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Hot Tensile Testing of Dissimilar Welding of SA213TP-347H with SA213 T23

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Abstract**—***This paper deals with the hot tensile testing of dissimilar metal butt welding of materials SA213TP-347H WITH SA213-T23. These materials are mainly used in the power plants for manufacturing reheater and superheater coils. Specimen will be butt welded in Orbital TIG welding machine having GTAW (Gas Tungsten Arc Welding) Process and shielding with Argon Gas. Dissimilar joint will be welded with each filler wire ER347H and ERNiCr3. Pre heating of base metals are to be done during welding process. Job will be Stress relieved with prescribed temperature and hot tensile properties analysis will be carried out. The other testing methods include hardness test, macro and micro analysis*.

Keywords**—** *Dissimilar welding, pre heat, hot tensile test.*

I. INTRODUCTION

To evaluate the hot tensile testing properties of, dissimilar metal butt welding of materials SA213TP-347 with SA213-T23 was carried out in Orbital Tig (OTIG) welding machine by Gas Tungsten Arc Welding (GTAW) process with Argon gas shielding.

Specimen joints were made using ER347H and ERNiCr3 filler materials separately and welded joints were stress relived at the prescribed temperature and radiography test was conducted. Further specimen joints were subjected to hot tensile, hardness test and macro & micro analysis

Specimen made from diameter 51 mm, thickness9 mm with J groove edge preparation. Tube ends which joined together were cleaned thoroughly. Specifications of materials are SA213TP-347 and SA213-T23.

II. BRIEF DESCRIPTIONS ABOUT SA 213 T23 MATERIAL

SA213 T23 is a ferritic low alloy steel and is developed from T22 by adding tungsten (1.6%), by reducing molybdenum (0.2%) and carbon contents (0.04-0.10%) and small additions of vanadium, columbium (Cb), nitrogen and boron. Due to these additions and proper heat treatment creep strength values and resulting allowable stresses are greatly increased. It has very high creep behavior at 550 ^{o}C with low hardness in the as welded condition, which is essential material quality requirement for the power plant equipments. It is found as replacement material for T21 and T22.

2.1 Brief Description About SA 213 347H Material:

SA213 347H is a stabilized austenitic stainless steel material with good general corrosion resistance and somewhat better resistance in strong oxidizing conditions. It has excellent resistance to intergranular corrosion after exposure to temperatures in the chromium carbide precipitation range of 800 – 1500°F (427 – 816°C). The alloy has good oxidation resistance and creep strength to 1500°F (816°C). It also possesses good low temperature toughness. Stainless steel tubes can be readily welded by most standard processes. A post weld heat treatment is not necessary.

TABLE I. Mechanical properties of SA213T23 and SA213 347H.

Properties	SA213T23	SA213 347H
Tensile strength (MPa) min	510	515
Yield strength (MPa) min	400	205
Elongation (in 50 mm/min) %	20	35
hardness max (Brinell/Vickers)	220 hbw/230 hv	192 hbw/200 hv

2.3 Filler Wire / Electrode:

ER347 and ERNiCr 3 (Inconel-82) filler wires are used to make joints between SA213 347H and SA213 T23.

ER 347 has good resistance to general corrosion and is suitable for applications where welds are subjected to high temperature (+750 ^{o}F)

ERNiCr3 (Inconel -82) is used for welding alloy steel to stainless steel.

TABLE II. Chemical composition of ER 347 and ErNiCr3.

	C	Cr	Ni	Nb	Mo	Mn	Si	P	S	Cu
ER 347H	0.04	19.5	9.5	0.04	0.30	1.3	0.4	0.025	0.015	0.10
ERNi Cr3	0.03	20.4	72.09	2.5	-	2.85	0.22	0.003	0.22	0.5

TABLE III. Mechanical properties of feed wire material.

Material	Tensile Strength min (MPa)	Yield Strength min (MPa)	Elongation in 50 mm, min (%)
ER347H	607	400	45
ERNiCr3	620	520	20

III. LITERATURE REVIEW

Dinesh W. Rathod et al. [1] hasexperimentallyanalysed of dissimilar metal weld joint of Ferritic to austenitic stainless steel. Ferritic steel (SA508 Gr.3.Cl.1) with austenitic stainless steel (SS304LN) welded. They used the Gas Tungsten Arc Welding (GTAW) for welding the dissimilar metals with ERNiCr3 and EniNiFe-3 consumables. They found that fine slag inclusion could promote the undesirable microstructure, which would lead to crack initiation and propagation with low stress field and reduced tensile properties and impact toughness.

Rutesh Mittal et al. [2] hasanalysed the microstructures and mechanical Properties of dissimilar T91+347H steel weldmentsby SMAW & GTAW process. Austenitic and Nickle based filler wires are used for welding. It was found that dissimilar metal joints made by GTAW process with filler wire ERNiCr3 have given better result.

N. Arunkumar et al. [3] has evaluated the mechanical Properties of dissimilar metal tube with (T91+SS347h) and (T91+T22) material combinations by GTAW& GMAW process. The joints fabricated by GTAW process exhibited higher strength value and enhancement in strength is approximately 21 % compared to GMAW joint. Low hardness was recorded in GMAW joint (190 VHN), where as hardness was maximum in the GTAW joints (293 VHN)

T S Senthil et al. [4] has experimentally analysed the dissimilar welding of materials used for fabrication of super heater coils for Boiler power applications. They carried out welding of T23 with T92, T23 with 347 H & T92 with 347 H, by Manual TIG process by using Inconel-82 filler wire. Hot tensile test was carried out on T23+T92, T92+T92 & T23+T23 combination welding. They concluded that SA213T23 & SA213 347H weldment has satisfactory bent ductility, weld tensile strength, toughness & metallurgical properties

P Mohyla et al. [5] has analysed the reliability and creep resistance in advanced low-alloy steels. They concluded that post weld heat treatment (PWHT) of T23 and T24 welds is necessary to achieve suitable hardness and plastic properties of welds. And also, it was found that weld joints of low-alloy creep resistant steels hardened by dispersed MX particles are subject to a process of secondary hardening during long term exposure at elevated temperatures and application of T23 and T24 steels for membrane water walls is effective only if post-weld heat treatment is carried out.

SatanphopAmsupan et al. [6] has studied the influence of the welding heat cycle on the HAZ properties of the T23 joints. It was found experimentally that preheat & PWHT is significant for T23 joints, to have reduced hardness at HAZ. Even though T23 materials are specifically designed to be welded without pre heat and post weld heat treatment (PWHT), Application of preheating & PWHT is necessary irrespective of the tube thickness.

3.1 Discussion

From the literature review the following are discussed below.

i) Welding process has significant influence on hardness of weldment area or heat affected zone (HAZ).
ii) Selection of electrode and filler wires is important for getting quality welding of the product.
iii) Pre heat & post weld heat is to be ensured as required on case to case basis.
iv) Process parameters are to be optimised for better results.
v) Slag inclusion is to be avoided at the weldment area

IV. Hot Tensile Testing

Hot tensile test is the method in which we use tensile testing machine with furnace & extensometer where the specimen is hold. By using this method we can find out the tensile strength, elongation, yield strength properties of different materials and its alloy, at high temperature. Also we can study the micro structural changes at high temperature by examine the fractured components under Scanning Electron Microscopy (SEM).

4.1 Advantages of Hot Tensile Test:

1. To investigate the behaviour of material at high temperature.
2. To study the mechanical, thermal properties of material elevated temperature.
3. To determine elastic limit, elongation, modulus of elasticity, proportional limit, reduction in area, tensile strength, yield point, yield strength at high temperature.
4. To study changes of micro structure at elevated temperature.

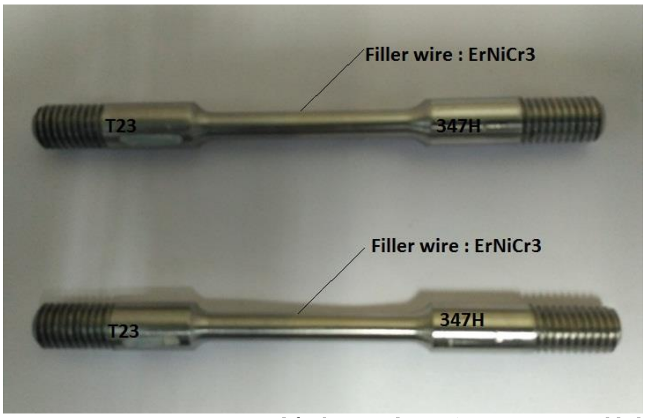


Fig. 1. Specimen pieces prepared for hot tensile test (T23+SS347H welded with Filler wire ErNiCr3).

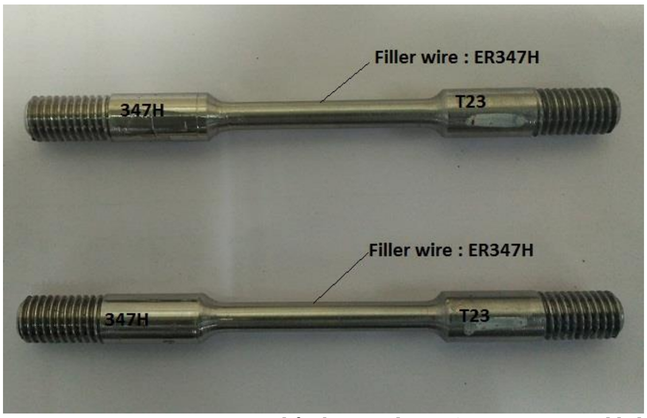


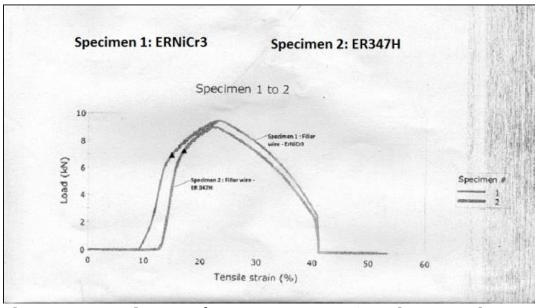
Fig. 2. Specimen pieces prepared for hot tensile test (SS347H+T23 welded with Filler wire ER347H).

4.2 Result of Hot Tensile Test: Hot tensile test was done on welded joints to determine the strength and ductility of the joint at elevated temperature and this is not a substitute for the creep test. The test was conducted at 600°C for T23+SS 347H

The dissimilar specimen made with ErNiCr3filler wire had elongated and yielded upto 248 MPa before going into plastic stage. It attained ultimate tensile strength of 337 MPa and percentage og elongation was 5% outside gauge measurement.

The dissimilar specimen made with ER347 filler wire had elongated and yielded upto 263 MPa before going into plastic stage. It attained ultimate tensile strength of 324 MPa and percentage of elongation was also 5% outside gauge

measurement The values obtained are given in the table below.
The position of fracture in the both the cases were at the T23 base metal side. Hence the welded joints are stronger than the base metal.



Graph. 1. Hot tensile test of specimen 1 & 2 (Load Vs Displacement).

TABLE IV. Hot tensile test results of the specimen (SS347H+T23).
Test temperature: 600°C

Filler wire	Specimen size in mm	Yield stress in MPa	UTS in MPa	Position of fracture	% elongation on 25mm
ErNiCr3	Dia 5.98	248	337	T23 Base metal side	5(OGM)
ER347H	Dia 5.95	263	324	T23 base metal side	5(OGM)

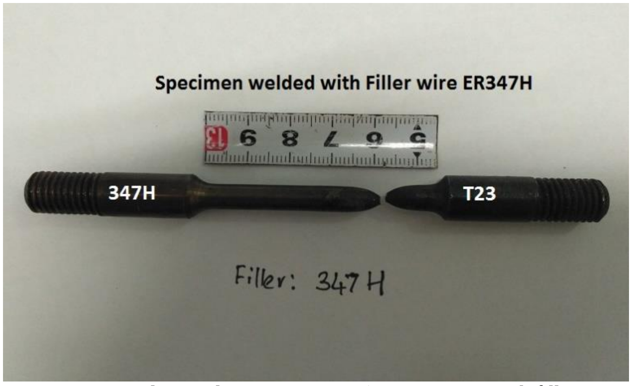


Fig. 3. Hot tensile tested specimen piece (SS347H+T23 with filler wire ER347H).

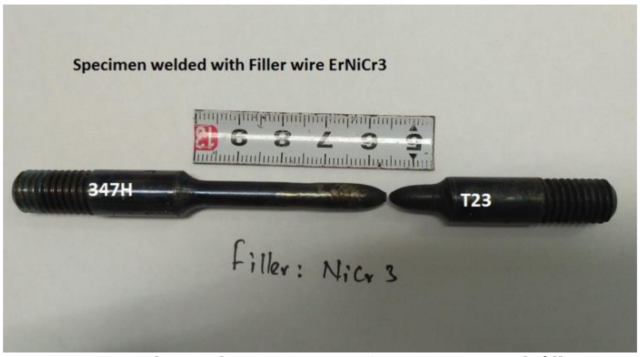


Fig. 4. Hot tensile tested specimen piece (SS347H+T23 with filler wire ErNiCr3).

V. MACRO ANALYSIS

In this test the Specimen is polished & etched and examined by naked eye or magnified up to X15. The test reveals No. of Passes, Surface Defects and Weld Penetration.

Macroscopic examination of the welded samples aimed at verifying weld soundness, revealed no evidence of cracking or other detectable flaws.

The macro structure, penetration and geometry of the specimen (347H+T23) welded with filler wire ER347& ErNiCr3 is shown in Figure respectively. It shows that weld have good penetration with proper side wall fusion and have no sign of crack and porosity.

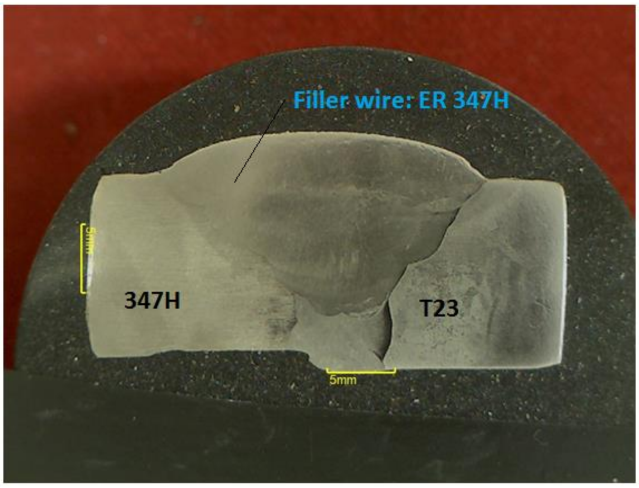


Fig. 5. Combination of 347H+T23 welded with filler wire ER347H.

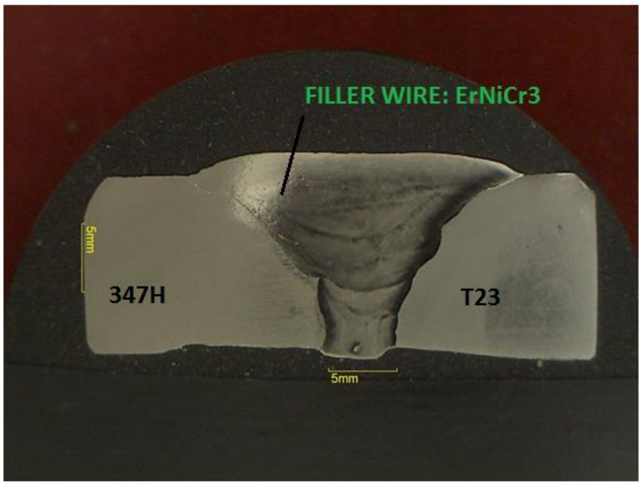


Fig. 6. Combination of 347H+T23 welded with filler wire ERNiCr3.

VI. MICRO ANALYSIS

In this test the Specimen is polished & etched and examined with magnification from X20 to X2000. The test reveals Micro-Structure of weldment, Cracks & Inclusions of microscopic size and Heat Affected Zone

Microstructural characterization of multi pass weld of 347H + T23 with two different filler wires of ErNiCr3 & ER347H was done. The base metal, interface of base metal and weld metal microstructure studies were carried out.

Figure 7 shows the T23 base metal microstructure, showing predominantly bainitic structure.

Figure 8 shows the austenitic microstructure of SS347H

Further micro analysis study of weld metal and interface surface of weld and base metal did not show any presence of any micro cracks and lack of fusion

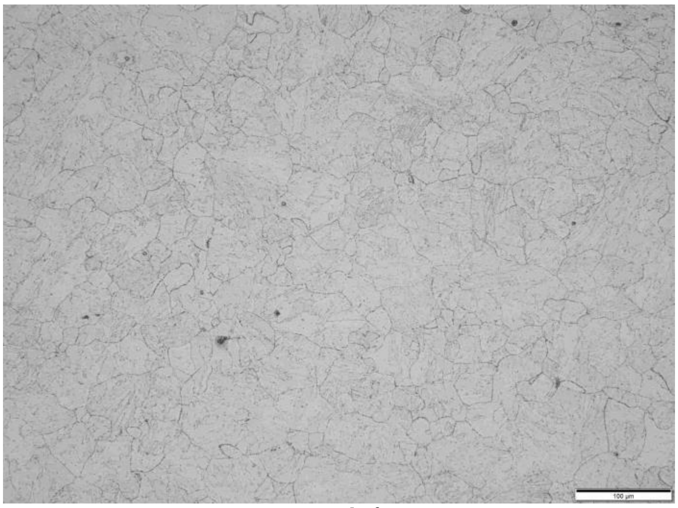


Fig. 7. Base metal of T23, 200x.

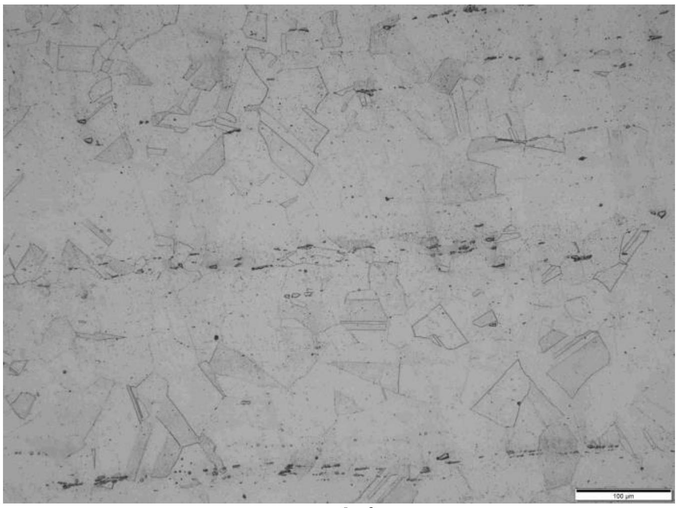


Fig. 8. Base metal of 347H, 200x.

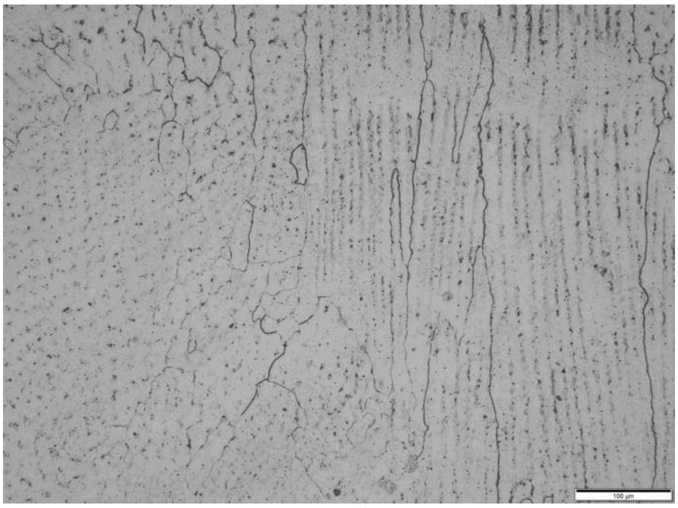


Fig. 9. Weld metal of ErNiCr3, 200x.

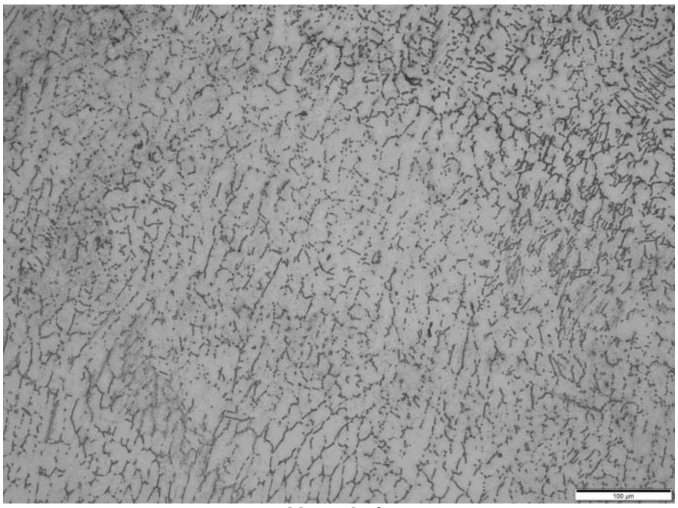


Fig. 10. Weld metal of 347H, 200x.

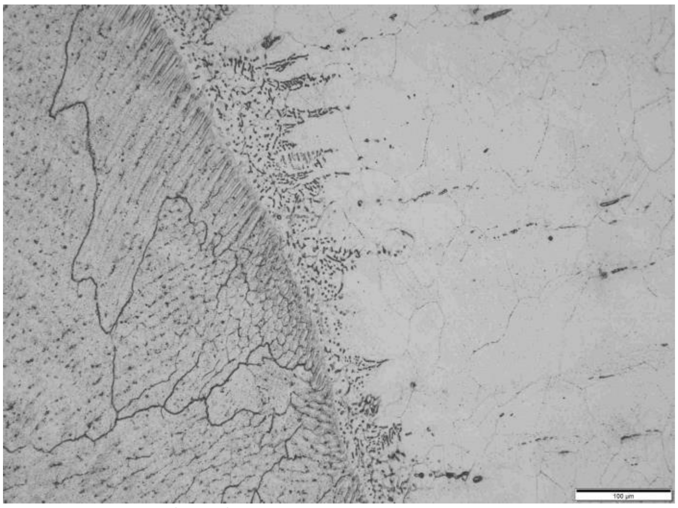


Fig. 11. Interface of Base metal 347& weld metal ErNiCr3, 200x.

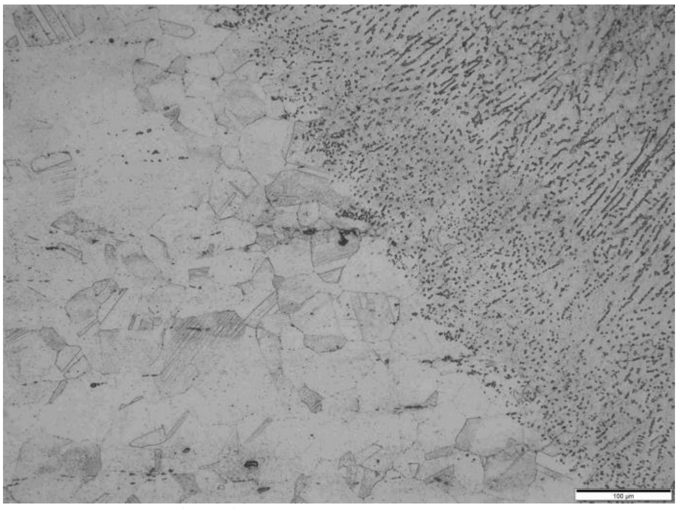


Fig. 12. Interface of Base metal 347& weld metal ER347, 200x.

VII. HARDNESS TEST

Hardness testing is typically undertaken to assess resistance to plastic deformation, a value of tremendous importance to the determination of part quality in a wide range of industries and applications.

Exposure to loads, pressures and extreme temperatures in manufacturing has the potential to affect the performance of parts comprised of metals and metal alloys. Due to complex specimen geometry and linear correlation between hardness and tensile strength in metals, hardness testing is often the best way of establishing that components will survive and perform in their intended applications

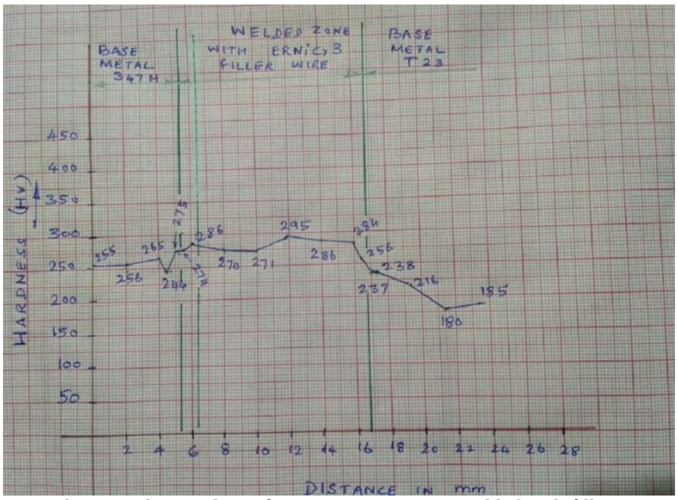
The Vickers hardness was carried out on the welded joints in the post weld heat treated condition.

7.1 Hardness of Specimen 347H+T23 Welded with Filler Wire ErNiCr3

From the location 1 to 4 hardness test was taken at the 347 H base metal and it shows there is a slight variation in hardness. Location 5 is the interface of the base metal 347H and weld metal (Filler wire ERNiCr3) and there is a marginal increase in hardness.

TABLE V. Hardness values of specimen 347H+T23 welded with filler wire ErNiCr3.

Location	Distance in mm	Hardness HV
1	0	255
2	2	256
3	4	265
4	4.5	244
5	5	275
6	5.5	274
7	6	286
8	8	270
9	10	271
10	12	295
11	14	286
12	16	284
13	16.5	256
14	17	237
15	17.5	238
16	19.5	216
17	21.5	180
18	23.5	185



Graph. 2. Hardness values of specimen 347H+T23 welded with filler wire ErNiCr3.

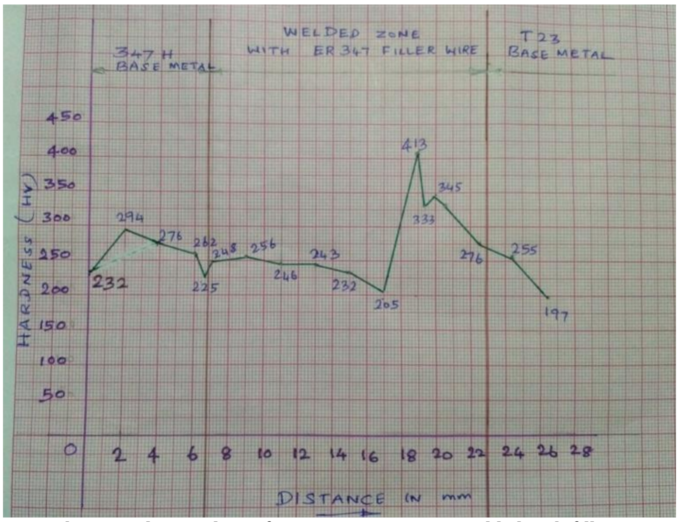
From location 6 to 13, hardness was taken at the weld metal zone and it indicates that there were not much variation in its value except at location 13, hardness was decreased by 28 HV than the previous location. It indicates that at the interface of weld metal (Filler wire ERNiCr3) and base metal T23 there is a decrease in hardness value. Further from location 14 to 18, hardness test was taken at the T23 base metal. Hardness values of specimen 347H+T23 welded with filler wire ErNiCr3 is shown in the table V.

7.2 Hardness of Specimen 347H+T23 Welded with Filler Wire ER347H

Similarly in the case of specimen 347H+T23 welded with filler wire 347H hardness test was conducted at different locations. Location 1 to 5 indicates the 347H base metal, from 6 to 13 indicates the weld metal zone (Filler wire ER347H) and location 14 to 18 indicates the T23 base metal zone.

TABLE VI. Hardness values of specimen 347H+T23 welded with filler wire ER347H.

Location	Distance in mm	Hardness HV
1	0	232
2	2	294
3	4	276
4	6	262
5	6.5	225
6	7	248
7	9	256
8	11	246
9	13	243
10	15	232
11	17	205
12	19	413
13	19.5	333
14	20	345
15	20.5	337
16	22.5	276
17	24.5	255
18	26.5	197



Graph. 3. Hardness values of specimen 347H+T23 welded with filler wire ER347H

There is a slight variation in hardness value in the 347H base metal. Hardness was found at higher values from location

12 to 15 due to improper pre heating during welding process. : Hardness values of specimen 347H+T23 welded with filler wire ER347H is shown in the table VI.

VIII. Conclusions

The following observations were made on the dissimilar joints of SS347H +T23, made with ER347H & ErNiCr3 filler wires.

a) Hot tensile test proved that even at the elevated temperature (600^{o}C), weld metal behaved better than the base metal. It also shows the ultimate tensile strength is decreased when the specimen was tested at higher temperature.
b) The macro and micro analysis of weld structure shows the no sign of crack and porosity.
c) Hardness value of the specimen welded with ERNiCr3 filler wire was found less than 290 at any location. Whereas in the case of specimen welded with ER347H filler wire, hardness was found varied from 337 to 413 HV at the interface of weld metal and T23 base metal. This might be due to improper pre heating during weld process.

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