Microstructure characteristic of TIG and laser welding of Super Duplex Stainless Steel

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Abstract:

The present study is concerned with active tungsten inert gas (ATIG) and laser beam welding techniques and their effects on size and microstructure of fusion zone, then on hardness of weld joints of the super duplex stainless steel (SDSS 2507) plates of 3mm thickness. The results achieved in this study disclosed that different types welding techniques play an important role in obtaining satisfactory properties of welded joint. Using nitrogen as shielding gas with argon content in case laser beam welding has resulted in improving microstructure of welded joint in comparison with that of TIG were silica flux was used as an activated material, the hardness profiles reveal that there is no significant difference between hardness of beam metal, BM and that of weld metal, WM but significant increase in hardness of HAZ regardless of welding process. The phase transformations produced during laser beam welding resulted improper ferrite/austenite balance due to decreasing austenite content but in a TIG welding there was an increasing in ferrite content.

Key words: Super duplex stainless steel, active tungsten inert gas (TIG) welding and laser beam welding, microstructure, hardness.

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Introduction:

Ferrite austenite super duplex stainless steels are widely used in industries of chemistry, food, paper, pharmacy, marine and many other fields [1,2] due to their high performances. super duplex stainless steels have higher strength than austenite stainless steels, higher toughness than ferrite stainless steels, good weld ability, and high resistance to stress corrosion cracking, hydrogen embattlement and inter granular corrosion. These noted properties of super duplex stainless steels result from a unique microstructure configuration. The microstructure of α/γ super duplex stainless steels formed by a proper hot-working is a mixture of fine ferrite and austenite phases, referred as micro- super duplex structure. However, an improper hot working causes coarse mixture of α and γ phases that reduces the strength and toughness of the steel. Such property combinations have led to an increased application of these alloys by the chemical, petrochemical, marine industries, in power generation and in offshore applications. The superior corrosion resistance, strength and/or combination of both properties due to their strict composition control and micro structural balance have provided enables these stainless grades to be used in many applications. [3,4]. In addition to chromium and molybdenum, nickel and nitrogen are the other two major alloying elements. Significant improvements both in material design and weld ability have been made leading DSS to range from the cost efficient lean grades to the high alloyed super duplex grades for more demanding applications [6,7]. In this study micro structural properties of active TIG welding and laser beam welding of 1.4410 super duplex stainless steel grades have been investigated and microstructure-property relation was evaluated. The relative amounts of α/γ phases were investigated in the HAZ in both welding processes for their of SDSS. The possibilities and limitations in using these processes for these grades in industrial fields with proper ferrite-austenite ratio have also been investigated.

Experimental Procedure:

Sample preparation:

The material used in the current investigation was 3mm thick plate of super duplex stainless steel 2507 (EN 1.4410, UNS S32750). The chemical composition of as received were (wt%) 24.35Cr, 5.6Ni, 0.75Mn, 0.029C, 0.629Si, 0.013P, 3.35Mo, 0.065Cu, 64.55Fe and mechanical properties 795(MPa)Tensile strength, 550 (MPa) Yield strength, and 25(%) Elongation. The microstructure of base metal (SDSS 2507) is shown in Figure 2-1. The SDSS BM showed an elongated grain structure with nearly equal amounts of austenite and ferrite, which is typical in the rolled products.

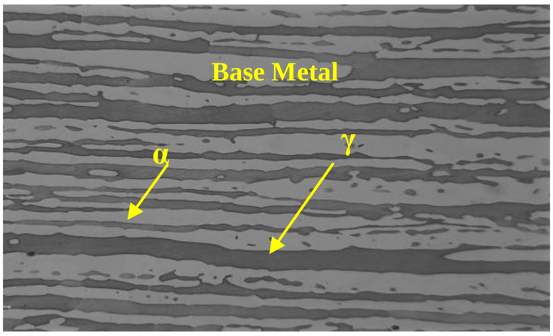

Figure 2-1 Microstructure of SDSS (as received)

Welding Processes:

TIG activated by silica powder flux; the welding parameters were as in the following ranges: 110- 120A, 22-24 V and 12-15cm/min.

Laser-butt welding was carried out on (SDSS 2507). The examined sample of 100mm length contains a welded joint at its center. A TRUMPF Power Weld laser welding system was used for the welding experiments. Welding parameters were: laser power (P) 4kW, welding speed (V) 200cm/min, shielding gases (95% Ar + 5 % N2) as backing gas and pure argon as shielded gas 20 l/min flow rate.

After welding, the samples were inspected, visually and by liquid penetrated then, the specimens were cut x-sectioned transverse to the welding direction. The specimens were prepared for metallographic examinations using standard techniques. The configuration of fusion zone was examined using stereoscope while microstructure of fusion zone was examined using light microscopy. Micro hardness was measured across the welded joints; using a Vickers hardness tester under a 200grm load and 10 seconds on prepared microstructure samples in an attempt to relate hardness to phase constituents after welding. These tests were performed at room temperature according to relevant standards.

Results and Discussion:

Metallographic Analysis:

Optical micrograph of a cross section of ATIG welded joint shows a relatively wide heat affected zone, HAZ was observed. The coarse grained region adjacent to the fusion line could be resulted from nearly complete austenite dissolution on heating and subsequent ferrite grain growth. High magnifications of HAZ (adjacent to fusion line) microstructure are shown in Figure 3-1a, b. The micrographs of the laser welded sample are shown in Figure 3-2a, b. were relatively smaller HAZ was observed and fine grain structure was noticeable. This is due to solidification of the weld metal at high cooling rate compared to that of conventional ATIG welding. Figure 3-1a shows the first zone (high temperature HAZ) near the fusion line and transforms almost completely to ferrite during welding operations. Low temperature (HAZ) is located adjacent to the high temperature HAZ. This area has passed during welding through within the precipitation, range of intermetallics (950^{o}C - 550^{o}C). The ferrite to austenite balance is practically unchanged but precipitation of intermetallics may reduce corrosion resistance [8]. Figure 3-1b shows the weld metal microstructure magnification taken at the centerline of cap. The examination of the WM shows a typical dual phase microstructure of austenite and ferrite, there was no indication of intermetallic phase precipitation.

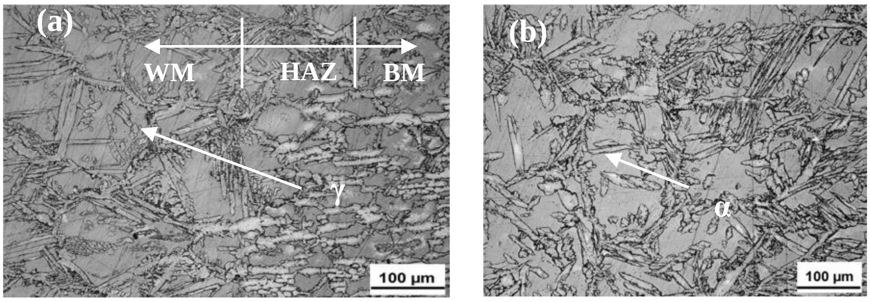

Figure 3-1a, b Microstructure of SDSS welding of ATIG welding (a) HAZ between the base metal and the weld metal, (b) weld metal

Figure 3-2a. shows the HAZ microstructures magnification taken near the fusion line at the cap. These microstructures show no indication of intermetallic precipitation. As shown in the images it is hard to determine the extent of the HAZ of a SDSS. However; the true HAZ of a SDSS weld ment can be divided in to two main zones. Figure 3-1b shows the second zone (high temperature HAZ) is near the fusion line and transforms almost completely to ferrite during welding operations.

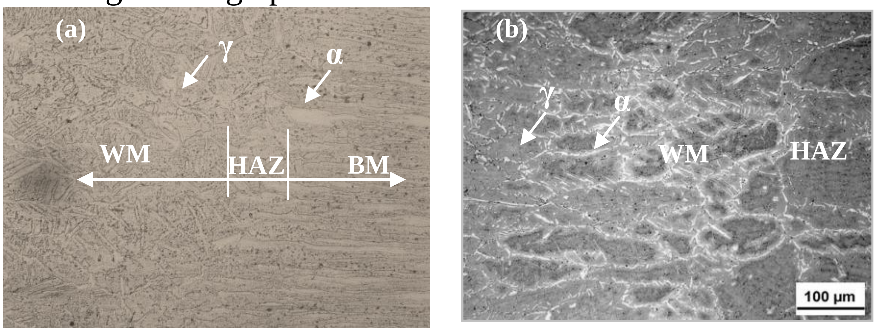

Figure 3-2a, b Microstructure of SDSS welding of laser welding (a) HAZ between the base metal and the weld metal, (b) weld metal

The ferrite solidification, followed by the solid state ferrite-austenite transformation cooling during welding can be illustrated in a pseudo binary diagram, see Figure 3-3[9]. Laser beam processes, which do not use filler metal, are not recommended since they provide welds with a high ferrite proportion, owing to low heat in the heat affected zone and in corresponding loss of toughness. Maximum average ferrite content should be within 40 to 50%. Improvement may be achieved only by bulk annealing after welding at temperature 1150 to 1050 °C however, this treatment represents an undesired operation as it increases the welding costs [10].

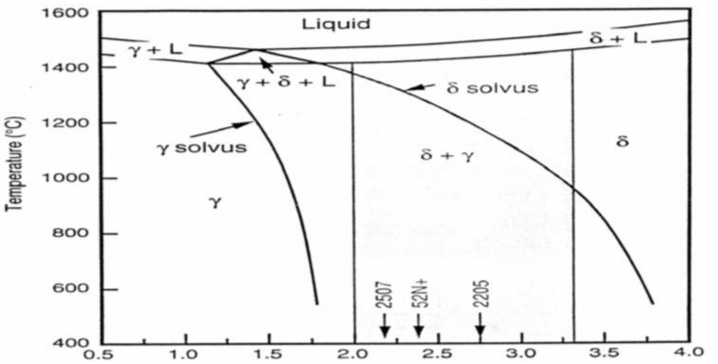

Figure 3-3 Pseudo binary diagram plotted using WRC-1992 equivalent relationships [11].

Laser welding with its rapid cooling rate resulted in improper ferrite/austenite balance due to decreasing austenite content and subsequently, increasing ferrite content in comparison with base metal [12].

Vickers hardness properties:

Effect of process welding on Hardness:

Maximum weld (WM) metal hardness was found to be 305 and 310Hv, the former from SDSS TIG and the latter was obtained from SDSS laser welds. in the regain of heat effect zone (HAZ) were found the maximum hardness 320Hv in the case of TIG, while 340Hv in the laser weld. Figure 3-4 shows the profile of hardens. The main feature in the laser welded material was the increased hardness compared to the TIG welds in accordance with the literature and this is ascribed to the presence of high amount of ferrite [13].

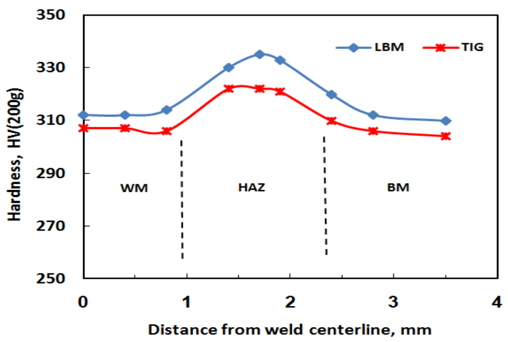

Figure 3-4 Hardness profile through WM, HAZ and BM of LBE and TIG

Both welding processes exhibit similar profiles, the hardness profiles reveal that there is no significant difference between hardness of BM and that of WM, but significant slight increase in weld metal compared with the base metal but a large increase in HAZ regardless of welding process in case of using an activated TIG welding with SiO_2 may improved the hardness and in the case of laser welding using nitrogen additions (5%) to the shielding gas also have a beneficial effect on weld metal so can improve ferrite/austenite reformation.

Conclusion:

1. Generally; the microstructure of the HAZ is critical for properties of the weld joints. HAZ of SDSS can be divided in to two regions: an overheated zone or high temperature and a low temperature HAZ both of them consist of a ferrite matrix containing a network of austenite grains.
2. Concerning the micrograph of the laser welded sample are relatively small HAZ was observed the fine grain growth was noticeable feature in a highly directional nature of the microstructure of weld metal.
3. A high temperature heat affected zone (HAZ) of TIG welding was observed near the fusion line and transforms almost completely to ferrite during welding operations.

4. Laser welding with its rapid cooling rate resulted in improper ferrite/austenite balance due to decreasing austenite content and subsequently, increasing ferrite content in comparison with base metal.
5. Using nitrogen additions to the shielding gas have a beneficial effect on weld metal which improve ferrite/austenite reformation in the case of laser beam welding.
6. Hardness Profile of both welds, laser and TIG have revealed mainly an increase in heat effected zone hardness.

دراسة سلوك للتركيب المجهري لصلب المزدوج الفائق الخواص بعملية اللحام الليزر والقوس التنجستن

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المستخلص:

تتركز الدراسة الحالية على سلوك الصلب المزدوج الفائق الخواص (EN 1.4410, UNS S32750) 24.35Cr، 5.6Ni، 3.35Mo و بسمك 3مم. بعملية اللحام الليزر وعملية اللحام بقوس التنجستن المحمي بغاز الأرجوان الخامل على التركيبة المجهرية وقياسات الصلادة لمنطقة اللحام والمنطقة المتأثرة بالحرارة، وبفحص الوصلات الملحومة بصريا، تلا ذلك فحص البنية المهجرية وقياس الصلادة.كل النتائج المتحصل من هده الدراسة أثبتت أن كلا من التقنيتين لعبت دور مهم في الحصول على خواص ميكانيكية جيدة للقطع الملحومة وباستخدام النيتروجين كغاز محمي وبمكون الأرجون في تقنية الليزر أدى إلى تحسين البنية الداخلية للقطعة الملحومة مقارنة مع نضيرتها

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الملحومة بتقنية قوس التنجستن النشط فانه نتج عن ذلك تغير في النسب القياسية لطوري الفيريت والأوستينيت في منطقة اللحام والمنطقة المتأثرة بالحرارة. وعلى هدا الأساس في عملية اللحام بالليزر المحمي بغازي النيتروجين والأرجون معدل التبريد يكون سريع جدا مما أدى إلى عدم خلل في النسب القياسية لطور يالفيريت والأوستينيت. وبالتالي أدى ذلك إلى الحصول على خواص ميكانيكية أفضل للوصلات الملحومة مقارنة بتلك التي تم الحصول عليها باستخدام غاز الأرجون في حالة اللحام القوس الكهربي.وهدا يرجع الى كبر حجم كل من منطقة معدن اللحام والمنطقة المتأثرة بالحرارة في حالة الوصلات الملحومة بالليزربالمقارنة بتلك الخاصة بالوصلات الملحومة بقوس التنجستن المحمي. وهذا يعني أن صغر حجم منطقة اللحام أكثر أهمية من درجة تغير البنية المجهرية (نسبة فيريت/أوستينيت) وذلك للحفاظ على الخواص الميكانيكية للوصلات الملحومة، بمعنى آخر فان تقليل حجم منطقة اللحام يكون أكثر تأثيرا في الحفاظ على الخواص الميكانيكية للوصلات الملحومة وذلك بالمقارنة بتغير نسبة فيريت/أوستينيت في منطقة اللحام.وأستنتج أن قياسات الصلادة أعلى في تقنية لحام الليزر من لحام بقوس التنجستن المحمي بغاز خامل.

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