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CHARACTERIZATION OF MICRO STRUCTURE AND MECHANICAL PROPERTIES OF INCONEL 625 SHEET OFND:YAG LASERWELDING

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ABSTRACT

During this research Inconel alloy 625 is used because, it has high strength, excellent uniform corrosion resistance, resistance to stress cracking and excellent pitting resistance in 500°-600°F (260-316°C) water. These properties make it interesting to aerospace field. It is used in Jet engine combustor component, aircraft ducting systems, engine exhaust systems, thrust-reverser systems, turbine seals, compressor vanes and heat-exchanger tubing in environmental control systems. In this research work, full penetration welding 1.5-mm-thin Inconel 625 sheet in a butt configuration was carried out with Nd: YAG laser welding machine of 600 W.Influence of welding speed and laser power on the macroscopic geometry, microstructure, micro-hardness and tensile properties of Inconel 625 was investigated.

Keywords: Inconel 625, Mechanical Properties, Microhardness,Nd: YAG laser welding, Optical Microscope

1. INTRODUCTION

Inconel 625 is a Nickel base super alloy whoseStrength is derived from the stiffening effect of molybdenum and niobium on its nickel-chromium matrix; thus precipitation hardening treatments are not required. These elements combination are responsible for superior resistance corrosion and oxidation environment of unusual severity as well as to high-temperature effects such as oxidation and carburization, have high strength, resistance to stress cracking and excellent pitting resistance [1].These properties make it suitable for aerospace, power plants nuclear industry, chemical processing field and marine engineering applications [2].The components made by Inconel 625 are jet engines and gas turbine components, including blades, disks, rotors, and combustor/burner cans, combustion system transition liners [3] as well as compressor and turbine [4].F. Caiazzo et al. [5] investigated Laser welding of Inconel 625 edge joint beads in square groove configuration by disk laser. He found that low value of heat input reduces the porosity and results in stable bead conformation. By decreasing heat input, decrease in grain size is also observed.K. Devendranath et al.[6] Investigated the weldability of dissimilar metals involving Inconel 625 and Super-duplex Stainless steel obtained from continuous current (CC) and pulsed current (PC) gas tungsten arc welding (GTAW) and observed grain coarsening at heat affected zoneof UNS S32750. Gang Li et al.[7] investigate the microstructure and showed that microstructure near SUS304 side fusion zone was cellular and near Inconel 625 fusion zone was columnar dendrites. Janicki et al. [8] carried out fibre laser welding of 0.8 mm Inconel 625 sheet and studies influence of laser welding parameters on weld quality and mechanical properties. He found that proper laser parameter selection provides non porous fully penetrated welds and yield, tensile strength was similar to the base metal. Adil Widaatalla et al. [9] carried out fibre laser welding of Inconel 625 and found that laser welding techniques can be used to improve the cost and quality of combustor component manufacturing.From the literature review it has been clear that very less work has been performed on welding of INCONEL 625 alloy with the Nd: YAG laser. Dissimilar Welding of Inconel 625 and Stainless steel has been done in literature. Welding of Inconel 625 alloy has been done in the past from the CW fiber, CO2 lasers and conventional welding processes and morphological and mechanical investigation has been done. So in this study the Joining of Inconel 625 similar butt welds using 600 Watt Nd: YAG laser was performed and morphological and mechanical investigation of the welded joint was done.

II. EXPERIMENTAL SET UP

600 W JK600HP Nd: YAG Laser Systems has been used to conduct the experiment on Inconel 625 alloy. The images of experimental set-up are shown in Fig. 1, and Industrial Robot IRB 1410 is used to control the movement of laser head. The spot size of the laser beam was 0.6 mm and focal length 160 mm.The Argon (Ar) gas as used for shielding purpose. The pressure for Argon gas was 1 bar and gas flow rate was 7 lit/min. In order to obtain good quality laser welding laser power, welding speed were varied and other parameters remains constant.

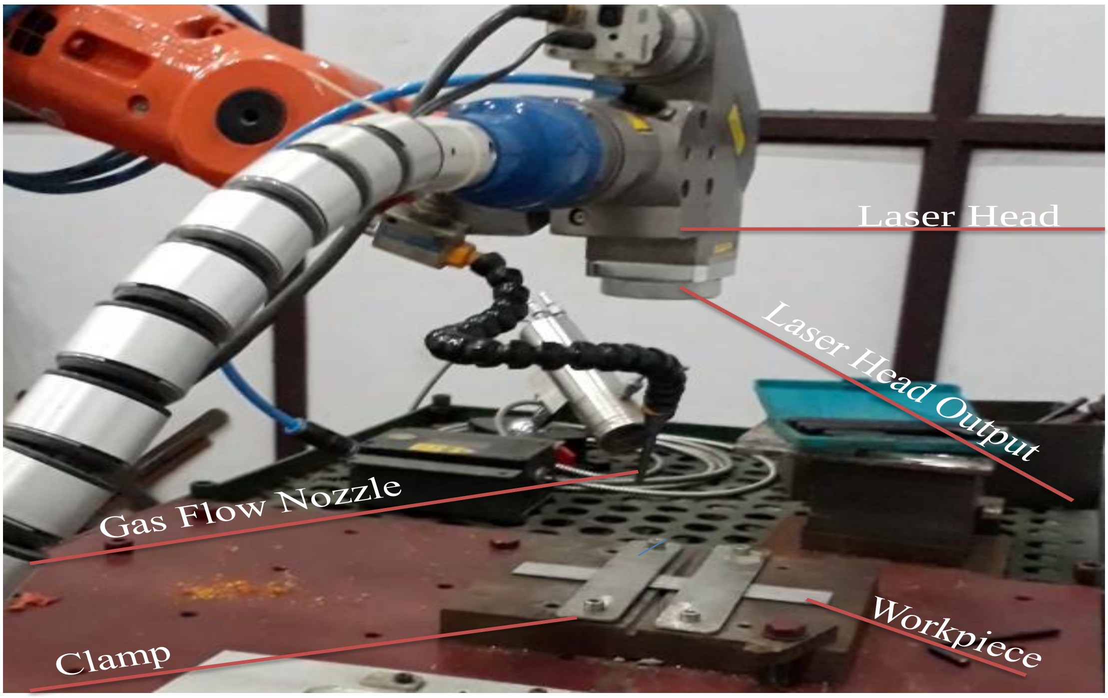

Figure-1. Setup of Nd: YAG laser welding

III. EXPERIMENTAL PROCEDURE

Specification of Nd: YAG laser system is shown in the Table 1. The schematic representation of CAD model of Nd: YAG laser welding is shown in Fig. 2.

Table-1.Laser system specification

Laser ModelNumber	Laser System	Maximum power	Focal Length	Focal Spot Diameter
JK600HP	Nd: YAG	600 W	160 mm	0.6 mm

Table-2.Laser Processing parameters used in the present research work

Input System Parameters	Value
Spot Diameter in mm	0.6
Gas Nozzle Angle	45 degree
Shielding Gas	Ar
Focal Length	160 mm
Shielding Gas Flow Rate in litre/min	7
Pulse Width in ms	2.1

Table 3: Input work parameters

Input Work Parameters	Value
Work piece	Inconel 625 sheet (82.5mm × 25mm × 1.5mm)
Thickness of work piece in mm	1.5 mm
Holding device	Mechanical Clamp
Types of welding	Butt Welding
Filler wire	Autogenous, no filler wire required

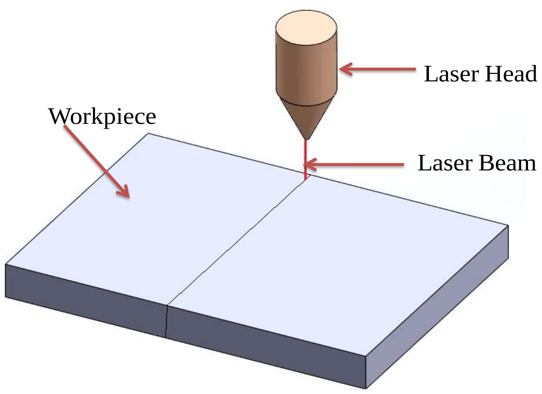

Figure-2. CAD model of Nd: YAG laser welding

In this research work Inconel 625 of 1.5 mm thickness is used. The base material is cut into 82.5 mm × 25 mm × 1.5 mm on Wire EDM machine. The faying surfaces and neighborhood of all the specimens were brushed and then cleaned with acetone to remove surface oxides and other contaminants prior to clamping to produce defect-free joint. The full penetration welding is performed in a single pass by Nd: YAG laser welding by applying argon as a shielding gas. The processing parameters like laser power and speed were varied.For microstructure examination at fusion zone, heat-affected zone and base metal zone, specimens were cut from the welded portion along with some portions of the base metal. The moulds for the specimens were prepared using moulding machine by maintaining the temperature and pressure of 160^0C and 100Kg/cm^2. The mould material used was phenolic powder. The specimens were then polished using SiC paper of grit size, 600, 800, 1000, 1200, 1500 and 200 rotating clockwise for the first three grit sizes and counter clockwise for rest three respectively. The polishing time for each specimen is 10 minutes. The specimens were etched using prepared reagent (HF+HNO_3+distilled water). The specimens were poured inside the reagent for one minute. The polished specimens are etched by marble's solution (10 g $CuSo_4$ + 50 ml HCl +50 ml H_2O) to reveal the microstructure [10]. Microhardness testing was performed in a LECO Micro-hardness tester LM 248AT using 100 gfload and a dwell time of 10 sec.

IV. RESULT AND DISCUSSION

4.1 Morphological Study

The images of the welded sample at different processing condition were taken atOlympus microscope for the study of bead geometry and microstructure.The figure clearly shows a decrease inwidth of the welded sample with increase in weld speed and an increase in width with increase in weld power.

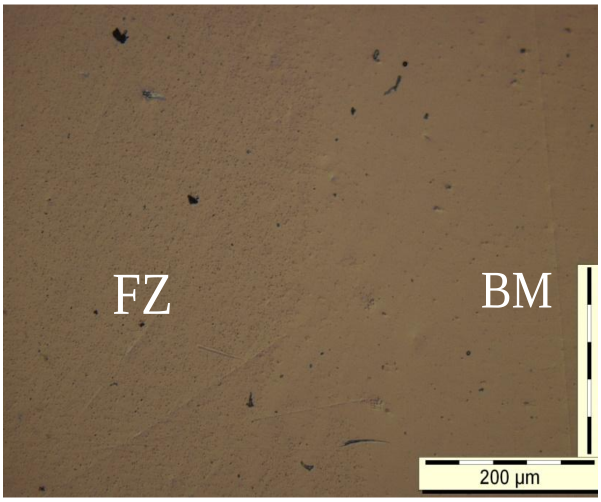

Figure-3(a). optical image of sample welded at 430 watt power and 170 mm/min speed.

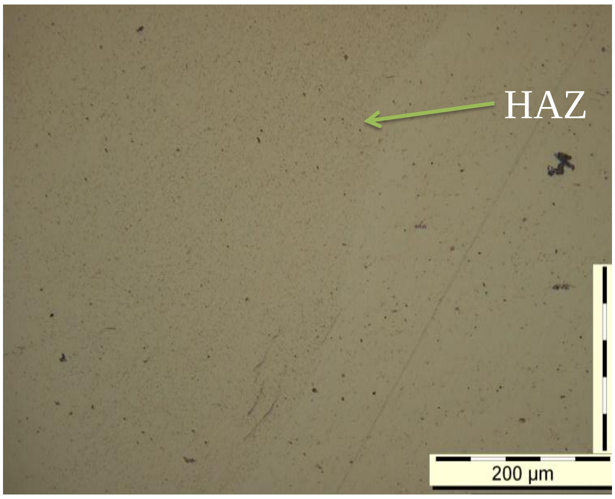

Figure-3(b). optical image of sample welded at 430 watt power and 140 mm/min speed.

The microstructure at the fusion zone is to be changed significantly at the temperature beyond the effective liquids temperature due to re-melting and solidification of metal in this zone. However the microstructure of

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fusion zone is much more complex due to the physical interaction between the heat source and the base metal. At the HAZ microstructure has larger grain size due to heat distribution.

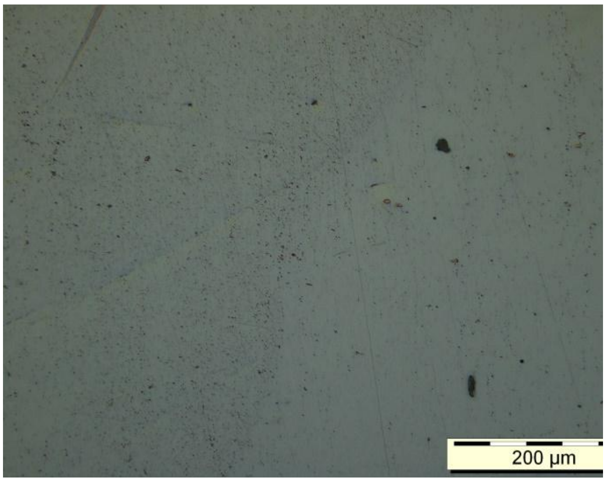

Figure-3(c).optical image of sample welded at 380 watt power and 170 mm/min speed.

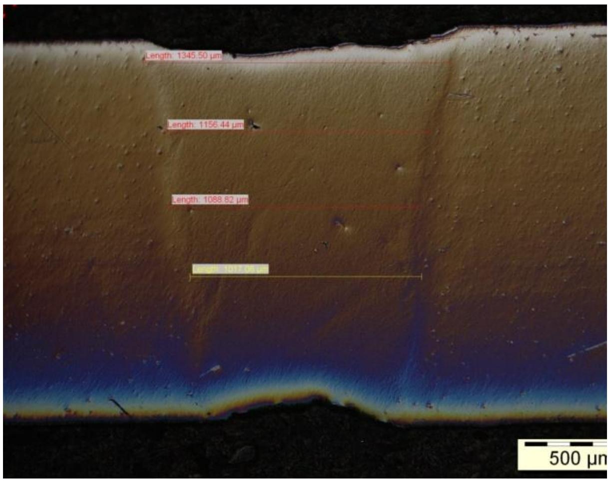

Figure-3(d).optical image of weld bead at 380 watt power and 140 mm/min speed.

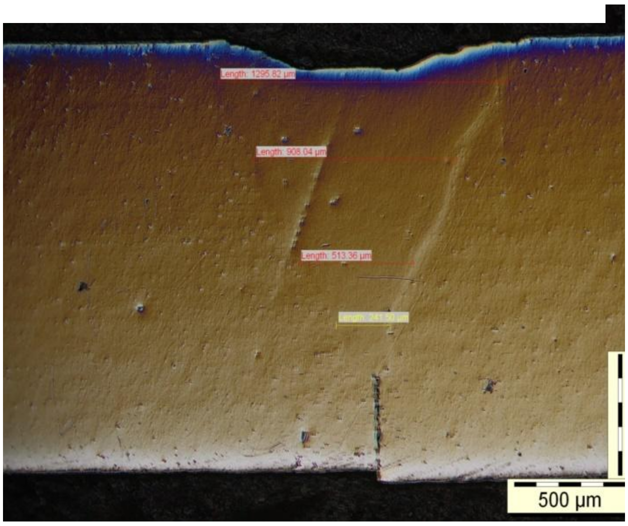

Figure-3(e).optical image of weld bead at 330 watt power and 170 mm/min speed.

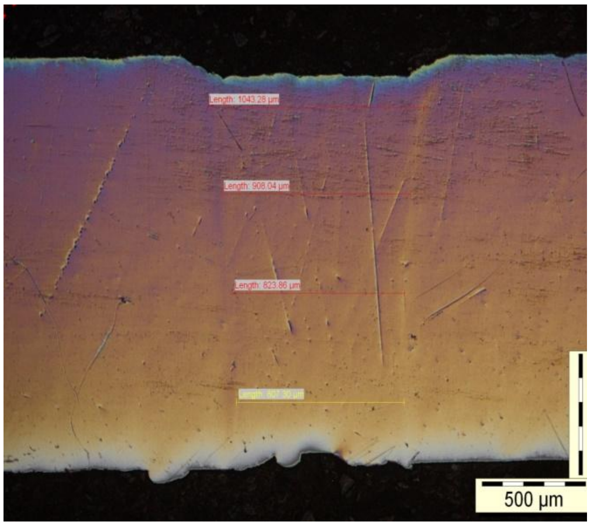

Figure-3(f).optical image of weld bead at 380 watt power and 200 mm/min speed.

At scanning speed of 140 mm/min with varying power from 330 to 430 Watt the size of fusion zone [FZ] are 0.81mm, 1.3mm, 1.61mm. Similarly for other scanning speed in the graph with varying power in the given range size of FZ increases. FZ vs. Power graph of welded sample has been plotted and as shown in figure.

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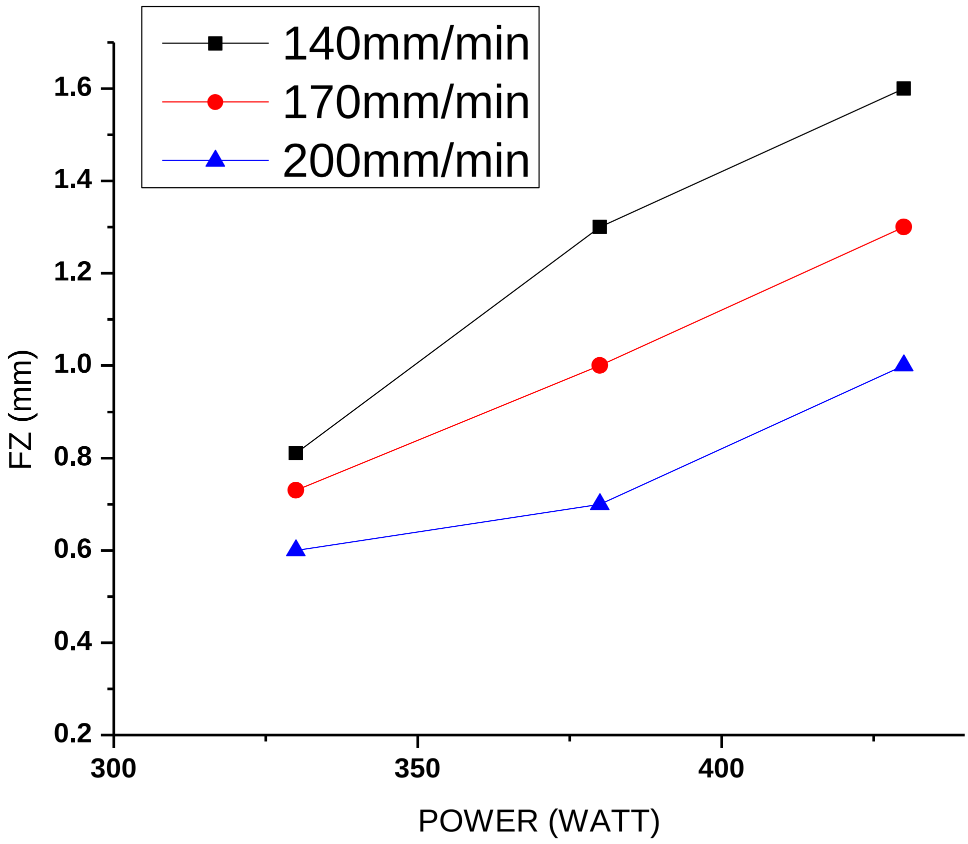

.Figure-4. Plot of laser power vs fusion zone

4.2 Micro-hardness

The graph clearly shows that at constant power with the increasing scanning speed micro-hardness of the welded sample increases due to higher cooling rate at high speed. For example at 430 Watt with varying speed from 140 to 200 mm/min. Vicker hardness value of welded sample are 256 HV, 257 HV and 270 HV. Micro hardness vs Power graph of welded sample has been plotted shown in fig.5.

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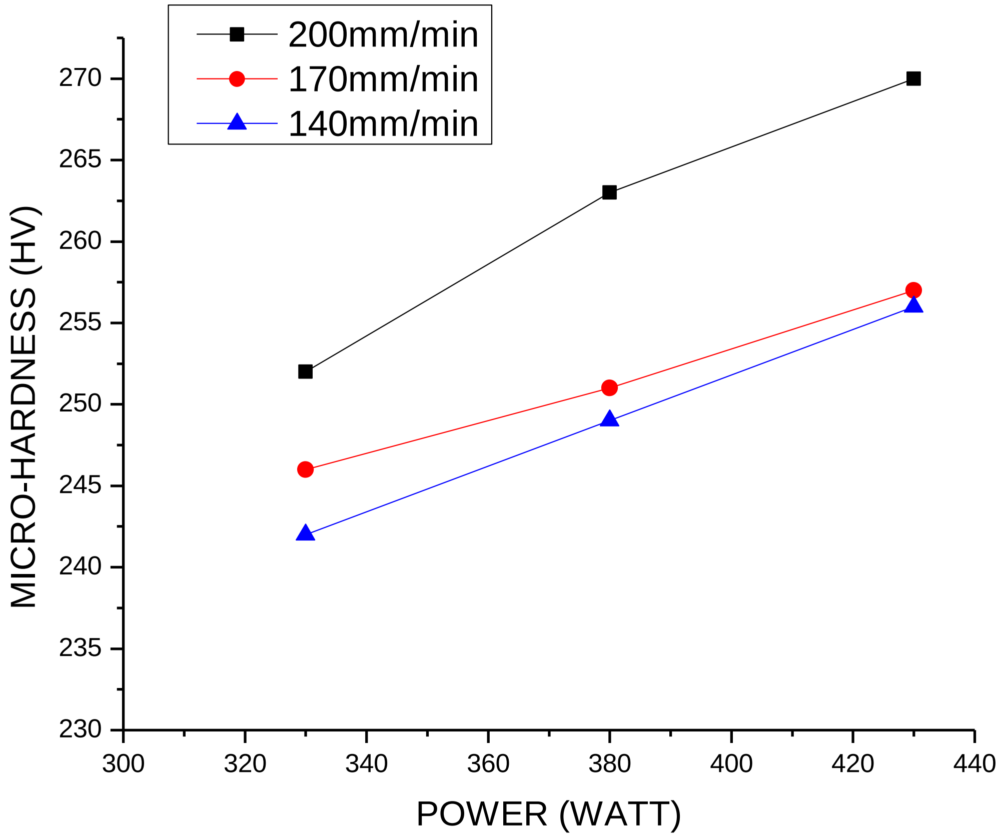

Figure-5. Plot of laser power vs micro hardness

4.3 Tensile test

After welding the Sample is cut according to ASTM E8 standard for tensile test as shown in fig. 6 by wire EDM machine. The tensile specimen made are of I-section having 30mm length for clamping for each side, 25mm width and rest were the middle portion having the curvature at the corner of radius 15mm. The width of the middle portion of specimen was 1.5mm as 5mm from each side has been cut to get the specimen for testing in the weld zone.Tensile testing has been performed at room temperature using a Zwick Roell tensile test machine operating with a cross-head speed of 10mm/min with 50kN load cell. The tensile strength of the original sample has been determined as 850 MPa.Testing results of welded sample has maximum failure strength of 720 MPa at 430 Watt and 200 mm/min scanning speed, which is closer to the parent material. Tensile test of welded sample has been performed and graph, Power vs. tensile strength plotted in Fig. 7.

Figure-6.Specimen for tensile test

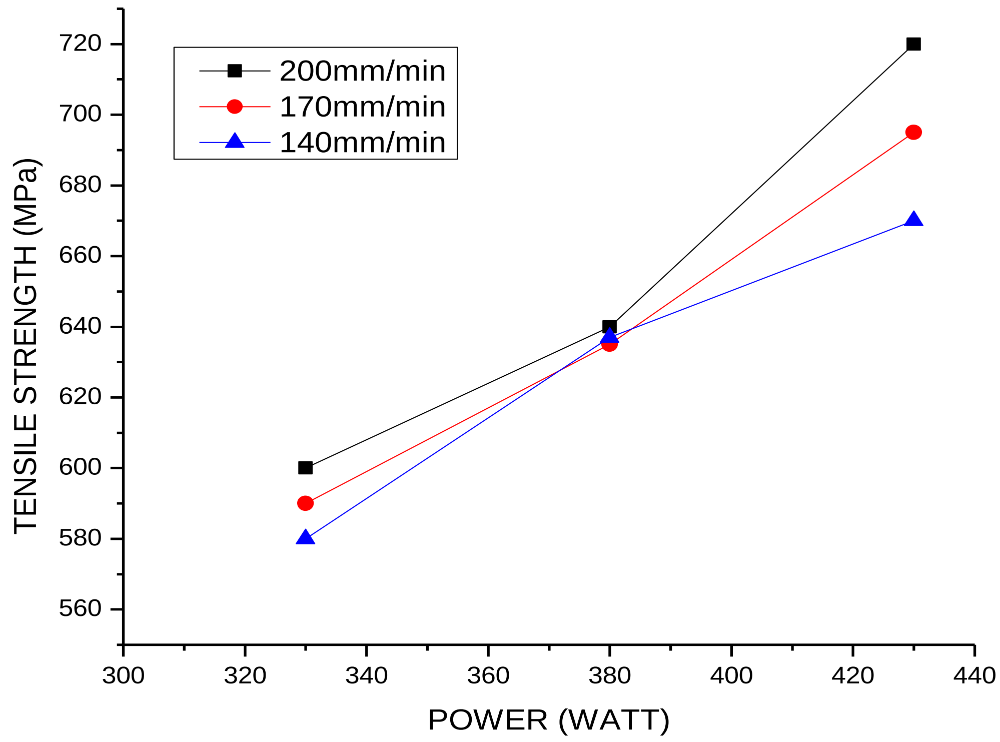

Figure-7. Plot of laser power vs. tensile strength

V. CONCLUSIONS

The Nd: YAG laser of 600 Watt has been employed for the welding ofInconel 625 sheets of 1.5mm thickness. Influence of welding speed and laserpower on the macroscopic geometry, microstructure, micro-hardness and tensileproperties of LBW butt joints in Inconel 625 was investigated.

- It shows that the size of weld region may control by varying the laser power, welding speed and beam diameter. The width of weld decreases with the increase in scanning speed and an increase in width with increase in weld power.
- The Vickers micro-hardness values of weld pool region across the weld are higher than both the weld interface and the parent material. The hardness value increases with increase in welding speed at a fixed power supply. High hardness gradient is brought about by a high cooling rate.
- In the tensile test, all specimens fail at almost same strength compared with base material.
- In real application, a largerthickness is used and the present investigation may provide an insight for the laser welding of thicker Inconel 625 alloy sheets. Also laser welding of dissimilar materials is a recent (relatively) approach in the field of welding research. This should be exploited.Explanation of results obtained in the present study is one limitation of the present study.The results should be validated through proper mathematical modeling.

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