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Welding Techniques for dissimilar metal joining with Duplex Stainless Steel: A Literature Review

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Abstract: Duplex stainless steel is extensively used in industries due to its structural combination of ferrite (BCC) and austenite (FCC) grains. This unique combination makes DSS more synergistic interaction with different phases which makes difficult in welding. During the dissimilar metal weld process difficulties occur in heat affected zone, functional properties leads to failure of the components and therefore loss of cost, time and efforts. This paper investigates literature review on different weld jointed techniques, such as Explosive welding, Friction stir, Laser beam, Resistance, GMAW, GTAW, and Submerged arc welding. This paper analyses DSS welds with all the welding techniques to other base materials with the high heat input and different thermal cycles. The review the best way to weld DSS is by using GTA Welding process.

Keywords* — *Dissimilar metal welding, Duplex stainless steel(DSS) , GMAW, GTAW, Heat Effected Zone, and Submerged arc welding.

NOMENCLATURE

GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
SMAW	Submerged arc welding
EBW	Electron-beam welding
LBW	Laser-beam welding
FRW	Friction welding
EW	Explosive welding
RW	Resistance welding
DW	Diffusion welding
ASW	Arc Stud Welding
HAZ	Heat Effected Zone
DMW	Dissimilar metal welding

I. INTRODUCTION

Emerging technologies in manufacturing industries such as functionality, light weight and increase performance raises the use of hybrid structures, multi-materials and thus the requirement for welding of dissimilar materials. The different materials with different properties are combindly utilized to design the product performance required. This dissimilar metal welding (DMW) is reported in different industries like: Aeronautics, Automotive, Clothing, Implants, Marine, power generation and tooling applications [9]. An organized approach is necessary in selection of new materials in mixing with other materials, modern manufacturing technologies [7]. The dissimilar material joints should have unique strength and incompitable on ductility, elastic modulus, fatigue/fracture mechanics, thermal expansion etc.

II. DUPLEX STAINLESS STEEL WELDING PROCESSES

DSS is extensively used in mechanical and corrosion property industries. The phase structure of DSS is designed to have a ferrite (BCC) and austenitic (FCC) approximately 60/40 to 40/60 percentage. DSS consists of dual phases with Cr% + Mo% and austenite forming elements like Ni and N show in figure1. Dual phase of DSS shows good mechanical properties with high yield strength and ultimate strength. In many industrial applications DSS is replacing austenitic stainless steels (ASS), DSS exhibit some special qualities makes it superior corrosion resistance and higher mechanical strength than ASS, but economically ASS is less expansive than DSS because of its production difficulties [1].

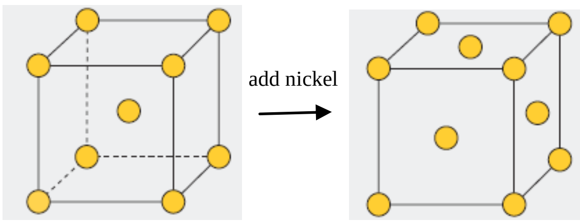

Figure1. Crystallographic structure changes from BCC to FCC.

The weld deposits vary from one welding process to other due to oxygen in the typical weld process. Higher toughness is achieved with GTAW, PAW, GMAW than

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with SAW, SMAW and FCAW to the toughness testing at -400C in ASTM A923. FCAW failed in these toughness requirements and due to this reason it is not widely used [1]. In this paper duplex stainless steel UNS S32205 dissimilar welding with other metals only reviewed.

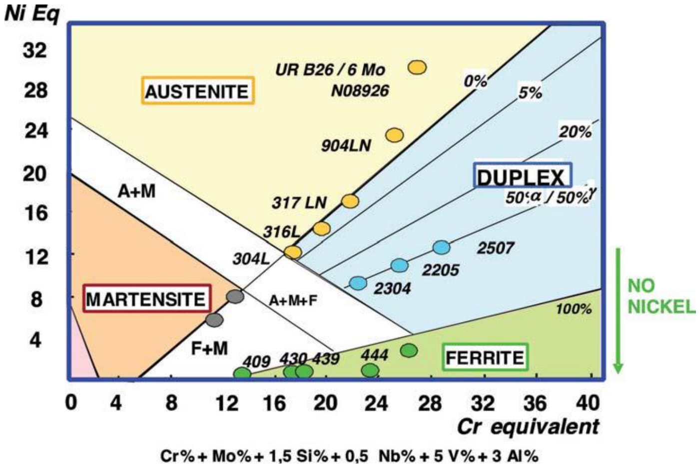

Figure.2 Schaeffler diagram which illustrates the stainless steel families versus chemical analysis [1].

III. DISSIMILAR WELDING OF DUPLEX STAINLESS STEEL WELDMENT

A. Moteshakker et al [2] studied dissimilar welding of AISI 316L and SAF 2205 using GTA Welding accomplished by AWS ER 309L, AWS ER 316L, and AWS ER 347 welding wires. Results showed that higher value of carbides and carbon are identified in AWS ER 347 weld, and doesn't identify in reaming two welding wires. AWS ER 309L welding area in round tensile specimen result better elongation than AWS ER 347 and AWS ER 316L. Results suggested that AWS ER 309L given better weld for welding DSS to ASS by GTA Welding.

Bas¸yig˘it, A et al [3] investigated joining of S32205 plate with M8 x 40mm AISI 304 ASS studs by using Arc Stud welding. Weldments were inspected by visual and radiographic inspection, bending, microstructure, and microhardness tests were applied to two stainless steel materials. Results showed that ASS were safely joined to DSS grades by ASW technique in aggressive corrosive media, especially in chloride containing solutions present, choice of the duplex series is inevitable.

Çelikkol Emrullah et al [4] studied dissimilar joining of Hastelloy C-276 to SAF 2205 by GTAW. Notch impact test, fractographical examinations were performed on the weld joints. Four passes were used in the range of 0.48-1.10 kJ/mm, and with different cooling rates different morphologies of solidified structure were identified. Moreover columnar and dendrites structure were identified in root region, equiaxed dendrites were identified in face. The impact notch test shows impact toughness of 116 J in HAZ of nickel based alloy, 82 J HAZ of SAF 2205.

Jing Wang et al [6] studied dissimilar joining of API X70 to UNS S31803 by using metal inert gas welding and tungsten inert gas welding. and 92 J in weld metal. The results imply that in SAF 2205 HAZ deeper dimples and coarse grains were identified. whereas equiaxed dendrites were identified in Hastelloy C-276 results crack propagation taken place throughout the fusion line.

G. Madhusudan Reddy et al [8] studied dissimilar welds of ASS (AISI 304), FSS (AISI 430), and DSS (AISI 2205) using EBW and FSW. SEM, electron probe, Optical microscopy, impact toughness, residual stress, hardness, and tensile strength testing were conducted to study microstructural changes and mechanical behavior of welds. Dissimilar metal ferritic–duplex, austenitic–ferritic, and austenitic–DSS welds were coarse grains, predominantly equiaxed on austenitic, DSS side, and they were columnar on the FSS side. Significant diffusion of elements were identified in EBW and insignificant in FSW. Results showed that high compressive stresses were identified on DSS side interface compared to ASS interface. The notch and impact tensile strength of EBW were higher than the friction weldments and all welds showed toughness less than base metals.

P.Bala Srinivasan et al [10] reported that type II boundary (higher Mo and Cr levels were obsereved) phases were identifed in the HAZ of the SMAW welded joints of the IS 2062 steels and UNS 31803. E309 and E2209 electrodes were used and E2209 electrode showed better results in both hardness and impact test. E309 electrode weld showed superior corrosion resistance than E2209 weds and in chloride solution it showed highest susceptibility in pitting. This study suggested that effect of E2209 electrode is more suitable in joing dissimilar weld joints for DSS and CS compared with E309 electrode.

R. Sridhar et al [11] sucessfully joined Inconel 625 to SAF 2205 using manual GTAW process. ERNiCrMo-3 and ER2209 filler metals were used for welding and it was observed in tensile te st, fracture failure taken in the weld zones of both the fillers. Results show that Nb-rich phases were obsedved in inter-dendritic areas and there was a temperature differences between the filler and base metals which leads to precipitation formation in weld zone. Temparature difference at HAZ of Inconel 625 made Cr, Mo, Nb elements enriched and appeared as precipitates in the form of segregation. Results reavles that ER2209 weldments have more average ultimate tensile strength than ERNiCrMo-3 weldment. However ERNiCrMo-3 weldments are higher Impact toughness than ER2209 one, and the mode of fracture of the both weldments is ductile–brittle in nature.

Ridha Mohammed Ghusoon et al [12] analysed the influenicing weld parameters, like beam diameter, peak power,pulse repetioion rate,and pulse width on weld beads

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geomentry on DSS 2205 and AiSi 304 SS. Welds has been carried out using pulsed-fiber laser welding. The microstrutral progression effects of weld beads were observed using SEM analysis and results shows that joints were fully austeniti solidification mode and reday for solidification cracking. Results showed that during micro-hardness test improvement was identifeied in austenitic and DSS base metals. Measured tensile strength in joint were higher than base metals in all the joints.

Table1.Comparison of welding techniques [19].

welding process /specifications	GTAW	GMAW	LBW	EBW	PAW	EW
Electrode	No consumable	consumable	No consumable	No consumable	No consumable	NIl
weld pool used for protection	Fusions	Fusions	Fusions	Fusions	Fusions	Shock force on the explosion
Techniques	Some	Some	High tech	High tech	High tech	Little
Required skills and experience	medium	medium	required	required	required	required
Safety	safe	safe	safe	safe	safe	Unsafe
Seam strength	excellent	excellent	very strong	very strong	very strong	Very week
Cost	Low	Low	high	high	high	Low
Application	wide	wide	close	close	close	close

Serdar Mercan et al [13-14] estimated the fatique strength of AISI 1020 steel and AISI 2205 DSS. The dissimilar joining was done by using FRW with different opertinon parameters. For better quality of friction weld accumulation pressure, accumulation time, friction time and rpm were ues used as welding parameters. Rotary bending fatigue test, tensile test and impact test were examined; results showed that with increased friction time the limit ranges are decrecing.

S.L. Hernandez-Trujillo et al [15] discussed about effects of Electromagnectic field in dissimilar AISI 2205 DSS and AISI 316L ASS joint using GMAW process. Results showed that HTHAZ of DSS was the hardest zone, moreover the size was reduced (from 6.77 to 4.04 mm2) for the welds with and without electromagnetic field.

S. Jana [16] successfully joined Cromweld 3Cr12 to Avesta 2205 by using shielded metal arc (SMAW), the arc energies used in a range of 0.4 to 1.7 kJ/mm. Microstructure, corrosion test and Mechanical properties test (hardness, impact, tensile and toughness) were conducted on HAZ (heat affected zone). Microstructure shows coursing grains in Avesta 2205 and very important ferrite grains in 3Cr12 weldments. Increase in arc heat input increases area of HAZ, moreover this effects hardness in HAZ area and 3Cr12 weld metal. Decreased ductility and increased tensile strength was identified in Cromweld 3Cr12 weld. Ductile fracture was identified in Avesta 2205 during the impact toughness and weld fusion zones Ferrite grain coarse were identified. Corrosion rate is relatively low in Avesta 2205 between 0.5 and 1.0 ram/ year with low susceptibility to intergran- ular corrosion.

Yan Li et al [17] used to join AISI 2205 DSS and AZ1B magnesium alloy by explosive cladding. The bimetallic composite identified with melted pockets and the surface morphology was a less regular wavy. Microhardness test was conducted and in observations hardness is more in interfere zones than original value, this results violent plastic deformation and grain refinement at the collision interface. Results showed that tensile shear strength of bonding interface zone was 105.63MPa and moreover it was higher than the AZ1B base. Microstructure was observed with EBSD and strong refinement was identified near the interaction zones.

Ying Zou et al [19] used advanced active-TIG welding method to weld ASTM 240 DSS and ASTM A353 FSS. Double shielded gas flow system was used and different O_2 content levels are altered as shielded gas.

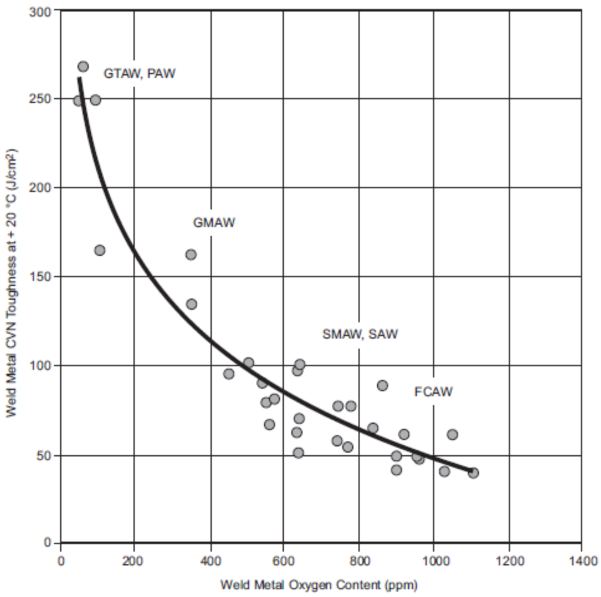

Figure.3 Oxygen impact on toughness of the weldmetal [1].

IV.GENERAL USES OF DU PLEX STAINLESS STEEL

DSS is used in many applications in the construction of industrial equipment such as [18]

1- Heat exchangers
2- Piping systems in the chemicals & Pressure vessels
3- Offshore industries
4- Process instrumentation such as pumps and valves
5- Aircraft construction

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6- Medical implants
7- Sports goods such as golf clubs and tennis rackets
8- Spectacle frames & parts for structural units
9- Ornaments.
10- Paint and pulp industries.

V. CONCLUSION

In the existing review, investigations are made on recent reserch articles on disimilar welding of DSS 2205 and the following conclusions are drawn.

(1) High heat input welding processes such as EBW, EW, GMAW, GTAW, LBW and PAW are suitable for disimillar welding of DSS within the allowable joining parameters.

(2) Higher impact strength values are identified in DMW fabricated with GTAW process and strength improvement compared to SMAW is 10%, and in GMAW 20%.

(3) Dissimilar welding of DSS with other stainless steel results austenitic transforms in the ferrite form.

VI. FURTURE PERSPECTIVES OF RESEARCH

Weldments can replace with other austenitic stainless steels for dissimilar metals welding using GTAW which is a key aspect in various industries, with various advantages like safe welding, economical, better choice in dissimilar weld environments.

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