Mechanical Examination of Inconel 625 Fabricated via Wire Arc Additive Manufacturing

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Abstract

Businesses that need products made with less scraps and materials wasted are increasingly using the additive layer manufacturing technology. In an additive process, the product is created layer by layer to construct a component. In this work, using Wire Plus Arc Additive Manufacturing (WAAM) and the Cold Metal Transfer (CMT) welding technique, the mechanical characteristics of a rectangular inconel 625 specimen exposed to loads such as tensile, hot tensile, impact, and bending were examined. To examine the microstructural alterations that have taken place in the built-up, scanning electron microscopy is also used.

Keywords: wire arc additive manufacturing; Inconel 625; WAAM; CMT

1. Introduction

Additive Manufacturing (AM) processes have been one of the rapidly developing technologies in the recent years. It is a process of making parts in layers from a 3-dimensional model data [1-2]. AM processes are mainly Powder based or Wire based. In powder based AM technique, metallic powders are selectively melted and deposited layer by layer. [3-5] In Wire based method, the electrode wire Inconel 625 is melt by cold metal transfer welding process. Being wire based, this method offers high deposition rates compared to powder based methods[6].R.C. Hall's study reveals the relationship between microstructural changes, variation in composition, post heat treatment and their effect on mechanical properties of Inconel 625 alloy [7-9].

The use of CMT welding process offers high low heat input to melt the wire which significantly reduces the high residual stresses and distortion in the part produced [10]. The part produced by single bead deposition has a wall thickness of 3 mm.

2. Experimentation

2.1. Experimental Framework for part building

The schematic of the Cold Metal Transfer equipment (FRONIUS, Austria, Model: TPS CMT) used in this work is shown in Figure 1a. The feed wire used in this experiment is inconel 625 wire of diameter 1.6 mm, its chemical composition is listed in Table 1. The substrate material used in this part building is Inconel 625 of specification 150 mm x 150 mm x 5 mm. The chemical composition of Inconel 625 is shown in Table 1. The Optimized parameters of the WAAM processing used in this work were listed in Table 2. Two thin-walled rectangles (7 mm in thickness, 200 mm in length, and 100 mm in height) were manufactured using CMT based WAAM process.

Figure 1. Wire arc additive manufacturing equipment

Table 1. Chemical composition of Inconel 625 (Wt%)

Element	Ni	C	Mn	Si	Ti	Al	Co	Mb	Cb	Fe	Cr
Percenta	52.82	0.08	0.35	0.35	0.6	0.8	1.0	3.0	5.0	17.0	19.0

Table 2. Deposition parameters

Build Parameters	**Values**
Wire feed rate (mm/min)	200
Thickness of layer (mm)	1.0
Peak current (A)	150
Peak time ratio	25%
Ratio of base current to peak current	10%
Pulsing frequency (Hz)	2.0

The purpose of this research is to characterize inconel 625 parts manufactured by WAAM process using CMT process.. Five number of inconel 625 parts were used for mechanical characterization like tensile, hot tensile, impact, bending properties.

3. Characterization and Testing

3.1 Transverse Tensile Test

Additive layer manufacturing technology involves manufacturing a part in layers. So the mechanical properties of the parts manufactured are influenced by the quality of overlap between each molten weld beads in the perpendicular direction, and also the re-melting quality between each layer in its fore-aft direction. Based on these considerations, in this research, the tensile test specimen is prepared as per the AWS B4.0 standard. The specimen size is 150 X 15 X 7mm [16]. The test results are given as follows:

DIRECTION	UTS	YS	% ELONGATION
LONGITUDINAL	1290	1070	16
TRANSVERSE	1310	1100	17

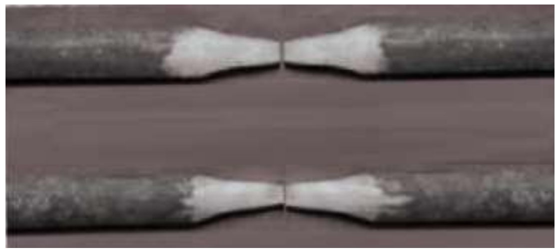

Figure 2. Tensile test specimens

3.2 Hot Tensile Test

The hot tensile test is carried out to evaluate the behavior of metal materials when subjected to high temperature and high tensile load. High temperature tensile testing is performed to determine the ultimate tensile strength of the material at elevated temperatures to assess the performance of inconel Ta
625 exposed to high temperatures. The test results are tabulated below:

ble 3. Hot tensile test

Metal Tested	Tested at temperature (°c)	Uts in mpa
Inconel 625	1000	1020
Inconel 625	1050	990
Inconel 625	1100	980

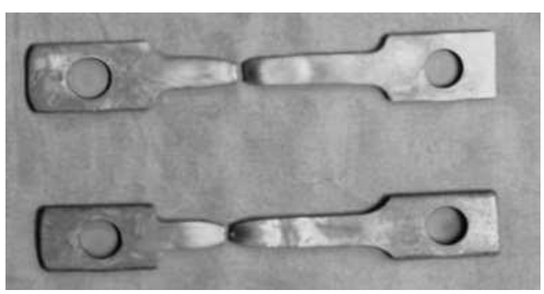

Figure 3. Hot tensile test specimens

3.3 Impact Test

Impact test is performed to determine the amount of impact a specimen absorbs before fracturing. The impact test results prove that the inconel 625 specimens fabricated by wire plus arc additive manufacturing process absorb higher impact energy which in turn proves that the WAAM fabricated inconel components have better impact strength.

The Impact test results are tabulated below:

Test temp: Room temp

Sample size: 60 x 8 x 6 mm

Specimens	Impact energy (joules)
Inconel 625 - Specimen 1	21
Inconel 625 - Specimen 2	45
Inconel 625 - Specimen 3	57

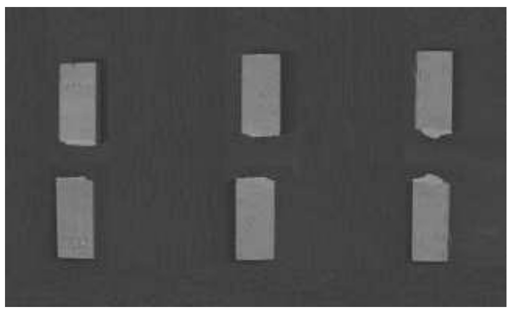

Figure 6. Impact Test Specimens

3.4 Microstructural analysis

A Variable Pressure Scanning Electron Microscope, Hitachi S-3400N examines the specimen fractured under tensile test. The specimen observed under SEM was sectioned parallel to the surface of fracture. The microstructure of fractured surface was observed under various magnifications. The SEM image reveals the presence of precipitates of carbides and micro-voids. The alloy with a carbon content of 0.0314 percent forms carbide when combines with elements like niobium and titanium. At a higher magnification micro-voids were revealed that confirms that ductile fracture.

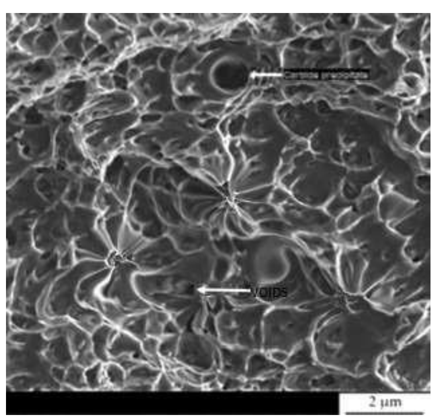

Figure 7. SEM image of fractured tensile specimens

4. Conclusion:

In this research work, mechanical characterization of CMT based Wire Arc Additive Manufactured Inconel 625 alloy has been carried out. The characterization includes results from various tests like tensile, hottensile and impact. Properties at elevated temperatures were also studied. Scanning Electron Microscopic inspection of the material is also done. The results proved that, the CMT based Wire arc Additive Manufacturing process holds good for fabrication of inconel 625 alloy. Due to its higher deposition rates this WAAM process is much faster than the other powder based additive manufacturing processes.

5. References:

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