INFLUENCE OF WC PARTICLE SIZE AND VOLUME FRACTION ON WEAR PROPERTIES OF NICRBSI/WC COATINGS

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To increase the lifetime of mechanical parts submitted to severe abrasive environments, a strategy is to reinforce their top surface by depositing a more resistant layer. This approach is particularly interesting for metallic parts exhibiting a poor wear resistance at high temperature. The incorporation of a dispersed ceramic phase within the reinforcing layer is known to increase dramatically the resistance and hardness of the top surface layer. In the present work, laser cladding was used to process thick metal/ceramic coatings on steel substrates. Metal matrix composite (MMC) coatings composed of Ni-based alloy containing hard tungsten carbide particles have been considered to improve the wear resistance of steel parts (S235 low carbon steel). The secondary phase amount and its particle size have been studied. In order to limit the formation of cracks during the layer cooling down, subsequent to laser cladding, pre- and post- heating at 400 °C of the samples were performed.

INTRODUCTION

Metal matrix composites (MMC) are manufactured by dispersing a reinforcement phase, ceramic or metallic, in a metal matrix. These composites are of great interest because they possess characteristics of both ceramics and metals. Indeed, MMC allow combining high hardness of ceramics and ductility and toughness of metals. By adding different kind of reinforcement particles, it is possible to adjust the properties depending on the solicitations they will have to face practically: improvement of mechanical properties, corrosion and wear resistance, high temperature behaviour, thermal shocks resistance, etc. There are 3 different categories of MMC : continuous fibers, discontinuous fibers and particles [1]. In the case of wear resistance materials, particles are the most suitable choice [2].

A common technique to obtain cheaper materials exhibiting a high wear resistance is to coat them in order to improve their surface properties. The production costs of such materials are significantly reduced if the protection of the part is located only on the solicited areas. Laser cladding is more and more studied to produce such coatings. The technique presents various advantages compared to other thick coatings deposition methods: a minimal dilution, a small heat affected zone (HAZ), a good surface quality and a minimal distortion of the substrate [3-5]. MMC produced by laser cladding usually considered for wear applications are Co- [6-8] or Ni- [5; 8-11] based alloys mixed with hard carbides particles (SiC, TiC, WC…). In this study, we are considering the fabrication and wear characterization of thick Ni-based coatings reinforced with “non cemented” WC spherical particles with different sizes ranging from 40 µm to more than 1 mm.

EXPERIMENTAL

Materials

Ni-based alloy (NiCrBSi, Surfit 1560®, Hoganas) was used as metal matrix and spherical WC particles as reinforcement ceramic phase (Spherotene®, Technogenia) showing a hardness around 3000 HV. Coatings were deposited on low carbon steel S235 substrates. The particle size distribution of Ni-based powder is between 50 and 150 µm. For the WC particles, 3 different grades were studied: (i) from 40 to 160 µm, (ii) from 250 to 400 µm and (iii) from 750 to 1200 µm (measurements: QicPic image analysis sensor – Sympa TEC).

Experimental procedure

Coatings were carried out by laser cladding. The system consisted in a 1 kW (cw mode) Nd-YAG laser source (Lumonics) equipped with a Precitec coaxial nozzle for powder delivery. Laser beam has a 1,5 mm spot diameter and a 12 mm focal distance. Coatings were deposited with an overlap of 50% between consecutive tracks. The amount of WC in the matrix was varied between 0 vol% and 30 vol% for all grades, however a 50 vol % WC sample was also processed using the 250-400 µm particles grade. Depending on the amount of WC in the coatings, laser power was adjusted for each composition to get qualitatively dense and adherent coatings. Scanning speed was kept fixed at 20 mm/s and powder mass flow rate at 12 g/min. All coatings were performed with Ar gas for shielding and powder carrying. Substrates were pre- and post-heated at a temperature of 400°C. After deposition, coatings were machined to obtain a smooth surface and polished with diamond paste for microscopic inspection. Clad coatings were examined by optical and scanning electron microscopy (SEM).

The wear resistance of the composite coatings with the 40-160 µm WC particles was measured using three different wear testing apparatus: wheel test and pin-on-disk test, either continuous (in collaboration with VTT) or oscillating (in collaboration with BAM) both at room and high temperature (400°C). Pins used for pin-on-disk tests were 10 mm ball of alumina (Al_2O_3) and cemented tungsten carbide (WC-Co). Wheel tests were performed with a steel wheel and corundum abrasive particles (in accordance with EN ISO 10545-6). For bigger WC particles (250-400 µm and 750-1200 µm), only wheel test was performed.

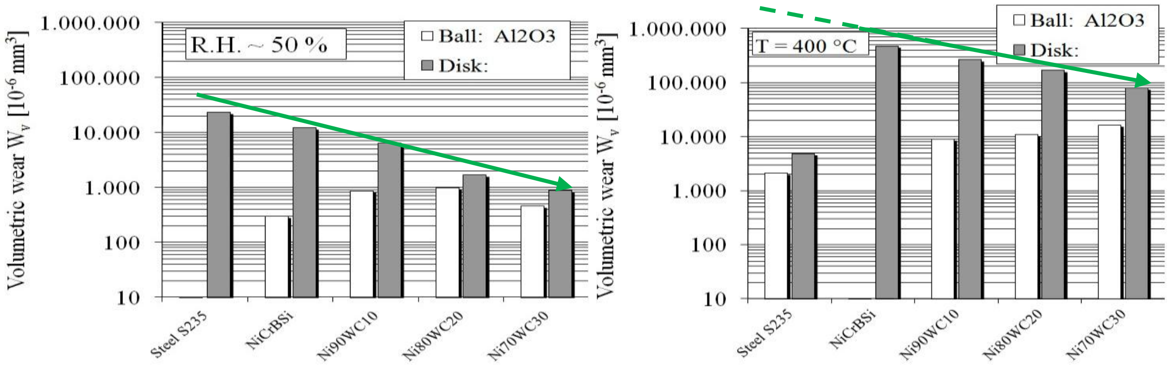
RESULTS AND DISCUSSION

Influence of the volume fraction by abrasive wear

This study was mainly performed on composite coatings with 40-160 µm grade WC particles and concerned the two different pin-on-disk tests.

Fig. 1 shows the results for oscillating pin-on-disk tests performed at room temperature (50% moisture) and high temperature (400 °C) with alumina pin. Obviously, the wear resistance of composite coatings is improved by comparison with the NiCrBSi matrix and steel substrate and this improvement increases with the addition of WC particles (Fig.1, left). At high temperature, the same influence is observed for the growing WC volume fraction but the wear resistance of the steel is apparently much higher than expected (Fig.1, right). This singular behaviour may be explained by a transfer of a matter's layer coming from the pin onto the wear track in the tested sample. The tests performed on composite coatings reveal significant wear resistance improvements in comparison with both the steel reference and the pure matrix. This observation holds, whatever the nature of the pin used for testing. Wear tests performed with continuous sliding pin-on-disk reveal a similar trend: the wear resistance of the composites increases with the amount of dispersed WC particles (until 30 vol.%).

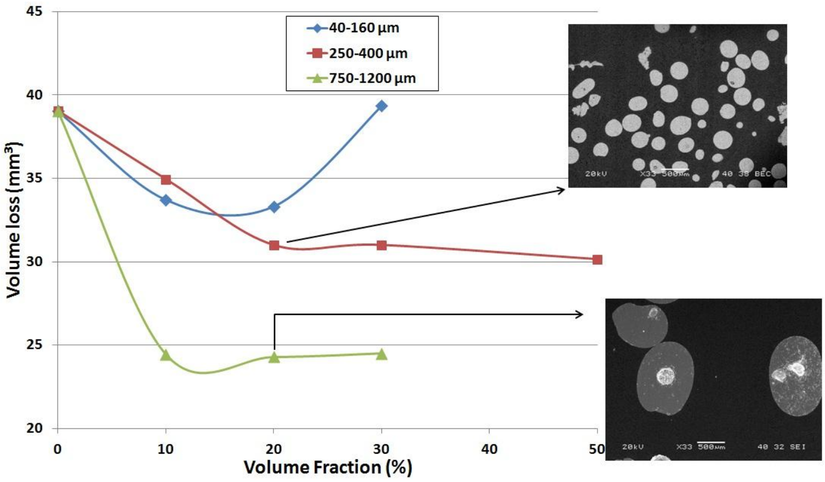
FIGURE 1: Oscillating pin-on-disk test results for Al_2O_3 ball: (left) at room temperature - 50% humidity rate (right) at 400 °C.



Influence of the grades by erosive wear

According to Hertz' theory in a sphere/plan local contact, the contact surface, the sinking and the local pressure diminish as the radius of the sphere gets bigger [12-13]. So, it suggests that MMC layers with larger particles should wear less than smaller particles grades. To prove it, three particle grades were used to produce composite coatings and were characterized by wheel test with erosive corundum particles. Results are shown in Fig. 2. It appears clearly that there is an influence of the particle size: less volume loss (i.e. better wear resistance) is noticed for the particles lying between 750-1200 µm compared to that of the 40-160 µm particles. It seems also that the impact of volume fraction for the smallest grade is not as marked as for the abrasive test shown above. For bigger grades, a plateau occurs between 10 and 20 vol% for the 250-400 µm particles and no influence of the volume fraction over 10 vol.% appears for the 750-1200 µm WC particles addition.

FIGURE 2: Results of wheel test comparing different grades of WC particles in MMC coatings.



CONCLUSIONS

Metal Matrix Composites (MMC) were produced by laser cladding process that allows to melt the metal particles and keep the ceramic particles unmelted with their original properties. It has been shown that volume fraction has an significant influence on abrasive wear resistance for spherical particles with a grade lying between 40 and 160 µm. Furthermore, adding bigger particles (up to 1,2 mm) in the coatings seems to improve the erosive wear resistance of such coatings.

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