

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

Investigation of Crackability of Austenitic Stainless Steel Grade 202 by Using Y-Groove Test

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ABSTRACT: The hydrogen-assisted cracking susceptibility of modified stainless-steel weld is evaluated by Y-groove and gapped bead-on plate test. It is found that a combination of preheat is able to prevent cracking. However, the preheat temperature This is attributed to the higher weld restraint experienced in NDT than Y-groove test. For both the tests, the weld metal is found to be more susceptible to cracking than the heat affected zone. The results indicated that the root crack rate of the stainless steel 202 at room temperature reached a high value, and it could be decreased to zero when preheating at 150°C. Local transverse residual stress which was larger than the yield strength of materials is mechanical factors causing cracks.

KEY WORDS: Hydrogen-assisted cracking, Austenitic stainless steel-202, Preheating, TIG Welding, NDT Test.

I. INTRODUCTION

Hydrogen-assisted cracking (HAC) is one of the important considerations during welding of high strength steels, as welds can crack during fabrication or undetected cracks left behind in components fabricated using such steels can cause serious threat to the structural integrity of the weld joint and eventually lead to in-service failure of the component. HAC is also called cold cracking or delayed cracking as the cracking often occurs at ambient temperature hours or days after the completion of the welding. The conditions for HAC to occur in steel welds are presence of diffusible hydrogen, susceptible microstructure, residual stress in the weld. The sources of hydrogen to the weld are the welding consumables as well as the moisture or any undesirable hydrocarbon residue present during welding.

The martensitic microstructure with high hardness is most susceptible to HAC. Hence, during welding, efforts are made to reduce risk of HAC by avoiding the development of a susceptible microstructure and minimizing the hydrogen level in the welding. Probability of developing a susceptible microstructure in the weld or heat affected zone (HAZ) is assessed from the composition of the base metal and weld metal, heat input, and preheating chosen for the welding. However, in the case of high stainless-steel welding, it is difficult to prevent formation of martensite in the HAZ and in the weld metal [if matching composition of the welding consumable is used as in stainless steel (GR.202)] by varying the welding parameters. Hence, reducing the diffusible hydrogen in the weld is the best option available to prevent HAC in the welds of stainless steels. In order to reduce the hydrogen level, low hydrogen welding consumables and proper baking of the consumables to remove its moisture content are recommended. The preheating reduces the

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cooling rate of the weld, which offers more time for hydrogen to diffuse out before the weld is cooled down to ambient temperature the residual stresses arises from the steep thermal gradient and non-uniform temperature distribution in the weld and HAZ region due to the application of highly concentrated and instantaneous heat source during welding and phase transformation of the material involved in heating and cooling cycles of welding.

Various test methods are followed to assess the HAC susceptibility of steel welds. In the former, the joint geometry chosen for the test introduces restraint in the weld to promote cracking while in the latter; weld is loaded externally to facilitate cracking. In the case of externally restraint tests, the restraint levels can be varied and cracking susceptibility can be studied as a function of the restraint parameter chosen in the test (like load, stress or strain). The susceptibility of a weld to HAC can be examined by Y-groove test. In most of the tests conducted to assess the susceptibility of steels to HAC or to determine welding parameters that would ensure HAC does not occur in the weld, it is not possible to study how diffusible hydrogen present in the weld is influencing the HAC, though removal of hydrogen is the important objective of the welding parameters chosen for welding. This is because the test coupons prepared for cracking susceptibility tests are not suitable for measurement of diffusible hydrogen remaining in them. As a result, for given steel, direct correlation between the diffusible hydrogen content in the weld and the risk of cracking is not possible. For example, minimum diffusible hydrogen in the weld that can be tolerated without the risk of HAC for given steel cannot be estimated from these tests. High chromium steels are extensively used in fossil power plants and nuclear reactors due of their high temperature creep strength and good oxidation resistance. Stainless steel has been used to fabricate the Restaurant equipment (Steam Boiler).

II. METHODOLOGY

2.1 Y-GROOVE CRACKABILITY TEST:

In this project British standard is followed for the experiment. The specimens (200*75*10) are prepared for butt welding with Y- edge preparation having 2mm root gap and a 60° groove angle. First symmetrical anchor or constraining welds are made on both ends and then the test weld of length about 80mm is made in the central section.

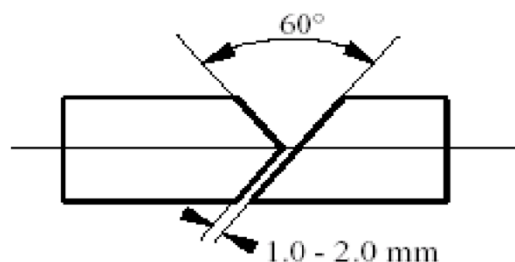


Fig: 1. Y- Groove cutting

The test pieces were machined by sawing, milling and grinding. Ensure that surfaces to be welded are milled or ground finish. Where the principal rolling direction of the plate can be determined, arrange the rolling directions of the plates to be the same and parallel to the welding direction. Ensure that the surfaces to be welded are ground smooth and free from scale, rust, oil, grease and other contaminants. Deposit the welds with a procedure to avoid hydrogen cracking, using preheat. Dry all consumables used for anchor welds in accordance with manufacturers' recommendations to give the lowest possible hydrogen levels. The filler material was also Stainless-steel Gr.202L wires with diameter of 2 mm, and dried at 75 °C for 2 h, and the welding was performed by manual. In order to reduce the accidental and statistical error, 2 prototypes were prepared and the results of the crack rate at one condition were averaged. The welding temperature in the test section was strictly controlled in ± 3 °C of preheating temperature. The

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welding was started when the temperature of the whole test plate has reached the specified preheating temperature. And the welding arc started and ended outside the test section. Specimens for Y-groove tests are prepared with two different groove geometries. The straight Y-groove test is generally done to assess the cracking susceptibility of weld metal, whereas the inclined Y-groove test is performed to estimate the cracking susceptibility of HAZ of a weld joint. In this study, both straight and inclined Y-groove tests were carried out for stainless steel 202.

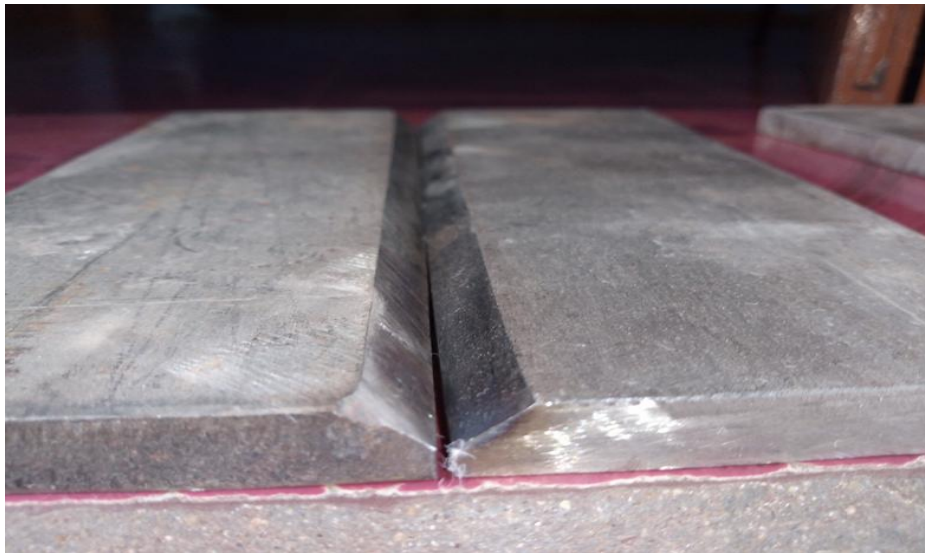


Fig: 2. STRAIGHT Y- GROOVE CUTTING

Details of specimen fabrication are available elsewhere. Welding was performed without any preheat and with 100, 150, and 200 °C preheat. Based on the results of these tests, one set of straight and inclined Y-groove weld joint was prepared with 100 °C preheat followed by post-heating at 100 °C for 30 min. The preheating and post-heating of the samples were carried out by oxy-acetylene flame heating. The samples were kept for 24 h after completion of the welding. Microscopic examinations for detection of cracks were performed after cutting each sample in same locations.

2.2 TIG WELDING:

The designation TIG comes from USA and is an abbreviation of Tungsten Inert Gas. Tungsten - also called wolfram - is a metal with a fusion point of more than 3300°C, which means more than double the fusion point of the metals which are usually welded. Inert Gas is the same thing as inactive gas, which means a type of gas that will not combine with other elements. In Germany this method is called WIG welding, the W meaning wolfram. TIG welding is the international standardised designation for this welding method. The Principle of TIG Welding is an electric arc welding process in which the fusion energy is produced by an electric arc burning between the workpiece and the tungsten electrode. During the welding process the electrode, the arc and the weld pool are protected against the damaging effects of the atmospheric air by an inert shielding gas. By means of a gas nozzle the shielding gas is lead to the welding zone where it replaces the atmospheric air. TIG welding differs from the other arc welding processes by the fact that the electrode is not consumed like the electrodes in other processes such as MIG.

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2.3 BASIC MECHANISM OF TIG WELDING:

TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas (argon or helium), and a filler metal is normally used. The power is supplied from the power source (rectifier), through a hand-piece or welding torch and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece using a constant-current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapours. The tungsten electrode and the welding zone are protected from the surrounding air by inert gas. Tungsten electrodes are commonly available from 0.5 mm to 6.4 mm diameter and 150 - 200 mm length. The current carrying capacity of each size of electrode depends on whether it is connected to negative or positive terminal of DC power source. The power source required to maintain the TIG arc has a drooping or constant current characteristic which provides an essentially constant current output when the arc length is varied over several millimetres. Hence, the natural variations in the arc length which occur in manual welding have little effect on welding current. The capacity to limit the current to the set value is equally crucial when the electrode is short circuited to the work piece, otherwise excessively high current will flow, damaging the electrode. Open circuit voltage of power source ranges from 60 to 80V.

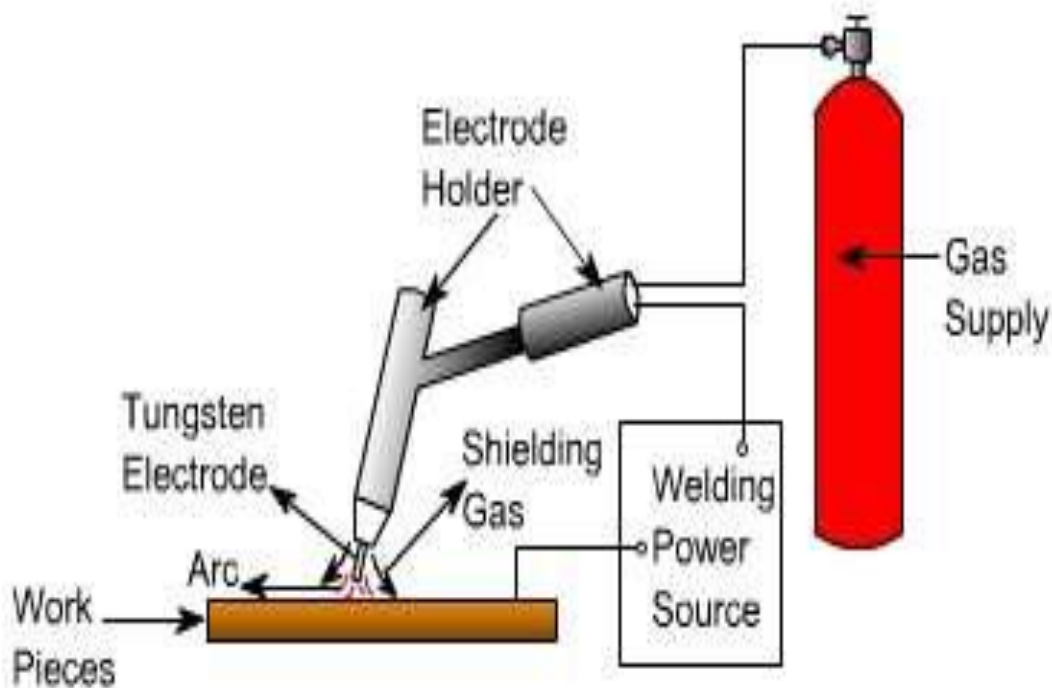


FIG: 3 Schematic diagram of TIG welding.

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2.4 MECHANICAL PROPERTIES OF STAINLESS STEEL(Gr.202):

S.NO	PHYSICAL/ MECHANICAL PROPERTY	VALUE
1.	Density	7.80 g/cm ³
2.	Thermal expansion	17x10 ⁻⁶ /k
3.	Modulus of elasticity	200Gpa
4.	Thermal conductivity	15 W/m.k
5.	Tensile strength	655 Mpa

Table: 1

2.5 CHEMICAL COMPOSITION:

S.NO	ELEMENT	CONTENT (%)
1.	Carbon	0.12
2.	Manganese	5.5
3.	Silicone	0.9
4.	Chromium	16
5.	Nickel	0.5
6.	Molybdenum	0.2
7.	Phosphorus	0.06
8.	Nitrogen	0.25

Table: 2

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III. TESTING

3.1 MICROSCOPE TO IMAGE CAPTURING:

The welded specimens are cut down to the size of 10*10 for the purpose of microscopic image capturing. In this process the collected samples are investigated by microscopic capturing, and the defects on the welded parts can also be investigated. And the images are collected. There are no defects on the welded samples. The microscopic images are shown below.

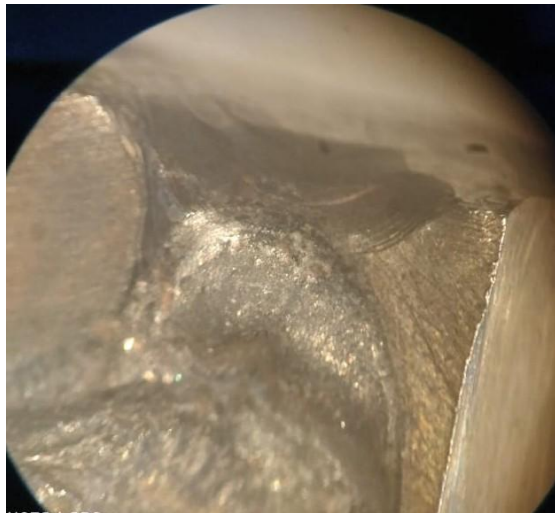


Fig: 4 Microscopic image

3.2 NDT TESTING:

3.2.1 LIQUID DYE PENETRANT METHOD:

Liquid penetrant inspection (LPI) is one of the most widely used non-destructive evaluation (NDE) methods. Its popularity can be attributed to two main factors, which are its relative ease of use and its flexibility. The technique is based on the ability of a liquid to be drawn into a "clean" surface breaking flaw by capillary action. This method is an inexpensive and convenient technique for surface defect inspection. The limitations of the liquid penetrant technique include the inability to inspect subsurface flaws and a loss of resolution on porous materials. Liquid penetrant testing is largely used on nonmagnetic materials for which magnetic particle inspection is not possible. Materials that are commonly inspected using LPI include the following; metals (aluminium, copper, steel, titanium, etc.), glass, many ceramic materials, rubber, plastics. Liquid penetrant inspection is used to inspect of flaws that break the surface of the sample. Some of these flaws are listed below; fatigue cracks, quench cracks grinding cracks, overload and impact fractures, porosity, laps seams, pin holes in welds, lack of fusion or braising along the edge of the bond line.

3.2.2 Procedure:

In this method the surfaces to be inspected should be free from any coatings, paint, grease, dirt, dust, etc., therefore, should be cleaned with an appropriate way. Special care should be taken not to give additional damage to the surface to be inspected during the cleaning process. Otherwise, the original nature of surface could be disturbed and the results could be erroneous with the additional interferences of the surface features formed during the cleaning process. Surface cleaning can be performed with alcohol. Special chemicals like cleaner-remover can also be applied if needed. In the experiment, only cleaner-remover will be sufficient. Subsequent to surface cleaning, the surface is let to dry for 2 minutes. Commercially available cans of liquid penetrant dyes with different colors are used to reveal the surface defects.

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Fig: 5. Liquid penetrant test

3.2.3 Steps used in the experiment:

1. Clean the surface with alcohol and let surface dry for 5 min.
2. Apply the liquid penetrant spray (red can) to the surface and brush for further penetration. Then, wait for 20 min.
3. Wipe the surface with a clean textile and subsequently apply remover spray (blue can) to remove excess residues on the surface and wait for a few min.
4. Apply the developer spray (yellow can) at a distance of about 30cm from the surface. The developer will absorb the penetrant that infiltrated to the surface features such as cracks, splits, etc., and then reacted with it to form a geometric shape which is the negative of the geometry of the surface features from which the penetrant is sucked.
5. The polymerized material may be collected on a sticky paper for future evaluation and related documentation, if needed.



Fig: 6. Liquid penetrant test (Remover)

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3.3 ULTRASONIC INSPECTION:

For this experiment, USM-2 type ultrasonic unit will be used. The props used supports to work at frequency of 5 MHz. Echo techniques will be employed to find the cracks. Instrument will be tuned to a frequency of 5 MHz. An appropriate couplant used should not cause corrosion or other damage. During the inspection the calibration will be done on the reference standard, if needed. Two different test blocks will be employed in this test, sufficient amount of couplant will be applied to the transducer scan areas on the forward and after sides of the support fitting. The display will be monitored for crack indications.



Fig: 7. Ultrasonic testing

A crack signal will be similar to the following:

3.3.1 The following steps should be applied during the experiment:

1. The couplant should be applied on the inspected area.
2. For the circular test specimen, the prop will be placed in the corresponding space in the supporting fitting tool. Enough couplant should be used between the probe and tool.
3. For the flat specimen, no tool is needed, couplant only applied between the inspected surface and the probe.
4. Special attention should be paid on the location where possible cracks exist.
5. A discontinuity like a crack produces a peak on the screen.
6. Attention should also be given to the movement of the possible peak caused by the cracks on the specimen.

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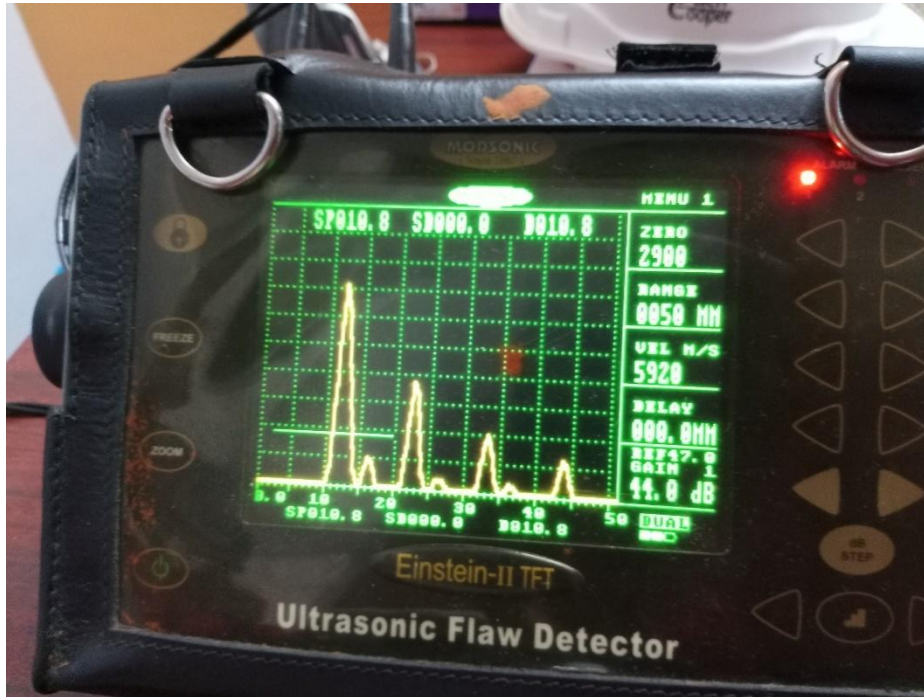


Fig: 8. Ultrasonic flaw detector

IV. RESULT

4.1 LPT (Liquid penetrant test):

SPECIMEN NO.	PRE HEAT TEMP (°C)	CURRENT (I) IN (AMPS)	FINDINGS
1.	200	125	No Defect.
2.	150	150	No Defect.
3.	100	175	Surface finish not properly.

Table: 3

4.2 UT (ULTRASONIC TESTING):

SPECIMEN NO.	PRE HEAT TEMP (°C)	CURRENT (I) IN (AMPS)	FINDINGS
1.	200	125	NO Defect.
2.	150	150	No Defect.
3.	100	175	No lamination found for the welding plate Surface finish not properly (193mm to 200mm)

Table: 4

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IV. APPLICATIONS

- Architectural applications such as windows and doors.
- Restaurant equipments (Boilers), Sinks, Cooking utensils.
- Ship containers and road tanker.
- Railway cars, Hose clamps.

V. ADVANTAGES

- It is resistance to fire and heat allowing it to resist scaling and retain strength at high temperatures.
- Its high corrosion resistance allowing it to be used in rigorous environments.
- The Y-Groove cutting gives more welded area, when compared to the V-Groove cutting.
- Y-Groove provides complete fusion, low stress, and 100% penetration.
- Good distortion control.
- Welds shrink evenly and are less likely to distort.

VI. CONCLUSION

Based on the results obtained in this study, the following conclusions can be drawn. The pre-heating temperature is important for good surface finish. And it can improve the strength of the material. The different levels of current should provide the well strengthened joint of the plates. The pulse welding provides the good molecules bonding. And it can't be cracked. The pre heating temperature helps to develop the strength of the plates and improve the molecules bonding. Specimen No.3 which is having a preheat temperature of 100 degree with a 175 amps current input is found to have defects in the surface. None of the specimens have considerable cracks in the surface.

VII. ACKNOWLEDGEMENT

- Assistance concerning the weld metal such as structure, notch, and defect see by microscope to image capturing of computing aspects of the investigation by KALASALINGAM UNIVERSITY, SRIVILLIPUTHUR.
- TIG welding is welded by Mr. Muthu to weld the stainless steel 202 material plate at SAMATHANAPURAM.
- Then assist NDT tests help to lab facilitate give and conducted tests for penetrant test, ultrasonic surface test IMAYA NDT Institute Sripuram Tirunelveli.

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