IJRSET MARCH 2017 Volume 4, Issue 3 Pages: 5-9
ISSN 2394-739X
International Journal for Research in Science Engineering and Technology

EXPERIMENTAL INVESTIGATION OF MICROSTRUCTURE AND MECHANICAL PROPERTIES OF ND: YAG LASER WELDED NICKEL-CHROMIUM BASED ALLOY (INCONEL 625)

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ABSTRACT: The influence of various welding parameters on microstructure and the mechanical properties of laser welded Nickel based super alloy Inconel 625 sheets of thickness 1.5 mm were investigated. The various welding parameters used are welding speed (mm/min), pulse width (mm) and laser power (watt). The experimental results for this super alloy showed that the growth of grain structure in the weld zone has been increased significantly. The microstructure of the various samples at fusion zone and heat affected zone (HAZ) was characterized by the optical microscope and field effect scanning electron microscope (FESEM). In comparison with base metal the mechanical properties, i.e. tensile strength of the material has been 90% of its original strength and the micro-hardness of the fusion zone has the maximum value and then at the heat affected zone. The Nd: YAG pulsed laser has been used because of its overlapping factor during welding that reduces porosity in the weld zone.

Keywords: [Nd: YAG laser welding, microstructure, field emission scanning electron microscope (FESEM), micro-hardness.]

1. INTRODUCTION

Inconel Alloy 625 is a nickel-based superalloy that possesses high strength properties and resistance to elevated temperatures. It also demonstrates remarkable protection against corrosion and oxidation. Its ability to withstand high stress and a wide range of temperatures, both in and out of water, as well as being able to resist corrosion while being exposed to highly acidic environments makes it a fitting choice for nuclear and marine applications . Some modifications were made to its original composition that have enabled it to be even more creep-resistant and weldable. Because of this, the uses of Inconel 625 have expanded into a wide range of industries such as the chemical processing industry, and for marine and nuclear applications to make pumps and valves and other high pressure equipment.Inconel 625 was designed as a solid solution strengthened material with no significant microstructure. This holds true at low and high temperatures, but there is a region (923 to 1148 K) where precipitates form that are detrimental to the creep properties, and thus the strength, of the alloy. Under any creep conditions (high temperature with an applied stress), M23C6-type carbides form at the grain boundaries. When tested at 973 K, γ” precipitates begin forming. These γ” phase precipitates are ordered A3 B type with a composition of Ni3(Nb, Al, Ti) and a tetragonal crystal structure. They form a disk-shaped morphology and are coherent with respect to the matrix. When tested at 998 K, a δ-phase precipitate begins forming which consist of Ni3(Nb, Mo) in a orthorhombic crystal structure.

They form in a needle-like morphology and are incoherent with the matrix. Both of these precipitates can be completely dissolved back into the matrix when the sample is heated 1148 K. This leads to the ability to recover creep properties of the alloy to prolong the materials lifetime.

Many researchers were done their research work in their own way for the material Inconel 625 alloy and also investigated for the microstructures and many other mechanical properties of the material with different kinds of laser welding techniques. The researchers were not investigated for these properties with Nd: YAG laser welding of the material. This alloy is mainly consists with the group VIII elements namely Nickel (Ni), Chromium (Cr), Iron (Fe), Cobalt (Co), Molybdenum (Mo) etc. Laser beam welding (LBW) is a welding technique used to join multiple pieces of metal through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. The process is frequently used in high volume applications using automation, such as in the automotive industry. It is based on keyhole or penetration mode welding..

The laser source provides a concentrated and high density heat source, allowing for narrow, deep weld bead with high welding scan speed.

The depth of penetration is proportional to the amount of power supplied, but is also dependent on the location of the focal point: penetration is maximized when the focal point is slightly below the surface of the workpiece .The process is mostly used in high volume production industries, such as in the automotive industry.

But now-a-days it has profound application in various metal working fields due to its advantageous effects over other machining operations.

Laser beam welding has high power density which results in small heat affected zone due to high heating and cooling rates. Laser beam welding is a versatile process, which can weld almost all materials including aluminium, titanium, carbon steels, HSLA steel and stainless steel. Due to high cooling rates, cracking is a concern when welding high-carbon steels. The weld quality is high. The speed of welding is proportional to the amount of power supplied but also depends on the type and thickness of the workpieces.For this study solid state laser is used i.eNd:YAG laser.Nd:YAG lasers can operate in both pulsed and continuous mode, but the other types are limited to pulsed mode.

The original and still popular solid-state design is a single crystal shaped as a rod approximately 20 mm in diameter and 200 mm long, and the ends are ground flat. This rod is surrounded by a flash tube containing xenon or krypton. When flashed, a pulse of light lasting about two milliseconds is emitted by the laser.

Disk shaped crystals are growing in popularity in the industry, and flashlamps are giving way to diodes due to their high efficiency. Typical power output for ruby lasers is 10–20 W, while the Nd:YAG laser outputs between 0.04–6,000 W. To deliver the laser beam to the weld area, fiber optics are usually employed.

In this present study, fibre laser welding of Inconel 625 alloy of 1.5 mm thin sheet was investigated.

The investigation was done for the microstructure and the mechanical properties i.e. micro-hardness of the alloy in the weld zone by varying various parameters like welding speed and laser power.

2. EXPERIMENTAL SETUP

The welding is done by varying the process parameters are Power output and welding speed. The shielding gas used during welding in Nitrogen gas. Shielding gas pressure is 3 bar.

A schematic diagram for this setup is shown in figure.To obtain good laser welding quality, welding parameter like welding power, welding speed has been varied and rest of all welding parameters are kept constant.

SI.NO	Power In watt	Speed In mm/s	Heat input In J	Pulse width (mm)
1.	325	2.6	8.2	2.0
2.	340	2.6	9.5	2.0
3.	355	2.8	9.8	2.0
4.	370	3.0	9.7	2.0

Table 1: Variable parameters for welding processes

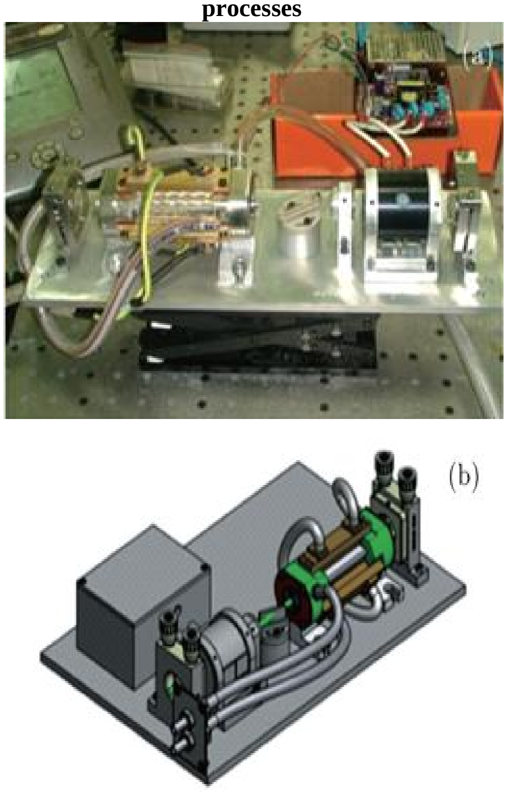

Figure-1 Experimental setup of Nd:YAG laser (a) and schematic diagram of setup (b).

3. THE EXPERIMENTAL PROCEDURE

In this present work First the Nickel-chromium based super alloy namely Inconel 625 sheet of thickness 1.5mm is cut in the dimension 160mm×25mm.All the cutting operations are done using wire electro-discharge machine (WEDM).Then the both half portion of the specimens were arranged and clamped using a setup. The specimens are then Butt welded using Nd:YAG laser. Welding is performed by the single pass full penetration by fiber laser welding with nitrogen gas as a shielding gas. The welding parameters like welding power, welding speed are varied.

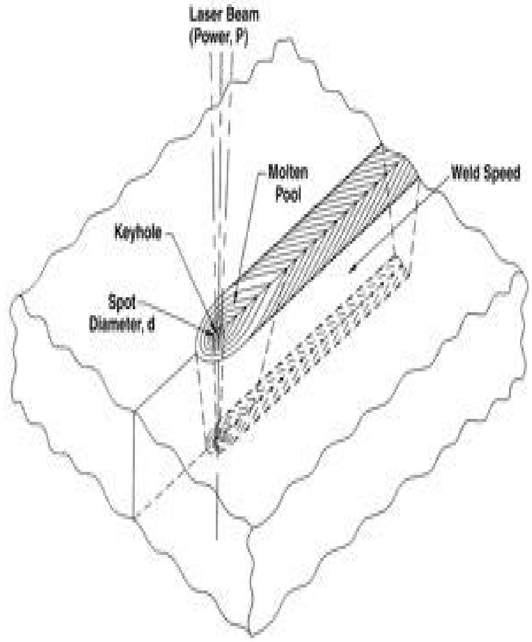

Figure- 2 A schematic diagram of Laser welding

The welded portions of the cut material after making tensile specimen were used for making specimen for micro-structural analysis and micro-hardness testing. The mould is prepared using compact moulding machine with phenolic powder for the weld specimen keeping weld face upward. Then the specimens were polished usingSiC emery paper of various grit size.

The polished surface of the samples was etched at room temperature for 3 minutes for FESEM observations. Aqua regia (20 ml HNO_3 + 60 ml HCl Very strong) is used for FESEM.Vicker's hardness test has been performed by applying load of 3KN force by indenting the tip of diamond at various regionfor 10 sec.

4. RESULT AND CONCLUSION

4.1 Microstructure analysis

The characterization of the material was done using its microstructure analysis and comparing the microstructures of the material in the welded zone with the base metal zone. The images of the microstructures were taken up to 10KX magnification using field emission scanning electron microscope (FESEM) and from 5X to 50X magnification images were taken by using optical microscope.

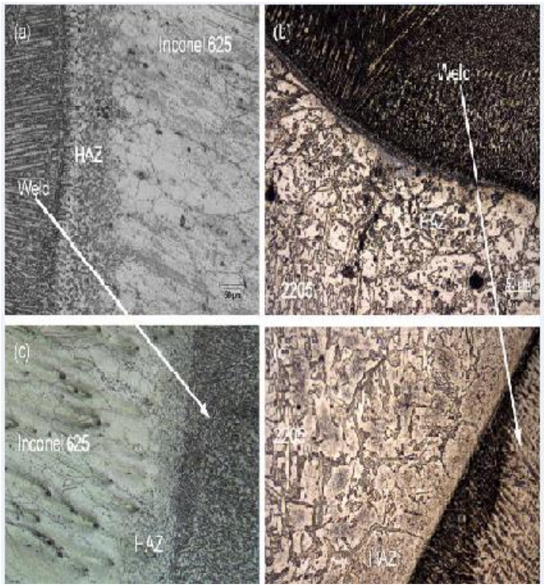

Figure-3 A microstructure of fusion zone using FESEM.

4.2 Microhardness

The vicker's micro-hardnesstesting machine was to get the micro-hardness value of the samples at the various regions. It gives the hardness value of the material in Vicker's hardness unit (HV). The machine has an indent made of diamond material as it is the hardest material among all elements present in the world.. The load applied on the material during testing was 0.3 kgf i.e. 3N. After applying load on the sample, the indentation mark on the sample was measured in both direction i.e. d_1 and d_2. The hardness value was indicated or shown digitally in the indicator[12].

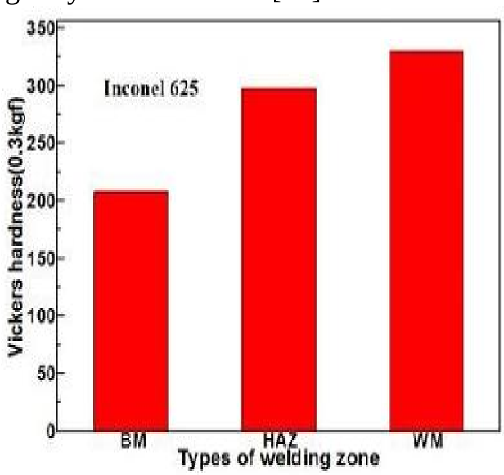

Figure-.4 Bar graph for Microhardness at different zone

The graph shows that the hardness value is more in the weld zone as compared to other i.e. at base metal zone. This indicates that the material has lost some of its ductility property because of high cooling rate. The maximum hardness value for both the tested specimen has approx. 260HV in the weld zone.

4.3. Corrosion potential

The weld metal zone indicates the smallest corrosion current density, while the base metal zone exhibited the largest value. As a result, the higher hardness, the larger ferrite microstructure, the nobler corrosion potential, and the smaller passivity current density[14][15].

5. SUMMARY

Thin inconel 625 alloy sheets with thickness 1.5mm were welded using a 600W Nd: YAG laser machine. The effects on the microstructure and the micro-hardness in the weld zone of Inconel 625 alloy after welded by Nd: YAG laser source were studied and the following key observations were found:

1. After FESEM analysis, microstructure of the material was found to be dendrite structure.
2. The micro-hardness found by vicker's hardness test maximum at fusion zone(FZ) then at Heat affected zone (HAZ) and then at Base metal(BM).
3. Solidification cracks were found in the fusion zone and also some overheated point in near fusion was found.
4. Hardness of fusion zone increased due to increase in heat input that decreased the average input power.
5. In tensile testing,In comparison with base metal tensile strength of the material has been 90% of its original strength.

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