To cite this version :

Patrice PEYRE - Additive Layer Manufacturing using Metal Deposition - Metals - Vol. 10, n°4, p.1-3 - 2020

Additive Layer Manufacturing using Metal Deposition

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1. Introduction and Scope

Among the additive layer manufacturing techniques for metals, those involving metal deposition, including laser cladding/Direct Energy Deposition (DED, with powder feeding) or Wire and Arc Additive Manufacturing (WAAM, with wire feeding), exhibit several attractive features. For instance, one can mention high mass efficiency (50–80% for LMD, 100% for WAAM), large build rates (more than 100 cm^3/h), sound microstructures with a limited amount of porosities, and the ability to build graded or multimaterials. Even though corresponding processes have been developed a rather long time ago, there is still an important demand for research work in various topics such as deposition of novel or graded materials, postprocessing, and wear behavior of deposited materials.

The current Special Issue, including six contributions, aims at presenting recent and original work dedicated to all these aspects, with a more specific focus on coatings than on 3D structures.

2. Contributions

Six papers have been published in this Special Issue of *Metals* on ALM using metal deposition. They can be roughly separated in three distinct topics, presented here below.

2.1. In-Situ Manufacturing of Innovative Materials

Novel materials can easily be manufactured in-situ by metal deposition techniques, either from alloying parent materials or from in-situ chemical reactions.

An interesting example is the DED manufacturing of γ-TiAl coatings on Ti-6Al-4V substrates, starting from pure Al and Ti elemental powders [1] instead of prealloyed powders. The paper demonstrates the feasibility of obtaining satisfactory and low-cost Ti-Al deposits under normal atmospheric conditions, versus more usual EBM conditions involving a stronger limitation of O_2 content. This was made possible by an optimization of the Ti and Al powder feeding, through a control of two separate powder hoppers. One major conclusion is the dominant role played by Al at % versus heat-treatment conditions in determining hardness and the mechanical properties. Metallurgically, twinning was also considered as an important contributor to elevated hardness values.

The WAAM process was investigated as a promising technique to generate Fe/Al walls by fusing simulateously an AISI304 stainless steel wire and a A4043 Al-Si alloy wire on a low carbon steel substrate. The optimization of the process, and especially of the inter-layer dwell time to limit cold cracking, was carried out through a thermal camera control of the surface temperature (less than 400 °C) between subsequent deposits. An interesting point to notice is that a +50% hardness increase can be obtained with an optimization of the continuous current regime (at higher scan speed), attributed by the authors to a grain refinement effect. Future investigations, focused on the influence of Al, Cr, and Ni contents in the welds, and especially solid-solution strengthening of the steel matrix by increased Al fraction, or an estimation of the $Al_{1.1}Ni_{0.9}$ intermetallic volume fraction, should add a more precise understanding of observed results.

2.2. *Wear Resistance of Deposited Materials*

Laser metal deposition is a well known efficient method for improving wear resistance, and more widely the lifetime, of metalic materials. The main novelty of Liu et al.'s work [2,3] is to use nonspherical powders coming from industrial Fe-Si-Al ribbons leftovers, thus reducing the cost of raw materials and of the global process. Through the deposition of a 2 mm thick coating on a 1045 carbon steel, significant improvements of the wear resistance (factor 10 reduction of mass loss) are demonstrated, coming from the high hardness deposit, and surprisingly with a rather low influence of (P,V) process parameters.

In nearly the same topic, high-wear resistance steel (HWS) coatings are obtained by Baek et al. [4] on carbon steel substrates. In this work, a specific focus is put on the influence of a postdeposition quenching/tempering heat treatment. Through a detailed microstructural and mechanical investigation of laser coatings, a satisfactory compromise between toughness and tensile resistance was demonstrated for heat-treated HWS, mostly attributed to an increase of martensite volume fraction and the formation of fine and uniformly distributed carbides.

The preservation of the amorphous nature during laser deposition is partly confirmed in the innovative paper of Hou et al. [5]. Considering a Fe-Cr-Mo-Co-C-B alloy powder, and rather classical DED conditions, sound laser deposits were obtained, which were subsequently analyzed by X-ray Diffraction (XRD). XRD indicated a 53% volume fraction of amorphous phase, compared with 85% volume fraction in the starting powder, with the difference beeing attributed to dilution effects. Due to a six-times-higher hardness in the clad, significant improvements of the wear resistance were then obtained.

2.3. *Hybrided Processes*

Postprocessing heat or mechanical treatments applied on as-built ALM materials are mandatory to obtain desired metallurgical–mechanical properties. However, hybrid processes, involving sequences of manufacturing/post-treatments all along the building process, are not that common. On a similar topic, one can mention Kalentics's work involving SLM and laser shock peening [6]. In the paper by Yang et al. [7], a combined ultrasonic impact treatment (UIT) + WAAM process was used to modify microstructures and mechanical properties of a Ti-6Al-4V alloy. The beneficial effect of this hybrid process was as follows: a reduction of Von Mises equivalent stresses, the formation of a refined and more equiaxed grain structure, and an improvement of yield and ultimate tensile strengths. The only detrimental effect was found to be a severe reduction of elongation to failures.

3. Conclusions

In the six original research papers presented in this Special Issue on ALM using metal deposition, the reader will benefit from an overview of current research works, which mainly highlight the wide spectrum of possible materials' developments.

Conflicts of Interest: The author declares no conflict of interest.

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