using granules with a new polymeric composite binder (PMMA + MMA), epoxy resin (Epoxy 520) and ceramic (TP 20×20), we can say that, the use of new granules gives good results for improvement and intensification of AVT, with a less expensive cost, ensuring high properties of granules without any influence on the environment. It's good to note that, the abrasive granules based on polymer binder increase productivity; ensuring a stable surface quality, an economy of abrasive granules which reflect their wear resistance.

Table 2. Comparative tests of MMA + PMMA and the epoxy resin 520

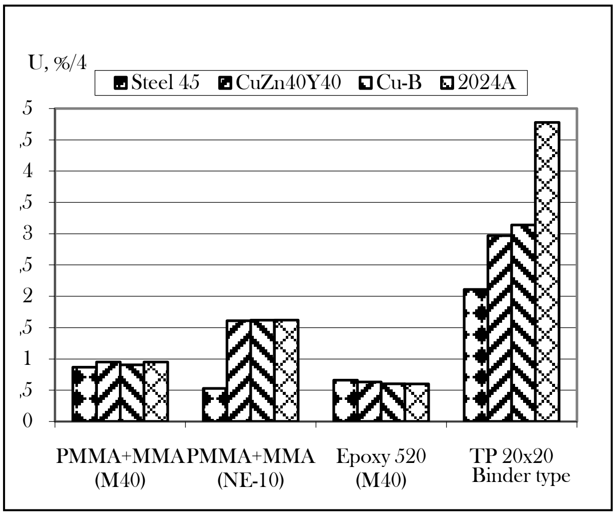
№	Type of binder	Type of processed material (AFNOR)	Cutting capacity R×10^{-4} g/h×cm^2
1	PMMA+MMA (M40)	Steel 45	1.78
2	PMMA+MMA (NE-10)	Steel 45	2.073
3	PMMA+MMA (M40)	CuZn40Y40	2.73
4	PMMA+MMA (NE-10)	CuZn40Y40	3.75
5	PMMA+MMA (M40)	Cu-B	9.43
6	PMMA+MMA (NE-10)	Cu-B	14.063
7	PMMA+MMA (M40)	2024A	16.62
8	PMMA+MMA (NE-10)	2024A	32.67
9	EPOXY-520 (M40)	Steel 45	1.27
10	EPOXY-520 (M40)	CuZn40Y40	2.02
11	EPOXY-520 (M40)	Cu-B	7.75
12	EPOXY-520 (M40)	2024A	14.43
13	TP 20×20	Steel 45	1.85
14	TP 20×20	CuZn40Y40	3.1
15	TP 20×20	Cu-B	5.6
16	TP 20×20	2024A	2.44

Following Table 2

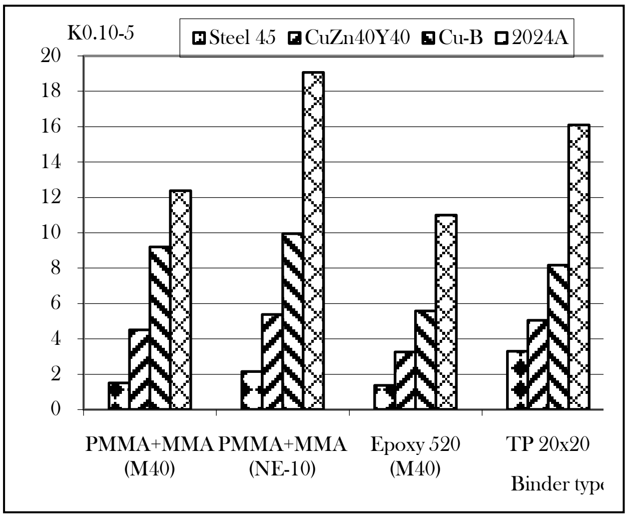
№	Wear resistance U, %/4	Treatment coefficient K_0×10^{-5} 1/cm^2	Established roughness R_a, µm
1	0.867	1.5	0.77
2	0.528	2.144	1.16
3	0.95	4.5	0.642
4	1.61	5.37	0.718
5	0.905	9.19	0.924
6	1.619	9.94	1.248
7	0.95	12.37	1.172
8	1.62	19.06	2.006
9	0.66	1.36	0.8
10	0.631	3.25	0.71
11	0.602	5.57	1.01
12	0.6	10.99	1.97
13	2.11	3.29	1.84
14	2.97	5.04	1.212
15	3.141	8.16	1.17
16	4.78	16.09	2.99



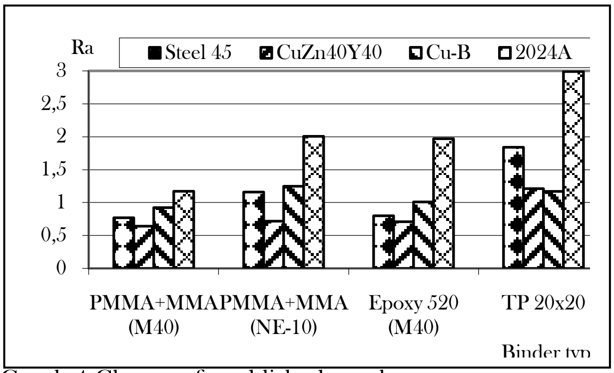
Graph 1 Change of cutting capacity



Graph 2 Change of wear resistance



Graph 3 Change of treatment coefficient



Graph 4 Change of established roughness

Conclusion

The surface treatment and particularly AVT is a very complex process, requesting attention because many factors are involved both during treatment, so far that it's known as Mass Finishing. In this work we try to:

- Reveal a mysterious phenomenon, a cutting tool which is present by abrasive granules, which are composed of the rest of abrasive discs and ceramic with a particle size of 8 to 40 μm.
- Accomplish a set of theoretical and experimental studies, to improve the quality of abrasive granules and increase the efficiency of AVT.
- Develop a system of operating parameters of abrasive granules, allowing conducting comparative studies of several granules compositions.
- Thus, this work presents the classification of abrasive granules containing a polymeric binder, taking into consideration the operating parameters (functional) of abrasive granules according to their nature and their designation.

The right chooses of the granules component is the key to improving the performance of vibratory treatment.

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