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Effect of laser cladding parameters on the microstructure and properties of high chromium hardfacing alloys

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Abstract

Mechanical components operating under high-stress and high-temperature environments require enhanced mechanical and tribological properties. In this research, different high chromium steels (Fe-Cr-C-Ni-Mo-Mn) have been coated over a 316L substrate using coaxial laser cladding. Optimized properties of the clad (such as adhesion, compactness, microstructure and dilution rate) have been obtained by a broad parameter search (laser power, powder feeding rate, scanning speed and preheating). Varying such parameters induces change in the microstructure, chemical distribution, morphology and properties of deposits. These have been thoroughly characterized in terms of metallurgical structure, phase compositions and functional properties using dedicated metallurgical mechanical and wear analysis. Samples obtained by laser cladding and plasma arc-transferred cladding have been compared. Laser cladding exhibits a significant strengthening mechanism for this hardfacing alloy. This results from a finer dendritic structure with a modified Chromium and Molybdenum precipitations distribution in the eutectic interdendritic phase.

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Keywords: Laser cladding; high chromium alloy steel; microstructure; nano-indentation; sliding wear

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1. Introduction

Laser cladding is a modern technology for the deposition of wear and corrosion protective coatings on engine parts and tools, applied especially in aircraft and automotive industries. It allows many different substrate and

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coating materials to be combined, ranging from iron, cobalt or nickel based hard alloys on steels to ceramic coatings on aluminium, (Dowden, 2009).

In laser cladding, the laser beam is defocused on the workpiece with a selected spot size. The powder is carried by an inert gas through a specific nozzle and is projected into the melt pool. The laser optics and powder nozzle are moved across the workpiece surface to deposit the complete layers.

In plasma transferred arc (PTA) cladding, the coating powder is transported by an inert gas stream into the plasma of an electric arc, where it is melted. Molten powder is then transferred to the substrate by a main arc, and is laid down as a track. The width of the track may be increased by oscillating the arc at an angle to the travel direction. A high clad thickness and a large track width can be produced in a single pass. The clad is homogeneous, and a strong metallurgical bond is formed with the substrate. In comparison with laser cladding, because the energy input is higher, the Heat Affected Zone (HAZ) is more extended, the distortion is greater, and the dilution rate is higher. This may not be a concern for large area coverage, but it limits the suitability of the process for small components.

In view of the above, two samples were coated by different process claddings, laser and (PTA). A powder of a high chromium alloy was used during projection in both processes.

Many studies have focused in the influence of laser parameters in the microstructure refinement. Hemmati et al (2011) have studied the effect of cladding speed on the phase constitution and the final properties of AISI 431. It was a martensitic stainless steel coating deposited by laser fibre at cladding speeds up to 117 mm/s.

In the current research, effects of laser cladding and PTA process parameters on phase constitution, hardness and wear rate of the high chromium hardfacing alloys deposited coatings are examined and controlling mechanisms are explained.

2. Experimental

2.1 Process Set-up

The laser cladding has been carried out by a 3KW Nd: YAG laser (TRUMPF HL3006D) operating in continuous wave (λ=1064nm) and inside an optomec machine (LENS 850-R). This machine includes a large work envelope (900 x 1500 x 900mm), a 5-axis CNC control system, an integrated Gas Purification System which maintains O_2 level continuously ≤ 10 ppm in the work envelope and an integrated dual powder feeders.

A defocused near-Gaussian laser spot is provided by a 600 µm optical fibre delivery. The offset between the laser head and deposition point was a constant distance of 10 mm, resulting in a near 1.3 mm beam diameter.

The substrate material was 316L stainless steel plate, 100 x 50 x 10 mm in length, width and height, respectively. The chemical composition range of ASTM 316L stainless steel appears in table 1.

Table 1. Chemical composition of substrate on 316L stainless steel provided by the supplier.

Element	Fe	C	Si	Mn	P	S	Cr	Mo	Ni	N
(Wt %)	balance	0.027	0.42	1.59	0.036	0.018	16.85	2.02	10.01	0.06

The high chromium hardfacing alloy was deposed onto stainless steel plates by both laser cladding and plasma arc transferred methods. These two different processes were used to investigate their influence on resulting microstructures. The experimental conditions of both PTA and laser cladding processes are summarized in table 2.

Table 2. Laser Process parameter.

Parameter	Power [W]	Current intensity [A]	Arc voltage [V]	Speed [m/min]	Powder feeding rate [g/min]	Temperature of preheating
Laser	1000	-	-	0.8	5	300°C
PTA	-	120	20	0.8	20	20°C