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SURFACE TEXTURE OF SINTERED IRON-GRAPHITE MMCs INFILTRATED BY COPPER ALLOYS AFTER GRINDING

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Summary

The influence of grinding conditions on surface texture of sintered FeGr1.2 metal matrix composites infiltrated by copper based alloys such as CuSn5 and CuSn5Pb2.5 is considered. The composition of MMC and parameters of grinding practically do not influence the texture of the treated surface after grinding using with white Al_2O_3 wheel. Conditions of sparking out have the decisive influence on the results of grinding. Four passes of sparking out reduce the vertical roughness parameters more than twice, mean width of the surface element *RSm* more than three times and material ratio of the profile *Rmr*(50) about twice.

Keywords: composites, infiltration, grinding, sparking out, surface texture

Struktura geometryczna powierzchni po szlifowaniu spiekanych materiałów kompozytowych nasyconych stopami miedzi

Streszczenie

W pracy ustalono wpływ warunków szlifowania na strukturę geometryczną powierzchni spiekanych materiałów kompozytowych FeGr1.2, nasyconych stopami miedzi CuSn5 i CuSn5Pb2.5. Ustalono, że skład chemiczny kompozytu i parametry szlifowania nie wpływają na strukturę geometryczną powierzchni obrobionej ściernicą z elektrokorundu białego Al_2O_3. Warunki wyiskrzania mają natomiast decydujący wpływ na efekty szlifowania. Cztery przejścia wyiskrzania zmniejszają parametry pionowe chropowatości powierzchni ponad 2 razy, średnią szerokość elementów profilu ponad 3 razy i udział materiałowy profilu *Rmr*(50) ok. 2 razy.

Słowa kluczowe: kompozyty, szlifowanie, wyiskrzanie, struktura geometryczna powierzchni

1. Introduction

Different sintered materials are widely used in various industries. Antifriction sintered materials are mainly used in slide bearings. Such bearings are easily mounted in units, produced in a considerable range of sizes at relatively low costs, often have simplified design involving less space, require reduced maintenance and so on. Antifriction sintered materials can be based

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both on ferrous and non-ferrous metals. Non-ferrous metals may also be added to ferrous based materials to improve their functional properties. In this case metal matrix composites (MMCs) are formed as premixes consisting of elemental powders or using metal matrix infiltration by appropriate alloys.

The information about specifics of grinding of MMCs is restricted. It refers mainly to the composites based on aluminum matrix with silicon carbide additives. They are superior to other MMCs due to their low cost. Aurich et al. [1] determined the influence of the grinding parameters on the surface and subsurface profiles of the workpiece. The special AA 2124 + 25% SiCp a high performance resin bonded diamond grinding wheel was used owing to the abrasive nature of SiC reinforcements. Zhong [2] described diamond grinding experiments performed on aluminium based MMCs reinforced with SiC or Al_2O_3 particles. Rough grinding by the use of SiC wheel followed by fine grinding by the use of fine-grit diamond wheel was recommended at depths of cut of 0.5-1 μm.

As described in [3], smoother surface can be obtained for 10% SiCp reinforced 2 124 aluminium composite material in ELID grinding using metal-bonded grinding wheel. According to Blau [4], Ti-6Al-4V-based MMC reinforced with TiB_2 and TiC particles had almost the same final arithmetic average surface roughness after grinding. It was ascertained in [5, 6], that better surface finish and damage free surfaces can be obtained by applying low grinding force at high wheel and workpiece velocities with white Al_2O_3 wheels during cylindrical grinding of MMCs based on LM25 aluminium alloy with SiC particles. *Ra* values decrease with an increase in wheel velocity and workpiece velocity. *Ra* values also increase with an increase in feed and depth of cut. Grinding process of aluminium based MMC reinforced by Al_2O_3 particles was investigated in [7] using grinding wheels having SiC in a vitrified matrix and diamond in a resin-bonded matrix. The surface finish values were scattered in the range of 0.15-0.70 μm for the rough-ground samples, whilst a narrower range of 0.20-0.35 μm was achieved for fine-ground samples. There were no cracks and defects found on the ground surfaces.

According to Kwak et al. [8], the table speed had less effect on the surface roughness compared to depth of cut during grinding of the aluminum-based MMCs reinforced with SiC particles. Ilio et al. [9] proved that conventional abrasive grinding wheels have shown better results, in terms of grinding force, surface roughness and flat area percentage than super abrasive ones during machining of SiC aluminium composites.

It is noted in [10], that a process like grinding is required to produce MMC components to the desired final dimensions, with good surface finish and a damage free surface. Improper machining conditions not only escalate the component cost, but also cause sub-surface damage in MMC components. The quality of the surface influences on the component performance by way of tribological response. The surface finish is influenced by grinding condition, the nature of composite and the wheel specification.

A surface integrity of components is crucial in the case of MMC use as anti-friction material for slide bearings. However there is nothing about grinding of such MMCs in the reviewed articles. The aim of this paper is to investigate surface texture of sintered Fe-Gr metal matrix composites infiltrated by copper alloys after grinding.

2. Materials and methods

Sintered FeGr1.2 material was used as the base. Ready-made powders of iron and pencil graphite were used during preparation of samples. The mixture of components was prepared in a mixer of "drunken barrel" type and then the samples were pressed using a hydraulic press with 1000 kN force. There were 3 materials investigated: 1) base material of 25% porosity infiltrated by CuSn5 alloy; 2) base material of 15% porosity infiltrated by CuSn5 alloy; 3) base material of 15% porosity infiltrated by CuSn5Pb2.5 alloy. Infiltration of the base material matrix was carried out in protective-reducing atmosphere of endothermic gas at 1080-1100°C.

Microstructure of MMC materials are shown in Fig. 1. The microstructure of FeGr1.2 matrix is a perlite with low content of torn cementite grid. The microstructure of infiltrated MMC with primary porosity of 25% consists of matrix grains separated by a continuous copper phase (white areas in Fig. 1 a). When the primary porosity amounts to 15%, this effect is not observed, the copper phase is located mainly at the grain boundaries (Fig. 1 b). In the third material infiltrated by CuSn5Pb25 the free lead particles which are located in the copper phase (black areas in Fig. 1 c) are observed.

a) b) c)

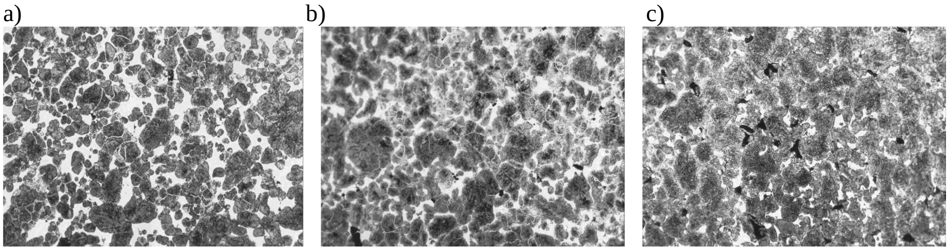

Fig. 1. Microstructure of MMC materials: a) base FeCr1.2 material of 25% porosity infiltrated by CuSn5 alloy, b) base FeCr1.2 material of 15% porosity infiltrated by CuSn5 alloy, c) base FeCr1.2 material of 15% porosity infiltrated by CuSn5Pb2.5 alloy

Samples were treated using a surface grinder made with white Al_2O_3 wheel 99A-46-K-5-V. Emulsion of 4% percentage on the base of concentrated product

“Emulgol ES” was used as lubricating fluid. Conditions of grinding were accepted accordingly to a full factorial design 2^3 and they are represented in Tab. 1. The grinding velocity was 35m/s. Grinding was carried out without sparking-out, as well as with two or four passages of sparking-out.

A surface morphology after grinding was analyzed using scanning electron microscope JSM 5600-LV, roughness parameters were measured using portable surface roughness tester SJ-301. Surface roughness parameters such as: arithmetical mean deviation of the assessed profile *Ra*, maximum height of the profile *Rz*, maximum peak height *Rp*, maximum valley depth *Rv*, mean width of the surface element *RSm* and material ratio of the profile *Rmr*(*c*) were measured.

Table 1. Parameters of surface grinding

Number of experiment	Radial table feed (depth of grinding) f_r, mm	Tangential table feed (workpiece velocity) v_{ft}, m/min	Axial table feed f_a, mm/double stroke
1	0.005	4	3
2	0.045	4	3
3	0.005	15	3
4	0.045	15	3
5	0.005	4	6
6	0.045	4	6
7	0.005	15	6
8	0.045	15	6

3. Results of investigation

It is known that grinding parameters and sparking out conditions have a significant effect on the texture of the treated surface. At first the number of passes was determined which is required for ensure a good texture of the MMC surfaces. It was found that the influence of sparking-out conditions on the surface roughness of parts of infiltrated materials is the same as for conventional steels, and significantly differs of sintered porous antifriction materials. It was observed in [11], that it is enough to execute two sparking-out passages during grinding sintered porous materials. But in the case of infiltrated MMCs two sparking-out passages practically do not change a surface microrelief irrespectively of a combination of grinding parameters. Waviness, deep hairlines, traces of metal side flow, adhesive particles and other defects can be seen on the surfaces which arise as a result of the action of single abrasive grains with minimal depth of grinding. Number of these defects decreases significantly after four passes of sparking-out, as it is shown in Fig. 2 and 3.

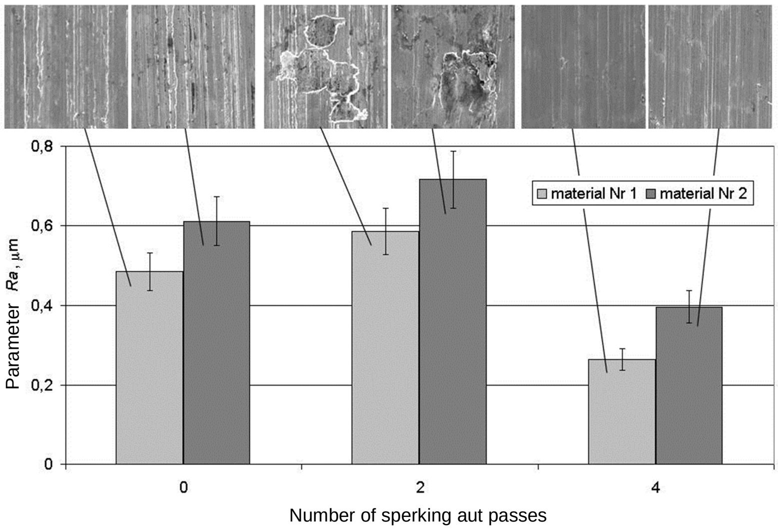

Fig. 2. Influence of the number of sparking out passes on *Ra* roughness parameter

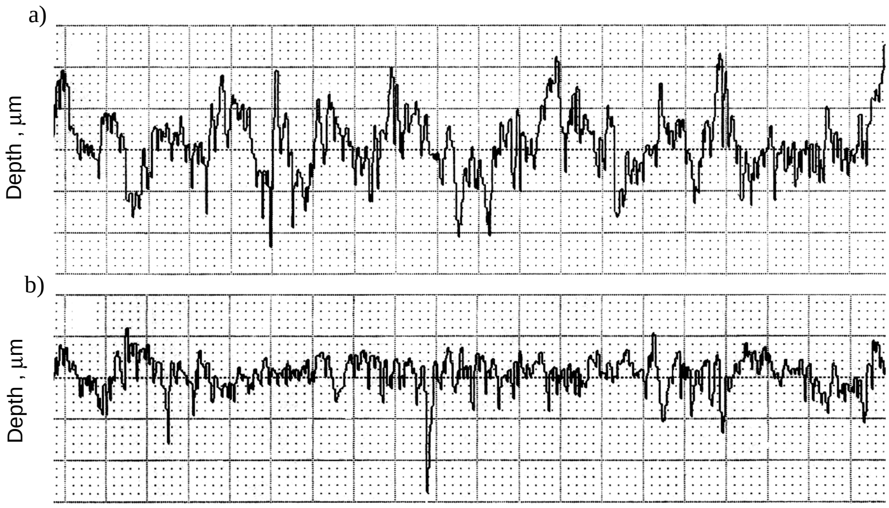

Fig. 3. Typical records of ground surface profiles: a) without sparking,
b) with sparking out. Horizontal scale – 2 µm/cm, vertical scale – 200 µm/cm

Values of some vertical roughness parameters such as arithmetical mean deviation of the assessed profile *Ra*, maximum peak height *Rp*, maximum valley depth *Rv* and maximum height of the profile *Rz* are shown in Fig. 4. The statistical analysis of the results of full factorial design showed that the composition of ground material and the parameters of grinding have not significant effect on these parameters (Tab. 2).

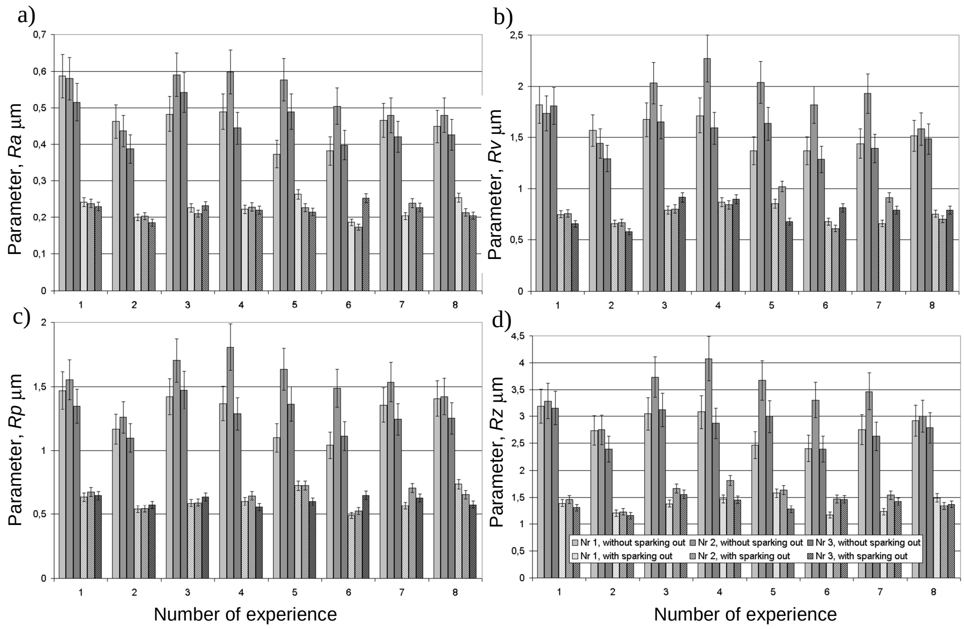

Fig. 4. Vertical roughness parameters of ground surfaces: a) Ra, b) Rv, c) Rp, d) Rz

Table 2. Values of some surface roughness parameters

Material	Grinding conditions	*Ra*, µm	*Rp*, µm	*Rv*, µm	*Rz*, µm
No 1	Without sparking out	0.37-0.58	1.04-1.47	1.37-1.81	2.4-3.2
	With sparking out	0.18-0.25	0.49-0.74	0.66-0.87	1.2-1.6
No 2	Without sparking out	0.43-0.59	1.42-1.81	1.44-2.27	2.75-4.1
	With sparking out	0.17-0.24	0.52-0.72	0.61-1.02	1.35-1.62
No 3	Without sparking out	0.38-0.52	1.1-1.47	1.28-1.81	2.4-3.16
	With sparking out	0.18-0.25	0.55-0.65	0.65-0.92	1.15-1.56

Values of a mean width of the surface element *RSm* and a material ratio of the profile *Rmr* of material No 1 are shown in Fig. 5. It is easy to see that a sparking out reduces essentially the values of the *RSm* parameter and improves a character of *Rmr* curve. Both of these parameters directly affect the wear resistance of the surface. It was confirmed during the tribological tests of the investigated materials, as it was obtained in [12]. The wear resistance of surfaces ground with sparking out was 1.8-3 times higher than the of surfaces ground without sparking out.

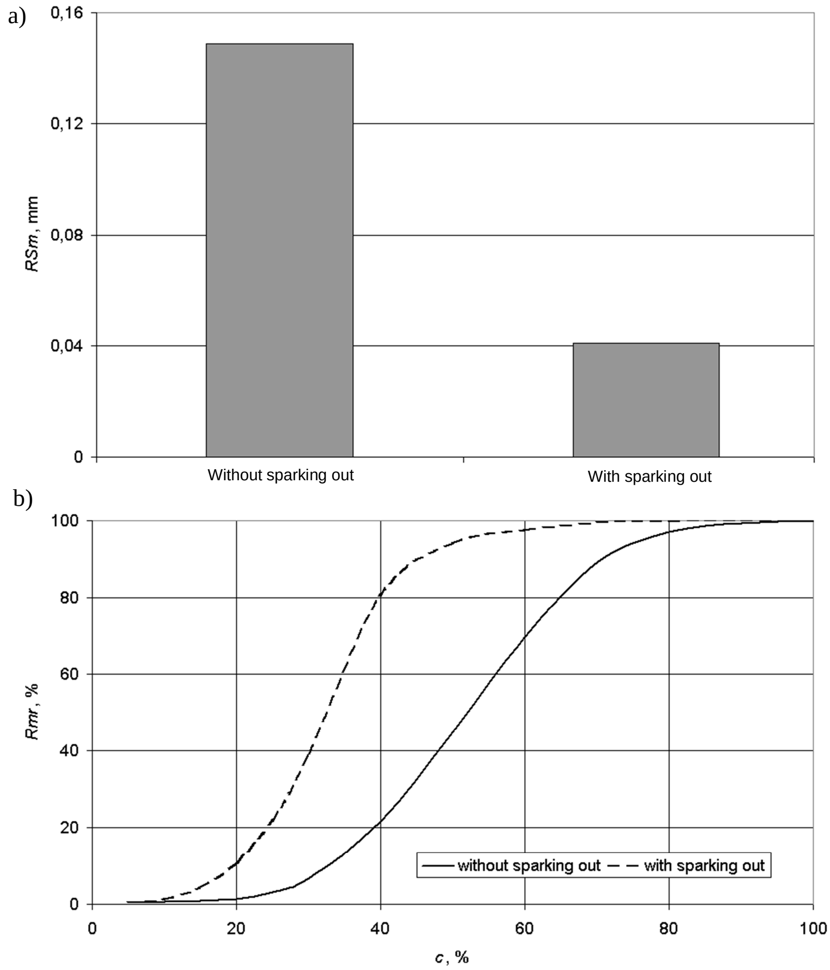

Fig. 5. Influence of sparking out on values of a mean width of the surface element *RSm* (a) and a material ratio of the profile *Rmr* of material Nr 1 (b)

4. Conclusions

MMCs based on the FeGr1.2 matrix infiltrated by CuSn5 and CuSn5Pb2.5 alloys have good grindability. Their composition and parameters of grinding practically do not influence the texture of the treated surface after grinding using white Al_2O_3 wheel. Conditions of sparking out have the decisive influence on the result of grinding. Four passes of sparking out reduce the vertical roughness parameters more than twice, mean width of the surface element *RSm* more than 3 times and increase material ratio of the profile *Rmr*(50) about twice.

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