The Study of Wear Behavior of Plasma Sprayed Alumina - Titania Composite Coating

M. Gheirati¹, M.H. Fathi², A.R. Ahmadi³

1- Introduction
Plasma spray technology is one of the most versatile coating technologies available today. Recent technological advancements, including more efficient equipment and improved production methods, have made the application of plasma spray coatings practical. The process is widely used in preparing surface coatings for industry pieces; recent advancements have rendered the repair and installation of industrial equipment timely and cost efficient. This technology has been employed to generate coatings that are more resistant to mechanical wear, erosion, corrosion, or oxidation that can damage metallic surfaces under a variety of external conditions.

In this study, it was attempted to design and prepare an optimum composite coating of Alumina - Titania via plasma spray technique using various terms of the plasma input power, and study the influence of morphology, microhardness and elastic properties of the prepared coating on erosion behavior.

2- Experimental Work
In preparing the coating, a composite powder of Alumina-Titania, with 3 wt. % Titania, was prepared through mechanical activation. Commercially available Alumina spray powder, with particle size of about 50 microns, and a Titania powder, with particle size of about 100 nm, were acquired for this purpose (Sigma Aldrich). The composite powder was prepared using a high-energy planetary ball mill (FretchPulverisette 5) performing the mechanical activation for six hours.

Plasma spraying experiments were carried out using an atmosphere plasma spraying (APS) system with Metallization PS50M (PoodrAfshan Company (PACO), Isfahan Science and Technology Town, Isfahan, Iran) under operating conditions: stand-off distance 115 mm and the powder feed rate of 20 gr/min. The primary plasma gas was Argon and the secondary gas was Nitrogen with gas flow rates of 70 and 14 SLPM (Standard Liter per Minute),respectively. Carrier gas for powder transport was Argon. The input power was variable and the velocity of the powder at the nozzle’s outlet was 30 m/sec. Other operation parameters utilized in spraying of the Alumina-Titania powder are listed in Table 1.

Microstructure and morphology of the as-sprayed coatings were investigated using a VEGA\TESCAN-LMU scanning electron microscope (SEM) (SEM laboratory of Razi Metallurgical Research Center (RMRC), Tehran, Iran) equipped with an energy-dispersive x-ray analyzer (EDAX). Prior to the SEM study, samples were coated with a thin layer of gold. Subsequently, images with a magnification of 500 times were used to evaluate the surface morphology.

Erosion test on the coatings was performed using a slurry pot arrangement with 15% concentration of alumina particles in distilled water. Alumina particles with an average grain size of 60 microns were used for the testing. The specimens were placed in the holder, rotating at 700 rpm such that the coating surface comes in contact with the erosive slurry. The specimens were ultrasonically cleaned and weighed after every 2 h of test run. Weight loss of coated specimens during the slurry erosion test was measured using an electronic balance with a resolution of 0.1 mgr. The test was performed for 12 h. The erosion performance was evaluated in terms of weight loss observed during the test.

3- Results and Discussion
As shown in Fig. 1(a),since the plasma temperature is not high enough for complete melting of the particle at input power of 24kW, the majority of the particles reaching the surface are in solid and semi-solid states. The weak adhesion of these particles causes deep holes and porosity on the surface of the coating. For this case, most pores and porosity are formed at the interface of unmelted or partially melted particles. The porosity provides a place for weakening the wear and erosion performance of the coatings.

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Table 1. Operation condition for deposition of the Alumina-Titania composite coating

<table>
<thead>
<tr>
<th>Feedstock type</th>
<th>Metallization PS50M</th>
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<tbody>
<tr>
<td>Input Power, kW</td>
<td>24, 28, 32</td>
</tr>
<tr>
<td>Stand off distance, mm</td>
<td>115</td>
</tr>
<tr>
<td>Plasma gas, SLPM</td>
<td>Ar, 70</td>
</tr>
<tr>
<td>Auxiliary gas, SLPM</td>
<td>N₂, 14</td>
</tr>
<tr>
<td>Powder feedrate, g/min</td>
<td>20</td>
</tr>
<tr>
<td>Torch transfer speed, mm/s</td>
<td>25</td>
</tr>
</tbody>
</table>
In Fig 1 (b) the presence of a small share (about 10%) of semi-solid particles in the coating structure can be seen. These particles are completely protected by the split surrounding. Reported research papers show that the appropriate amount of protected particles can inhibit the growth of microcracks in the coating. For this case, the presence of a high percentage of molten particles resulted in the remarkable ability of the particles to flatten in collision with the substrate. This flattening of the particles increases the interface between the coating layers, reduces the amount of porosity, and enhances the coating adhesion and density. The increased coating density induced by the presence of molten particles on the coating surface can create compressive stresses in the coating layers, which inhibits the growth of microcracks and increases hardness of the coating. Furthermore, the presence of these particles improves the fatigue behavior, residual stress, and quality of the coating.

As shown in Fig. 1 (c), for the input power of 32 kW, the majority of the particles reaching the substrate surface had completely melted. In this state, the high temperature of the plasma facilitates the complete melting of the particles and the evaporation of a small percentage of the particles reaches the substrate. The remnants of evaporated particles increase the porosity and decreases the density of the coating. The high temperature of the plasma and the rapid cooling rate of the coating has resulted in the increased content of gamma alumina phase for this case. The decreasing coating density and increasing porosity, in turn, introduce a problem for wear, erosion, and microhardness performance of the coating. The increased gamma phase, reduced microhardness, and increased toughness of the coating have different impacts on the performance of the coating.

Erosion test for ceramic coatings is a standard procedure for estimating the lifetime of the coating. Slurry erosion depends on the particle velocity, angle of particles collision with the surface, texture of the particles, and morphology of the coating. For small collision angles, particles separate from the surface with the friction mechanism, whereas for large angles, it is the growth of microcracks and pores that can undermine the erosion performance of the coating. For erosive wear in the slurry of alumina, collisions can occur at any angle. Here, factors differentiating the performance of erosion are microstructure, microhardness, and toughness of the coating. Dependence of the electrical input power of Alumina-Titania composite coating with erosion behavior is shown in Fig. 2. As shown in the Figure, it was observed that the erosive performance of the coating is improved by decreasing the amount of voids, microcracks, porosity and solid and semi-solid particles.

4- Conclusion
In the present study, Alumina-Titania with 3% wt. Titania composite coating, as wear and erosion resistant coating, was chosen to evaluate the influence of input power on the wear and erosion behavior and performance of plasma sprayed coatings. The results showed that elastic properties have the most influence on the erosion performance of the coating. It was concluded that the input power of 28 kW, caused an increase of microhardness and elastic properties of the coating, simultaneously.