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Non-destructive residual stress analysis and microstructural behaviour of laser deposited titanium and copper alloy

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Abstract

Titanium alloy (Grade 5) has been regarded as the most useful alloys for the aerospace applications, due to their light weight properties. The addition of copper to this alloy allows the improvement in the mechanical properties. The increase in the laser power has influenced the coarseness of the α-Ti lamella; and thus slows down the cooling rate during solidification.The X ray diffraction method has been used to analyse the residual stresses using the biaxial and shear-stressed model. Very infinitesimal microns were taken into consideration for the penetration depth. The results generated indicate that a decrease in the compressive residual stresses is attributed to the increase in the laser power and the variation of the heat input within the clad during processing. The differences in the thermal expansion with respect to the increase in the volume of deposition as the laser power increases have significanteffect on the compressive residual stress.

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*Keywords:*laser metal deposition; microstructures; residual stress; XRD, Ti6Al4V/Cu clad.

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1. Introduction

Research is a continuous phenomenon which needs focus in the field of surface engineering in order to recurrently improve the existing material's properties during production or fabrication. The applications of titanium and its alloys in the aerospace, medical, chemical industries, energy and automotive industrial services are due to their possessed excellent mechanical, physical and corrosion-resistance properties [1] [2]. Some additional alloys have been introduced to titanium alloy in order to improve their mechanical properties. The alloying additions in titanium can be divided into three different classes - the α-stabilizers, the neutral stabilizers and the β-stabilizers. Elements such as V, Mo, Cu Cr, Fe and Mn serve to introduce the β-phase steadiness in the α-phase microstructure [3]. All manufacturing methods introduce residual stress into the mechanical components and stimulate the ultimate

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tensile strength, fatigue behaviour and the corrosion resistance effects [4]. At low temperature, the diffusion of alloying elements is difficult to cause a phase transformation, and the basis for the residual stress in titanium alloy is differential thermal expansion of the α andβ phases. During cooling from high temperature, the pre-existing residual stresses created in the two phase alloys are relaxed which were as a result of the decrease in the time dependent of the β lattice parameters [5]. The method of residual stress relaxation is important to ensure that selective laser melted material remains a possible manufacturing method for complex geometries [6]. The formation of residual stress for a laser deposited Ti6Al4V alloy is independent on the controlled heat input of the deposition rate. Thus, a larger heat input lessens the residual stress of a deposited Ti6Al4V alloy [7]. Creep is regarded as the main stress release mechanism at high temperature, and when the residual stress reached the critical value, the stress level is reduced through crack growth initiation [8]. It was deduced clearly that the improvements in mechanical properties of a metal can be achieved by suitable alloying additions and micro-structural design. Sufficient short-term creep strength was observed and controlled when superior hot workability was brought about by the presence of the β-phase and the α/β phase microstructures. Desired microstructure such as the basket weave microstructure was obtained through thermo-mechanical processing. This was found to offer better creep resistance than an equiaxed α/β phase microstructure [9]. Appropriate process parameters are always suggested to produce parts with better geometrical accuracy [10].

The main purpose of this paper is to analyse the residual stress in the laser deposited Ti6Al4V/Cu alloy using the X-ray Diffraction (XRD) residual stress measurement technique.

Nomenclature

α/β	alpha-beta phase
KeV	radiation energy
Å	wavelength
υ	Poisson's ratio
hkl	miller indices
LMD	laser metal deposition

2. Materials and approaches

The experiment was conducted on a 2000 Watts Ytterbium fibre laser at the National Laser Centre, Council of Scientific and Industrial Research (NLC-CSIR), Pretoria, South Africa. The laser has a wavelength of 1.047µm and associated with a Kuka robot having a three way nozzle system attached at its end effector. Ti6Al4V alloy and Cu powders were poured into two separate cleaned cylindrical containers. The powders were fed from the two cylindrical hoppers and flow out through a three way nozzle. Table 1 shows the experimental matrix used in this present study.

Table 1.Experimental matrix

Sample Name	Laser Power (W)	Scanning Speed (m/min)	Powder Flow rate (rpm)		Gas Flow rate (l/min)	
			Ti6Al4V	Cu	Ti6Al4V	Cu
S33	1200	0.7	2.4	0.1	3	1
P27	1600	0.3	2.5	0.1	3	1
P35	1200	0.3	2.4	0.1	3	1
P36	1400	0.3	2.4	0.1	3	1
P37	1600	0.3	2.4	0.1	3	1
Ti6Al4V	1600	0.3	2.4	Nil	3	Nil

The cross sections of the samples were mounted in poly fast prior to further characterization. The samples were ground (plain and fine grinding), polished and etched according to E3-11 ASTM standard guide for preparation of

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