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A Possibility to Improve Resistance of Cast-iron Wood Chip Fine Grinder Liners to Abrasive Wear

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Abstract

The paper deals with the issue of potential for improvement of resistance of wood chip fine grinders to abrasive wear by providing them with WCCoCr coating applied with the use of atmospheric plasma spraying (APS). The study focused on establishing parameters of the technological process of spraying a 250–270 µm thick coating onto surface of ductile cast iron castings used to date as grinder linings. The presented data include results of microstructure examination, chemical composition analysis, HV hardness measurements, and scratch tests for both previous and new variant of linings. The obtained scratch test results indicate that the material of the coating is characterized with definitely lower susceptibility to scratching. The scratch made on coating was 75–84 µm wide and 7.2–8.2 µm deep, while the scratch on cast iron was distinctly wider (200–220 µm) and deeper (8.5–12.8 µm). In case of cast iron, the range of variability in scratch width and depth was definitely larger. This can be explained with large difference in hardness of individual components of microstructure of cast iron and significantly larger plastic deformation of cast iron compared to the coating revealed in the course of indenter motion over surfaces of the two materials. It has been found that application of WCCoCr coating offered better resistance of lining surfaces to scratching which can be considered a rationale for undertaking in-service tests.

Keywords: Ductile cast iron, WCCoCr coating, Microstructure, Scratch test

1. Introduction

Strong competition characterizing the chipboard market forces manufacturers to undertake efforts towards development of more robust tooling used in the wood chip production process. An important stage of the process is the wood chip fine grinding. In the process, wood particles move in a slit between outer surface of a drum with diameter of 1500 mm rotating at 1000 rpm and surfaces of cast-iron lining segments mounted on a immobile fixed drum. Excessive wear of lining surfaces has an adverse effect on particle-size distribution profile characterizing the fine-ground products (Fig. 1).

a) b)

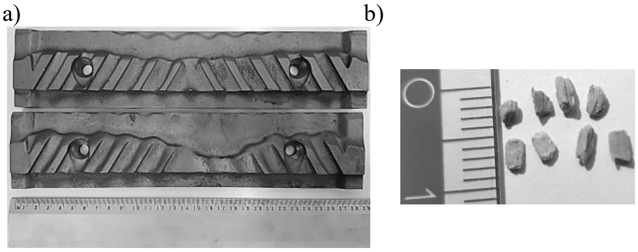


Fig. 1. Excessively worn lining surface (a) resulting in increased percentage share of large-size particle fraction with excessive size (b), unacceptable for the chipboard production process

Any results of mechanical (screen) analysis showing that percentage share of particles with size 2–4 mm exceeding 0.1% are considered a signal of the need to replace linings with new ones.

Currently, the majority of chipboard manufacturers use a pearlitic-ferritic ductile cast iron of GJS 500 grade as the material for lining castings. Heat treatment of such cast iron components aimed at obtaining ausferritic matrix failed to improve their service life.

To improve abrasion resistance of cast-iron components, they are typically provided with overlay welds or coatings. To this end, a number of welding processes are employed such as the Gas Tungsten Arc Welding (GTAW) [1], Plasma Transferred Arc (PTA) [2], Flame Spraying (FS) [3], and Thermal Spraying Processes, especially High Velocity Oxy Fuel (HVOF) [4], and Atmospheric Plasma Spraying (APS).

The use of GTAW, PTA and FS processes is connected with introduction of certain heat quantities into substrate material which are large enough to produce the fusion zone (FZ), the partially melted zone (PMZ), and the heat affected zone (HAZ) [1]. As a result of fast cooling, a cementite eutectic (ledeburite) occurs in FZ, a cementite eutectic and hardening products in PMZ, and hardening products in HAZ [1, 5].

A factor decisive for susceptibility of substrate material to crack nucleation and development is presence of cementite eutectic and martensite. Further, a condition favorable to occurrence of the cracks are tensile stresses which in turn occur as a result of differences in value of the coefficient of linear expansion between the substrate material and the padding weld or coating. In HAZ, cracks nucleate on graphite precipitates or on graphite-matrix boundaries and develop deep into the matrix [3, 5]. The use of thermal spraying processes allows to avoid problems connected with evolution of substrate microstructure and the related problem of cracking, but the coating is bonded with the substrate only by means of a mechanical joint.

The objective of the study presented in this paper was to examine the possibility to improve resistance of cast-iron wood chip fine grinder linings to abrasive wear by providing their working surfaces with WCCoCr coating using the atmospheric plasma spraying (APS) process.

2. Research material and methodology

The substrate material onto which the coating was applied was a ductile cast iron with ferritic-pearlitic matrix (Fig. 2), chemical composition of which is presented in Table 1.

As the coating material, WCCoCr powder was used. A view of powder particles is shown in Figure 3. Chemical composition of the coating was evaluated with the use of electron scanning microscope (SEM) equipped with INCA x-Act electron back scattered diffraction system (Oxford Instruments). Powder particles with sizes from the range 1–35 μm and spherical shape contained: 75.5–78.8% W, 11–12.8% C, 8–10.5% Co, and 1.3–2.2% Cr. Particles with size 7–40 μm and irregular shapes contained: 73.3–81.2% W, 5.9–13.7% C, 3.6–16.7% Co, and 0.7–3.1% Cr.

Before application of the plasma spraying process, surfaces of ductile cast iron specimens were degreased with acetone and then subjected to blasting with an abradant (EFK930 alumina with 125–180 mm grain size) in jet of compressed air supplied under pressure of 6 bar. The nozzle-specimen surface distance was about 1000 mm. The apparatus used was KCW-1200-1150+FCPd abrasive blasting machine.

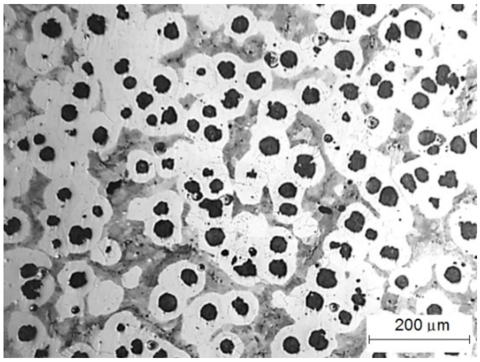


Fig. 2. Microstructure of substrate material. Graphite, ferrite and pearlite. Section etched with Nital. Magnification ×100

Table 1.
Chemical composition of substrate material

Element content, % wt.								
C	Si	Mn	P	S	Ni	Cu	Mg	Fe
3.43	2.5	0.1	0.02	0.01	0.02	0.01	0.051	to bal.

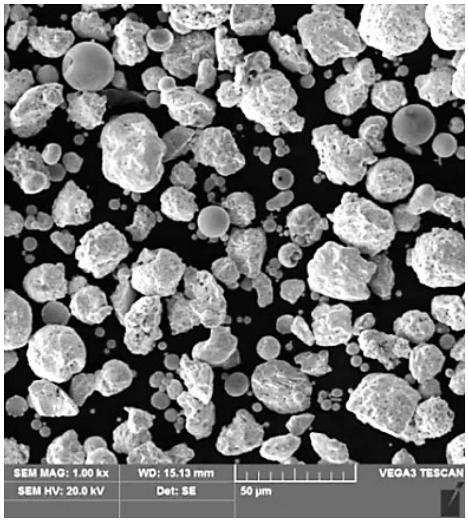


Fig. 3. WCCoCr 86104 powder particles

The atmospheric plasma spraying (APS) process was carried out on a robotized spraying system by Sulzer Metco. The F4-MB-HBS burner was mounted on the arm of ABB model IRB 2400 robot. The powder was supplied by Twin-120-A/H powder feeder with volumetric control of powder feed rate.

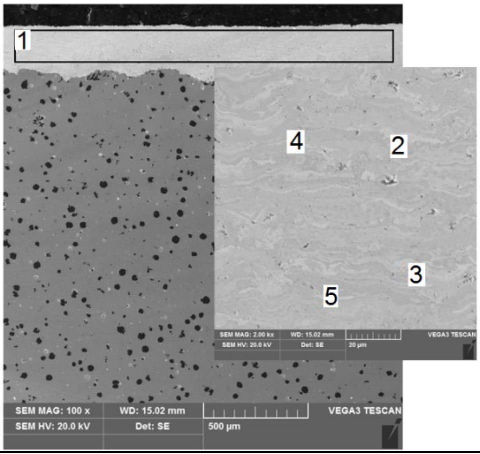
Parameters of the spraying process were determined based on preliminary tests carried out in advance, as a result of which the following were adopted as criteria of correctness of coating application: thickness in the range from 250 to 270 μm; good compactness; and good bonding between the coating and the substrate material. The following technological parameters of the plasma spraying process were used:

- plasma gun advancement rate: 16 mm/s;
- electric current intensity: 630 A;
- plasma-generating gases: Ar, 60 l/min, H, 10 l/min;
- powder distribution: powder feeder disc - 2%, mixer - 90%;
- plasma gun-sprayed element distance: 110 mm;
- powder carrier gas: Ar, 3 l/min;
- cooling gas type: air, under pressure of 6 bar;
- number of runs to obtain 250–300 µm thick coating: 20.

Microstructure and chemical composition were examined with the use of TESCAN VEGA3 electron scanning microscope, equipped with INCA x-Act adapter for chemistry microanalysis (Oxford Instruments).

Measurements of hardness (HV0.3) of the substrate material and WCCoCr coating were taken with the use of Vickers hardness tester.

The scratch test was carried out with the use of Revetest scratch tester (CSM Instruments). A diamond Rockwell-type indenter C-281 was used with tip radius 200 µm and apex angle 120° loaded with force of 20 N. The scratch test was supplemented with observation of scratch marks carried out with the use of scanning microscope.



Point	C	Cr	Co	W	Total
1	7.62	1.70	11.81	78.87	100.00
2	2.34	0.01	0.24	97.42	100.00
3	1.86	0.02	0.23	97.89	100.00
4	12.70	2.59	13.18	71.53	100.00
5	12.11	2.33	12.59	72.98	100.00

Fig. 4. Microstructure and chemical composition in macro- and micro-areas of the coating sprayed onto ductile cast iron substrate

3. Research results and analysis

Microstructure of WCCoCr coating plasma-sprayed onto ductile cast iron substrate (SEM), together with results of macro-analysis of the coating microstructure and point-like microanalysis of its composition is shown in Figure 4.

Results of visual inspection of the coating-substrate boundary (Fig. 4) indicate absence of linear discontinuities which weights in favor of good coating-substrate adhesion. Neither changes in microstructure nor cracks were found in the substrate material which could be attributed to the plasma spraying process.

Examination with the use of SEM allowed to reveal two microstructure components differing in their color. It has been found that the darker component (Fig. 4, points 4 and 5) was characterized with high tungsten content (about 72% W), high cobalt content (about 13% Co), and high carbon content (about 12% C). The lighter component of microstructure (Fig. 4, points 2 and 3) contained more tungsten (about 98% W), but definitely less cobalt (about 0.25% Co), chromium (about 0.02% Cr), and carbon (about 2% C) in comparison to the darker features.

Results of HV0.3 hardness measurements for WCCoCr coating material and ductile cast iron substrate are presented in Table 2.

The obtained results show that hardness of WCCoCr coating is four times higher than this of the substrate.

Results of the scratch test are presented in Figure 5 and 6, whereas views of scratch surface fragments are shown in Figure 7.

Table 2.
Results of HV0.3 hardness measurements for WCCoCr coating and ductile cast iron

Material	HV0.3 hardness
WCCoCr coating	926–976
Ductile cast iron	220–245

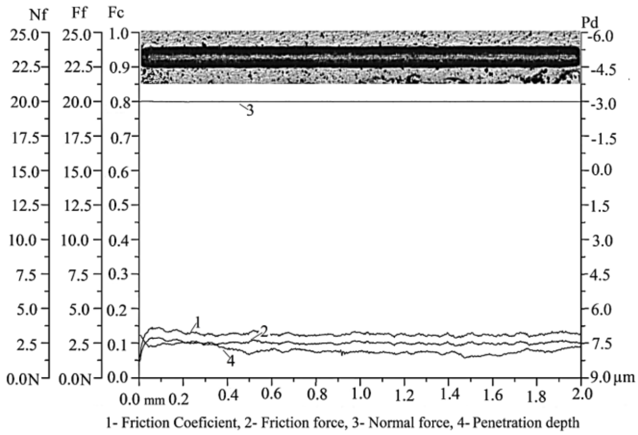


Fig. 5. Scratch test results for WCCoCr coating

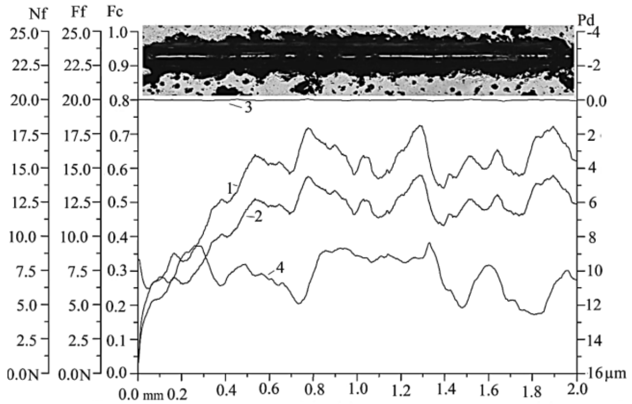


Fig. 6. Scratch test results ductile cast iron

a)

b)

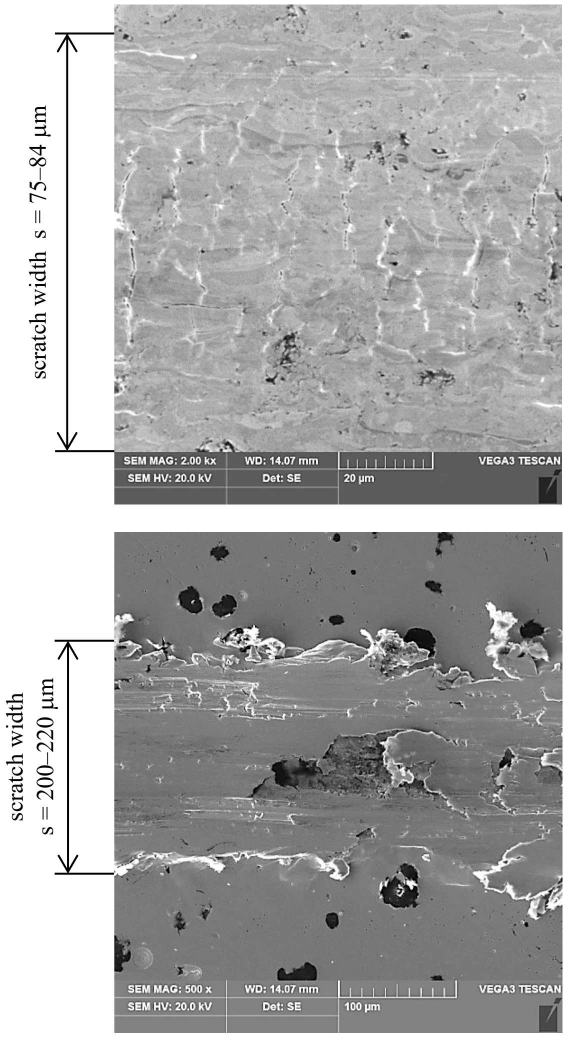


Fig. 7. A view of surface of scratches made on (a) WCCoCr coating and (b) on ductile cast iron substrate. Non-etched sections

The obtained scratch test results indicate that the material of the coating is characterized with definitely lower susceptibility to scratching. The scratch made on coating was 75–84 μm wide and 7.2–8.2 μm deep, while the scratch on cast iron was distinctly wider (200–220 μm) and deeper (8.5–12.8 μm). In case of cast iron, the range of variability in scratch width and depth was definitely larger. This can be explained with large difference in hardness of individual components of microstructure of cast iron and significantly larger plastic deformation of cast iron compared to the coating revealed in the course of indenter motion over surfaces of the two materials.

4. Conclusions

On the ground of the performed research study it has been found that WCCoCr coating is characterized with significantly higher hardness and better resistance to scratching with diamond indenter compared to the cast iron used to date for wood chip fine grinder liners.

Application of plasma-sprayed WCCoCr coating as a working surface layer for cast-iron liners of wood chip fine grinder drums revealed a new potential for extension of service life of these components.

Acknowledgments

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