

# Dissimilar Steel Welding of Super Heater Coils for Power Boiler Applications

<sup>1</sup>T.S.Senthil, <sup>2</sup>J.Murugesan, <sup>3</sup>D.Rajesh, <sup>4</sup>N.Balaji

<sup>1,2,3,4</sup>Department of Mechanical Engineering, Panimalar Engineering College, Chennai, India  
reachtss@gmail.com, murugesan.kpm@gmail.com, rajesh2energy@gmail.com, balajidomepec@gmail.com

**Abstract**—This paper deals mainly with two types of new materials namely SA213T23, SA213T92 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 argongass shielding. Two combinations of dissimilar welds were carried out and testing was also done. Testing methods comprises of radiography test, transverse tensile, facebend, rootbend, 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.

## I. 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 powerplants calls for new improved creep resistant materials in areas like super heater and reheater applications. The improved properties found in ferritic alloy steels conforming to ASME SA213 code. The use of such steel with higher operating conditions substantially enhances the cycle efficiency and consequential reduction in fuel cost and reducing environmental pollution.

## II. 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 T23 SA 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 I. OPERATING CONDITION OF VARIOUS BOILERS

Power plant	Pressure kg/cm <sup>2</sup> (max)	Temperature °C (max)
SUBCRITICAL	167	540
SUPERCRITICAL	240	580
ULTRASUPER CRITICAL	280	640

### Benefits of Using SA213T23 and SA213T92

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

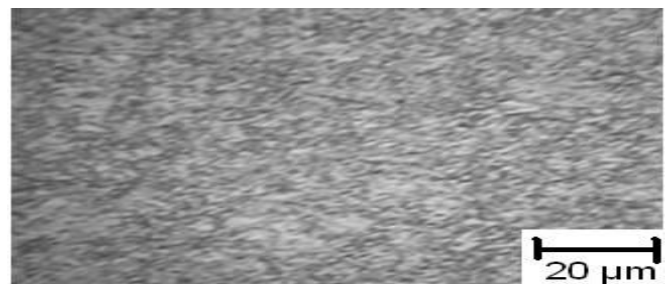


Fig.1 Microstructure of T23 base metal-Bainitic-Martensitic structure

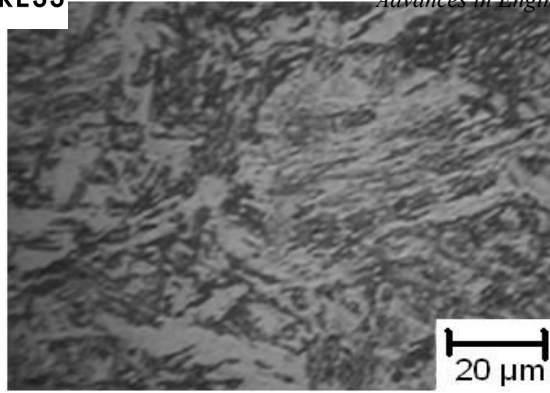


Fig 2. Microstructure of T92 base metal-Tempered Martensitic structure.

TABLE II. CHEMICAL COMPOSITION

Material	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	Niobium	Tungsten
SA213T22	0.05-0.15	0.03-0.60	0.025	0.025	0.5		1.9-2.6	0.87-1.13			
SA213T23	0.04-0.10	0.1-0.60	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
SA213T91	0.07-0.14	0.03-0.60	0.02	0.01	0.02-0.50	0.4	8.0-9.5	0.85-1.05	0.18-0.25	0.06-0.1	
SA213T92	0.07-0.13	0.03-0.60	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	0.03	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			8nc-1.10	

TABLE III. MECHANICAL PROPERTIES

Material	Tensile strength Min (mpa)	Yield strength Min (mpa)	Elongation in 50mm min (%)	Hardness max brinell/vickers
SA213T22	415	205	30	163 hbw/170 hv
SA213T23	510	400	20	220 hbw/230 hv
SA213T91	585	415	20	250 hbw/265 hv
SA213T92	620	440	20	250 hbw/265 hv
TP304H	550	205	35	192 hbw/200 hv
TP347H	515	205	35	192 hbw/200 hv

TABLE IV. TIG WELDING COMBINATIONS

Combination	Filler metal
SA213T23 + SA213T92	T23 filler metal
SS347H + SA213T23	Inconel-82
SS347H + SA213T92	Inconel-82
SA213T92 + SA213T92	T23 filler metal
SA213T23 + SA213T23	T23 filler metal



Figure 3. TIG welding combinations

WELDING PARAMETERS	
T23-T92	
Process	:Manual TIG
Material	:SA213T23-SA213T92
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 liters/min  
No. of Passes :3

T23-SS347H  
Process :Manual TIG  
Material :SA213T 23-SA213SS347H  
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

### III. RESULTS AND DISCUSSION

#### A. 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 250X12.5X9mm. 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 III. TRANVERSE 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



Fig. 4.Photos revealing transverse tensile test results

#### B. BendTest

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:

SL.No.	Combination	Face/RootBend	Result
1	T23+T92	ROOTBEND	Passed-No open discontinuity
2	T23+T92	FACEBEND	Passed-No open discontinuity
3	T92-SS347H	FACEBEND	Passed-No open discontinuity
4	T92-SS347H	ROOTBEND	Passed-No open discontinuity
5	T23+T92	FACEBEND	Passed-No open discontinuity

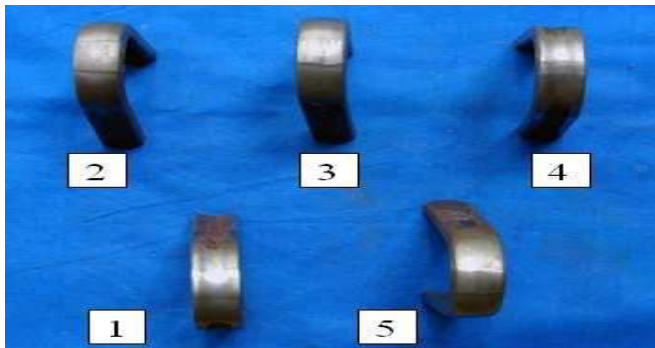


Fig. 5.Photos revealing bend test results

#### C. ImpactTest

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 x10 x55 mm

TABLE IV. 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



Fig. 6.Photos revealing Impact Test Results

#### D. 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 V. HOT TENSILE TEST

Combination	Testedat temperature (°C)	Uts in mpa	Locationof failure
T23+t92	700	317	Basemetal -t23
T92+t92	700	322	Basemetal
T23+t23	700	367	Basemetal



Fig.7 .Photos revealing Hot tensile Test Results.

#### E. Non Destructive X-Ray Radiography

Radiography technique is based upon exposing the weld ments to short wavelength radiations in the form of X-rays from suitable sources chasan 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 :Ir192
- Sfd:60mm
- Exposuretime :100 second
- MaterialThickness :9m

**This test reveals:**

- SurfaceCracks
- Porosity
- BlowHoles

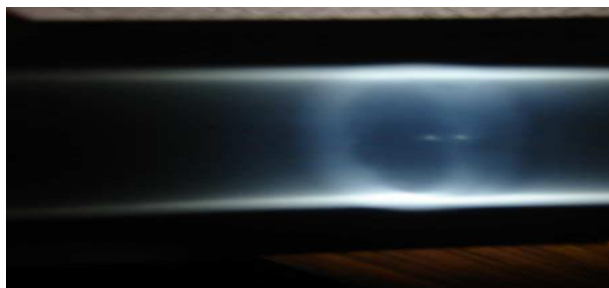


Figure 8a.Photo 1



Figure 8b.Photo 2.



Fig. 9a.Macro examination T92+ASS 347H.



Fig. 9b.Macro examinationT92+T23.

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

**F. Metallography Tests**

**MacroTest :**

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

**G. MicroTest**

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:

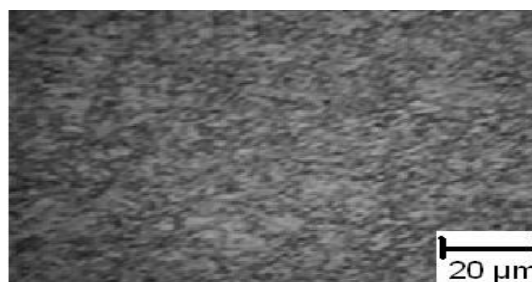
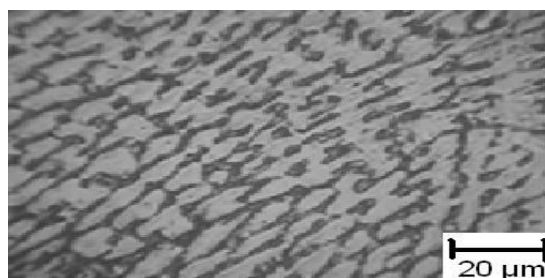


Fig. 10.a. Microstructure ASS 347H+T92 weld, b.Microstructure ofT92+T23weld.

#### IV. 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 SA213T23 and SA213T92 has satisfactory bent-ductility, weld tensile strength, toughness & metallurgical properties. This work recommends new steel grades like SA213T23 and SA213T92 for power-boiler applications. More over this work proves that the use of tube materials SA 213T23 and SA 213T92 leads to reduction in component wall thickness which leads to a reduction in component weight which in turn reduces the overall cost.

#### REFERENCES

- [1] ASMESECTIONIIC, SFA5.28
- [2] J.D.Farren.JN.DuPont,"Fabricationof Carbon Steel to Stainless Steel Transition Joints using Direct Laser Deposition A Feasibility Study",WeldingJournal– March2007.
- [3] A.W.Marshall. Z.Zhang "Elding Consumables for P92 and T23 steels", Welding and repair for power plants, June 2002.
- [4] N. F. Eaton, B. A. Glossop,"The Welding of Dissimilar creep-resistingferriticsteels".
- [5] IanFarmer, "Narrowing the gap with hot wire Orbital TIG", Editor Welding and Metal Fabrication Magazine.
- [6] B.Scarlin, R.Gerdes, R.Vanstone. "Materials Development for Ultra Super Critical Steam Turbines", Advances in material technology for fossil power plants – 2004
- [7] J. F. Henry,J. D. Fishburn, I. J. Perin, "Advanced Super Critical Technology : Back to the future" Advances in material technology for fossil power plants – 2004  
J.T.Kim."Development of Martensitic/ferritic heat resistant steels for USC power plants", The 3rd international conference on Advances Structural Steels, Gyeongin, Korea, (August 22-24, 2006)
- [8] ASMESECTIONIXQualification
- [9] AWS Handbook Volume IV, Materials and Application, Part-2 Eighth Edition
- [10] R.W.Swindeman, Oak Ridge National Laboratory, USA., B.W.Roberts Consultant, Tennessee, U.S.A., K.Coleman, Electrical Power ResearchInstitute, U.S.A., " Issues in replacing Cr-Mosteels & Stainless with 9Cr-1Mo-Vsteel" International Journal of Pressure Vessels & Piping81 (2004) 507-512