



UDC 621.923.6: 621.318.4: 621.002.1
DOI: 10.20535/2077-7264.1(91).2026.354614

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**THE EFFECT OF FINE CUBONITE GRINDING MODES
ON THE SURFACES ROUGHNESS OF COMPOSITE PARTS
BASED ON BRASS WASTE FOR STENCIL PRINTING MACHINES**

The article is devoted to research on determining the influence of fine grinding modes with cubic boron nitride (CBN, cubonite) tools on the roughness parameter Ra of the working surfaces of new antifriction composite parts based on L63 brass grinding waste with CaF₂ solid lubricant additives, intended for screen printing machine units.

Keywords: grinding waste; brass L63; composite part; cubonite grinding; roughness; antifriction properties; friction units; screen printing machine.

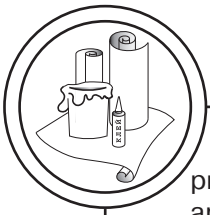
Introduction

The main task of designers and manufacturers is to satisfy product quality requirements as much as possible, which is determined by the needs of the global market. Growing competition places ever-increasing demands on product quality, which can only be achieved by combining scientific analysis and research results with the characteristics of product quality formation in the process of modern production technologies. The quality parameters of parts are largely determined by the properties of their surface working layer, the characteristics of which are formed in the technological production process.

Among the existing technological measures that improve the quality of parts in the final technological operations, various methods of mechanical processing of working surfaces are widely used. Reality has shown that with correctly selected technological operations, processing modes, and controlled factors, the reliability and durability of products can be significantly increased. At the same time, incorrectly determined technological modes can lead to the destruction of surface layers already at the stage of part production or to its untimely failure during operation.

This fully applies to the requirements for parts of high-performance

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printing equipment, in particular, antifriction parts of screen printing machines and apparatuses, such as Sakurai MS-102All, 2VURJBCZ, Saturn 2538, roll-to-roll screen printing cylinder machines Maestro (with direct servo drive), etc. [1].

The antifriction parts of these screen printing machines operate at speeds of up to 2.0 m/s and loads of up to 3.0 MPa in air [1]. For this purpose, antifriction bushings, inserts, etc. made of cast brass L63, LS59-1, which are analogues of foreign brass CuZn37 (EN 1652 CW508L), CuZn39PbI (EN CW611N) or ASTM C27200 and ASTM C37000, which operate under liquid lubrication conditions [1]. Brass alloys are one of the important types of copper-based alloys. They are widely used for many mechanical and industrial applications, such as mechanical, electrical, and hydraulic systems [2–4]. Brass alloys offer an advantageous combination of low cost, improved machinability, corrosion resistance, and good formability [2–4].

The drawback of cast brass parts is their early wear, which leads to an increase in the friction coefficient and wear intensity, especially with increasing loads and speeds of printing machines, when liquid oil becomes less or completely ineffective. Therefore, it is obvious that the stable operation of antifriction brass cast parts directly depends on the stability of the supply of lubricating oil to the contact area and on its quality.

Antifriction composites do not have these disadvantages and offer many advantages and a wide range of possibilities over cast materials, especially when working in severe conditions, where it beco-

mes possible to combine components that cannot be combined using traditional casting technology [5].

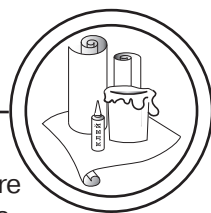
In this case, powder metallurgy technology has no alternative. Powder metallurgy technological methods make it possible to manufacture antifriction composites of various compositions with specially introduced substances, unlike traditional metallurgical remelting [1, 5].

Such substances include, for example, those that act as solid lubricants—graphite, sulphides, selenides, fluorides, and other substances. They actively participate in the friction films formation that form on the contacting parts' surfaces during operation. Such films have a decisive influence on the functional properties of the antifriction part (bearing bush) and its reliability and durability in general [1, 5].

However, despite the significant advantages of powder technology over traditional metallurgical melting, its widespread use is often very limited. This is due to the high cost of the starting powders and the equipment for their production.

At the same time, large volumes of potentially cheap and accessible raw materials are generated at many industrial enterprises. These are grinding wastes of ferrous and non-ferrous alloys, which are generated in large quantities during the grinding of various parts in the manufacturing process [5, 6]. Such grinding wastes contain a number of valuable alloying elements.

However, due to contamination with abrasive particles from grinding tools and residues of lubricants and coolants, these metal grinding wastes are not used in the production cycle, but are transported to landfills and dumps.



As shown by the authors' research [1, 5, 6], the application of certain technological measures allows obtaining fundamentally new effective composite materials based on recycled grinding waste and parts made from them, which can be an alternative to traditional cast parts.

Copper-based alloy grinding waste, in particular brass grinding waste, occupies a special place among industrial grinding waste. Such brass waste contains valuable chemical elements such as Cu, Zn, Pb, Sb, Fe, Bi, P, etc., but is not used as a valuable raw material in the production cycle for the manufacture of new parts [1, 5].

Grinding waste from brass, as well as other alloys [1, 5], is transported to landfills due to its contamination, as mentioned above.

The described circumstances illustrate the ever-increasing landfills and dumpsites volume and the ever-intensifying pollution of the biosphere.

At the same time, research by authors [1, 5, 7] on the development of technological measures aimed at regenerating grinding waste with its subsequent use for the manufacture of new types of antifriction composites for various operating conditions has shown positive results.

The authors [1, 5–7] have developed a series of technological processes (depending on the type of base metal) for the complete metal grinding waste recovery from certain grades of steel and non-ferrous alloys. This made it possible to realize obtaining of new antifriction composites from regenerated waste for various operating conditions.

This fully applies to the developments in the design of techno-

logical modes for the manufacture of new antifriction composites based on regenerated L63 brass waste [1, 7].

However, a number of issues remain unresolved. These primarily concern the formation of quality parameters for the working surfaces of new composite self-lubricating parts based on recycled L63 brass waste with CaF_2 solid lubricant additives [1, 8].

This particular issue remains one of the central ones, determining the functional behavior of the friction part and unit, primarily in screen printing machines.

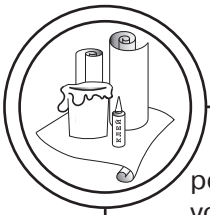
The running-in time of the contact pair and the speed of the formation of an anti-seize self-lubricating film directly depend on the initial quality parameters of the antifriction part's working surface especially when operating without liquid lubrication.

It should be emphasized that the quality parameters of composite self-lubricating friction parts are formed during the final mechanical processing, which, in turn, significantly affects the nature of the antifriction films formed, the so-called secondary structures.

Such antifriction films are capable to ensure the self-lubricating mode, stable and reliable operation of the antifriction unit and the entire screen printing machine as a whole.

Therefore, the problem of ensuring the working surfaces' quality of new composite antifriction self-lubricating parts based on brass grinding waste is topical and timely.

As it is known [5, 9–16], such parameters of the part surfaces' quality as geometric accuracy, Ra roughness parameter value, surface work hardening value and its



penetration depth into the part volume, residual stress values and signs in the surface layer significantly affect the wear resistance, durability, and maintainability not only of individual parts, but also of mechanisms as a whole [5].

Surface quality is of great importance and is particularly important in high-precision and high-productivity machining processes. In addition, the use of high-speed cutting provides increased productivity, workpiece dimensional accuracy, and improved surface finish quality [11, 12].

Artificial neural networks (ANN) and response surface methodology (RSM) were used to determine the influence of cutting conditions (cutting speed, feed rate, and cutting depth) on cutting force, surface roughness, and tool wear during the machining of alloys. In micro-milling, the main quality problems are tool wear and breakage, as well as intense burr formation and poor surface quality. The corresponding study investigated the influence of the cutting trajectory on the cutting force and surface quality in the micro-milling process under different cooling conditions (e.g., dry, air blowing, and flow cooling agent) at fixed cutting parameters [12].

The paper [12] discusses six methods of contact finishing of alloy surfaces, including diamond finishing, precision grinding, superfinishing, vibratory polishing, electrical discharge machining, and electropolishing, as well as their current industrial applications and limitations.

In research works, chip morphology and energy consumption were used as the main quality characteristics (criteria) for ranking machining performance [12, 17]. The

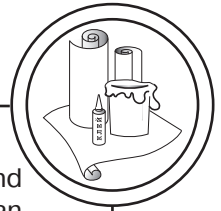
works made the first attempt to optimize two quality characteristics, cutting force and surface roughness, during the turning of the studied brass alloys. The methodology used for optimization was supported by signal-to-noise ratio data, as determined by Taguchi's experimental design and analysis of variance (ANOVA). This method is an effective and economical way to process and optimize industrial processes [18–20].

The works [12, 21, 22] are an original contribution concerning the optimization of the machinability of environmentally friendly lead-free brass alloys (CuZn42, CuZn38As, and CuZn36) compared to conventional lead brass alloy (CuZn39Pb3). These works are novel because there were no other published works in this particular field that provided recommendations for optimizing cutting force and surface roughness during the machining of lead-free brass alloys. These findings also reflect the original experimental and statistical work performed by the authors [12, 21, 22].

In summary, it can be said that the above-mentioned scientific works and the developments presented in them are of considerable practical interest for the mechanical processing of brass, but they all consider only cast brass alloys.

However, unfortunately, now there are no research works devoted to technological measures for improving the quality parameters of the composite antifriction parts' working surfaces, in particular, based on brass grinding waste.

Therefore, the development of new technologies for the finishing of parts from new wear-resistant



self-lubricating composites based on brass grinding waste is an important scientific and practical task. The development of new modes for surfaces fine grinding with modern abrasive tools, in particular, cubonites, will largely determine the quality parameters of these parts for friction units of screen printing machines.

This illustrates the relevance of the chosen scientific topic, which requires a complex of comprehensive research.

The objective of the work is to determine the effect of fine grinding modes using cubic boron nitride tools on the Ra roughness parameters of the working surfaces of new antifriction composite parts based on L63 brass grinding waste with CaF_2 solid lubricant additives, intended for screen printing machine components.

Methods

The object of research is an antifriction self-lubricating composite based on L63 brass grinding waste with admixtures of CaF_2 solid lubricant of the following composition, wt.%: brass grinding waste L63 +(6.0–9.0) CaF_2 [1, 7].

Surface finish refers to the overall texture and topography of a surface. It is an essential manufacturing measure which controls the quality of a part and is best described using three main factors which are the surface roughness, waviness, and lay (fig. 1) [12].

The surface roughness refers to the surface irregularities which are generated on the surface as a result of the machining process [5, 9–14].

As a rule, common parameters which are used to describe the sur-

face roughness include the Ra and Rms. The Ra is the arithmetic mean of peak height (Rp) and valley depth (Rv), whilst the Rms refers to the root mean square of the microscopic Rp and Rv values. The waviness of a surface refers to geometrical imperfections and is also termed as the macro-roughness of the surface. Waviness is usually the result of vibrations between the workpiece and the cutting tool, causing differences in the depth of cut [12].

Whilst advanced techniques have been developed to characterise the surface roughness, detection of surface waviness relies predominantly on visual observations [12]. The surface lay refers to the direction of the dominant surface pattern and is the result of the effect which the cutting tool has on the surface. It can usually be visually observed and can have straight, circular or radial forms [12, 15, 16].

The required surface quality parameters are most often achieved by fine abrasive grinding, with fine internal cylindrical grinding used for machining the internal surfaces of holes, fine external cylindrical grinding for external surfaces, and precision flat grinding for machining flat surfaces [5, 15–17].

For fine grinding of surfaces of anti-friction composites based on

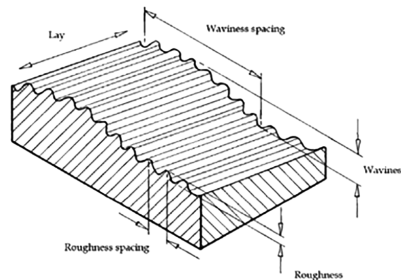
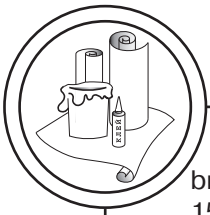


Fig. 1. Schematic representation showing the roughness, waviness and lay on a surface [12]



brass waste, abrasive wheels [5, 15, 16] made of cubic boron nitride (cubonite, CNB) with a grain size of 100, 50, 28, 20, 14, 10, and 7 μm on metal (M), ceramic (K), glyphthal (Gl), bakelite (B), and bakelite-rubber (Br) bonds with a 100 % concentration of the main grain fraction to compare their effect on the quality of the machined surface.

The results of friction process analysis show that the running-in time and wear intensity of surfaces directly depend on the initial parameters of contact surface quality, in particular, on the Ra roughness parameter.

To obtain reliable results when measuring the surface roughness of working surfaces of a brass waste-based antifriction composite after fine cubonite grinding, the following standards were used: ISO 4287–96, ISO 4288–97, ISO 21920–1:2021, EN ISO 21920–1:2022: Geometrical product specifications (GPS) — Surface texture: Profile — Part 1: Indication of surface texture (ISO 21920–1:2021). For this purpose, a MarSurf SD 26 contact profilometer (Mahr, Werl, Germany) was used. Measurements on the profilometer were performed on five measuring lines, each 4 mm long, defined at separate locations for each sample, and on 20 measuring tracks 240 μm long for each of the five images obtained as 3D images [5].

For comparative tribological tests, 30 samples with dimensions of $\varnothing 10 \times 20$ mm were manufactured, both from a new composite based on L63 brass waste with CaF_2 solid lubricant and from cast L63 brass. The tribological tests were performed on a VMT-1 friction machine using a face friction test with-

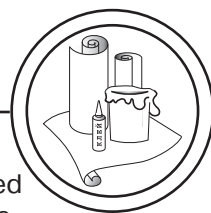
out liquid lubrication under the following conditions: sliding speed of 1.0–3.0 m/s and a load of 3.0 MPa in air, paired with a counterface made of 20X steel (DSTU 7806:2015), which corresponds to the foreign steel grades 5117, 5120 (G51170, G51200 ASTM A322 U.S. standards) or 20Cr4, 1.7027 steel (EN 10277, EN ISO 683-17 standards) with a hardness of HRC 54–55. The friction distance during testing was 5 km. Five samples were tested at each sliding speed of 1.0, 2.0, and 3.0 m/s for both the studied composite and cast brass. The sliding speeds and loads for the tribological tests were selected based on the actual speeds in the screen printing machines' friction units.

Results and discussion

The Ra roughness parameters of the samples were measured after processing under various conditions of cross feed, workpiece speed (longitudinal feed), and grinding depth during the development and testing of fine cubic grinding modes. The results were presented in table 1.

As shown in table 1, there is a direct relationship between the factors Ra, Sc, Vp, and t [5]. The cutting depth t and the cross-feed Sc have the greatest influence on the Ra roughness parameter, while the workpiece speed Vp has the least.

That is, knowing the specific values of Sc, t, Vp for the selected tool, it is possible to approximately determine what the Ra parameter will be and assess the correctness of the selected technological modes for cubonite grinding in terms of the requirements for the Ra parameter of the antifriction part.



A study of the effect of cutting tools' grain size and the bonding material on the Ra roughness parameter demonstrated the advantages of fine-grained cubonite grinding wheels with a bakelite-rubber bond, as illustrated by the example of samples flat grinding (table 2).

The improvement in the Ra roughness parameter can be explained by the fact that cubonite grains have a sufficiently sharp shape, specifically a larger angle of sharpness at the grain tip and the smallest rounding radius of an individual grain compared to green silicon carbide grains (table 2, 63SM14G1 and 63SM7G1 wheels).

At the same time, table 2 shows that the best Ra roughness values for the machined surfaces of parts made from new composites based

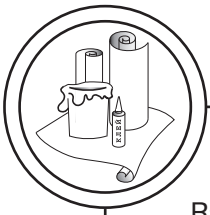
on L63 brass waste are provided by cubonite wheels on a Br1 bakelite-rubber bond. This can be explained by the greater elasticity of the bakelite-rubber bond. Thus, during grinding under the action of cutting forces, each grain is damped in the direction of the elastic-plastic bond [5]. This results in an actual reduction in the cutting depth t .

The Ra roughness parameter is minimized by changing the conditions under which surface roughness is formed. This parameter is one of the most important factors [5, 15, 16] characterizing surface quality after fine cubonite grinding and contributes to reducing running-in time and significantly increasing the wear resistance and reliability of the friction unit in a screen printing machine.

Table 1
Ra roughness parameters for fine cubonite grinding of a composite made from brass waste L63+(6.0–9.0)% CaF₂

Cross feed, S_c , mm/double-stroke	Part's speed (longitudinal speed), V_p , m/min	Grinding depth, t , mm		
		0.002	0.01	0.05
		Ra, μm		
0.1	2	0.223	0.364	0.702
	5	0.341	0.409	0.734
	10	0.358	0.436	0.887
0.2	2	0.380	0.441	0.966
	5	0.416	0.455	1.128
	10	0.422	0.530	1.309
0.5	2	0.551	0.796	1.577
	5	0.623	0.881	1.800
	10	0.660	0.945	1.170
1.0	2	0.831	0.962	2.220
	5	0.917	1.135	2.505
	10	1.143	1.233	2.684

Note: Machine — FF-350 'Abawerek' (Germany), abrasive — CNBM14Br on bakelite-rubber bond, wheel speed — 22 m/sec, processing — without cooling.



Similar to flat grinding, the best Ra roughness parameters for fine circular external and internal cubonite grinding of cylindrical surfaces on composite parts are achieved by using CNB cubonite-based wheels on a bakelite-rubber bond (Br1), with a grain size of 14–28 μm (M14–M28) and the use of fine grinding parameters ($V_p \rightarrow \text{min}$; $S_c \rightarrow \text{min}$; $t \rightarrow \text{min}$).

The effectiveness of the determined fine cubic boron nitride grinding modes was confirmed by profilometric analyses of sample surfaces before grinding (immediately after manufacture) and after cubonite grinding (fig. 2).

As shown in fig. 2, the surfaces micro-relief of the samples made from new composites based on purified L63 brass grinding waste changed significantly after fine cu-

bonite grinding. At the same time, the measured Ra roughness values were minimized.

The obtained microtopography of the surfaces contributed to the formation of self-lubricating antifriction films on the friction surfaces, which influenced the tribological characteristics of the new composite based on L63 brass waste and CaF_2 solid lubricant. The comparative antifriction properties of the studied composite and cast brass samples have been presented in table 3.

As shown by the results of the comparative tests presented in table 3, the studied composite based on L63 brass grinding waste with CaF_2 solid lubricant exhibits antifriction properties that exceed those of cast L63 brass under loads up to 3.0 MPa and sliding speeds up to 3.0 m/s without liquid lubrication.

Table 2
Effect of grain size and tool bond material on the surface roughness parameter Ra during fine flat cubic grinding of composite samples from brass waste L63+ (6.0–9.0)% CaF_2

Abrasive wheel	Wheel bond material	Surface roughness parameter, Ra, μm
CNB10Br1	Bakelite-rubber Br1	0.910
CNB5Br1	Bakelite-rubber Br1	0.864
CNB28Br1	Bakelite-rubber Br1	0.280
CNB14Br1	Bakelite-rubber Br1	0.223
CNB10Br1	Bakelite-rubber Br1	0.245
CNB7Br1	Bakelite-rubber Br1	0.197
CNB5M1	Metal M1	1.182
CNB28K1	Ceramic K1	0.477
63SM14GI	Glyphtal	0.668
63SM7GI	Glyphtal	0.377

Note: Machine — FF-350 'Abawerek' (Germany), grinding modes: wheel speed — 22 m/sec, longitudinal feed (workpiece speed) — 2 m/min; cross feed — 0.1 mm/double-stroke; cutting depth — 0.002 mm; processing — without cooling.

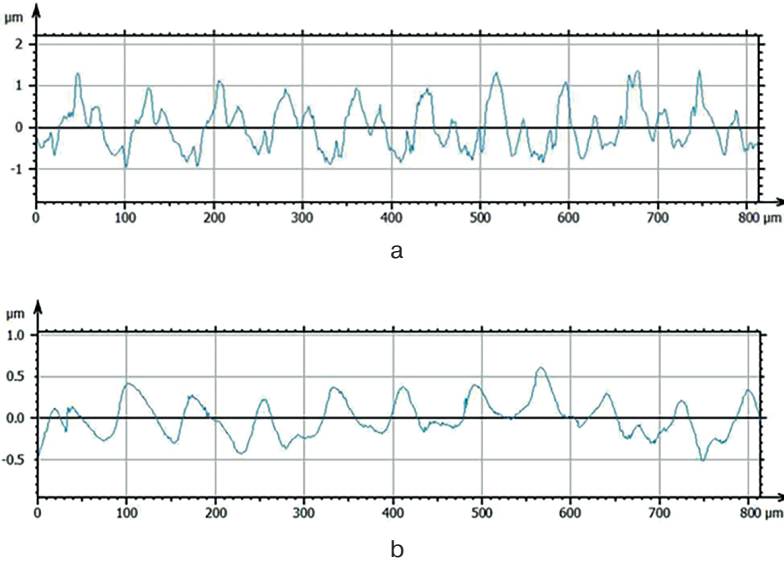
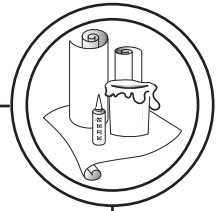


Fig. 2. Profilograms of samples' surfaces from composite L63 +(6.0?9.0)% CaF₂: a — before grinding, Ra = 0.766 μm; b — after grinding, Ra = 0.223 μm. Grinding with a CNBM14Br1 wheel; wheel speed — 22 m/sec; longitudinal feed (workpiece speed) — 2 m/min; cross feed — 0.1 mm/double-stroke; cutting depth — 0.002 mm; processing — without cooling

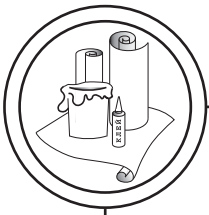
The minimization of the friction coefficient and wear rate of the new composite is directly associated with the formation of an antifriction film containing the solid lubricant CaF₂, a process that was sim-

plified and accelerated by the preliminary fine surface finishing. As a result, the new composite operates stably under permanent lubricating under exactly determined friction conditions.

Table 3

Antifriction properties of the studied materials [1]

Composition, wt. %	Sliding Speed, m/sec, Load 3.0 MPa						Note
	1.0		2.0		3.0		
	Frict. Coef.	Wear Rate, μm/km	Frict. Coef.	Wear Rate, μm/km	Frict. Coef.	Wear Rate, μm/km	
Composite Brass Waste L63+(6.0–9.0) CaF ₂	0.15–0.17	47.0–52.0	0.18–0.19	68.0–74.0	0.25–0.26	252.0–258.0	Self-lubricating mode; friction films are formed on the surface
L63 Cast Brass [2–4]	0.35–0.36	352.0–366.0	0.38–0.39	928.0–944.0	—		Surfaces are unprotected, increased wear, surface seizure



Conclusions

Summarizing the results obtained during the fine cubic grinding of composite antifriction parts based on brass L63 grinding waste with CaF_2 solid lubricant additives, intended for screen printing machine components, the following important scientific and practical conclusions can be drawn.

1. It has been shown the grain size, the bond material of the cubic nitride wheel, and the fine cubonite grinding modes significantly affect the surface roughness parameter Ra.

2. The best Ra roughness values are achieved with cubonite grinding wheels (CNB) with a grain size of 14–28 μm on a bakelite-rubber bond and fine cutting modes, namely, wheel speed — 22 m/s, longitudinal feed — 2 m/min, cross feed — 0.1 mm/double stroke, cutting depth — 2 μm .

3. The obtained microtopography of composite sample surfaces

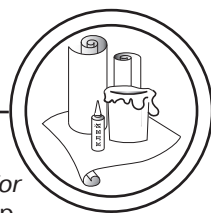
after grinding helps reduce the running-in time of contact parts and accelerates the formation of self-lubricating films on friction surfaces. This minimises the friction coefficient and wear intensity under exactly determined operating conditions of new composite parts when working without liquid lubrication.

4. Comparative tests of the studied composite based on L63 brass grinding waste with CaF_2 solid lubricant and L63 cast brass showed the advantages of the new material's antifriction properties under friction conditions at loads up to 3.0 MPa and speeds of 1.0–3.0 m/s without liquid lubrication.

5. The results of the carried out studies allow us to recommend the use of new self-lubricating antifriction composites based on recycled L63 brass waste with solid lubricant additives in the friction units of screen printing machines as an effective alternative to cast brass parts.

References/Список використаної літератури

1. Roik, T. A., Gavrysh, O. A., & Maistrenko, Iu. Iu. (May, 2025). Structure and tribological properties of wear-resistant composites produced from brass waste for screen printing machine parts. *Powder Metallurgy and Metal Ceramics*, Springer Nature, Switzerland AG, part of Springer Nature 2025, 64(1–2), 27–35. Retrieved from <https://link.springer.com/article/10.1007/s11106-025-00503-2> [in English].
2. Bohun, L., Pleshakov, E., Shvachko, S., & Tepla, T. (2017). *Kolorovi metaly ta splavy. Mid ta midni splavy [Non-ferrous metals and alloys. Copper and copper alloys]*. Part 1. Lviv: Lviv Polytechnic Publishing House, 124 p. Retrieved from <https://librarygo.lpnu.ua/?elbook=kolorovi-metaly-ta-splavy-chastyna-1-mid-ta-midni-splavy> [in Ukrainian].
3. Pozhuev, V. I., Ivashchenko, V. I., Chervonyi, I. F., & Hrytsai, V. P. (2007). *Metalurhiia kolorovykh metaliv [Non-Ferrous Metallurgy]*. Part I. Zaporizhzhia: ZGIA, 351 p. Retrieved from https://pdf.lib.vntu.edu.ua/books/2021/Chervoniy_P1_2008_351.pdf [in Ukrainian].
4. (2006). *Copper in Architecture. Design Handbook. Architectural Application*. Copper Development Association Inc., 324 p. Retrieved from https://copper.org/applications/architecture/arch_dhb/ [in English].
5. Kyrychok, P. O., Roik, T. A., Gavrysh, O. A., Maistrenko, Iu. Iu., & Oliinyk, V. H. (2025). *Prohresyvni tekhnolohii syntezu i tonkoi obrobky novykh antyfryktsiynykh kompozytnykh detalei dlia vuzliv drukarskykh mashyn [Progressive technolo-*



gies of synthesis and fine processing of new antifriction composite parts for components of printing machines]. Part 2. K.: ArtEk Publishing House, 281 p. Retrieved from <https://ela.kpi.ua/handle/123456789/72196> [in Ukrainian].

6. Zemlik, M., Roik, T., Gavrysh, O., Maistrenko, I., Bocian, M., & Jamrozak, K. (2026). Structure and Properties of a Self-Lubricating Antifriction Composite Based on Regenerated Bearing-Steel Waste for Friction Units of Stencil-Printing Machines. *Applied Science*. MDPI, Basel, Switzerland, 16(1), 415, 1–14. <https://doi.org/10.3390/app16010415> [in English].

7. Roik, T. A., Gavrysh, O. A., & Maistrenko, Yu. Yu. *Sposib oderzhannia samozmashchuvальноho antyfraktsiynoho kompozyta na osnovi shlifovalnykh vidkhodiv latuni [Method for obtaining a self-lubricating antifriction composite based on brass grinding waste]* // Patent u202404836 Ukraine. Publish 11.06.2025. Retrieved from <https://sis.nipo.gov.ua/uk/search/detail/1860832/> [in Ukrainian].

8. Jianxin, D., & Tongkun, C. (March 2007). Self-lubricant mechanisms via the in situ formed tribofilm of sintered ceramics with CaF₂ additions when sliding against hardened steel. *International Journal of Refractory Metals and Hard Materials*. Elsevier, 25(2), 189–197. <https://doi.org/10.1016/j.ijrmhm.2006.04.010> [in English].

9. Dziura, V. O., & Marushchak, P. O. (2021). *Tekhnologichni metody zabezpechennia parametriv yakosti poverkhon til obertannia ta yikh profilometrychnyi kontrol [Technological methods for ensuring the quality parameters of rotating body surfaces and their profilometric control]*. Ternopil: FOP Palianytsia V. A., 170 p. Retrieved from <https://elartu.tntu.edu.ua/handle/lib/36000> [in Ukrainian].

10. Toulfatzis, A. I., Pantazopoulos, G. A., David, C. N., Sagris, D. S., & Paipetis, A. S. (Basel, Switzerland, 2018). Machinability of Eco-Friendly Lead-Free Brass Alloys: Cutting-Force and Surface-Roughness Optimization. *Metals*, MDPI, 8(4), 1–9. <https://doi.org/10.3390/met8040250> [in English].

11. Picotto, G. B. (Berlin, Germany, 2004). Industrial Metrology: Surfaces and Roundness. *Measurement Science and Technology*. Springer, 15(2), 487–487. DOI:10.1088/0957-0233/15/2/B02 [in English].

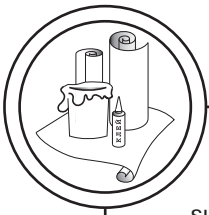
12. Micallef, C., Zhuk, Y., & Aria, A. I. (Basel, Switzerland, 2020). Recent Progress in Precision Machining and Surface Finishing of Tungsten Carbide Hard Composite Coatings. *Coatings*. MDPI, 10(8), 731. <https://doi.org/10.3390/coatings10080731> [in English].

13. Townsend, A., Senin, N., Blunt, L., Leach, R. K., & Taylor, J. S. (October 2016). Surface texture metrology for metal additive manufacturing: a review. *Precision Engineering*. Elsevier, 46, 34–47. <https://doi.org/10.1016/j.precisioneng.2016.06.001> [in English].

14. Mazur, M. P., Vnukov, Yu. M., Hrabchenko, A. I., Dobroskok, B. L., Zaloha, V. O., Novosiolov, Yu. K., & Yakubov, F. Yu. (2011). *Osnovy teorii rizannia materialiv [Fundamentals of the theory of cutting materials]*. Lviv: New World, 2000, 471 p. Retrieved from <https://xn--e1ajqk.kiev.ua/wp-content/uploads/2019/12/Mazur-M.-P.-Osnova-teori-rizannya-meterialiv.pdf> [in Ukrainian].

15. Novikov, M. V. (2006). *Abrazyvni materialy [Abrasive materials]*. Kyiv: Institute of Encyclopedic Studies of NAS of Ukraine. Retrieved from http://esu.com.ua/search_articles.php?id=42203 [in Ukrainian].

16. Manokhin, A. S., Klymenko, S. A., Beresniev, V. M., Klymenko, S. A., Kopeikina, M. Yu., Stolbovyi, V. O., & Litovchenko, S. V. (2023). *Rizalni instrumenty z kompozytiv na osnovi kubichnoho nitrydu boru z pokryttiam [Cutting tools made of coated cubic boron nitride composite]*. Kyiv: Naukova Dumka, 174 p. <https://doi.org/10.15407/978-966-00-1844-0> [in Ukrainian].



17. Georgiev, K., Katsarova, P., & Chopov, I. (2018). Experimental study of surface roughness on a processed detail of tungsten carbide by using a grinding device on a diamond turning machine. *International Journal of Innovations in Engineering and Technology (IJJET)*, 10(2), 082–087. <http://dx.doi.org/10.21172/ijjet.102.12> [in English].

18. Amadeh, A., & Ebadpour, R. (2013). Effect of cobalt content on wear and corrosion behaviors of electrodeposited Ni-Co/WC nano-composite coatings. *Journal of nanoscience and nanotechnology*, 13, 1360–1363. DOI: 10.1166/jnn.2013.6025 <https://pubmed.ncbi.nlm.nih.gov/23646637/> [in English].

19. Surviliene, S., Češuniene, A., Jasulaitiene, V., & Bučinskiene, D. (2008). Influence of SiC+WC addition to Cr(VI) bath on corrosion behaviour of coatings in sulphate solution. *Transactions of the IMF, The International Journal of Surface Engineering and Coatings*, 86(6), 308–314. <https://doi.org/10.1179/174591908X3711159> [in English].

20. Zhao, G., Li, J., Huang, Y., Yang, L., Ye, Y., Walsh, F. C., Chen, J., & Wang, S. (2017). Robust Ni/WC superhydrophobic surfaces by electrodeposition. *RSC Advances. Royal Society of Chemistry*, 7, 44896–44903. Retrieved from <https://eprints.soton.ac.uk/414483/2/c7ra08535d.pdf> [in English].

21. Kim, H. S., Kim, W. Y., & Song, K. H. (September 2012). Effect of post-heat treatment in ECAP processed Cu-40%Zn brass. *Journal of Alloys and Compounds*. Elsevier. 536, Supplement 1, 25, 200–203. <https://doi.org/10.1016/j.jallcom.2011.11.079> [in English].

22. Toulfatzis, A. I., Pantazopoulos, G. A., Besseris, G. J., & Paipetis, A. S. (2016). Machinability evaluation and screening of leaded and lead-free brasses using a non-linear robust multifactorial profiler. *The International Journal of Advanced Manufacturing Technology*. Springer Nature, 86, 3241–3254. Retrieved from <https://link.springer.com/article/10.1007/s00170-016-8435-5> [in English].

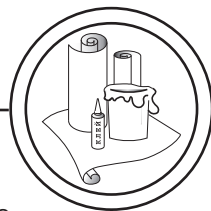
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About the author's contribution to the research

Roik T. A. — formulation of the problem and general research objectives, development of a comprehensive research methodology, development of manufacturing and precision finishing technologies for composites, general conclusions and recommendations.

Gavrysh O. A. — analytical research and data collection on the specified issues, justification and development of technological modes for fine cubonite grinding, grinding tools selection, and comparative analysis of results.

Maistrenko Iu. Iu. — development and testing of manufacturing technologies modes of composites, tribological characteristics experimental studies, and summary of comparative test results.

Jamroziak K. — experimental studies on testing technological modes of composites' fine mechanical processing, comparative profilometric studies, generalization of the obtained results.

Pyka D. — surface microtopography experimental studies before and after fine grinding, antifriction characteristics measurement, analysis of results.

Вплив режимів тонкого кубонітового шліфування на шорсткість поверхонь композитних деталей на основі відходів латуні для машин трафаретного друку

Стаття присвячена дослідженням з визначення впливу режимів тонкого шліфування інструментами з кубічного нітриду бора (КНБ, кубоніт) на параметр шорсткості R_a робочих поверхонь нових антифрикційних композитних деталей на основі шліфувальних відходів латуні Л63 з домішками твердого мастила CaF_2 , призначених для вузлів машин трафаретного друку. Об'єктом досліджень були зразки з нового самозмащувального антифрикційного композиту наступного складу: шліфувальні відходи латуні Л63+(6,0–9,0)% CaF_2 . Для тонкого шліфування поверхонь антифрикційних композитів на основі відходів латуні Л63 застосовувались абразивні круги з кубоніту зернистістю 100, 50, 28, 20, 14, 10 та 7 мкм на металевій (М), керамічній (К), гліфталевій (Гл), бакелітній (Б) та бакелітно-гумовій (Бр) зв'язках зі 100%-ю концентрацією основної зеренної фракції для порівняння їх впливу на якість поверхні оброблення. Вимірювання шорсткості робочих поверхонь антифрикційного композиту на основі відходів латуні після тонкого кубонітового шліфування виконували згідно стандартів ISO 4287–96, ISO 4288–97, ISO 21920–1:2021, EN ISO 21920–1:2022: Geometrical product specifications (GPS) – Surface texture: Profile – Part 1: Indication of surface texture (ISO 21920–1:2021). Для цього використовували контактний профілометр MarSurf SD 26 (Mahr, Werl, Німеччина). Порівняльні трибовипробування зразків з нових композитів та з литою латунню



Л63 здійснювали на машині тертя ВМТ-1 за схемою торцевого тертя без змащення рідким мастилом за наступних режимів: швидкість ковзання 1,0–3,0 м/с і навантаження 3,0 МПа на повітрі, в парі з контртілом зі сталі 20Х (ДСТУ 7806:2015), яка відповідає закордонним маркам сталей 5117, 5120 (G51170, G51200 ASTM A322 стандарти США) або сталі 20Cr4, 1.7027 (стандарт EN 10277, EN ISO 683-17) з твердістю HRC 54–55. Показано, що на параметр шорсткості поверхні Ra суттєво впливають зернистість, матеріал кубонітового круга та режими тонкого кубонітового шліфування. Найкращі значення параметру шорсткості Ra забезпечують шліфувальні круги з кубоніту (КНБ) зернистістю 14–28 мкм на бакелітно-гумовій зв'язці та тонкі режими різання, а саме, швидкість круга – 22 м/с, поздовжня подача – 2 м/хв, поперечна подача – 0,1 мм/подв. хід, глибина різання – 2 мкм. Мікротопографія поверхонь композитних зразків після шліфування сприяє зменшенню часу припрацювання контактних деталей, прискорює утворення самозмащувальних плівок на поверхнях тертя. Це мінімізує коефіцієнт тертя і інтенсивність зношування у визначених умовах експлуатації нових композитних деталей при роботі без змащування рідким мастилом. Порівняльні випробування досліджуваного композиту на основі шліфувальних відходів латуні Л63 з твердим мастилом CaF_2 і литої латуні Л63 показали переваги у антифрикційних властивостях нового матеріалу в умовах тертя за навантажень до 3,0 МПа і швидкостей 1,0–3,0 м/с без змащування рідким мастилом. Отримані результати дозволяють рекомендувати застосування нових самозмащувальних антифрикційних композитів на основі відновлених відходів латуні Л63 з домішками твердого мастила у вузлах тертя машин трафаретного друку як ефективну альтернативу деталям з литої латуні.

Ключові слова: шліфувальні відходи; латунь Л63; композитна деталь; кубонітове шліфування; шорсткість; антифрикційні властивості; вузли тертя; машина трафаретного друку.

Надійшла до редакції/Received: 26.02.26

Рецензія/Peer review: 15.03.26

Опубліковано/Printed: 10.04.26