



Investigations of Welding Parameters Impacts on Mechanical & Corrosion Behavior of Steel Welds

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A B S T R A C T

Now days while the welded product of duplex stainless steels (DSS) is to be used for Cl- containing environment & sour service applications for example petrochemical, off-shore platforms, oil, gas, paper & pulp industries etc. The resistance to chloride stress corrosion cracking (CSCC) during service application has always been a threat for the manufacturer & the end user of the product. Resistance regards SCC under chloride existing environment based on current ferrite content under carefully welded duplex (ferrite-austenitic) stainless steel framework. DSS ferrite specifications required by various organizations are 30 to 60%, 30 to 70 Ferrite Number, 35 to 75%, etc. In this study, DSS 2205 material all weld metal consumable test coupons within ferrite content range 14% to 30% or 20 FN to 40 FN have been prepared & investigated. Investigations have shown that yield strength & tensile strength needs regard base metal & filler metal classifications were higher at every ferrite levels observations & no SCC cracking analyzed after 1000 hours exposure at ferrite level below 15%.

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Introduction

In the new occasions various new materials have been created to address the issues of the diverse modern areas. Among the assortments of Stainless steels, Duplex Stainless steels have been assuming a significant part in the space of compound and petrochemical handling ventures, atomic force enterprises, and so forth, inferable from their phenomenal properties, particularly consumption opposition. Duplex hardened steels have a place with a group of grades consolidating great consumption obstruction along high strength and simplicity of manufacture. Their Mechanical properties are between those of the austenitic and ferrite hardened steels yet will in general be nearer to those of the ferrite and carbon steel. The protection from pitting and whole in chloride climate is an element of chromium, molybdenum, and nitrogen content. The exceptional properties of DSS are principally because of the stage balance i.e., the ferrite-austenite proportion (Saravanan *et al.*, 2019)

Along the improvement of duplex hardened steels, which have the blend of the best of the properties of austenitic and ferrite treated steels, viz., better return strength coupled along phenomenal erosion/stress consumption breaking opposition contrasted with austenitic treated steels and better formability and lower change temperature than ferrite treated steels, these steels have been distinguished as the promising materials for the cycle businesses and are in effect broadly utilized in different ventures, viz., petrochemical, seaward stages, oil and gas, paper and mash, and so on The greater part of the modern parts made of these duplex tempered steels are created essentially by welding utilizing practically all the ordinary welding processes like Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), Submerged Arc Welding (SAW) Etc., The remarkable properties of DSS are predominantly because of the stage balance i.e.,

the ferrite-austenite proportion (Shabir *et al.*, 2014)

Duplex steels solidify as 100 % ferrite. Because of having higher ferrite to austenite ratio at high temperature (above the ferrite solves), the alloys remain 100% ferrite. Below the ferrite solves, austenite can only nucleate & grow by solid state transformation mechanism. So practically any Hot metal working operations & annealing process of these are usually conducted below ferrite solves, where austenite & ferrite remain in equilibrium by controlling the processing temperature at cooling rate from that temperature, the ferrite & austenite proportion & distribution of phases can be controlled in the wrought Duplex Stainless steel (Mendoza *et al.*, 2010) (Shi *et al.*, 2018).

In (Johnson and Sanders, 2012) reported on yield strength issue & found that yield strength was maintained down to as low as 30 FN (about 21% ferrite), & no ferrite lower limit was identified. & no further investigation is made into SCC resistance. Among Industrial customers, there has been disagreement regarding this issue of required least ferrite content. The issue doesn't include GTAW or GMAW on the grounds that the low oxygen content (ordinarily under 150 ppm) of the weld metal gives high strength at moderately high ferrite content, so filler metal producers can focus on around half ferrite in their filler metal without worry about sturdiness (Srivastava *et al.*, 2018). However, for transition shielded filler metals (SMAW, FCAW, SAW), the higher oxygen content (commonly 600 ppm or more) diminishes sturdiness, so the filler metal producer focuses on weld metal stores at the low finish of indicated ferrite ranges to meet strength necessities at 40° C. There is, obviously, a level of variety in weld metal ferrite content and in reproducibility of estimation (Tasalloti, Kah and Martikainen, 2017).

So it happens off and on again that a fabricator estimates somewhat less than the predetermined ferrite necessity (Verma *et al.*, 2017) or the fabricator measures over as far as possible yet his client estimates ferrite content for a similar parcel of filler metal and gets a worth beneath as far as possible. Therefore there is a fight about whether or not the filler metal is adequate and a postponement in the undertaking results while the gatherings to the question attempt to determine it. This burns through a ton of time and cash (Xavier, Junior and De Castro, 2015). Metallurgical perspective, DSS requires hardening as 100% ferrite and development of austenite just in the strong state. This mode is answerable for both high return strength and protection from chloride SCC. The WRC1992 graph shows 100% ferrite cementing at as low as 20 Ferrite Number (around 14% ferrite). Another significant perception is that the WRC-1992 graph shows the connection between FN and Ni isn't direct (Khalifeh, A.R., Dehghan, A. & Hajjari, 2013).

Under research, the filler metal producer gives electrodes aimed at lower end regards normal DSS ferrite specifications, & below, & we have examined the SCC resistance & the yield strength of the welded joint. Testing tensile properties by a round all weld metal tensile specimen as found in AWS A5.4 specifications for stainless steel covered electrodes (1/2 inch or 12.7 mm diameter) or as found in ISO 157921 (10 mm diameter, joint type 1.3, as referenced in ISO 3581) were also carried out (Kotecki, D.J. & Lippoid, 2005).

By doing all weld metal tests, we tried to avoid any complications from the base metal & HAZ. Also, yield strength is meaningless in a transverse tensile test. To assess the pressure erosion breaking inclination in Chloride containing climate (Mendoza *et al.*, 2010), ASTM G123 Standard Test strategy for Evaluating Stress-Corrosion Cracking of Stainless Alloys along Different Nickel Content in Boiling Acidified Sodium Chloride Solution has been utilized in the current review (Muthupandi, V.,

Balasrinivasan, P., Seshadri, S.K. & Sundaresan, 2003).

This test strategy is expected to mimic breaking in water, particularly cooling waters that contain chloride (B. Messer, V. Oprea, 2007). It isn't planned to mimic breaking that happens at high temperatures (more prominent than 200°C or 390°F) along chloride or hydroxide. However, the use of Duplex Stainless Steels is limited to the temperature range -20 to +300°C due to precipitations of the detrimental phases above 300 °C To vary (reduce) the ferrite content, the electrode manufacturer has been requested to prepare sample quantity of SMAW electrodes along increasing the Ni content starting from the standard Ni level in the 2209 electrode design. Moreover, adding or subtracting nitrogen in the electrodes composition or Nitrogen gas purging was not advisable because that would change the PREN & confound the results. Therefore Cr, Mo & N were held constant. Only nickel was varied in the electrode composition because changing nickel does not change the PREN (P. B. Srinivasan, V. Muthupandi, W. Dietzel, 2006). This research organized as in section 2 literature review described, in section 3 research methodology described, in section 4 Results & discussion analysed, & final conclusion & future work described in section 5.

Literature Review

Literature review in respect of The Study of Investigations of Welding Parameters Impacts on Mechanical & Corrosion Behaviour of Steel Welds.

In (Won *et al.*, 2018) author has adequately joined Corrosion practices of the contact welded disparate aluminium composites were examined to see how galvanic impact assumes a part in changing erosion properties of the different weld. From the way that the weld had the comparable OCP worth to that of AA2017, it very well may be induced that the erosion qualities of the weld is heavily influenced by the AA2017 part in the weld and accordingly, just the AA2017 part in the weld had encountered

extreme consumption, leaving AA6063 under catholic insurance.

In (S., SinhmarDwivedi., 2017) author has examination on the miniature design, mechanical properties, and consumption conduct of grating mix welded joint of AA2014 in regular cooled (NC) and water cooled (WC) conditions have been accounted for. Optical microscopy and electrochemical Potentiodynamic polarization erosion test (Tafel bend) were done to describe the contact mix weld joints in both the cooling conditions.

In (P.Mastanaiaha and Reddy, 2018) author has inspected the grinding mix welds o thick precipitation-hard empower aluminium composites experience the ill effects of decreased joint strength because of disintegration/coarsening of the fortifying encourages. The article depict crossover pin profiled instrument that empowers sound welds at speeds 7-times quicker than an ordinary device (a tapered strung apparatus), without pin breakage.

In (Bocchi *et al.*, 2018) author inspected present paper is to dissect if and how the interaction boundaries (in particular rotational speed S and feed rate f) influence both the mechanical properties and the consumption conduct of grinding mix welded (FS Wed) butt joints made of AA7075 and AA2024 compounds and their blend. Ductile tests were performed symmetry to the welding heading on examples having the welding piece put in Gage length.

In (S. Sinhmar and D. K. Dwivedi, 2019) author has inspected Friction mix welding of AA2014 aluminium composite was performed at seven diverse speed mixes. Weld warm cycles were estimated at all the speed boundaries and comparing top temperatures were seen at higher instrument revolution speed and lower welding speed.

In (Na Li, Wenya Li, Yaxin Xu, Xiawei Yang, 2018) author has inspected investigation of aluminium compound 2024-T3 contact mix welded (FS Wed) joints under various revolution speeds at fixed travel speed of 200 mm/min is summed up. The impact of revolution speed on the hardness, pliable

mechanical properties just as consumption affectability of the welded joints was expressly explored.

In (Bocchi *et al.*, 2018) author detailed present paper is to examine if and how the interaction boundaries (to be specific rotational speed S and feed rate f) influence both the mechanical properties and the consumption conduct of erosion mix welded (FS Wed) butt joints made of AA7075 and AA2024 amalgams and their mix.

In (Zhang, Xiao and Ma, 2015) author has investigated The impact of water cooling and post-welding counterfeit maturing on the miniature design and mechanical properties of 5.6-mm thick grinding mix welded (FSW) 2219Al-T6 joints was exposed to nitty gritty examinations. Sound FSW joints could be created at the researched welding paces of 100–800 mm/min under both water-cooling and air-cooling conditions. The FSW warm cycle brought about a low hardness zone (LHZ) on both the withdrawing side and the propelling side.

In (T and M, 2018) author has contains Friction mix blind riveting (FSBR) is another joining technique which disposes of the need to predrilled an opening for bolt addition. Another uneven mechanical joining process, grating mix blind riveting (FSBR) was created to shape lap-shear joints for comparable and unique amalgam sheets in various blends. The comparable and disparate joints are produced using copper, Al 5052-H32, Al 6061-T6 metals.

In (Godwin Antony *et al.*, 2018) author have investigation Aluminium alloy 7068 of metal matrix composites & Titanium Carbide along various weight percentages (2%, 4%, 6%, 8%, & 10%) of Tic by using stir casting technique & investigating the Wear analysis along the different weight % of Tic & experiments will be conducting by the design of experiments (DOE). In (KARTHIKEYAN *et al.*, 2017) author used paper researches the effect of hotness input and post-weld maturing conduct at various temperatures on the laser paper welded Maraging steel grade 250. Three unique degrees of hotness inputs were picked and CO2 laser

welding was performed. Maturing was done at six distinct temperatures: 360°C, 400°C, 440°C, 480°C, 520°C and 560°C. The macrostructure and microstructure of the combination zone were gotten utilizing optical magnifying lens. The miniature hardness test was performed on the weld zone.

In author (B *et al.*, 2018) have objective of this research is to more readily comprehend the relationship between the constituent stages introduced in the super-duplex steel SAF 2507 when it is under welding process by arc safeguarding gas MIG-MAG (Metal Inert Gas-Metal Active Gas). Regular short out move and subsidiary STT (Surface Tension Transfer) utilizing the 2594 welding wire as a filler metal and the consequences for welding power in hardness, strength and pitting consumption are considered here.

In (Rajkumar, Jayaraman and Periasamy, 2019) author presented examination of surface crossover composites on aluminium combination 7075 substrate utilizing grinding mix handling (FSP) along different arrangement of supported particles like silicon carbide (SiC) and graphite (Gr). The conveyance of support in the piece zone was inspected by SEM along ED's examination. The strength and miniature hardness are looked at along the examples.

In (Sadeghian, Shamanian and Shafyei, 2014) author present review, miniature construction and mechanical properties of UNS S32750 very duplex hardened steel (SDSS)/API X-65 high strength low composite steel (HSLA) different joint were explored. For this reason, gas tungsten arc welding (GTAW) was utilized in two distinctive hotness inputs: 0.506 and 0.86 kJ/mm.

Research Methodology:

The research work presented in this paper contains process intensification & kinetic studies of Investigations of Welding Parameters Impacts on Mechanical & Corrosion Behaviour of Steel Welds.

Experimental Work

Concept of experiment involved under this development was described in this section. Section start along observations of chemical composition regards candidate metal & electrode composition considering through process parameters taken for welding, metallographic examination & various mechanical Testing as per ASTM / ASME BPVC SEC IX Codes & Corrosion testing as per ASTM Standards of the all weld test coupons prepared as per ASME BPVC Sec IX Code.

Three Test Coupons of UNS S32205 Duplex Stainless Steel Material Weld Test Coupons respectively of sizes 500 mm (L) X 150 mm (W) 25 mm (T), 700 mm (L) X 150 mm (W) 25 mm (T) & 500 mm (L) + 200 mm (L) X 150 mm (W) 25 mm (T) along single 60 degree V-groove prepared using SMAW GRINOX E2209-16 Electrodes of varying Nickel contents. Target values of nickel being used in experiments was Low Ni (9.5-10.5 %) Medium Ni (10.5-11.5%) & High Ni (11.5-12.5 %)

The test pieces were welded by ITW India Pvt. Ltd professional 2G qualified welders in the flat position as consumables designed was suitable for exclusively for welding in flat position. The welding was started after applying backing to electrodes as per the requirements given in the consumable standard.

Mechanical testing

Main aim of all welds Tensile Test is to execute welding consumables to assess mechanical properties obtained along it. Although, this result might deferent through those taken under actual production joints due to variances under procedure of welding like electrode diameter & size, deposition techniques, width of weave, welding position & material composition etc.

As per ISO 15792-1:2000(E) Welding consumables — Test methods — Part 1: Test methods for all-weld metal test specimens in steel, nickel & Nickel alloys Equivalent to ISO Standard for Welding Consumable test method AWS B4.0.

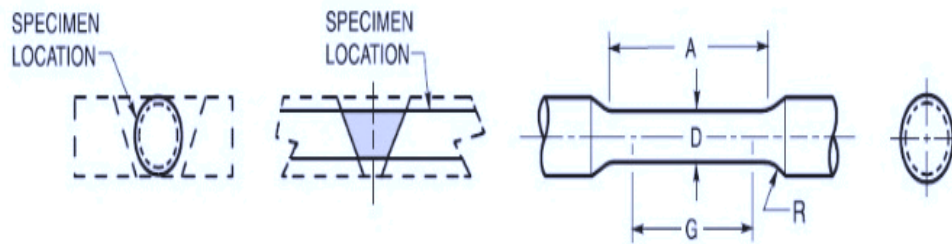


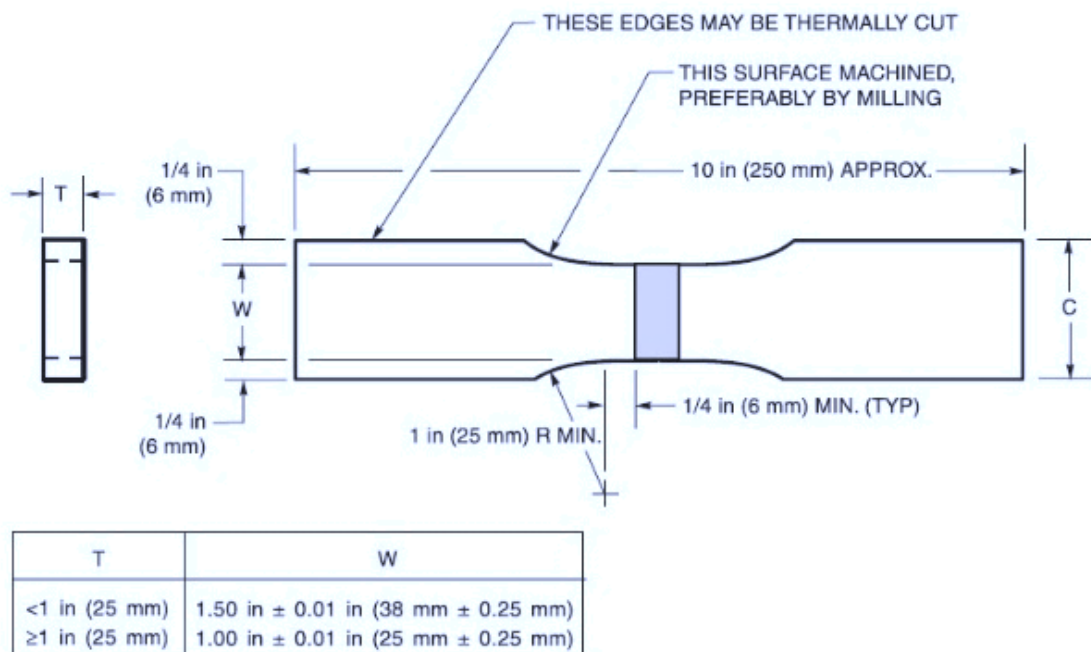
Fig.1. Standard Dimension for preparation of all weld test specimen.

Source

Transverse Rectangular Tension Test Specimen (Plate)

The purpose regards Transverse Tensile Test is to determine Mechanical power of welded joint. As fracture in Base metal indicates that Weld metal is stronger than base metal. Tension tests provide quantitative data of the mechanical properties like, Yield Strength at 0.2 % Proof Load, Ultimate Tensile strength, Percentage Elongation, reduction in area etc. that can be compared & analysed for use in the design & analysis of weld joint structures.

Fracture surfaces may also give information on the presence of some defects, discontinuities whose adverse effect may result in incomplete fusion, incomplete joint penetration, porosity, inclusions, & cracking. Transverse Tensile Test as was prepared as per ASME SEC IX Ed 2015 as shown in figure 2 below. The purpose of this specimen was to evaluate the yield strength, Tensile strength of the weld joint in transverse directions.



Results and Discussion

Results show the schematic of formation mechanism regards Investigations of Welding Parameters Impacts on Mechanical & Corrosion Behaviour of Steel Welds.

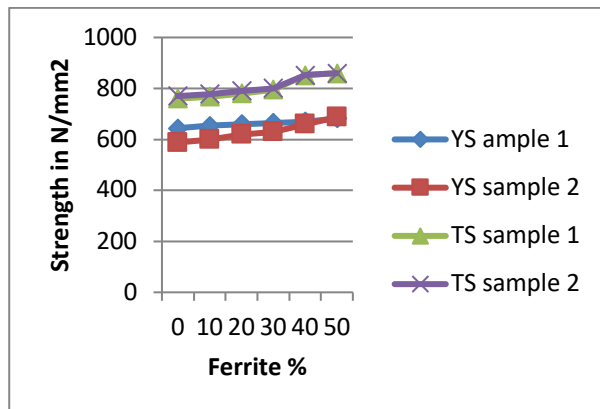


Fig.3. Tensile & Yield strength like function of % Ferrite for 2205

As can be observed from the above result which tensile & yield strengths was very marginally affected by ferrite content variation from 14% to 30%, or 20 FN to 40 FN, Moreover ASTM A240 standard for 2205 base metal specifies 450 MPa yield strength minimum, & 655 MPa tensile strength minimum. So all-weld metal test results comfortably meet those requirements.

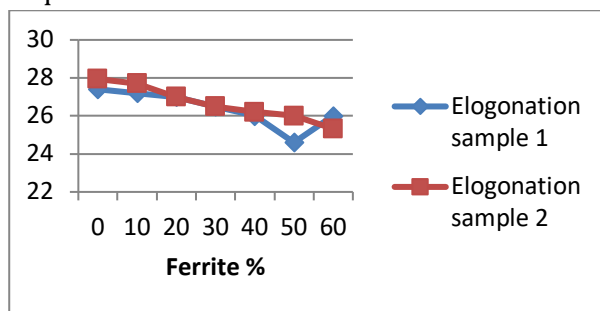


Fig.3. Ductility as a function of % Ferrite for 2205

There is a marginal change in the ductile behaviour, between 14-30 % Ferrite, as increase in the ductility beyond 24.5 at nearly 40 % ferrite to 27 % ductility at nearly 15 % Ferrite percentage, can be well expected by effect of nickel as austenite stabilizer, As more production of austenite phase, about 60 to 85 % , in weld deposits result in increase in ductility.

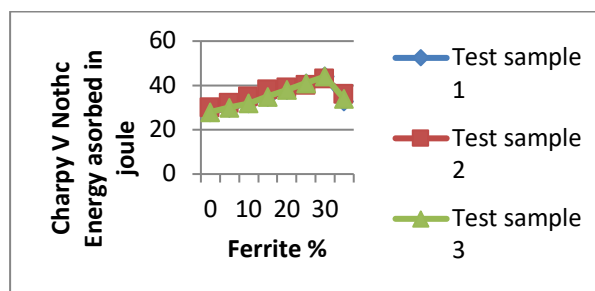


Fig.5. Charpy energy absorbed (Joule) at -40 °C as a function of Ferrite Content for 2205.

Above result indicates that there is a significant decrease in the impact strength values from 46 to 30 Joule, along decrease in Ferrite % from 30 to 14. Normally CVN minimum requirements is 27 Joule at -40°C, which is comfortably exceeded since various welding practice codes may require 27 J, 34 J or 47 J at -40°C. & when the user requires 47 J at -40°C, E2209-15 electrodes are often recommended because E2209-16 electrodes have difficulty meeting the 47J requirement due to the higher side oxygen content of the weld metal along E2209-16.

Conclusion and Further Research

10 Ni 22 Cr coupon (Low Ni) welded along 1.5 KJ/mm H.I produced fine grained austenite in the fusion zone along 40 % ferrite (Approximate FN 30), also indicated fair values of micro hardness of 280 VHN along respect to 270-280 VHN Base metal hardness values. 12 Ni 22 Cr coupon (High Ni) welded along average 1.3 KJ/mm H.I was supposed to suppress ferrite to austenite diffusion due to fast cooling involved in thermal cycle but 11.5-12.5 wt.% enriched (Low nickel) content in electrode succeeded in promoting up to 85wt. % austenite (15 % Ferrite content). This can also be justified through metallurgical point of view that Nitrogen being smaller atom compared to Fe, Cr, Ni, & Mn atoms, diffuses faster in austenite from ferrite than other alloying element thereby enhancing the austenite promotion at comparatively higher temperature during cooling from ferrite. The present study has been

conducted for UNS S32205 Duplex Stainless steels, in which nickel content has been increased gradually starting from the standard alloy design of SMAW Electrode. Enhancing Ni content, putting every another components as under standard composition, has the benefit of leaving the pitting resistance index (PREN) unchanged while the ferrite content is reduced. Nickel being costly element from economic point of view, effect of Manganese can be studies in the same fashion. Since Mn is also austenite promoter.

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