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Dissimilar Steel Welding of Super Heater Coils for Power Boiler Applications

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Abstract
This paper deals mainly with two types of new materials namely SA213 T23, SA213 T92 with special emphasis on dissimilar combinations due to its advantages in production welding of super heater tubes mainly in tube to tube joints and tube to header joints. Welding was carried out under manual TIG process with argon gas shielding. Two combinations of dissimilar welds were carried out and testing was also done. Testing methods comprises of radiography test, transverse tensile, face bend, root bend, impact, macro, micro and scanning electron microscope tests. The results from these tests prove that the dissimilar joints made with the newer steel grades holds good for super heater components of power boilers with better properties.

1. Introduction

The energy production is faced with introduction of increasingly stringent emission regardless to safeguard the health and to preserve the environment for future generations. Increasing thermal efficiency by improving the operating conditions is the best way to reduce emissions. Improved operating conditions in advanced power plants calls for new improved creep resistant materials in areas like super heater and re heater applications. The improved properties found in ferritic low alloy steels conforming toASMESA213 code. The use of such steels at higher operating conditions substantially enhances the cycle efficiency and consequential reduction in fuel cost and reducing environmental pollution.

2. Experiment

This experimental work is aimed to achieve the following:
- Characterization of dissimilar steel joints welded with newer grades of steels using orbital-TIG.
- Conventional grades used are SA 213 T22 and SA 213 T91.
- New Grades steel are SA 213 T23SA 213 T92.

Why New Grades for Super heater and Re heater Coils?
- Increasing emission controls call for increase in the efficiency of power plants.
- So power plants with higher operating temperature and pressure required.
- i.e. Ultra Super Critical plants to be constructed
- So new materials with better properties like creep resistance, corrosion resistance, oxidation resistance required.

Table 1. *Operating Condition of Various Boilers.*

Power plant	Pressurekg/cm^2(max)	Temperature°c (max)
SUBCRITICAL	167	540
SUPER CRITICAL	240	580
ULTRA SUPER CRITICAL	280	640

Benefits of Using SA 213 T23 and SA 213 T92

- Better tensile strength
- Better creep resistance
- Reduction in component wall thickness
- Reduction in component weight
- Reduction in overall cost

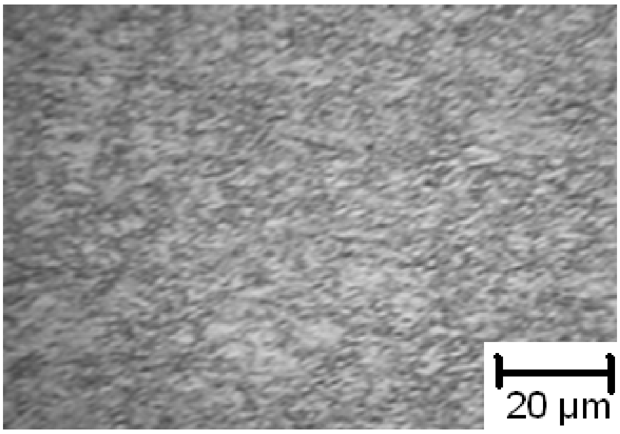

Figure 1. *Microstructure of T23basemetal - Bainitic-Martensitic structure.*

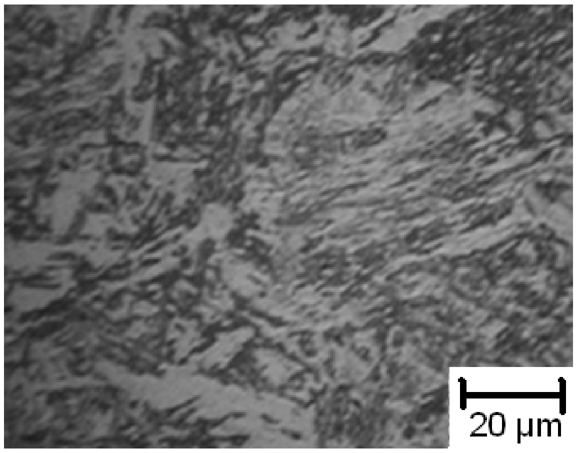

Figure2. *Microstructure of T92basemetal - Tempered Martensitic structure.*

Table 2. *Chemical Composition.*

Material	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	Niobium	Tungsten
Sa213 T22	0.05 – 0.15	.03 –0.60	0.025	0.025	0.5		1.9–2.6	0.87 –1.13			
Sa213 T23	0.04 –0.10	.1 –0.60	0.025	0.01	0.5		1.9–2.6	0.05 –0.30	0.20 –0.30	0.02 –0.08	1.45 –1.75
Sa213 T91	0.07 –0.14	.03 –0.60	0.02	0.01	.02 –0.50	0.4	8.0–9.5	0.85–1.05	0.18 –0.25	0.06 –0.1	
Sa213 T92	0.07 –0.13	.03 –0.60	0.02	0.01	0.50	0.4	8.5–9.5	0.3 –0.60	0.15 –0.25	0.04 –0.09	1.50 –2.00
Tp304h	0.07–0.13	0.5	0.045	0.03	.03	7.5 –10.5	17.0–19.0			0.20 –0.60	
Tp347h	0.03 –0.25	2	0.045	0.03	1	9.0–12.0	17.0–19.0			8xc –1.10	

Table 3. *Mechanical Properties.*

Material	Tensile strengthMin (mpa)	Yield strengthMin (mpa)	Elongation in 50 mm/min (%)	Hardness max brinell/vickers
Sa213t22	415	205	30	163 hbw/170 hv
Sa213t23	510	400	20	220hbw/230 hv
Sa213t91	585	415	20	250hbw/265 hv
Sa213t92	620	440	20	250hbw/265 hv
Tp304h	550	205	35	192hbw/200 hv
Tp347h	515	205	35	192hbw/200 hv

Table 4. *Tig Welding Combinations.*

Combination	Fillermetal
Sa 213 t23 + sa 213 t92	T23 filler metal
Ss 347 h + sa 213 t23	Inconel-82
Ss 347 h + sa 213 t92	Inconel-82
Sa 213 t92 + sa 213 t92	T23 filler metal
Sa 213 t23 + sa 213 t23	T23 filler metal

Figure 3. *Tig Welded Joints.*

Welding Parameters

T23 – T92

Process	: Manual TIG
Material	: SA213 T23 – SA213 T92
Size	: OD=44.5mm; WT = 9mm
Edge Preparation	: V-Joint
Included Angle	: 35°
Root Gap	: 2mm
Shielding Gas	: Argon
Filler	: T23
Preheat	: 220°C for 60 second
Gas Flow Rate	: 12 litres/min
No.of Passes	: 3

T23 – SS347H

Process	: Manual TIG
Material	: SA213 T23 – SA213 SS347H
Size	: OD=44.5mm; WT = 9mm
Edge Preparation	: V-Joint
Included Angle	: 35°
Root Gap	: 2mm
Shielding Gas	: Argon
Filler	: INCONEL-82
Preheat	:220°C for 60 second
Gas Flow Rate	: 12 litres/min
No.of Passes	: 3

3. Results & Discussions

3.1. Transverse Tensile Test

A tensile test determines the tensile strength of the weld. The tensile test specimen is prepared as per the standard AWS B4.0 The specimen size is 250 X 12.5 X 9mm. Since the fracture occurred in the base metal, the weld metal holds better tensile strength than the base metal and specimen passes the tensile test. The test results are given as follows:

Table 5. *Transverse tensile test.*

Weld joint detail	Uts (mpa)	Fracture position
T23 – t92	654	T23 base metal side
T23 – ss347h	540	T23 base metal side
T92 – ss347h	627	Ss347h base metal side

Figure 4. *Photos revealing transverse tensile test results.*

3.2. Bend Test

A bend test determines the ductility of the welded zone, weld penetration, fusion, strength etc. The specimen passed both root bend and face bend tests because there is no open discontinuity on the bent surface. The Bend test results are given as follows:

Table 6. *Bend test.*

Sl.No.	Combination	Face/Root Bend	Result
1	T23 +T92	ROOT BEND	Passed – No open discontinuity
2	T23 +T92	FACE BEND	Passed – No open discontinuity
3	T92 + SS347H	FACE BEND	Passed – No open discontinuity
4	T92 + SS347H	ROOT BEND	Passed – No open discontinuity
5	T23 +T92	FACE BEND	Passed – No open discontinuity

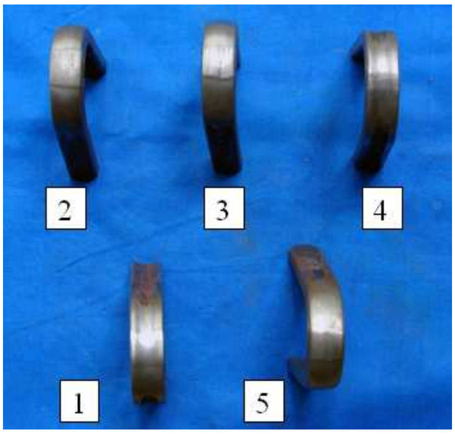

Figure 5. *Photos revealing bend test results.*

3.3. Impact Test

An impact test is done to determine the amount of impact a specimen will absorb before fracturing. The impact test results prove that the dissimilar specimens absorb higher impact energy than the similar metal combination which in turn proves that dissimilar metal combinations have better properties. The Impact test results are given as follows:

Impact test: Sample Test temp: Room temp, Sample size: 5 x 10 x 55 mm

Table 7. *Charpy V-notch with a notch depth of 2mm at the weld.*

Identification	Combination	Impact energy (joules)
1	T23 +t23	17
2	T92 +t92	20
3	T23 +t92	54
4	T23 +t92	45

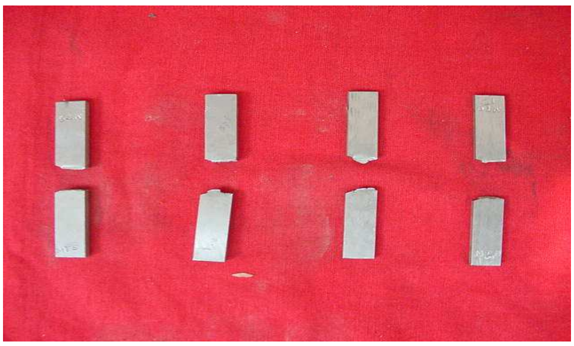

Figure 6. *Photos revealing Impact Test Results.*

3.4. Hot Tensile Test

The hot tensile test is carried out to determine the ultimate tensile strength of the material at elevated temperatures. Since the fracture occurred in the base metal, the weld metal holds better hot tensile strength than the base metal and specimen passes the tensile test. The test results are given as follows:

Table 8. *Hot tensile test.*

Combination	Tested at temperature (°c)	Uts in mpa	Location of failure
T23 +t92	700	317	Base metal – t23
T92 +t92	700	322	Base metal
T23 +t23	700	367	Base metal

Figure 7. *Photos revealing Hot tensile Test Results.*

3.5. Non Destructive X-Ray Radiography

Radiography technique is based upon exposing the weldments to short wavelength radiations in the form of X-rays from suitable source such as an X-ray tube or Co-60 or Ir-192. The source to film distance maintained is 600mm and the exposure time is 100s. The results obtained from this test shows that the defects are within the acceptable limits and therefore the joints were considered as good quality joints. The test results are given as follows:

Testing Parameters:

SOURCE	: Ir 192
Sfd	: 60mm
Exposure time	: 100 second
Material Thickness	: 9m

This test reveals:

- Surface Cracks
- Porosity
- Blow Holes

Figure 8a. *Photo 1.*

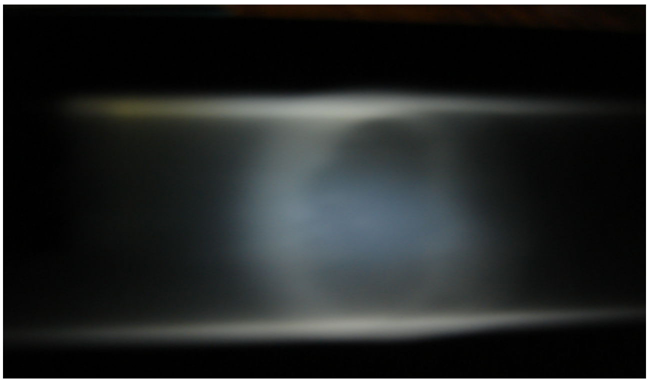

Figure 8b. *Photo 2.*

1. X-ray radiograph revealing gas holes in T23-SS347H
2. X-ray radiograph of defects free T23-T92 specimen

3.6. Metallography Tests

Macro Test

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

Figure 9a. *Macro examinationT92+ASS 347H.*

Figure 9b. *Macro examination T92+T23.*

3.7. Micro Test

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

Micro test Results:

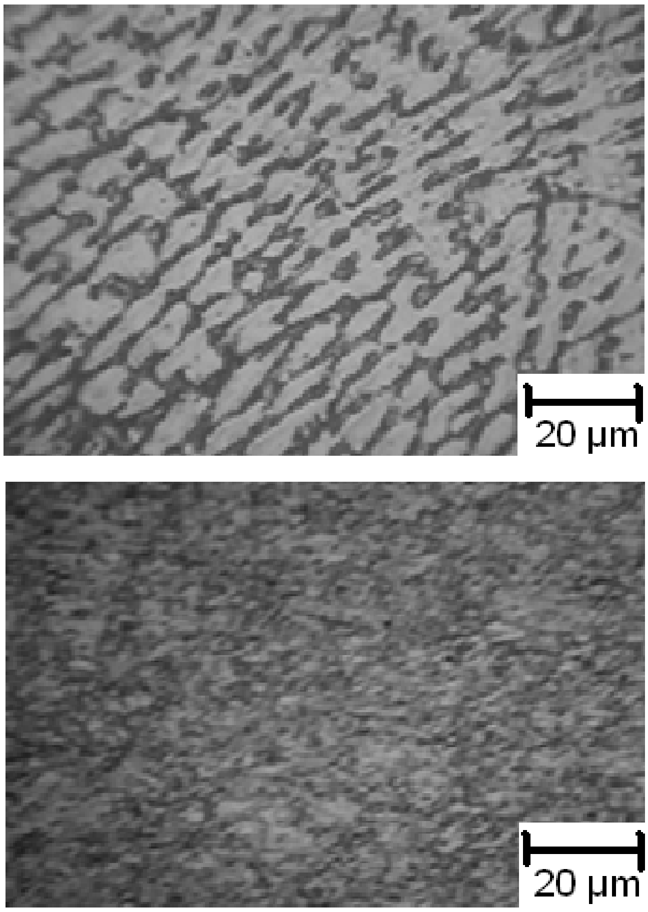

Figure 10.a. *Microstructure ASS 347H+T92 weld, b.Microstructure of T92+T23 weld.*

4. Conclusion

This experiment gives the characterization of dissimilar steel joints welded with newer steel grades using manual TIG process. This experimental work proves that the joints made with newer steel grades like SA 213 T23 and SA 213 T92 has satisfactory bent-ductility, weld tensile strength, toughness & metallurgical properties. This work recommends new steel grades like SA 213 T23 and SA 213 T92 for power-boiler applications. Moreover this work proves that the use of tube materials SA 213 T23 and SA 213 T92 leads to reduction in component wall thickness which leads to a reduction in component weight which in turn reduces the overall cost.

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