Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Structure, Mechanical Properties and Erosion Resistance of HVOF Sprayed Cr_3C_2+NiCr Coating on the Surface of Castings Made from Al-Si alloy

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The paper presents research of the microstructure and mechanical properties of HVOF (high velocity oxy-fuel process) sprayed Cr_3C_2–NiCr coating on the surface of castings made from Al-Si alloy in the presence of NiAl interlayer. The investigations were aimed at the adherence of the interlayer and the outer coating deposited by HVOF technique. The structure of *ceramic coating/interlayer/metallic substrate* system was examined using the methods of light (LM) and scanning (SEM) microscopies as well as the analysis of chemical composition in microareas (EDS).
The results were discussed in reference to examination of cyclic fatigue test and an assessment of wear resistance of the coating (*Cr_3C_2-NiCr)/NiAl/*substrate *(Al-Si alloy)* system in combination with the cracking and delamination analysis of the coating in the interface area. Good adhesion to the metal base with NiAl interlayer and durability in cyclic loads make carbide coatings more effective as protective coatings for castings made from Al-Si alloys operating under the conditions of heavy dust and variable loads.

Keywords: *high velocity oxy-fuel, Al-Si alloy, chromium carbide coatings, microstructure, erosive wear*

1. Introduction

One of the most recent methods allowing local change of surface layer properties is the hypersonic powder spraying at high speeds (HVOF- High Velocity Oxy Fuel). The process of hypersonic spraying with a relatively low spray stream temperature (about 2600°C) and short residence time of powder particles in the spray stream has significantly reduced adverse effects of variations in phase composition of coatings present in the conventional plasma spraying, including: carbide decay, drastic reduction of the degree of metallic and carbide material oxidation, which in turn has improved the performance characteristics of coatings [1-2]. The coatings applied by means of high-velocity technology HVOF have excellent wear resistance, reduced porosity and increased adhesion compared to conventional plasma spraying. The quality of coatings, their strength, hardness, density, adhesion, and related properties depend on the velocity of powder particles, which in this method exceeds that of sound. High collision speeds may cause very high pressure and severe plastic deformations, including occurrence of the rotational mechanism. Therefore, a unique feature of this technology is that, unlike all other thermal spraying methods, it ensures spraying of the coating with pressure stress. The pressure stress in a coating significantly increases sprayed material adhesion to the substrate and is also beneficial in terms of the fatigue properties of components being coated [3-4].

2. Materials and methods

The composite powder Cr_3C_2-20wt.% NiCr of a particle size range of 45-60μm used as feedstock. A commercial HVOF spraying equipment (HV-50 HVOF System in Plasma System S.A,), which uses kerosene and oxygen to generate a hypersonic combustion flame, was used to spray these powders onto aluminium alloy substrates of following chemical composition: AK9 (AlSi9Mg) 10.5% Si, 0.3% Mg, 0.35% Mn, 0.8% Fe). Before application of coating, the substrate was precoated with an interlayer of NiAl (80% Ni and 20% Al), applied also by plasma technique. Prior to spraying, the surface of the aluminium alloy was sand–blasted using 20–mesh alumina grits to a surface roughness of about Ra=30 μm. The thickness of coatings was approximately 300 μm.
The microstructure of the system type *coating/substrate* was examined by light microscopy (LM) and scanning electron microscopy (SEM) with the measurements of the chemical composition in microareas (EDS). Micro-hardness measurements of the coatings were performed on the

cross sections of normal samples relative to their surfaces with Vickers method with the load 1N. The fatigue resistance was tested in 3-point bending test on INSTRON 8800M machine with hydropulse system. In a single test three specimens (of dimensions of 100x15x5 mm) were used and the fatigue resistance data were reported as the average values. The dynamic tests were carried out under variable bending loads of 1 Hz amplitude. Total number of the loading cycles in each tested specimen was 5000. The fractography of the coating surface after bending test was done under a scanning microscopy. Erosion test was performed on a special device for testing erosive wear resistance.

3. The results

The typical microstructure of the HVOF-sprayed chromium carbide coating on Al-Si alloy is shown in Fig. 1. The coatings consisted of lamellae elongated in the direction parallel to coating surface. The cross section and top surface of the both coatings exhibited dense microstructure with high cohesion without cracks, and very fine Cr_3C_2 particles embedded in NiCr alloy matrix, coming to the size of nanocrystalline due to the high impact velocity of the coating particles. Darker regions are identifiable, consisting of micrometric Cr_3C_2 grains, on the other hand brighter Ni-Cr containing regions exist. HVOF sprayed Cr_3C_2-NiCr coatings, exhibit low porosity (approx. 4.2±0,2% measured on microscopic images) and high hardness. An average microhardness of the Cr_3C_2-NiCr coating is 1300HV0.1, for NiAl interlayer is 1000 HV0.1, and then decreases to the value of 310HV0.1 for the substrate.

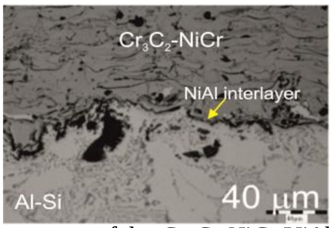

Fig. 1. Microstructure of the *Cr_3C_2-NiCr/NiAl/Al-Si* interface

Table 1. Test results of the cyclic bending

Sample	Bend stress [MPa]	Deflection [mm]
Al-Si	230	8
Cr_3C_2-NiCr/NiAl/Al-Si	290	29

For *Cr_3C_2-NiCr/NiCr/Al-Si alloy* samples observed increase in the maximum bending stress after cycles (Table 1). This can be explained by mechanism increase adhesion of the ceramic coating samples under the load (effect of strengthening during reciprocating motion). For this system, the damage occurs along the NiAl interlayer-substrate interface, with affecting it (Fig.2).

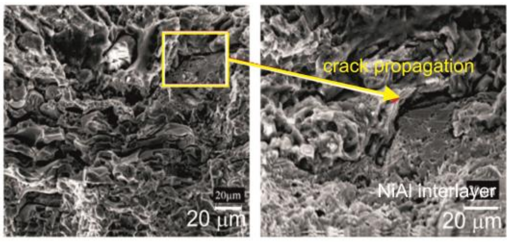

Fig. 2. Scanning micrographs of the fracture surface of the *Cr_3C_2-NiCr/NiAl/Al-Si* system after bending test.

4. Summary

The carbide coating Cr_3C_2-NiCr deposited on Al-Si alloy, using NiAl interlayer by HVOF technique is characterised by low porosity, dense structure, good adhesion and high hardness. In the structure of the coating there are very fine Cr_3C_2 particles embedded in NiCr matrix, coming to the size of nanocrystalline. The structure of this coating provides good resistance to cracking. The failure occurs along the *interlayer–substrate* interface and do not propagate to the substrate material. The carbide coating Cr_3C_2-NiCr on aluminium alloy has good erosive wear resistance associated with the effect of low porosity and high hardness as well as the phase composition of coating.

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