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ScienceDirect

Procedia CIRP 33 (2015) 452 – 457

www.elsevier.com/locate/procedia

9th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '14

Study of the laser remelting of a cold sprayed titanium layer.

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Abstract

Cold Gas Dynamic Spray is an emerging coating technology based on the use of a supersonic gas jet to accelerate (up to 1000 m/s) and to impact a powder, with size ranging from 1 to 50 µm in diameter, on a substrate. Due to the high speed, during the impact, the powder undergoes a severe plastic deformation such that it adheres on the substrate. Thanks to this method, it is possible to produce up to fully dense metallic coatings on substrates of different materials. With this technology, different kinds of powder (metals, polymers, ceramics, composite materials and nanocrystalline powders) or their mixing can be deposited. Among the various possible powders that can be deposited by cold spray, titanium is one of the most attractive materials thanks to its potential applications. A titanium layer produced onto a softer materials (i.e. aluminium alloys) could improve both the corrosion resistance and the wear properties of the components. However, the coating made with this technique could be affected by several problems, such as porosity, high roughness and low mechanical properties. A possible solution for this issues is the use of laser remelting post-deposition treatment. The present investigation deals with the application of a continuous wave diode laser in order to change the coating properties and metallographic structure. With this aim, laser remelting of a titanium cold sprayed layer were carried out on samples of grade 2 titanium alloy, 5 mm thick, obtained by cold spray technique, by using a 220 W diode laser at different scan speed. In order to avoid the influence of the particular substrate, the laser remelting process was carried after the detachment of the coating from the substrate. After laser treatments, light and SEM microscopy were carried out to analyze the geometry of remelted zone and the evolution of its microstructure morphology. Moreover, micro-hardness measurements were made to evaluate the mechanical properties. Three different metallurgical structures corresponding to the remelted zone, the heat affected zone and base material were observed. The remelted zone showed an elliptical shape, with a depth up to 0.7 mm and a martensitic microstructure. Furthermore, in this zone, hardness higher than the base material (more than threefold) was found. In conclusion, it is possible to affirm that the laser remelting is a promising technique to improve the superficial properties of titanium cold sprayed layers.

Keywords: : Cold Spray, Titanium, Laser Remelting, Diode Laser, Microstructure.

1. Introduction

Cold gas dynamic spray technique (CGDS) is an additive technology [1] that makes use of a converging/diverging nozzle (known as De Laval nozzle) and a high pressure, heated gas source (usually nitrogen) to create a supersonic gas flow. Metallic particles, usually in the size range of 10–100 µm, are injected into this gas flow and propelled to supersonic velocities. Typical particle velocities range from 500 to 1000 m/s and a high kinetic energy causes the impingement of the particles onto the substrate [2]. Depending on the material and particle speed, the particles will either rebound from the substrate (with or without erosion) or bond with the substrate [3]. The speed at which bonding is achieved, is referred to as critical velocity and depends on the particle sizes, particles distribution and the substrate material. Macroscopic plastic deformation resulting from the high impact velocity is generally believed to be the main bonding mechanism for metallic coatings deposited on metallic substrates [4–5]. The high impact momentum of the particles causes mechanical interlocking varying, depending on the application conditions and the metals employed. In this process, coating deposition occurs at relatively low temperatures compared to other spray technologies. Moreover, during the process the sprayed particles remain in the solid state. The coatings produced through this technology, exhibit remarkably high densities

Selection and peer-review under responsibility of the International Scientific Committee of “9th CIRP ICME Conference”
doi:10.1016/j.procir.2015.06.101

and conductivities, good corrosion resistance and a high hardness due to their cold worked microstructure [6]. The process provides a solution for applications where conventional metal spraying processes, such as flame, arc, plasma and HVOF spraying are inappropriate, in which problems such as coating porosity, oxidation and low adhesion may occur [7-8]. Furthermore, this process could be the only chance to produce coatings of harder materials on heat treatable aluminium alloys, due to the presence of an aging temperature that is easily reached during the thermal spray processes. Titanium is one of the most attractive metal for cold spray, thanks the potential multiple applications. Bulk titanium is finding increasing application in many industrial field, due to its corrosion resistance, as well as the biomedical industry where it is utilized in implants, because of its biocompatibility [9]. Furthermore titanium and its alloys are finding an increasing widespread use in the aeronautic field, due to their compatibility with CFRP. On the other hand, the use of titanium alloys is limited by the high costs, the difficulty of machining and the complexity of manufacturing. The application of Ti cold spray on other bulk metals is a potentially viable method for such applications. Cold spray has the potential to be an effective and economical way of converting manufactured Ti powders directly to finished products and advanced surfaces. Despite these premises the cold sprayed coatings have a number of drawbacks: porosity, superficial roughness and so on; these drawbacks could be overcome through post spraying superficial treatments, such as laser remelting [10]. Moreover, the increasingly greater and more demand imposed on materials, makes more difficult or even impossible to combine the different properties required in one single material; this results into the needing to develop new methodologies to improve the superficial properties of metallic materials. For this purpose, post-treatment by laser has been developed [11]. Laser surface melting is a promising process to improve the performance of sprayed coatings [12–13]. Although laser surface remelting has been actively investigated and applied to improve wear and corrosion properties for various metals [12, 14-15], although in literature laser remelting of titanium alloys is present, there is no investigation reported on cold spray deposition treatments.

The present investigation deals with laser remelting of a grade 2 titanium layer obtained by cold spray technique. Remelting tests were performed using a 220 W diode laser at different scan speed. After laser treatments, optical and SEM microscopy were carried out to analyze the geometry of remelted zone and the evolution of its microstructure morphology. Moreover, micro-hardness tests were performed to evaluate its mechanical properties.

Three different metallurgical structure corresponding to the remelted zone, the heat affected zone and base material were observed. The remelted zone showed an elliptical shape, with a depth up to 0.7 mm and a martensitic microstructure. Furthermore, in this zone, a hardness higher than the base material (more than threefold) was found.

In conclusion, it is possible to affirm that the laser remelting is a promising technique to improve the superficial properties of titanium cold sprayed layers.

2. Material, equipment and experimental procedures

2.1. Coating production

Commercially pure (grade 2) titanium particles with a mean granulometry of 40 µm were deposited onto an AA 2024-T3 plates 2 mm thick. The chemical composition and the main properties of grade 2 titanium are summarized in Table 1. In Fig. 1 it is reported a SEM micrograph of the powders. It is possible to observe that the powders have an irregular shape and moreover some conglomerates having bigger dimension are visible. Commercial cold spray facility DYMET403J (Obninsk-Center for Powder Spraying) was used for spraying. In order to avoid titanium particles oxidation during the spraying process, the deposition was carried out adopting Helium as carrier gas [16-17]. A round-shaped exit nozzle, 4.8 mm in final diameter, was adopted. In Fig. 2, a sketch of low pressure gas dynamic spray process is reported.

The parameters for the spaying process were chosen taking into account the previous literature [18]. In particular the particles were sprayed at a velocity of 680 m/s with Helium gas at 600 °C while the chamber pressure was about 15 bars. Under these conditions, a superficial layer of cold sprayed titanium powder, 5 mm thick, was obtained on the substrate of aluminium plates. After the deposition the titanium layer was detached from the substrate by means of a precision micro cutting machine with automatic feed, Presi-Mecatome T201.

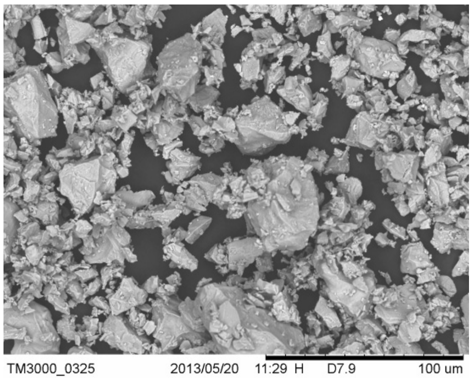

Fig. 1: SEM micrograph of the titanium powders before the spraying process.

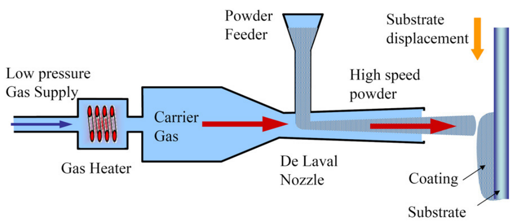

Fig. 2. Low pressure gas dynamic spray process schematization.