Parametric Optimization of Dissimilar Materials Using Laser Welding Technology- A Review

Jay N. Bhamare
P G Student
Department of Mechanical Engineering (CAD/CAM)
L.J Institute of Engineering and Technology, Ahmedabad.

Ankit D. Oza
Assistant professor
Department of Mechanical Engineering
L.J Institute of Engineering and Technology, Ahmedabad.

Abstract

Very less work has been done on laser welding of dissimilar material. Laser welding of AISI 1552 was studied in butt welding in SS304L. In order to decrease formation of intermetallic components during laser welding, effect of laser power, pulse duration and overlapping factor was investigated. Tensile test was performed to identify the effect of each parameter on the weld. Results showed that increasing peak power (in constant pulse energy), pulse duration (in constant peak power) and welding speed (in constant pulse energy and peak power) will decrease tensile strength. On the other hand, decreasing the mentioned parameters will cause destructive effects such as inadequate penetration depth, spattering and cavity formation. Improvement in the tensile strength was attributed to low values of intermetallic components in weld metal.
Keywords: YAG Laser Welding, AISI 1552, SS 304L.

I. INTRODUCTION

The word "LASER" is an acronym for Light Amplification by Stimulated Emission of Radiation There are two of types of Nd:YAG laser welders; continuous wave and pulsed. As the name suggests continuous wave or CW is either on or off, whereas pulsed lasers create welds by individual pulses. The pulsed laser utilizes high peak power to create the weld, whereas the CW laser uses average power. This allows the pulsed laser to use less energy to create the weld, with a smaller heat affected zone. This provides the pulsed laser with unrivalled spot welding performance and minimal heat input seam welding. Unitek Miyachi lasers are pulsed welders.

A. PRINCIPLE OF LASER GENERATION

The generation of a laser beam is essentially a three step process that occurs almost instantaneously. The pump source provides energy to the medium, exciting the laser medium atoms such that electrons held with in the atoms are elevated temporarily to higher energy states. The electrons held in this excited state cannot remain there indefinitely and drop down to a lower energy level. In this process, the electron looses the excess energy gained from the pump energy by emitting a photon. This is called spontaneous emission and the photons produced by this method are the seed for laser generation.The photons emitted by spontaneous emission eventually strike other electrons in the higher energy states. "Eventually" is a very short time due to the speed of light and density of excited atoms! The incoming photon "knocks" the electron from the excited state to a lower energy level creating another photon. These two photons are coherent meaning they are in phase, of the same wavelength, and traveling in the same direction. This is called stimulated emission The photons are emitted in all directions, however some travel along the laser medium to strike the resonator mirrors to be reflected back through the medium. The resonator mirrors define the preferential amplification direction for stimulated emission. In order for the amplification to occur there must be a greater percentage of atoms in the excited state than the lower energy levels. This "population inversion" of more atoms in the excited state leads to the conditions required for laser generation.

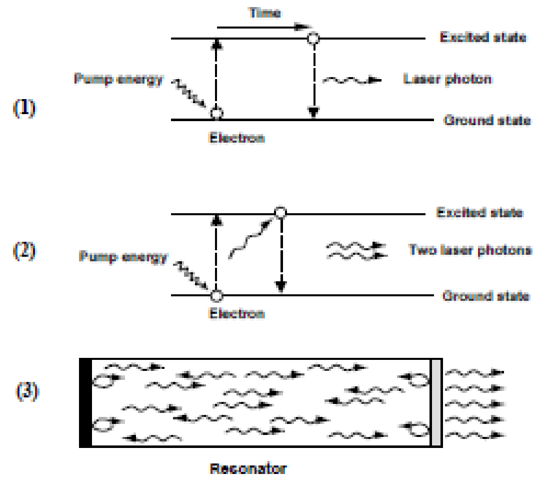

Fig. 1.1: Simplified Schematic Representation of The Three Stages To Laser Generation, Including (1) Spontaneous Emission (2) Stimulated Emission (3) Amplification

B. ND:YAG LASER MEDIUM

The laser rod used in Nd:YAG laser welders and markers is a synthetic crystal of Yttrium Aluminum Garnet. The YAG material is the "host" material that contains a small fraction of neodymium, the active element. The substitution of the yttrium ions with neodymium ions is called doping, and typically the doping percentage is around 1 – 1.5%. The doping level is selected to optimize the lasing effect and prevent excessive strain on the crystal, as the Nd3+ ion is physically larger than the Y3+ ion.
The YAG crystal is an ideal host for the lasing material Nd3+, being physicall hard, stable, optically isotropic, and has good thermal conductivity that permit laser operation at high average power levels. Neodymium is an excellent lasing material as it produces the highest level of powers than any other doping element. The dimensions of the laser rods are selected for power and optical quality, with the maximum rod size limited to around 15mm diameter and 200mm in length for reasons of crystal quality and thermal management.

II. LITERATURE REVIEW ON LASER WELDING

(1) *Dissimilar welding of carbon steel to 5754 aluminum alloy by Nd:YAG pulsed laser,* M.J. Torkamany, S. Tahamtan, J. Sabbaghzadeh, Materials and Design 31 (2010) 458–465.

In this paper dissimilar welding of carbon steel to 5754 aluminium Alloy, they used Nd:YAG to weld Al alloy and steel to using process parameter like Peak power 1-2.7 KW, Pulse duration 3.7- 10 ms, Velocity 5mm/sec, Pulse energy 10 J, Frequency 20/sec, Overlapping factor 40-90%, w/d ratio 1.5 mm, Power 200W. They observed OM, SEM, EDX, UTM . They found that High peak power cause mode dilution, Hardness is also increasing with increasing the peak power. Longer pulse duration cause large weld width and also penetration depth. Also they found that Welding efficiency increases with overlapping factor and Ideal parameter and of welding peak power is1.43KW, Pulse duration is 5 ms, Overlapping factor 80% Hardness value increases with increasing the penetration depth.

(2) *Metallurgical investigations of pulsed Nd:YAG laser welding of AISI 321 and AISI 630 stainless steels,S*.A.A. Akbari Mousavi , A.R. Sufizadeh, Materials and Design 30 (2009) 3150–3157.

Metallurgical investigations of pulsed Nd:YAG laser welding of AISI 321 and AISI 630 stainless steels of 0.6 mm thickness plate. They were focused on the effects of laser power, beam diameter and pulse duration on the depth and width of the welds. They measured Microstructures of the welded joints were investigated by optical and scanning electron microscopy. The results show that both weld depth and weld width increase with voltage. They also found that the pulse duration have bilateral effects on the weld bead depth and width and The maximum hardness resulted in the 630 stainless steel region and the minimum hardness occurred for the 321 stainless steel region. This was inferred from the micro hardness test.

(3) *Pulsed Nd:YAG laser welding of AISI 304 to AISI 420 stainless steels,*Jose´ Roberto Berretta, Wagner de Rossi, Maurıcio David Martins das Neve, Ivan Alves de Almeida, Nilson Dias Vieira Junior, Optics and Lasers in Engineering 45 (2007) 960–966.

Pulsed Nd:YAG laser welding of AISI 304 to AISI 420 stainless steels of 0.8 mm thick plate. They investigate to determine the influence of the laser beam position, with respect to the joint, on weld characteristics. They Prepared work pieces were welded with the laser beam incident on the joint. Joints attained under all the welding parametric conditions were constant. Changes in beam position had no effect on weld fillet geometry. If the laser beam is positioned on the joint or is shifted in the direction of AISI 304 steel, it will tend to favor the joint. If the laser beam is shifted to the opposite direction of AISI 420 steel, the structure becomes martensite The joints were examined in an optical microscope for cracks, pores and to determine the weld geometry. The microstructure of the weld and the heat affected zones were observed in a scanning electron microscope. An energy dispersive spectrometer, coupled to the scanning electron microscope, was used to determine variations in (weight %) the main chemical elements across the fillet weld. They used Vickers microhardness testing and tensile testing for determine the mechanical properties of the weld. The results of the various tests and examinations enabled definition of the best position for the incident laser beam with respect to the joint, for welding together the two stainless steels..

(4) *Pulsed Nd:YAG laser seam welding of AISI 316L stainless steel thin foils*, Vicente Afonso Ventrella, José Roberto Berretta, Wagner de Rossi, Journal of Materials Processing Technology 210 (2010) 1838–1843.

A pulsed neodymium: yttrium aluminum garnet laser weld to examine the influence of the pulse energy in the characteristics of the weld fillet. The base material used for this study was AISI 316L stainless steel foil with 100mm thickness. The welds were analyzed by optical microscopy, tensile shear tests and microhardness. The results indicate that pulse energy control is of considerable importance to thin foil weld quality because it can generate good mechanical properties and reduce discontinuities in weld joints. The ultimate tensile strength of the welded joints increased at first and then decreased as the pulse energy increased. The process appeared to be very sensitive to the gap between couples. They found that the thin foil weld quality pulse energy control holds considerable because of tits capanility to create excellent mechanical properties and minimize

(5) Experimental investigation on laser beam welding of martensitic stainless steels in a constrained overlap joint configuration, Khan L. Romoli,M. Fiaschi, F. Sarri,G. Dini, Materials and Design 30 (2009) 3150–3157.

In laser welding of martensitic stainless steels in a constrained overlap configuration. Experimental studies were concentrated on the effects of scan speed, laser diameter and laser power. The contour plots and energy density plots were drawn for determining relationships within various factors. They concluded that laser power and scan speed were two most significant factors affecting weld bead geometry and sheer force of the weld zone. Pulse diameter had least effect on weld geometry and shear force on weld zone. But its interaction effect beard a good value in case of weld bead and sheer force of laser weld. It was clear that welding resistance input increased with welding density up to certain limit. But as the welding density crossed the limit the density was utilized to increase penetration only. In SEM it was observed that the HAZ microstructures obtained in inner and outer shells of AISI 416 and AISI 440FSe were different from each other

(6) Experimental study of temperature and clamping force during Nd:YAG laser butt welding, Quan Sheng Liu S.M.Mahdavian , DavyAswin, SonglinDing,Optics & Laser Technology 41 (2009) 794–799

Clamping force as process parameter during laser butt welding of steel workpieces. They measured welding temperature for a butt welded joint during laser welding. The preset clamping force is varied during welding for different thicknesses of workpieces and weld joint strengths. The thermal expansion, cooling contraction, and workpiece width reduction during welding induce variations in the preset clamping force and consequently change the weld joint strength. From the results of welded workpieces they were revealed that a linear relationship between the maximum clamping force induced during welding and the initial preset clamping force exists, which can be used in the design of a clamping system. The temperature measurement indicated that the maximum welding temperature remains constant with the variation of clamping force.

III. CONCLUSION

From this critical literature review, We can conclude that most of researcher work on Nd:Yag laser welding they used measure number of responses with various process parameter such as Welding speed (mm/min), Pulse frequency (in Hz), Pulse diametrer (mm), Pulse energy (J), Pulse duration (ms), Average peak power density (kW/m2), Laser spot area (m2), Mean laser power (kW), Pulse repetition rate, pulse-to-pulse time (ms) and Duty cycle. So, We selected Welding speed (mm/min), Pulse frequency (in Hz), Pulse diameter (mm) But very few work on carried out on hardness and tensile strength of dissimilar material. So, we focused on improving tensile strength and hardness.

REFERENCES

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