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EFFECT OF DIAMOND SUPERFINISHING ON THE SURFACE ROUGHNESS OF ANTIFRICTION COMPOSITE PARTS MADE FROM SILUMINE WASTE FOR POST-PRINTING EQUIPMENT

The article presents the results of studies on the influence of fine superfinishing modes with synthetic diamond bars on the formation of the roughness parameter Ra of the surfaces of samples made of new antifriction composites based on industrial grinding waste silumin — aluminum alloys AK7, AK12M2, AK21M2.5N2.5, which are intended to equip post-printing equipment.

Keywords: composite; silumin waste; superfinishing; diamond bar; granularity; bond; cutting modes; roughness; post-printing machines.

Introduction

In implementing the tasks of increasing the reliability and durability of printing equipment components an important place belongs to the development of not only new technological processes for the parts manufacture, but also technological aspects of improving the quality parameters of the parts' working surfaces that perceive the main load in the process of contact interaction and ultimately determine the service life of both the individual part and the assembly, as well as the machine as a whole [1–5].

Usually, damage and destruction of antifriction parts under friction conditions begin from their surface, when the service life of such parts directly depends on the values of operating loads, initial properties of materials, geometric parameters of the part, roughness of working surfaces Ra, the magnitude and nature of residual stresses, adhesion parameters, etc. [1, 2]. Therefore, the tireless attention of scientists and practitioners is paid to both ensuring high surface quality parameters and maintaining the level of these parameters during operation.

Modern machine building, including printing, is increasingly using finishing processes that have undeniable advantages over fine grinding and that allow for the most cost-effective production of precision parts with high quality machined surfaces.

Such technological processes include superfinishing with fine-grained bars [6–10].

It should be noted that in recent years, the authors of [6, 11] have developed the latest grades of special alloy composites based on grinding waste silicones — aluminum alloys AK12MgN, AM4.5Cd, AK8M3ch, AK12MgN+(9–12)%MoS_2 for the manufacture of wear-resistant friction parts for post-printing equipment, which have become an effective alternative to traditionally used cast aluminum antifriction parts.

These composites are designed to operate under medium operating conditions at loads of up to 3.0 MPa and sliding speeds of up to 1.0 m/s in air, which is typical for a number of post-printing equipment.

This includes such equipment as automatic machines for the production of paper food bags Victoria C-420 (Victoria Trading Company, China), machines for gluing transparent windows into packaging such as WFD-600 (China), lines for gluing linerboard and micro-corrugated cardboard Heidelberg and Bobst (Germany), etc.

In the friction sections and units of this equipment, antifriction parts made of cast aluminum alloys that work with liquid lubricant are usually used.

It is known [1, 2, 12, 13] that the parts' wear resistance, as one of the main reliability parameters, largely depends on the quality parameters of friction surfaces and, first of all, on the roughness and physical properties of the surface layer. These parameters are formed during the finishing operations of fine abrasive machining.

Since new composites based on waste silumines have been developed relatively recently, there are still few extensive and comprehensive studies of their finishing processing using technological processes of superfinishing external surfaces with diamond bars [6, 7, 12, 13].

This is an obstacle to the full use of advanced technologies for precision machining of aluminum-based antifriction composites to significantly improve reliability, durability and maintainability by forming the best roughness parameters by finishing diamond superfinishing of parts working surfaces.

It has been established [2, 4, 12–14] that during the finishing of parts from antifriction composites based on silumin, it is necessary to obtain the highest quality qualifications for dimensions, deviations from the requirements of the part shape (non-circularity, waviness, taper, etc.) of less than 0.003–0.005 mm, waviness of less than 0.5 μm, surface roughness parameters Ra = 0.02–0.10 μm with minimal values of surface layer hardening.

These requirements require the use of special superhard materials, in particular, the latest grades of synthetic diamonds. Such materials have been created by scientists and are widely used in industry for finishing various materials [1, 2, 4, 12, 13].

For the authors of the article, the above became a prerequisite for the synthetic diamonds use in the processes of diamond superfinishing of high-alloy and difficult-to-machine composites based on silumin grinding waste.

Scientific and technical sources contain many publications on the use of tools based on new superhard materials grades, in particular,

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synthetic diamonds (DS) for machining parts for various purposes [6–10, 12–16].

The use of diamond processing allows to obtain the best quality parameters of the machined surfaces, primarily due to the such tool's specific features.

However, the absence of technological recommendations for diamond finishing of high-alloyed and difficult-to-machine composites leads to the use of diverse, often difficult technological processing modes, which are not always effective.

Unfortunately, the above is the reason for the widespread use of various technologies in industry, often significantly opposite in terms of recommendations. In practical terms, this leads to the use of machining processes that correspond to the capabilities and machine tools of a particular enterprise, rather than scientifically based recommendations [1, 2].

These arguments became the basis for the authors of the article to carry out a series of experimental studies on the effect of technological modes of superfinishing with diamond bars on the working surfaces' roughness parameters of new antifriction composite parts based on silumin grinding waste intended to equip post-printing machine units.

Objective of the work

The objective of this study was to investigate the surface roughness parameters when superfinishing with synthetic diamond bars the surfaces of samples for antifriction parts from composites based on silumines AK7, AK12M2, AK21M2.5N2.5 grinding waste, as well as studying the diamond granularity effect, diamond grain material type, tool's bond type, and main cutting modes on the roughness of machining surfaces of silumin composites for post-printing machine' parts.

Research methods

The objects of the study were the processes of superfinishing with synthetic diamond bars and their effect on the working surfaces' roughness of new antifriction composite friction parts based on waste silumines.

The subjects of the study were samples of composite parts based on grinding wastes of silumines AK7, AK12M2 and AK21M2.5N2.5.

The samples for the experiments were obtained using the synthesis technology [11] developed by the authors of this article on the basis of pre-cleaned and reduced grinding powders of silumines AK7, AK12M2 and AK21M2.5N2.5.

Experimental studies on superfinishing with diamond bars were performed on samples made in the amount of 40 pieces according to the procedure described in detail in [1, 2, 6, 12].

To obtain the maximum possible surface roughness parameters, the samples of the new composites were pre-grinded on a precision circular grinding machine AS-250 'Werzojt' (Germany) with a fine- grained grinding wheel made of green silicon carbide 63SM14SM2GI according to the cutting modes recommended in [1, 2].

As a result, the average initial roughness value of the machined surfaces before superfinishing was in the range of Ra = 0.20–0.25 μm.

The superfinishing was performed on a precision superfinishing machine FR-250 by Foster (USA). For superfine superfinishing, a lubricant-coolant was used with the following composition: I-20 machine oil — 10–15 %, oleic acid — 3 %, kerosene — the rest.

For superfinishing, diamond (or CBN) bars have been used, which were made on the basis of synthetic diamond (SD) micropowders with a grain size of 40, 28, 20, 10, 7, and 3 μm. Metal bonds M2-01 and M2-08, ceramic bonds K3-01 and SK4, and organic bonds B2-01 and B2-07 were used as bonds.

As it is known [6, 12–14, 16], bars with metal bonds are recommended only for preliminary superfinishing, and bars with ceramic bonds K3-01 and SK-4 are recommended to ensure a roughness of Ra = 0.08–0.12 μm.

To obtain the best performance of machined surfaces, superfinishing bars with organic bonds B2-01 and B2-07 are most often used, which are capable of providing a roughness quality in terms of Ra within 0.008–0.009 μm [6, 13, 14].

Some of the experiments were performed using fine-grained abrasive bars made of white corundum (23A), chromium corundum with a content of 1.0–2.0 % chromium dioxide CrO_2 (32A), and green silicon carbide (63C) on ceramic (K) and glyphthalic (Gl) bonds to compare the quality of samples' surface finishing (by the roughness parameter Ra) with different abrasive tools.

Particular attention was focused on the diamond powder concentration effect (100 % and 150 %) in the diamond layer of superfinishing bars on the surface roughness parameters Ra as a result of processing.

The studies of the surface quality parameters of new antifriction parts after superfinishing process were carried out by optical profilometry using an optical profilometer ProfilControl 7S (Pixargus GmbH).

Results and Discussion

The tasks of the article included studying the surface roughness parameters when superfinishing the samples' surfaces from new composites based on silumin grinding waste with abrasive bars and determining the effect of the material type, grinding wheel granularity, type of bonding, and effect of basic superfinishing modes on the quality characteristics of the machined surfaces of the studied samples. The results of superfinishing the surfaces of composite samples based on silumin grinding waste have been shown in tables 1–3.

Analyzing table 1, it can be seen that for processing composites with the same tool granularity, among all used abrasive and diamond superfinishing bars (green silicon carbide, white corundum, chrome corundum, synthetic diamond DS), the highest results in obtaining the minimum values of the surface roughness parameter Ra are obtained by using synthetic diamond DS as the material of the bars for superfinishing.

It should be noted that when comparing the surface roughness of Ra = 0.011 μm, obtained by processing with bars of green silicon carbide (63C) with a grain size of 10 μm on an elastic glyphthalic bond Gl — 63CM10Gl, with the surface roughness, obtained with

Table 1

Effect of abrasive, diamond bars and ultrafine superfinishing modes on the outer cylindrical surfaces' roughness parameters of the composite samples

Characteristics of the abrasive bar	Roughness Ra, μm								
	Sample material, composite type								
	AK21M2.5N2.5			AK12M2			AK7		
	Abrasive bars oscillation frequency, n_k, double stroke/min.								
	600	800	1000	600	800	1000	600	800	1000
23AM3CT2K	0.015	0.017	0.019	0.018	0.019	0.021	0.022	0.024	0.026
23AM3CT2Gl	0.014	0.015	0.016	0.014	0.018	0.020	0.021	0.022	0.023
32AM3CT2 Gl	0.013	0.014	0.015	0.015	0.017	0.019	0.020	0.019	0.021
63CM3CT2K	0.014	0.013	0.014	0.016	0.016	0.017	0.018	0.018	0.019
63CM3CT2Gl	0.012	0.012	0.013	0.014	0.014	0.015	0.016	0.017	0.019
23AM7CT1Gl	0.013	0.017	0.016	0.020	0.022	0.022	0.017	0.018	0.022
63CM7CT1Gl	0.012	0.014	0.017	0.018	0.021	0.020	0.015	0.019	0.021
23AM10CT1Gl	0.012	0.018	0.019	0.016	0.019	0.020	0.018	0.021	0.024
63CM10CT1Gl	0.011	0.013	0.018	0.015	0.016	0.020	0.016	0.017	0.022
DSM40M2-01	0.015	0.017	0.019	0.016	0.018	0.020	0.017	0.018	0.021
DSM40K3-01	0.017	0.018	0.020	0.018	0.019	0.021	0.019	0.020	0.022
DSM40B2-01	0.014	0.015	0.016	0.015	0.016	0.018	0.016	0.017	0.020
DSM28M2-01	0.011	0.012	0.013	0.012	0.013	0.014	0.014	0.015	0.019
DSM28K3-01	0.012	0.013	0.014	0.013	0.014	0.015	0.015	0.016	0.018
DSM28B2-01	0.010	0.011	0.012	0.011	0.012	0.013	0.012	0.013	0.014
DSM20M2-01	0.008	0.009	0.010	0.009	0.010	0.011	0.011	0.012	0.013
DSM20B2-01	0.007	0.008	0.009	0.008	0.009	0.010	0.009	0.010	0.011
DSM10M2-01	0.005	0.006	0.007	0.006	0.007	0.008	0.007	0.008	0.010
DSM10K3-01	0.006	0.007	0.008	0.007	0.008	0.009	0.008	0.009	0.010
DSM10B2-01	0.005	0.006	0.007	0.006	0.007	0.008	0.007	0.008	0.009
DSM7M2-01	0.004	0.006	0.006	0.005	0.006	0.007	0.008	0.008	0.009
DSM7K3-01	0.004	0.006	0.006	0.005	0.006	0.007	0.008	0.009	0.009
DSM7B2-01	0.003	0.004	0.005	0.004	0.005	0.006	0.005	0.006	0.008
DSM3M2-01	0.003	0.004	0.005	0.004	0.005	0.006	0.005	0.006	0.007
DSM3K3-01	0.002	0.003	0.004	0.003	0.004	0.005	0.006	0.007	0.007
DSM3B2-07	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.005	0.006

Notes: 1. Part rotation speed V_p = 120 m/min; 2. Speed of longitudinal-reverse displacements $V_{l.r.}$ = 0.5 m/min; 3. Amplitude of bars oscillations A = 3 mm; 4. Specific pressure of the bars q_0 = 1.0 MPa.

a synthetic diamond bar of the same gran size of 10 μm and also on an elastic organic bond B2-01 — DSM10B2-01 (Ra = 0.005 μm), it is clear that the machining roughness is more than twice as good when using a DS diamond bars.

The diamond superfinishing advantages in terms of roughness Ra are more significant when comparing fine-grained superfinishing bars made of synthetic diamonds DS (for example, with a grain size of ~ 3 μm) with other cutting materials (green silicon carbide 63C or chromium corundum 32A), when the roughness of the machining surface is improved by 5–7 times when using a synthetic diamond tool.

Such summarizations can be observed in the entire range of cutting modes. This can be explained by the fact that the cutting grains of synthetic diamond DS are the sharpest among the entire range of abrasive grains. They have significantly lower corner sharpening at the grain top γ and the grain top ρ rounding radii [1, 2, 12–16].

The analysis of the data in table 1 allows us to draw another important conclusion for practice — in the performed studies entire range, with a decrease in the grain size of superfinishing bars (3–40 μm), the machined surface roughness parameters Ra decrease, and therefore, the quality of the surfaces improves.

That is, taking into account the geometric parameters of the grains, with a decrease in grain size (for all abrasives), the chip cutting conditions improve, namely, the cutting forces are redistributed, the chip cross-section a_z decreases, the plastic deformation degree of the machining surface decreases. Therefore, an overall improvement in the process of forming surface roughness is observed.

It should also be noted that the use of elastic glyphthalic bonds for superfinishing bars contributes to the surface roughness improvement for all used tools and all the processed composites grades (table 1).

This can be explained by the bond' elastic properties, due to which the cutting abrasive grains are dampened under the cutting forces components at cutting thin chips, thereby reducing the actual cutting depth. This changes the conditions for the irregularities formation in the machined surface of the composite sample.

It should also be noted that a change in the abrasive bars' oscillation frequency nk (table 1) causes a change in the roughness parameter Ra during ultrafine superfinishing. So, an increase in the bars' oscillation frequency n_K causes a certain increase in the Ra parameter (within 5–10 %), which is obviously caused by a sharper impact of the cutting grains on the machined surface.

Further experimental studies have shown that the cutting modes during ultrafine diamond superfinishing, namely the part's rotation speed V_p and the speed of longitudinal–reverse movements of the superfinishing bar $V_{l.r.}$, significantly effect on the surface roughness parameters Ra (table 2).

As it can be seen from table 2, the machining surface roughness deteriorates somewhat (the Ra parameter increases by 10–15 %) with an increase in the part's rotation speed V_p and the longitudinal-reverse speed $V_{p.r.}$ of the superfinishing bar along the sample's axis. This fact is associated with the intensification of cutting modes, which is the superfinishing process, and in accordance with the general basis of the abrasive machining theory [6, 13, 16, 17]. In this case, there are changes in the temperature-force parameters of machining, the plastic deformation nature in the zone of the diamond grain cutting blade, the chip section a_z, and, as a result, the conditions for the micro-irregularities formation in the surface of the sample from the studied composite.

An equally important factor is the specific pressure q_0 of the diamond bars' superfinishing head, which effects on the surface roughness parameter. The results of studying the change in the roughness parameters Ra depending on the change in the specific pressure in the superfinishing process have been shown in table 3.

Analyzing the data in table 3, it can be generalized that in the entire range of the used diamond tools, the values of longitudinal-reverse displacement speeds $V_{l.r.}$, part's rotation speeds V_p, frequency and amplitude of abrasive bars oscilla-

Table 2

Dependence of surface roughness Ra on the part rotational speed V_p during diamond superfinishing of samples from a composite based on waste AK21M2.5N2.5 alloy

Characteristic of the diamond bar	Part's rotation speed V_p, m/min.	Roughness parameter Ra at the longitudinal–reverse speed $V_{l.r.}$, m/min.		
		0.5	1.0	1.5
		Ra, µm		
DSM40M2-01	80	0.016	0.019	0.021
DSM40B2-01	120	0.012	0.017	0.024
DSM28M2-01	80	0.009	0.010	0.011
DSM28K3-01	100	0.010	0.011	0.012
DSM28B2-01	120	0.009	0.010	0.011
DSM10M2-01	80	0.007	0.008	0.009
DSM10K3-01	100	0.005	0.006	0.008
DSM10B2-01	120	0.004	0.005	0.006
DSM7M2-01	80	0.003	0.004	0.005
DSM7K3-01	100	0.004	0.005	0.006
DSM7B2-01	120	0.003	0.004	0.005
DSM3M2-01	80	0.004	0.005	0.006
DSM3K3-01	100	0.003	0.004	0.005
DSM3B2-07	120	0.002	0.003	0.004

Notes: 1. Amplitude of bars oscillations A = 3 mm; 2. Abrasive bars oscillation frequency, n_k = 800 double stroke/min; 3. Specific pressure of the bars q_0 = 1.0 MPa.

tions, a gradual increase in the roughness parameter Ra is observed with an increase in the specific pressure q_0.

This fact is explained on the basis of the general principles of the friction and wear theory [18, 19], in particular, due to the increase in abrasive wear with an increase in the specific pressure on the friction pair, which is the processed composite sample and the superfinishing diamond bar.

Conclusions

The results of studies on ultrafine diamond superfinishing of the new composites based on silumins grinding waste for post-printing machines' antifriction units allow us to draw important scientific and practical conclusions:

1. The thin diamond superfinishing of new composite materials for antifriction units of post-printing machines have been investigated. This allows obtaining significantly higher quality parameters of the parts' working surfaces than when using other finishing technological processes.

2. It has been determined that the abrasive bar material, its grain size, the superfinishing bar's bond material, and the cutting modes during superfinishing significantly affect the roughness parameter Ra of the machined surface.

3. The minimum roughness parameters Ra of the machined surface area, which ensure satisfaction of the quality requirements for the friction surfaces of post-printing machines, can be obtained by using fine-grained synthetic diamonds (DS) with a grain size of 3–7 μm on an organic bond and by applying the following technological modes of cutting during diamond superfinishing: part's rotation speed V_p = 80–120 m/min; speed of longitudinal-reverse movements

Table 3

Dependence of the roughness parameter Ra on the specific pressure q_0 during diamond superfinishing of the samples based on AK12M2 alloy grinding waste

Characteristic of the abrasive bar	Specific pressure of the bars, q_0, MPa	Roughness parameter Ra at the longitudinal–reverse speed $V_{l.r.}$, m/min.		
		0.5	1.0	1.5
		Ra, μm		
DSM7B2-01	0.5	0.006	0.008	0.009
	1.0	0.007	0.007	0.010
	1.5	0.008	0.009	0.011
DSM3B2-07	0.5	0.005	0.005	0.009
	1.0	0.006	0.007	0.010
	1.5	0.007	0.008	0.011

Notes: 1. Part rotation speed V_p = 120 m/min; 2. Amplitude of bars oscillations A = 3 mm; 3. Abrasive bars oscillation frequency, n_k = 800 double stroke/min.

of the bar $V_{l.r.}$ = 0.5–1.0 m/min; specific pressure of the bars q_0 = = 0.9–1.1 MPa, amplitude of vibrations of the bars A = 3.0–5.0 mm; intensive use of lubricant and coolant.

4. Further research will be aimed at establishing the regularities of the influence of the latest cutting tools for superfinishing based on cubic boron nitride on the surface quality parameters formation during ultrafine superfinishing of cylindrical rotating parts — self-lubricating sliding bearings' bushings for antifriction units based on wide range of industrial grinding waste alloys intended for a wide range of operating conditions for printing and post-printing equipment.

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У статті наведено результати досліджень впливу режимів тонкого суперфінішування брусками з синтетичних алмазів на формування параметру шорсткості Ra поверхонь зразків з нових антифрикційних композитів на основі промислових шліфувальних відходів силумінів — алюмінієвих сплавів АК7, АК12М2, АК21М2,5Н2,5, що призначені для оснащення вузлів післядрукарської техніки.

Ключові слова: композит; силумінові відходи; суперфінішування; алмазний брусок; зернистість; зв’язка; режими різання; шорсткість; післядрукарські машини.

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