EVALUATION OF ND: YAG LASER WELDING EFFICIENCIES FOR 410 STAINLESS STEEL SHEETS

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***Abstract*— The laser material interaction, controlling of process parameters and their effect on melting, solidification and process efficiency are critical to understand the behavior of the weld joints. This paper aims to study the effect of welding power, pulse time, frequency on different process efficiencies in 410 Stainless Steel. The bead on 410 austenitic stainless steel plates is created by varying welding power, pulse time, frequency. A measurement from experimental results is used to predict the hardness test, tensile test, microstructure fatigue test of Nd: YAG laser welding process. The dimension parameter models are used to optimize the appropriate result in Taguchi method. These parameters have good agreement with the various available models in literature.**

***Index Terms*- Laser welding; Welded seam; Microstructure; Mechanical properties**

I. INTRODUCTION

Laser welding has high power density (of the order of 1 Megawatt/cm² (MW)),having high heating and cooling rates which result in small heat affected zones (HAZ).Industrial lasers are used for welding, cutting, drilling and surface treatment of a widerange of engineering materials. An inert gas, such as helium or argon, is used to protect the weld bead from contamination, and to reduce the formation of absorbing plasma.Depending upon the type of weld required a continuous or pulsed laser beam may be used.LBW is a very versatile process, which is capable of welding a variety of materials like stainless steels, carbon steels, aluminum, copper, tool steels, etc. The weld quality is high, although some cracking may occur in the weld region. The speed of welding is proportional to the amount of power supplied but also depends on the type and thickness of the work-pieces. Laser welding is of particular interest in the automotive industry, laser welding has been applied for joining sheet body panels, transmission components and chassis members during production [13].Quite recently, LBW has also been utilized to manufacture hybrid micro-systems consisting of different materials].

MATERIALS AND METHODS

The following section illustrates the various materials and methods involved in fabrication410 stainless steels.

1. Material properties:

410 is a martens tic stainless steel that provides good corrosion resistance plus high strength and hardness. It is magnetic in both the annealed and hardened conditions. A wide range of properties can be developed with different heat treatments. Applications requiring moderate corrosion resistance and high mechanical properties are ideal for this alloy. Typical uses include flat springs, knives, kitchen utensils and hand toolsAISI Type 410 is a martensitic stainless steel that provides high strength and hardness with moderate corrosion resistance. A wide range of properties can be developed with different heat treatments, with ultimate tensile strengths ranging from 500 to 1400 MPa. It is magnetic in both the annealed and hardened conditions. High carbon content results in the formation of chromium carbide compounds, providing excellent wear resistance and edge retention when hardened. Additionally, this grade provides excellent high temperature oxidation and scaling resistance, yet is economical due to the low alloy content. Thermal conductivity is improved and thermal expansion reduced relative to austentic stainless grades.Applications

Mechanical Properties:

Temper: Annealed

- Tensile Strength Maximum (psi): 65,000
- Yield Strength Maximum 0.2% offset (psi): 30,000
- % Elongation in 2” Maximum: 20%
- Hardness: Rockwell B80

Temper: Hardened + 350°F

- Tensile Strength Maximum (psi): 205,000
- Yield Strength Maximum 2% offset (psi): 185,000
- % Elongation in 2": 8%
- Hardness: Rockwell C40

All values specified are approximate maximums unless otherwise specified. Values are derived from the applicable AMS and ASTM specifications.

1.2 Composition:

- Carbon: 0.08 - 0.15
- Manganese: 1.00
- Phosphorus: 0.040
- Sulfur: 0.030
- Silicon: 1.00
- Chromium: 11.50-13.50
- Iron: Balance

All values are maximum values unless otherwise specified. Values derived from applicable AMS and ASTM specifications.

1.3 Heat Treatments:

Annealing:

- Heat slowly to 1500-1650°F (816-899°C), cool to 1100°F (593°C) in furnace, air cool.

Process Annealing:

- Heat to 1350-1450°F (732-788°C), air cool.

Hardening:

- Heat to 1700-1850°F (927 - 1010°C), air cool or oil quench.
- Follow by stress-relief or temper.

High Temperature Tempering:

- Heat to 1100 - 1400°F (593 - 760°C) for 1 to 4 hours, air cool.

Low Temperature Tempering:

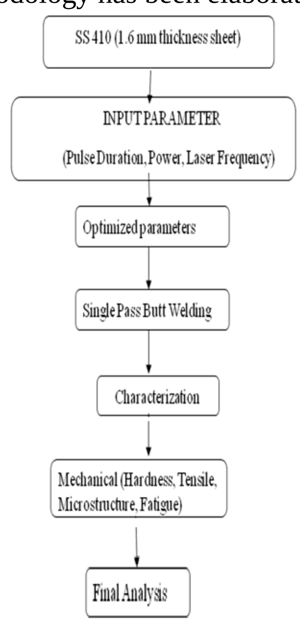
- Heat to 300 - 500°F (150 - 260°C) for 0.5 to 1 hours, air cool.

1.4 PHYSICAL DATA

Density (lb / cu. in.)	0.28
Specific Gravity	7.7
Specific Heat (Btu/lb/Deg F - [32-212 Deg F])	0.11
Electrical Resistivity (microhm-cm (at 68 Deg F))	342
Melting Point (Deg F)	2790
Modulus of Elasticity Tension	29

II. WORKING METHODOLOGY

The proposed work approach and methodology has been elaborately shown



III. EXPERIMENTAL WORK

The Nd:YAG laser is commonly used type of solid-state laser in many fields at present because of its good thermal properties and easy repairing. The generation of short pulse duration in laser is one of the researcher areas. Nd:YAG is chosen for most materials processing applications because of the high pulse repetition rates available [19]. The power supply of pulsed Nd:YAG laser is designed to produce a maximum average power. The beam quality and output power are depending on length of resonator [19]. The beam quality is important to the laser designer because the quality of a given beam profile depends on the application for which the beam is intended.

Fig. 1. Experimental setup showing Nd:YAG laser welding machine.

3.1 SELECTION OF MACHINING PARAMETERS

GRADE 410 STEELS CAN BE WELDED USING ALL CONVENTIONAL WELDING TECHNIQUES, BUT THE MATERIALS SHOULD PRE-HEATED AT 150 TO 260°C FOLLOWED BY POST-WELD ANNEALING TREATMENT, TO MITIGATE CRACKING. GRADE 410 WELDING RODS ARE RECOMMENDED FOR TEMPERING AND POST-HARDENING. IN THE "AS WELDED" CONDITIONS, GRADE 309 FILLER RODS CAN BE USED TO ACHIEVE A DUCTILE JOINT.ACCORDING TO AS 1554.6 STANDARDS, GRADE 309 ELECTRODES OR RODS ARE PREFERRED FOR WELDING 410 STEEL.

POWER KW	PULSE TIME ms	FREQUENCY HZ
2.2	3.2	10
2.2	3.6	12
2.2	4.0	14
2.4	3.2	12
2.4	3.6	14
2.4	4.0	10
2.6	3.2	14
2.6	3.6	10
2.6	4.0	12

ANALYSIS OF RESULT

4.HARDNESS TEST,VICKER'S HARDNESS TEST,IMPACT TEST,MICROHARDNESS TEST:-

4.1 EXPERIMENTAL DATA

4.2. HARDNESS TEST,VICKER'S HARDNESS TEST,IMPACT TEST,MICROHARDNESS TEST (ANALYSIS OF RESULT)

TRIAL NO.	DESIGNATION	POWER KW	PULSE TIME ms	FREQUENCY HZ	Vicke's Hardmess HV	TENSILE TEST N	IMPACT Joules	MICRO HARDNESS
1	$A_1B_1C_1$	2.2	3.2	10	127	7895.00	7	87
2	$A_1B_2C_2$	2.2	3.6	12	131	5129.00	8	223
3	$A_1B_3C_3$	2.2	4.0	14	129	7796.00	7	242
4	$A_2B_1C_2$	2.4	3.2	12	138	6423.00	8	155
5	$A_2B_2C_3$	2.4	3.6	14	140	6678.00	9	242
6	$A_2B_3C_1$	2.4	4.0	10	137	5491.00	8	99
7	$A_3B_1C_3$	2.6	3.2	14	146	5894.00	9	155
8	$A_3B_2C_1$	2.6	3.6	10	145	2226.00	6	242
9	$A_3B_3C_2$	2.6	4.0	12	147	7649.00	7	263

SURFACE ROUGHNESS AND S/N RATIOS VALUES FOR THE EXPERIMENTS

TRIAL NO.	DESIGNATION	POWER	PULSE	FREQUENCY	SNRA1 Vicke's Hardmess HV	SNRA1 TENSILE TEST N	**SNRA1** IMPACT Joules	SNRA1 MICRO HARDNESS
1	$A_1B_1C_1$	2.2	3.2	10	-42.0761	15.56303	38.79039	77.94704
2	$A_1B_2C_2$	2.2	3.6	12	-42.3454	18.0618	46.9661	74.20065
3	$A_1B_3C_3$	2.2	4.0	14	-42.2118	15.56303	47.67631	77.83744
4	$A_2B_1C_2$	2.4	3.2	12	-42.7976	18.0618	43.80663	76.15476
5	$A_2B_2C_3$	2.4	3.6	14	-42.9226	19.08485	47.67631	76.49293
6	$A_2B_3C_1$	2.4	4.0	10	-42.7344	18.0618	39.9127	74.79303
7	$A_3B_1C_3$	2.6	3.2	14	-43.2871	19.08485	43.80663	75.4082
8	$A_3B_2C_1$	2.6	3.6	10	-43.2274	15.56303	47.67631	66.9505
9	$A_3B_3C_2$	2.6	4.0	12	-43.3463	15.56303	48.39911	77.67209

IV. CONCLUSION

The important measurable parameter in welding process is welding power, pulse time, frequency. It depends upon processing and operating parameters, hardness test, tensile test, microstructure ,fatigue test of the material, surface conditions and laserpower source. The resulting proprieties are 1.hardness test maximum hardness-a1,b3 c2[power 2.2, pulse duration 4.0,frquency 12 2.Tensile test maximum tensile-a3, b1 c2[power 2.6, pulse duration 3.4,frquency 12 3.impact test maximum impact- a1, b3, c2[power 2.2, pulse duration 4.0,frquency 12 4.microhardness test maximum microhardness- a3, b1, c2[power 2.6, pulse duration 3.2, frquency 12.

REFERENCES

1. Effect of shielding gas on weldmetal properties in flux cored arc welding B.Kumaragurubaran,T.Senthilkumar, M.Vivekanandan andV. Balasubramanian SAE International2008-01-2285ISSN 0148- 7191 2285.

2 High Temperature tensile properties of Shielded metal arc welded ferritic stainless steel B.Kumaragurubaran,K. Shanmugam,V. Balasubramanian andT.Senthilkumar International Journal of Material Science, Vol. 3(2), 2008(ISSN 0973-4589) 229.

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

4. A. Arun Mani, T. Senthil Kumar, M. Chandrasekar Mechanical and metallurgical properties of dissimilar welded components (aisi 430 ferritic – aisi 304 austenitic stainless steels) by co2 laser beam welding (LBW) International Conference on Energy Efficient Technologies For Automobiles (EETA’ 15) Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115.

5. Han GuoMing , Zhao Jian, Li JianQang Dynamic simulation of the temperature field of stainless steel laser welding Materials and Design 28 (2007) 240–245.

6. M.M.A. Khan n, L.Romoli,G.Dini Evaluation of Nd: YAG Laser Welding Efficiencies for 304L Stainless Steel Procedia Materials Science 6 (2014) 1731 – 1739

7. Arivarasu M,Vishnu G, Hari P R,Vipin V P, Kaushik Katiki, Gokulkumar K, Manikandan M, Devendranath Ramkumar K, Arivazhagan N Micro-segregation studies on the Continuous Nd: YAG Laser Beam Welded AISI 316L Procedia Engineering 97 (2014) 892 – 901.

8. M.M.A. Khan n, L.Romoli,G.Dini Laser beam welding of dissimilar ferritic/martensitic stainless steels in a butt joint configuration Optics & Laser Technology 49 (2013) 125–136

9. Jose´ Roberto Berrettaa,_, Wagner de Rossib, Maurı´cio David Martins das Nevesc,Ivan Alves de Almeidab, Nilson Dias Vieira Junior Pulsed Nd:YAG laser welding of AISI 304 to AISI 420 stainless steels Optics and Lasers in Engineering 45 (2007) 960–966.

10. Shuhai Chen, Mingxin Zhang, Jihua Huang ⇑, Chengji Cui, Hua Zhang, Xingke Zhao Microstructures and mechanical property of laser butt welding
of titanium alloy to stainless steel Materials and Design 53 (2014) 504–511.

11. M.M.A. Khana,, L. Romolia, M. Fiaschib, F. Sarri b, G. Dinia Experimental investigation on laser beam welding of martensitic stainless steels in a constrained overlap joint configuration Journal of Materials Processing Technology 210 (2010) 1340–1353.

12. Jazeel Rahman Chukkana, M. Vasudevanb,, S. Muthukumarana, R. Ravi Kumarc,N. Chandrasekharb Simulation of laser butt welding of AISI 316L stainless steel sheetusing various heat sources and experimental validationJazeel Journal of Materials Processing Technology 219 (2015) 48–59.

13. N. Siva Shanmugam , G. Buvanashekaran b, K. Sankaranarayanasamy a Some studies on weld bead geometries for laser spot welding process using finite element analysis Materials and Design 34 (2012) 412–426.

14. A.Raveendra1, Dr.B.V.R.Ravi Kumar2 Experimental study on Pulsed and Non- Pulsed Current TIG Welding of Stainless Steel sheet(SS304) International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 6, June 2013

15. Vicente Afonso Ventrella Jose Roberto Berretta , Wagner de Rossi b Micro Welding of Ni-based Alloy Monel 400 Thin Foil by Pulsed Nd:YAG laser Physics Procedia 12 (2011) 347–354.

16. A. P. Tadamallea ,Y. P. Reddya ,E. Ramjeeb ,Vijayakumar Reddyb Evaluation of Nd: YAG Laser Welding Efficiencies for 304L Stainless Steel Procedia Materials Science 6 (2014) 1731 – 1739.