Effect of Spray Parameters on Stainless Steel Arc Sprayed Coating

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Abstract
Coating microstructures and properties are dependent on spray conditions in arc spraying. Characteristics of in-flight particle, splat and coatings were carried out in this work. Stainless steel wire was spraye d by arc-spray process with different spray conditions. It was found that gas pressure had insignificant effect on the average size of in-flight particles whereas spray distance had slight influence in which longer distance produced smaller particle size. Splats obtained from all spray conditions had flower morphology with a wide range of splat size distribution. Spray distance and gas pressure were found to have an effect on splat size in which shorter distance produced larger splat size while higher pressure gave smaller splat size due to more vigorous impact of particles at higher gas pressure. Coating thickness tended to increased with increasing gas pressure while roughness of all coatings produced were insignificantly different. Hardness and porosity of coatings depended very much on gas pressure but less dependent on spray distance. Oxide content in the coatings were more likely to increase with an increase of spray distance and gas pressure.

Keywords: Arc-spray, Coating, Splat, Stainless steel

1. Introduction
Arc spray has been known as a quick and high spraying rate technique to produce metallic and composite coatings. Coating microstructure depends very much on spray system and parameters employed [1]. Wire arc sprayed coating principally built up from molten droplet that propelled (so-called in-flight particles) by high compressed gas onto substrate. In-flight particles become splat after impact onto substrate. Splats adhere to substrate principally through interlocking mechanism, which follow by cohesion between splats. In-flight particle and splat characteristics will then reflect coating microstructures and properties [2]. Therefore, this work was aimed to investigate the effect of spray parameters on in-flight particles, splat, and coating characteristics of arc sprayed stainless steel.

2. Experimental Procedures and Methods

2.1 Preparation and characterization of in-flight particle and splat

Stainless steel (316LS) wire with diameter of 1.2 mm was sprayed by arc spray system (MEC Arcjet 95), using different spray parameters as shown in Table 1. In-flight particles were collected by spraying into distilled water and splats were collected by spraying onto polished stainless steel substrate [3]. Morphology of in-flight particles and splats were revealed by optical microscope (Olympus, BX60M). Size measurement for both in-flight particles and splats were performed by optical microscope with 100 particles and 100 splats to evaluate size distribution and calculate the average size.

2.2 Coating preparation and characterization

Stainless steel wire was sprayed onto polished mild steel substrates with different spray parameters detailed in Table 1. Number of spray passes were kept constant for all samples in order to compare coating thickness obtained.

Table 1. Experimental conditions for stainless steel 316LS wire arc spraying.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>C₁</th>
<th>C₂</th>
<th>C₃</th>
<th>C₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage (V)</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Spray distance (mm)</td>
<td>200</td>
<td>200</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Air pressure (kPa)</td>
<td>420</td>
<td>520</td>
<td>420</td>
<td>520</td>
</tr>
</tbody>
</table>
Surface roughness of the as-sprayed coatings were measured by roughness checker (Taylor Hobson, SURTRONIC 3+). Coatings were cross-sectioned, mounted with resin, ground with SiC papers and polished with 1 μm alumina slurry prior to characterization. Porosity and oxide content were evaluated by image analysis (ZIEEZ, AXIO). Vickers microhardness measurement (Toolquip, Galileo Microscan OD) was carried out using a load of 300 g.

3. Results and Discussion

3.1 In-flight particle and splat characterization

Spherical in-flight particles produced by stainless steel wire arc spraying (Fig.1 a-d) were obtained from all spray parameters. Fig.2 shows size distribution of in-flight particles with the average size of 58, 57, 45 and 46 μm obtained from spray condition C_1, C_2, C_3 and C_4, respectively. It was found that air pressure had no effect on in-flight particle size for both at 200 and 300 mm spray distance. This could be due to the atomizing gas pressure at 420 and 520 kPa were in the same range of atomizing power produced. Spray distance showed slight influence on particle size in which longer distance (C_3, C_4) tended to give smaller particle size (Fig.1 c and d). Morphology of splat obtained from all spray conditions was principally flower shape as shown in Fig.1 e-h. These mean fully melted particles splashed onto substrate with relatively high velocity. Fig. 3 shows size distribution of splats with the average size of 289, 220, 254, and 182 μm obtained from condition C_1, C_2, C_3, and C_4, respectively.

For the splats, both spray distance and air pressure were found to have an effect on splat size. It can be seen that at the same pressure, shorter spray distance (C_1, C_2) produced larger splat size (Fig.1 e and h). In addition, at the same distance, higher pressure gave smaller splat size as a result of molten particles vigorously splash onto substrate at high pressure.
3.2 Coating characterization

Microstructure of coatings were shown in Fig. 4. All coatings had generally dense structure. Thickness of coatings were shown in Fig. 5. It was found that at the same gas pressure employed, spray distance showed insignificant effect on coating thickness. In contrast, at the same spray distance and passes, higher gas pressure tended to give higher coating thickness. This could be due to, at high pressure which meant higher speed of droplets, resulted in more droplets reached the substrate. For the roughness as shown in Fig. 5, different spray parameters gave roughness of coatings in the range of 10-12 μm which obviously was not different. Porosity of coatings were shown in Fig. 5. At short spray distance (200 mm), gas pressure had no effect on porosity of coating whereas, at longer distance (300 mm) higher pressure (520 kPa) gave lower porosity by 7%. Oxide content was likely to increase with increasing gas pressure, especially at longer spray distance (Fig. 6). This could be explained as longer spray distance resulted in longer time for oxygen to react with molten droplets, together with more oxygen surrounded from higher gas pressure used. Hardness of coatings were found to depend very much on gas pressure as shown in Fig. 6. Coating hardness was increased up to 40% with increasing gas pressure by 100 kPa. It was from the fact that denser structure (lower porosity) could be obtained from higher speed of the in-flight particles.

4. Conclusions

1. Spray distance showed an influence on the average size for both in-flight particles and splats in which the longer distance the larger size obtained.
2. Gas pressure from the range performed in this study had an insignificant effect on size of in-flight particles but showed slight influence on splat size by decreasing splat size with an increase of gas pressure.
3. Only flower-shaped splat obtained from all spray conditions implied that solidification of in-flight particles occurred after vigorous impact.
4. Porosity and hardness of coatings were influenced by gas pressure rather than spray distance. Higher hardness of coating related to smaller splat size produced by higher gas pressure.

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References