Sebha University Journal of Pure & Applied Sciences Vol.22 No. 3 2023
DOI: 10.51984/JOPAS.V22I3.2728

مجلة جامعة سبها للعلوم البحتة والتطبيقية
Sebha University Journal of Pure & Applied Sciences

Journal homepage: www.sebhau.edu.ly/journal/index.php/jopas

Comparison of the Effects Metal Inert Gas and Laser Beam Welding on Duplex Stainless Steel Properties

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Keywords:
Duplex stainless steels (2507Dss)
metal inert gas welding (MIG)
laser beam welding (LBW)
hardness
tensile test

ABSTRACT

In this study, optimal characteristics for duplex stainless steels (2507DSS) are attained when austenite and ferrite are present in roughly equal amounts in the microstructure. Therefore, the purpose of this study is to compare how different metal inert gas (MIG) and laser welding (LBW) parameters affect the weld characters of joints that are butt welded joints of duplex stainless steel plate with thickness of 8mm, the speed is constant and changing beam power, with argon shielding gas. Conventional MIG welding parameters are ranges; current, voltage are constant with changing speed and using gas mixture Ar and CO2 with a filler metal, and a single V groove. Investigation of welded joints has been carried out using different methods visual inspection, optical micro structure, hardness measurements, energy dispersive X-ray (EDX) microanalysis and tensile test. The results achieved in this investigation disclosed that welding parameters obtaining satisfactory properties of welded joint; no visible welding flaws, porosity and incompetent penetration. The fusion zone's grain size is finer in LB than MIG welding. EDX microscopic analysis reveals a slightly different structure in MIG and LB welds of BM microstructure, with filler altering Fe element and C-carbone content, causing brittleness due to ferrite content. The hardness results showed that no appreciable differences between MIG and LB in the welding bool area zone were equalled (265- 289Hv) respectively. Tensile strength and ductility increased with MIG and LBW in HAZ, at the same time laser welded specimens showing the highest ductility and strength.

مقارنة تأثيرات اللحام التقليدي واللحام بالليزرعلى خصائص الفولاذ المقاوم للصدأ المزدوج

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مركز المهني الليبي المتقدم لتقنيات اللحام ، تاجوراء، ليبيا

الكلمات المفتاحية:
الفولاذ المقاوم للصدأ المزدوج
اللحام الليزر
اللحام التقليدي
الصلابة
الشد.

الملخص

في هذه الدراسة، تتميز الخصائص للفولاذ المقاوم للصدأ المزدوج (DSS2507) المثالية، وتعتمد الخواص المتميزة لهذا النوع من للفولاذ على وجود الفيريت والأوستنيت بنسب متساوية في البنية المجهرية. لذلك، فإن الغرض من هذه الدراسة مقارنة كيفية تأثير العوامل المختلفة للحام التقليدي (بالغاز الخامل) (MIG) واللحام بالليزر (LBW) في الوصلات الملحومة بسمك 8مم، والسرعة ثابتة وتغيير قوة الشعاع باستخدام غاز الأرجون المحمي. اما البارمترات اللحام التقليدي بالتيار والجهد ثابت مع تغير السرعة واستخدام خليط الغاز Ar و CO2 مع حشو معدني بزاوية حرف V. وتم تقييم الوصلات الملحومة بطرق مختلفة شملت الفحص البصري، وكذلك فحص البنية المجهرية وقياس الصلادة والتحليل الدقيق للأشعة السينية للطاقة (EDX) واجراء اختبار الشد. اوضحت النتائج في هذا الدراسة أن متغيرات اللحام حصلت على خصائص مرضية للوصلة الملحومة؛ لا توجد عيوب لحام سطحية ومسامية فى اللحام LB باستخدام طاقة ليزر عالية 5 كيلو وات وسرعة لحام 0.75متر/دقيقة. مقارنة مع لحام MIG.ويكون حجم الحبيبات في منطقة الاندماج أدق في LB من لحام MIG. يكشف التحليل المجهري EDX عن بنية مختلفة قليلاً في اللحامات MIG وLB للبنية المجهرية BM، له تأثير فى عملية اللحام MIG لعنصر الحديد ومحتوى الكربون C، مما يسبب فى ارتفاع

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Article History : Received 20 June 2023 - Received in revised form 10 September 2023 - Accepted 02 October 2023

الفريت. أظهرت نتائج الصلابة عدم وجود فروق ملحوظة بين MIG و LB في منطقة معدن اللحام (265 - Hv289). زادت قوة الشد والليونة مع MIG و LBW في HAZ، وفي نفس الوقت أظهرت العينات الملحومة بالليزر أعلى ليونة وقوة.

Introduction

The paper In recent years, with the continuous expansion of the application fields of duplex stainless steel, the demand for welding technology has increased which has accelerated the development of welding technology there has been an ever increasing necessitate for investigates the constitute and approximately come to fractions of ferrite (α) and austenite (γ) phases, 50/50 by volume. This microstructure can be achieved by balancing the alloying elements, heat treatment and/or thermomechanical processes. The change in the balance of phases during the welding process can induce the material mechanical properties with the possible formation of intermetallic compounds [1]. The quality of welded joints was assessed mainly metallographically (including optical microscopy). The consequences of ferrite content measurement in weld metal and in base metal show, that application of suitable post heat made possible to reduce the ferrite content in weld metal by 12 %. These results suggest that such a procedure leads to positive results [2]. The weld zone area grows as laser power increases. By concentrating the laser beam, a higher ferrite/austenite ratio for the joint samples was produced. Furthermore, the biggest elongation from strength test has been observed for the joint samples prepared with laser power 2.0kW [3]. Heat input affects straight on the cooling rate of the weld and there by ferrite-austenite ratio. Laser welding of duplex grades has been associated with excessively high ferrite contents, due to the low heat input and rapid cooling rate. The heat inputs can be modified by welding speed, focus point of laser beam and by additional materials. [4]. Slight changes in duplex stainless steel composition exert a great effect on the mutual proportion of austenitic and ferritic phases [5].

Due to the low heat input and rapid cooling rate, laser welding of duplex grades has been associated with excessively high ferrite contents. Insufficient time for adequate austenite reformation can result in considerable chromium nitride precipitation, which in turn may have a detrimental effect on toughness [7]. Those also have twice of the yield strengths compared to that of austenitic grades while holding worthy ductility and toughness. The thermal expansion coefficient and the heat transfer properties of the DSS are intermediate between its constituent. The cost of duplex stainless is less sensitive to nickel price as it contains smaller amount of nickel compare to that of common austenitic stainless steel [8].

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Result and Discussion

The (MIG) and (LB) welding process revealed no visible welding flaws, such as porosity, undercuts, outside cracks, incompetent penetration, a lack of fusion, when using MIG welding parameters as following ranges; 85A, 45V and 26cm/min and 98%Ar, 2% CO_2 and used filler metal ER2209 was found to be the good result, simultaneously, when used 5kW of laser power, welding speed at 0.75/min and shielding gas argon was found to be a good result of the laser parameters. The structure of 2507 duplex stainless steel is composed of ferrite (α) phase (dark region) and austenite (γ) phase, the austenite is distributed on the ferrite matrix and is distributed in strips as white phase the interface between the austenite and ferrite is not smooth when observed at higher magnification, but is jagged, which shows that during the cooling process after cooling, austenite is formed by nucleation and growth at the ferrite interface as shown in Figure 1. The (MIG) and (LB) welding process revealed no visible welding flaws, such as porosity, undercuts, outside cracks, incompetent penetration, a lack of fusion, when using MIG welding parameters as following ranges; 85A, 45V and 26cm/min and 98%Ar, 2% CO_2 and used filler metal ER2209 was found to be the good result, simultaneously, when used 5kW of laser power, welding speed at 0.75/min and shielding gas argon was found to be a good result of the laser parameters. The structure of 2507 duplex stainless steel is composed of ferrite (α) phase (dark region) and austenite (γ) phase, the austenite is distributed on the ferrite matrix and is distributed in strips as white phase the interface between the austenite and ferrite is not smooth when observed at higher magnification, but is jagged, which shows that during the cooling process after cooling, austenite is formed by nucleation and growth at the ferrite interface as shown in Figure 1.

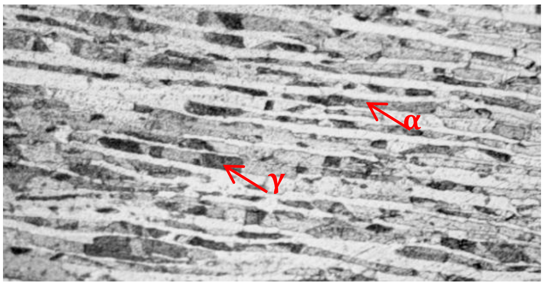

Fig 1: Microstructure of base metal of 2507 duplex stainless steel

Ferrite and austenite phases are seen in micrographs of welding fusion zones (FZ), but in the MIG welding zone, the filler is affected in these amounts by consisting of a ferrite phase rather than an austenite phase are given in Figures 2. On the other hand, the microstructure of the welds increscent austenite (γ) to the leaser welding is mainly composed of acicular ferrite with abundant dispersion of on microstructure of fusion zone, its grain size is finer observed in LB than MIG welds in HAZ. As a results as solidification of 2507duplex stainless steel, the low heat input associated with high cooling rate leads to form a microstructure with a higher volume fraction of austenite than ferrite. On the other hand, the low heat input associated with high cooling rate leads to form a microstructure with a higher volume fraction of austenite than ferrite. The small volume fraction of ferrite presented here should be from inhibiting ferrite to austenite transformation due to this last condition. Ferrite content in all welds of tested variants is higher in the root zone of penetration runs, as compared to surface and center. This is perhaps related to the fact that the root area was heated less than the surface during post-heat treatment runs and the root was shielded with the Ar gas [6].

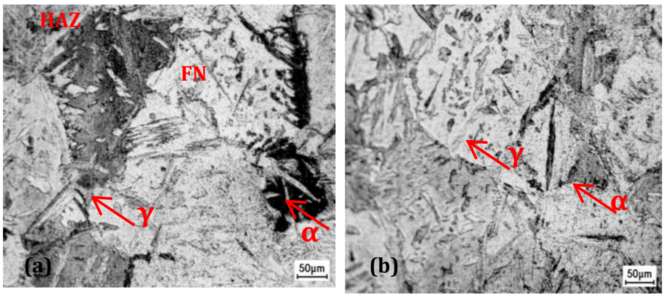

Fig 2: Heat affected zone microstructures of samples joined by (a) MIG (b) LB

Microchemical Analysis Balanced composite compound microanalysis 2507DSS. Figures. 3 and Table.1 shown the composition obtained from EDX microscopic analysis of the main alloying element for the base metal, MIG and LB welds of BM microstructure has slightly different structure in welding bool area zone (fusion zones (FZ) in MIG welded suggesting the filler changing the amount of Fe element in chemical composition and C are Carbone was apparent in composition which caused brittleness by presented some amount of ferrite rather than austenite phase. The primary solidification of the used duplex stainless steel occurs as delta ferrite and that the structure is completely ferritic at completion of solidification. [9].

Table 1: EDX microanalysis of used 2507DSS for the base metal, MIG and LB welds at (FZ)

Element	Cr	Mn	Ni	Mo	Fe
BM	24.6	1.20	6.0	3.05	66.80
MIG	24.25	1.37	5.96	3.10	65.32
LB	24.28	1.33	5.92	3.23	65.24

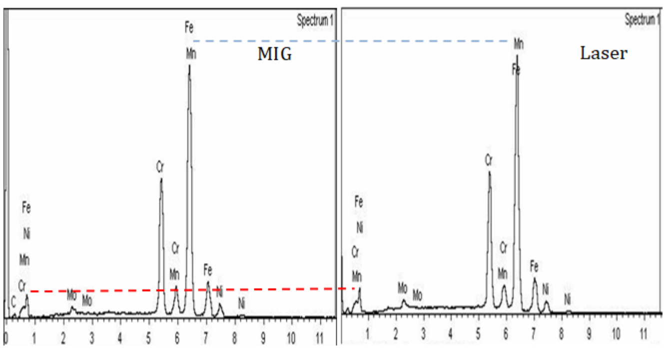

Fig 3: EDX microanalysis of (a) MIG and (b) LB welding

Comparisons of the promoting elements for the presence of ferrite phases in the weld metal, which are represented by the elements of chromium and manganese (Cr, Mn), which help in the formation of austenite in the MIG welding are given in Table1and Figures 4a. It is highest percentage of nickel and manganese (Ni, Mn) element compared to the laser welding process as in Figure 4b. It can be concluded that the balance between ferrite/austenite in the MIG welding metal is closer from the balance of the base metal and compared to the laser welding process.

Figure 4 shown as a micro hardness of (BM, HAZ and WM) of both MIG and laser welded joints both welding processes exhibit similar profiles. The hardness profiles reveals that there is no significant difference between hardness of BM and that of WM or HAZ (i.e. 265, 289) regardless of welding process, inspite of variation in ferrite/austenite ratio. Suggestions as hardness of 2507DSS, in general, are not remarkably affected by such variation.

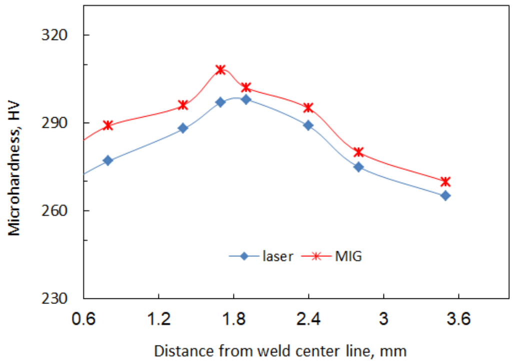

Fig 4: Hardness profiles of WM, HAZ and BM of MIG and laser welded joints

The Figure 5 and Table2 representation the tensile results of MIG and LB welding on different samples. It is observed the tensile strength and ductility at samples welded with MIG and laser beam welding were increased in the HAZ as a Good detected of homogeneous weld metal samples where laser welded specimens had the highest ductility and strength.

Table: 2 Tensile of 2507DSS for the base metal MIG and LB welded joints

Sample No	Tensile Strength (MPa)	Yield Strength (Mpa)	Elongation (%)
BM	790	530	25
MIG	717.38	600	26
Laser	824.71	400	28

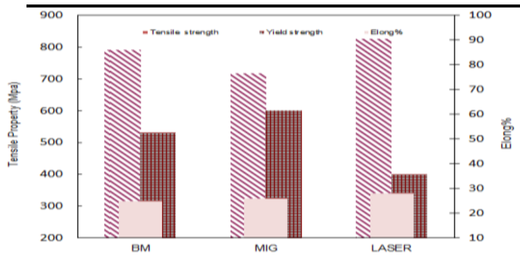

Fig 5: Tensile properties of BM, MIG and laser welded joints together with those of standard 2507DSS

Conclusion

The results obtained from present study are as follows:

1. Microstructure of fusion zone, its grain size is finer observed in LB than MIG welds in HAZ A microstructure with a greater volume proportion of austenite than ferrite is formed as a result of the 2507duplex stainless steel's solidification due to the low heat input and rapid cooling.
2. The microstructure observed that columnar regular structure appears in case of laser beam welding without additional material. The quantity of fine dispersed austenite island (light) inside of ferrite grains (darken) matrix increased.
3. The balance between ferrite/austenite in the MIG welding metal is closer from the balance of the base metal and compared to the laser welding process.
4. The hardness profiles reveals that there is no significant difference between hardness of MIG and LB in the welding bool area zone were equaled (265- 289Hv) respectively.
5. The autogenously laser welded specimens had the highest ductility and strength. . No big differences were observed in tensile strength

and ductility at samples welded with MIG and laser beam welding

References

[1]- Bruno Leonardy S, Gedeon S, “Influence of MIG/MAG Welding Process on Mechanical and Pitting Corrosion Behaviors on the Super-Duplex Stainless Steel SAF 2507 Welded Joints” Materials Sciences and Applications, 2018, 9, 228-245. ISSN Online: 2153-1188 ISSN Print: 2153-117X DOI: 10.4236.

[2]- M. Landowski, “Influence of Parameters of Laser Beam Welding on Structure of 2205 duplex stainless steel”. Poland Advances in Materials Science, Vol. 19, No. 1 (59), March 2019. DOI: 10.2478/adms-2019-0002.

[3]- Robert Sołtysiak, Tomasz Giętka, Agnieszka Sołtysiak, “The effect of laser welding power on the properties of the joint made of 1.4462 duplex stainless steel” Article first published online: January 29, 2018; Issue published: January 1, 2018 Received: April 11, 2017; Accepted: November 13, 2017.

[4]- Óbuda Fábián, Donát Bánk and Enikő,” Laser Welding Parameters Effect on the Weld Metals Properties at Duplex Stainless Steel, Advanced Technologies And Materials Vol. 43, No. 2 (2018) Doi: 10.24867/ATM-2018-2-002 Advanced Technologies& Material.

[5]- Muthupandi V., Bala Srinivasan P., Shankar V., Seshadri S.K. and Sundaresan S.: Effect of nickel and nitrogen addition on the microstructure and mechanical properties of power beam processed duplex stainless steel weld metals, Materials Letters, 2005, vol. 59, no. 18, pp. 2305-2309.

[6]- Lubos Kovac Prva Zvaracska; “Effect of laser welding conditions on austenite/ferrite ratio in duplex stainless steel 2507 welds” mode may 2013.

[7]- F. Kolenic & P. zvaracska, ‘’Effect of Laser welding conditions on austenite/ferrite ratio in duplex stainless steel 2507 welds’’, article in welding in the world, le soudage dans le monde· may 2013 DOI: 10.1007/BF03321292.

[8]- A. Pramanik, G. Littlefair, A.K. Basak, ‘’ Weldability of duplex stainless steel’’, center for advanced microscopy, australian national university, canberra act 0200 australia.

[9]- T. sharef; ‘’Laser Welding of Duplex Stainless Steels:

[10]- Effect of Laser Welding Parameters on Fusion Zone’’, lap lambert Academic Publishing (August 21, 2013).