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WEAR AND CORROSION PERFORMANCES OF NEW FRICTION MATERIALS FOR AUTOMOTIVE INDUSTRY

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Preliminary Note – Prethodno priopćenje

In this study, after a NiCr bond layer was deposited on a pearlitic, grey cast iron rotor disc of the kind used in a production passenger car (Toyota Corolla 1600 cc), Cr_3C_2-NiCr and Al_2O_3-TiO_2powders were sprayed using High Velocity Oxygen Fuel(HVOF) and plasma spray processes, respectively. The discs were subjected to cosmetic corrosion test according to SAE J2334 test standard. Additionally, wear tests were carried out using a reciprocating wear tester by rubbing a 10 mm diameter Al_2O_3 ball on the specimens machined from rotor discs in salt solution. It was found that the Cr_3C_2-NiCr coating (HSCN) sprayed using HVOF method exhibited highest hardness and highest corrosion and wear resistances.

Key words: wear, friction, corrosion, friction material, coating, automotive industry

Postojanost na trošenje i koroziju novih frikcijski postojanih materijala za automobilsku industriju. Nakon nanošenja NiCr sloja na disk od sivog lijeva tipa koji se koristi u proizvodnji putničkog automobila (Toyota Corolla 1600 CC), Cr_3C_2-NiCr i Al_2O_3-TiO_2 prašak je nanešen naštrcavanjem HVOF i plazma postupkom. Disk je izložen korozijskom ispitivanju sukladno standardu SAE J2334. Dodatno je provedeno ispitivanje na trošenje na testeru za uzajamno trošenje 10 mm zrna Al_2O_3 na uzorcima izrađenim iz rotacijskog diska u slanoj komori. Utvrđeno je da je Cr_3C_2-NiCr sloj (HSCN) naštrca HVOF postupkom pokazao veću tvrdoću i veću korozijsku postojanost i otpornost na koroziju.

Ključne riječi: trošenje, trenje, korozija, frikcijski materijali, oblaganje, automobilska industrija

INTRODUCTION

A substantial proportion of the disk brake rotors in use today is fabricated from gray cast iron with its relatively low cost and desirable properties such as low melting point, good fluidity and castability, ease of machining [1]. While due to their poor resistances to wear, corrosion and thermal fatigue under severe operating conditions, gray cast irons are unlikely to be satisfactory rotor materials [2-3] without a different alloy system or a coating as potential material for friction systems. In literature, a great deal of effort has been given to develop tribo tests for brake materials conducted under dry sliding conditions [4-6]. However, publications concerning the wear and corrosion behaviour of rotor discs in salt solution using laboratory scale test are seldom found in the tribology literature. Results from these tests will provide excellent correlation to severe corrosive field environments with respect to wear and corrosion performances.

EXPERIMENTAL DETAILS

A grey cast iron (3,58 C–2,28 Si–0,57 Mn) with graphite flakes embedded in a matrix of pearlite (Figure 1) and a hardness of 222 HV0,2 as the substrate was used in this study. Before the coating process, the grey cast iron substrates were roughened by sand blasting and then coated with a Ni-Cr bond layer (~50 μm) in order to ameliorate the adhesion to the substrate. The Cr_3C_2-NiCr and Al_2O_3-TiO_2powders were sprayed over the bond layer by HVOF and plasma spray processes, respectively. The process parameters are listed in Table 1.

The characterization of the coatings was made by microscopic examinations, thickness, and hardness measurements. Microscopic examinations were conducted on the cross-sections of the coated samples by a scanning electron microscope, after grinding and polishing in standard manner. The thickness and the hardness of the coatings were measured on the polished cross-sections. The hardness was measured by micro Vickers hardness tester under a normal load of 200 g.

The corrosion performance of discs was tested through SAE J2334 lab test procedure by use of spray method of salt solution (0,5 % NaCl + 0,1 %$CaCl_2$ + 0,075 %$NaHCO_3$). The results of the corrosion tests were evaluated by measuring the weights of the discs before and after the corrosion tests. The surfaces of the specimens were characterized before and after corrosion tests using an optical microscopy (OM).

The sliding wear behaviors of the original and coated discs were examined with a reciprocating wear tester

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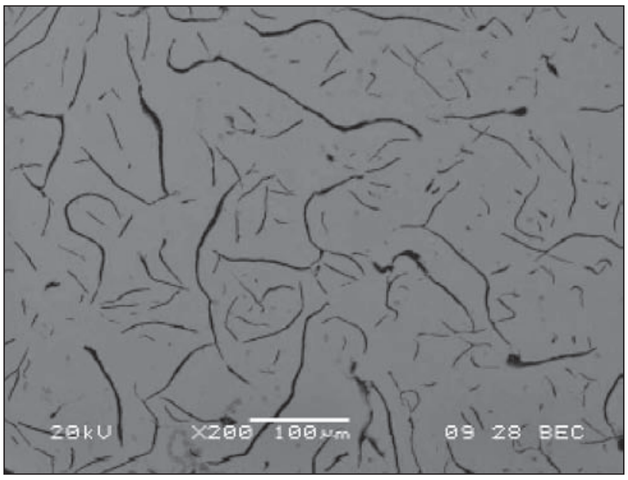


Figure1 SEM micrograph showing microstructure of grey cast iron disc material

Table 1 **Process parameters**

HVOF spray parameters	Value
Flow rate of O_2/ m^3/h	45
Flow rate of H_2/ m^3/h	6
Flow rate of Kerosene / l/h	12
Powder feed rate / g/min	66
Spray distance / mm	250
Plasma spray parameters	Value
Electric current / A	500
Electric voltage / V	70
Powder feed rate / g/min	40
Spray distance / mm	110

in salt solution. In the present work, reciprocating wear test specimens of size 15×15×5mm were machined from rotor discs of size ∅255×22 mm.Wear tests were carried out by applying a normal load of 1,5 N to the plate specimens with a 10 mm diameter Al_2O_3 ball. During the tests, the sliding velocity of the balls on the surfaces was 0,026 m/s for 25 min sliding time. After the tests, the wear tracks developed on the surfaces were detected by a profilometer. The results of thereciprocating wear test were based on 2-D profile images of the wear tracks.

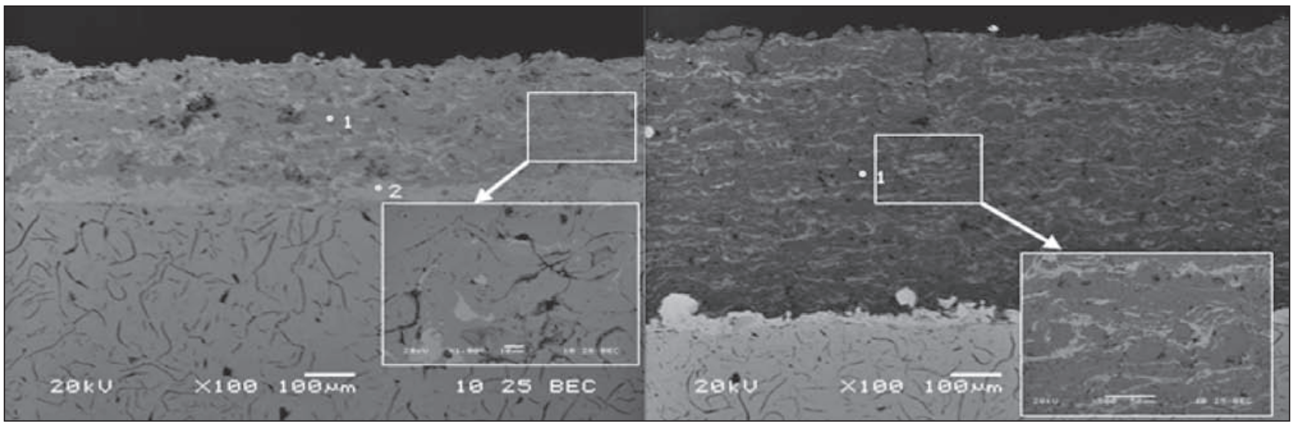
RESULTS AND DISCUSSION

The coated samples showed well-bonded layers with a thickness of 300 μm and 550 μm, and microhardness of 766HV0,2 and 643HV0,2 for the HVOF sprayed Cr_3C_2-NiCr (HSCN) and plasma sprayed Al_2O_3-TiO_2 (PSAT) coatings, respectively.Figure2 a and b shows cross-section images of HSCN and PSAT coatings. The HSCN coating consists of a metallic Ni–Cr matrix having different shades of grey, rich in Cr and C from the Cr_3C_2 phase dissolved in the Ni–Cr matrix to a different extent, together with mixed carbide (light regions) interspersed with pores (black regions). While, light regions in the PSAT coating are TiO_2 and grey and black ones correspond to Al_2O_3 and pores, respectively. A close examination of the microstructure reveals that the typical cracks present in the PSAT coating.

The results of corrosion tests conducted on the discs by use of spray method of salt solution are presented in Figure 3. As seen in Figure 3, the weight loss of grey cast iron disc sharply increased during testing. However, those of the HSCN and PSAT coatings increased in the early period and then yielded a decrease after a testing time of 1 day. In general, extensive deterioration according to the surface appearances after corrosion tests had taken place on the surface of the grey cast iron disc; while it was much less pronounced on the surface of the HSCN and PSAT coatings, which could suggest a better performance against corrosion in salt solution.

Also, for the PSAT coating, the cracks may facilitate the electrolyte penetration and the consequently attack to the substrate. The HSCN coating studied here has a dense and compact microstructure which acts as a barrier for the electrolyte ingress during the first time of immersion.

The results of wear tests carried out with salt solution for all specimens are compared in Figure 4. Among the specimens, the grey cast iron substrate had the largest wear loss ($10,2×10^{-4}$ mm^3) and the HSCN coating, which showed enhanced corrosion (Figure 3), had the lowest wear loss ($7,8×10^{-4}$ mm^3). Fedrizzi et al. [7] reported that Cr_3C_2 coatings tested by a block on-ring wear tester in 3,5% NaCl solution exhibited a limited



(a) (b)

Figure 2 SEM cross-section images of (a) HSCN and (b) PSAT samples

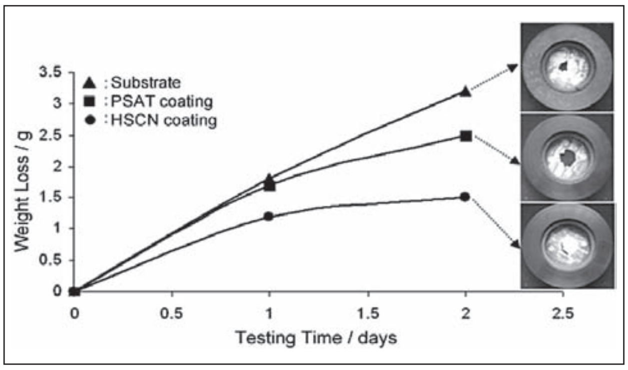


Figure 3 Weight loss data obtained throughout the spray method and surface topographies of the examined discs

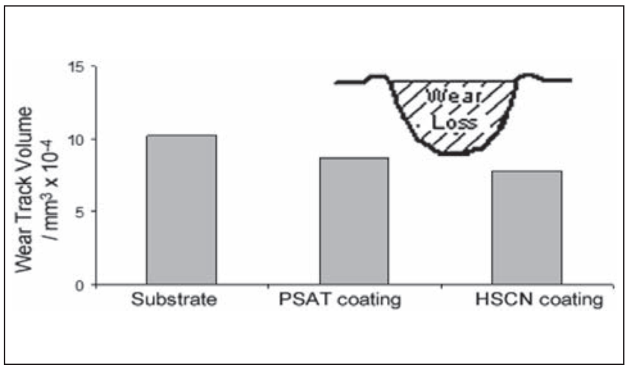


Figure4 Wear track volumes of the examined specimens

crack initiation with increasing fracture toughness and Cr_3C_2coatings with NiCr had a faster repassivation characteristic.

The cracks appeared on the cross-section of the PSAT coating is previously stated (Figure 2). Compared with the coatings, the HSCN coating, which did not contain cracks in the microstructure, exhibited higher hardness and better corrosion and wear resistances than the PSAT coating.

CONCLUSION

In the present study, the corrosion and wear behavior of Cr_3C_2-NiCr and Al_2O_3-TiO_2 coatings deposited on commercially grey cast iron substrate by HVOF and plasma spray techniques has been examined. HVOF sprayed Cr_3C_2-NiCr coating tested in salt solution showed a good combination of higher corrosion and wear resistances, compared to those of grey cast iron substrate and plasma sprayed Al_2O_3-TiO_2 coating.

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