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Friction stir processing of austenitic stainless steel and copper cold spray coatings: feasibility study

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Feasibility tests of friction stir processing (FSP) of stainless steel and copper coating deposited by cold spray was performed. The microstructure observation revealed that the coating microstructure in the stir zone was significantly modified in both cases. EBSD analysis confirmed that full material recrystallization during FSP allowed to formation of dense and uniform fine-grain structure. The microhardness maps, optical microscope observation and SEM analysis confirmed significant improvement of the uniformity of coating microstructure in comparison of as-built coatings. The mixture of substrate material with the coating was also observed.

Keywords: Friction Stir Processing, Cold Spray, Stainless steel, Microstructure

1. Introduction

Cold spray is the solid-state material deposition technology. In this process, the metal particles accelerated in supersonic gas flow impact the surface at the velocity 600-1200 m/s. The powders adhere to the surface due to local material recrystallization of the particle induced by high-speed plastic deformation during impact. [1]. The properties of cold spray deposits significantly differ from the reference values measured for the bulk material. In particular, due to specific structure of the particle-particle interface and small grain size at the particle periphery, the ductility of cold spray deposits is very low [2]. Application of friction stir processing (FSP) could be applied for post-processing of cold spray deposits in order to improve their mechanical properties. In FSP process, a rotating tool inserted into the material generates the frictional heating contact. During tool movement along the contact line, plastic material flow occurs at a temperature below the melting point as for cold spray. The plastic flow transfers the material from the advancing side to retreating side, leading to the formation of a stirred region [3]. The main purpose of this work was the feasibility study of friction stir processing of austenitic stainless steel and copper cold spray deposits with the depth affected by the treatment equal to 1 mm or more in order to improve the coating structure and properties.

2. Methods

2.1. Materials and equipment

Cold spray coatings were deposited using sphesrical powdes of 316L stainless steel and copper. The FSP treatment was performed using a Friction Stir Welding gantry machine (MTS-ISTIR) with a tungsten carbide tool.

2.2. Results

Friction stir processing significantly changed the structure of both types of deposits. Typical cross-section image of the stainless steel coating after FSP is provided in Figure 1. The coating structure in the stirring zone was completely modified due to intense material deformation. No splats and inter-splat porosity are visible. It was also observed that the interface between the affected and non-affected zones was well distinguish-able on the cross-section images after strong chemical etching, especially at advancing side. Cross-section observations also show that in the case of stainless steel the depth of material affected by FSP was significantly higher than the coating thickness. Taking into account the length of the pin (1.4mm), it is well seen that in case of stainless steel the stirring zone is deeper than the penetration depth of the pin.

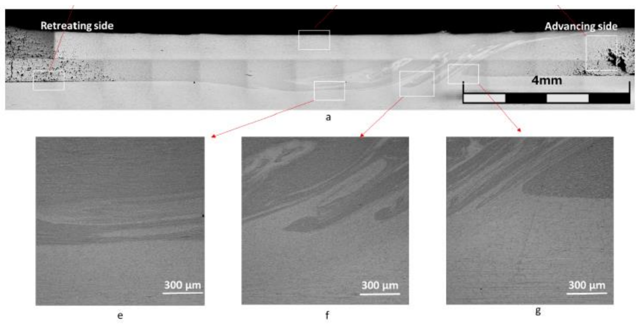

Figure 1: Cross-section micrographs of cold spray 316L coating after FSP

3. Discussion

Friction stir processing of relatively thick (1.5 mm) austenitic stainless steel and copper cold spray coatings is feasible. Material recrystallization in the stir zone allowed to modify the coating microstructure. Instead of splat structure with significant amounts of pores and defects, a uniform fine-grain structure was formed. Microhardness measurements confirm significant improvement of the uniformity of coating microstructure. Further research should be devoted to the investigation of the coating material properties after FSP treatment.

4. References

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