CP3

A PRELIMINARY COMPARISON OF THE CORROSION BEHAVIOUR OF ADDITIVELY AND CONVENTIONALLY MANUFACTURED 18NI300 MARAGING STEEL FOR MOULDS

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ABSTRACT

The corrosion behaviour of a maraging steel 18Ni300 manufactured by Laser Powder Bed Fusion (L-PBF) was compared to that of a conventional tool steel. Electrochemical test conditions were chosen to approximate the corrosive environments encountered during injection moulding of polyvinyl chloride (PVC) parts. The corrosion behaviour of the steel produced by both routes was evaluated before and after an ageing treatment at 510 ºC for six hours. Cuboid specimens were fabricated and a polished area of 100 mm^2 was immersed in a 0.1M HCl solution for 7 days. Open circuit potential (OCP) and polarization curves were used to monitor the material exposed to the corrosive environment. The obtained results indicate that the conventionally produced aged steel is less susceptible to corrosion and that the steel manufactured by L-PBF (not aged condition) showed better resistance to pitting.

Keywords: Additive manufacturing, Powder bed fusion, Corrosion of moulds, PVC

1. INTRODUCTION

L-PBF is a mature additive manufacturing (AM) technology that can complement conventional mould making [1]. This technology has enabled mould redesign through topological optimization, thereby increasing mould efficiency [2]. There are still some concerns regarding the corrosion behaviour of materials manufactured by L-PBF [3]. Steel moulds to produce PVC parts require good corrosion resistance due to the formation of corrosive HCl by-products [4]. Special tool steels, such as 1.2316 (X38CrMo16), should be used. However, this martensitic steel with a high carbon content of ~0.36% is prone to cracking and to deformation during L-PBF [5]. Low-carbon maraging steel 18Ni300, has been successfully manufactured by L-PBF and used instead of 1.2316 [6]. However, its corrosion resistance has not been well studied or compared with the conventionally manufactured material. To address this mould maker's concern, this work performs a preliminary evaluation of the corrosion behaviour of a 18Ni300 manufactured by L-PBF and casting. Electrochemical tests were performed under acidic conditions to predict the corrosion potential of the steel produced by both routes.

2. DESCRIPTION

Materials and sample preparation

The starting material for L-PBF of cuboid samples was a nearly spherical gas-atomized powder of 18Ni300 (Renishaw Ltd., UK) with D_{50}=35 µm and D_{90}=48 µm. An AM 500Q SLM series 3D printer machine (Renishaw Ltd., UK) equipped with four ytterbium fibre lasers of 500 W was used. A set of previously validated parameters was selected [7,8]. **Fig. 1a** shows the L-PBF of the cubes and **Fig. 1b** shows a cube after manufacturing. The second series of cubes was machined from a conventionally cast 18Ni300 plate. A heat treatment at 510 ºC for 6 hours was performed on some of the cubes and their surface was polished with sandpaper and 1 µm diamond paste to obtain a mirror-like surface.

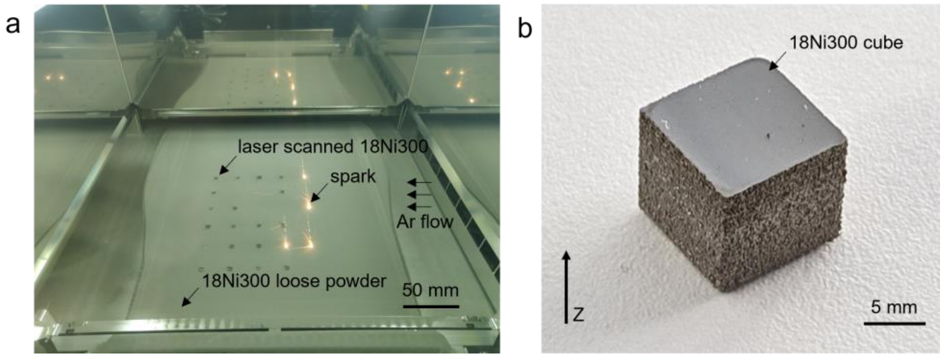

Fig. 1 - a. L-PBF of the cubes; b. 18Ni300 cube after manufacturing with the surface polished.

Methods and analysis

Electrochemical tests were performed using an Autolab PGStat302N (Eco Chemie) potentiostat at room temperature. A saturated calomel electrode (SCE, 0.241 V *vs*. NHE) served as a reference and a large area platinum coil served as a counter electrode. The electrolytic medium was an aqueous 0.1M HCl solution prepared with MILLI-Q water (18.2 MΩ.cm at 25 °C) and naturally aerated. Polarization curves were recorded after 7 days of immersion (**Fig. 2a**) in equilibrium conditions of the E_{OCP}. All polarization curves were recorded at a rate of 10 mV/min. **Fig. 2b** shows the obtained polarization curves of the 18Ni300.

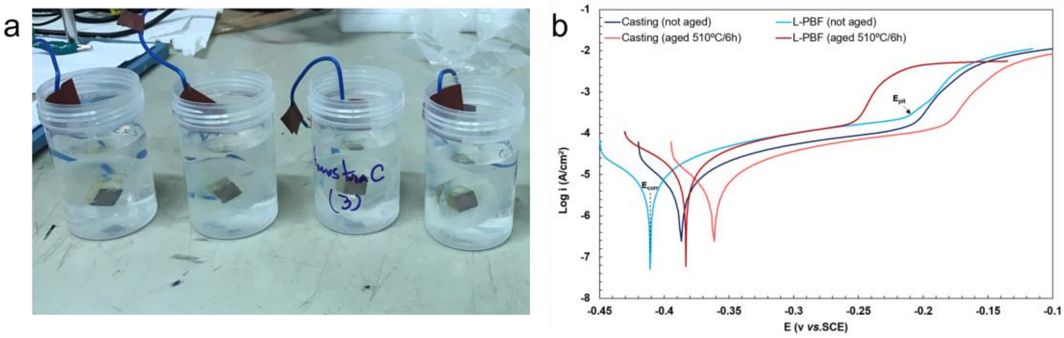

Fig. 2- a. Immersed cuboid specimens for electrochemical tests; b. polarization curves of the 18Ni300 manufactured by SLM and casting obtained after 7 days of immersion in a 0.1M HCl solution.

Aged 18Ni300 obtained by both routes has less negative E_{corr} values compared to the unaged condition, suggesting less susceptibility to corrosion when immersed in HCl solution probably due to the formation of nano intermetallic with Ni, Mo and Ti during the ageing treatment [8]. 18Ni300 manufactured with L-PBF (unaged) exhibited the higher ΔE value (≈ 0.201 V), $\Delta E = |E_{corr} - E_{pit,}|$, indicating better resistance to pitting corrosion. Aged L-PBF is more susceptible to pitting corrosion than the aged cast steel.

Table 1 - Results of the E_{corr}, E_{pit}, ΔE obtained from the polarization curves in Fig. 3.

18Ni300 sample	E_{corr} (V *vs.* SCE)	E_{pit} (V *vs.* SCE)	ΔE (V)
L-PBF (not aged)	-0.411	-0.210	0.201
Casting (not aged)	-0.387	-0.203	0.178
L-PBF (aged 510ºC/6h)	-0.361	-0.252	0.109
Casting (aged 510ºC/6h)	-0.383	-0.185	0.198

4. CONCLUSIONS

From these preliminary experiments, the following conclusions can be summarized:

- Aged 18Ni300 produced by both routes is less susceptible to corrosion than not-aged steel when immersed in HCl solution which is very important for mould applications since this steel is used in the aged condition;

- The 18Ni300 manufactured by L-PBF with ageing is more susceptible to pitting corrosion than the aged cast steel.

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