

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

# Experimental Investigation and Analysis of Dissimilar welding of AISI 316 L and IS 2062 using GTAW

S.Giridharan<sup>1</sup>, TTM.Kannan<sup>2</sup>, K.Balamurugan<sup>3</sup>, Arun Kumar<sup>4</sup>, Vignesh<sup>5</sup>

Asst. Professor, Department of Mechanical Engineering, PRIST University, Thanjavur, India<sup>1</sup>

Associate Professor, Department of Mechanical Engineering, Indra Ganesan College of Engineering ,Trichy, India<sup>2,3</sup>

UG students, Department of Mechanical Engineering, PRCET, Thanjavur, India<sup>4,5</sup>

**ABSTRACT:** Joining of dissimilar metals has found its use extensively in power generation, electronic, nuclear reactors, petrochemical and chemical industries. This Experimental work investigates the technical considerations of dissimilar metal welding between IS2062 Grade C mild steel and 316L stainless steel using the GTAW process. Finite element analysis of dissimilar metal joints are also analyzed and compared with experimental work. Experiments are performed to study about the microstructure, Tensile strength and bending behavior of dissimilar metal joints.

**KEYWORDS:** dissimilar welding, GTAW, Microstructure, Tensile strength, Bend test , Analysis.

### I. INTRODUCTION

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding is an arc welding process that uses an non consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. Chengwu et al. [1] in their work on weld interface microstructure and mechanical properties of copper-steel dissimilar welding, the microstructure near the interface between Cu plate and the intermixing zone was investigated. Experimental results showed that for the welded joint with high dilution ratio of copper, there was a transition zone with numerous filler particles near the interface. However, if the dilution ratio of copper is low, the transition zone is only generated near the upper side of the interface. At the lower side of the interface, the turbulent bursting behavior in the welding pool led to the penetration of liquid metal into Cu. The welded joint with lower dilution ratio of copper in the fusion zone exhibited higher tensile strength. Jiang and Guan [2] studied the thermal stress and residual stress in dissimilar steels. They suggested that large residual stresses are induced by welding in the weld metal and heat affected zone (HAZ), which superimpose and increase the thermal stress. Gyun Na, Kim and Lim [3] studied the residual stress and its prediction for dissimilar welds at nuclear plants using Fuzzy Neural network models. The factors that have an impact upon fatigue strength are residual stress, stress concentration, the mechanical properties of the material, and its micro and macro structure. They stated that residual stress is one of the most important factors but its effect on high-cycle fatigue is of more concern than the other factors. Residual stress is a tension or compression that exists in a material without any external load being applied, and the residual stresses in a component or structure are caused by incompatible internal permanent strains. Welding, which is one of the most significant causes of residual stress, typically produces large tensile stresses, the maximum value of which is approximately equal to the yield strength of materials that are joined by lower compressive residual stresses in a component. The residual stress of welding can significantly impair the performance and reliability of welded structures. The integrity of welded joints must be ensured against fatigue or corrosion during their long use in welded components or structures. On stress corrosion cracking

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

stated that stress-corrosion cracking usually occurs when the following three factors exist at the same time: susceptible material, corrosive environment, and tensile stress including residual stress. Thus, residual stress becomes very critical for stress-corrosion cracking when it is difficult to improve the material corrosiveness of the components and their environment under operating conditions. Khan et al. [4] studied laser beam welding of dissimilar stainless steels in a fillet joint configuration and during the study metallurgical analysis of the weld interface was done. Fusion zone microstructures contained a variety of complex austenite ferrite structures. Local micro-hardness of fusion zone was greater than that of both base metals. The welding fusion zone microstructure consists of mostly primary ferrite dendrites with an inter-dendrites layer of austenite. This austenite forms through a peritectic–eutectic reaction and exists at the ferrite solidification boundaries at the end of solidification. Some lathy ferrite morphology is also observed in this zone. This is due to restricted diffusion during ferrite–austenite transformation that results in a residual ferrite pattern. They came to the conclusion that formation of ferrite along the austenite grain boundary in the heat affected zone on austenite side is observed. At the same time, microstructures are composed of two-phase ferrite and martensite with intra-granular carbide on ferrite side. Also the variation in local micro-hardness observed across the weld depends on the fraction intermix of each base metal and the redistribution of austenite- and ferrite-promoting elements in the weld. Itoh et al. [5] got a patent on the joined structure on the dissimilar metallic materials. This invention relates generally to a joined structure of dissimilar metallic materials having different characteristics. More specifically, the invention relates to a joined structure of a current carrying contact or arching contact which are used for, e.g., a power breaker, or a coating end structure of a metal base and a coating material for improving conductivity and heat resistance. Delphin, Sattari-Far and Brickstad [6] studied the effect of thermal and weld residual stresses on CTOD (Crack Tip Opening Displacement) in elastic-plastic fracture analysis. They stated that structures may fail because of crack growth both in welds and in the heat affected zone (HAZ). The welding process itself induces residual stresses in the weld and HAZ, which contribute to crack growth. They used a non-linear thermoplastic finite element model to simulate the circumferential weld in a relatively thin-walled stainless steel pipe. After the pipe had cooled down after welding a circumferential surface crack was introduced. The crack, located in the centre of the weld, was subjected to two types of loads. Firstly, the welded pipe was subjected to a primary tensile load, and then to a secondary thermal load. They stated that the choice of hardening model is important. It is believed that kinematic hardening is a better choice than isotropic hardening in low cycle simulations i.e. in a few-pass welding process, as in the present study. For the case of weld residual stresses in combination with high thermal stresses, it is found that the plasticity induced by the thermal stresses is not sufficient to suppress the influence of weld residual stresses on CTOD, even for very high thermal loads. The residual stresses can be relaxed by unloading from a primary tensile load. Mai and Stowage [7] did their work on characterization of dissimilar joints of steel-kovar, copper-steel and aluminium-copper. It was stated in their work that joining of dissimilar materials is one of the challenging tasks facing modern manufacturers. Dissimilar metal welding technologies find application in many sectors such as micro-electronics, medical, optoelectronics and micro systems. The tiny geometry of the joints and the different optical and thermal properties of the materials makes laser welding one of the most suitable production methods.

### II. FINITE ELEMENT ANALYSIS OF DISSIMILAR METAL JOINTS

The results that are obtained after the weld simulation can be taken considering . In the first case AISI 309L stainless steel has been taken as the weld filler metal whose properties are taken the same as AISI 316L stainless steel which is one of the parent metals. So the results inferred from all the stress acted on it. Thermal stress has developed inside the welded part as both of its ends across the weld have been fixed against any kind of motion by setting up in nodal displacement in all directions as zero. This is the boundary conditions used in all areas.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

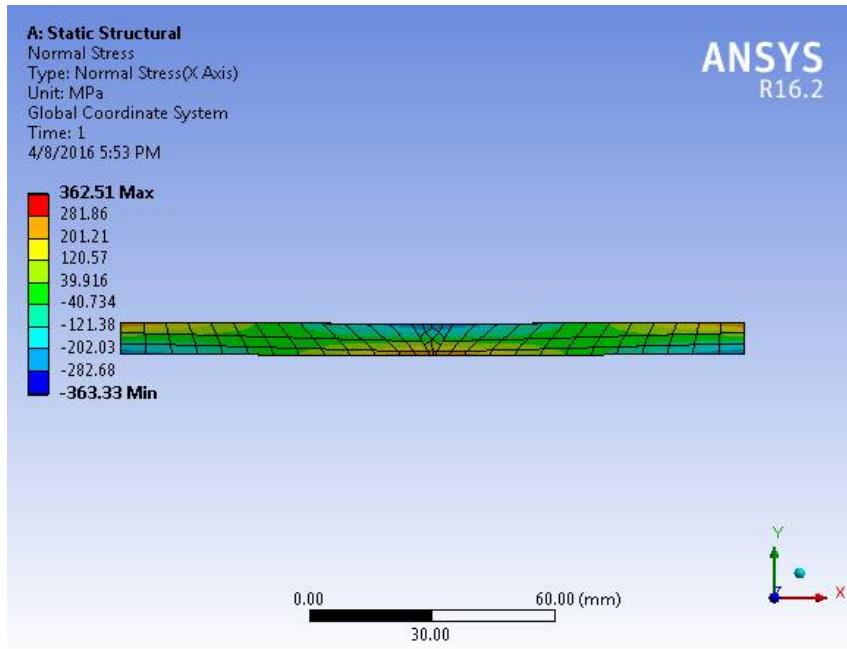


Fig 1 Normal stress contour of Model

The normal stress varies from 362 MPa tensile to 363MPa compressive. The peak of the tensile lies along the centerline of the weld metal. However peak of the compressive stress lies in the weld interface of weld filler metal and IS 2062 mild steel.(fig1)

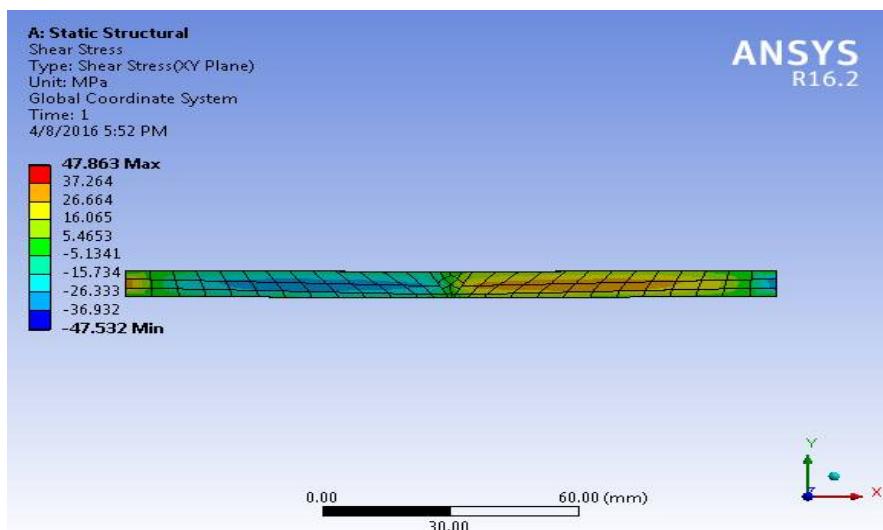


Fig2 Shear stress contour of Model

The shear stress varies from 478 MPa positive to 475 MPa negative. However peak of the shear stress lies in the weld interface of weld filler metal and 2062 mild steel. From the above two cases it is very clear that the weld interface on

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

the 2062 mild steel is the highest risk zone, where the failure is most likely to occur. The shear stress distribution along the line P is shown in Fig. 2

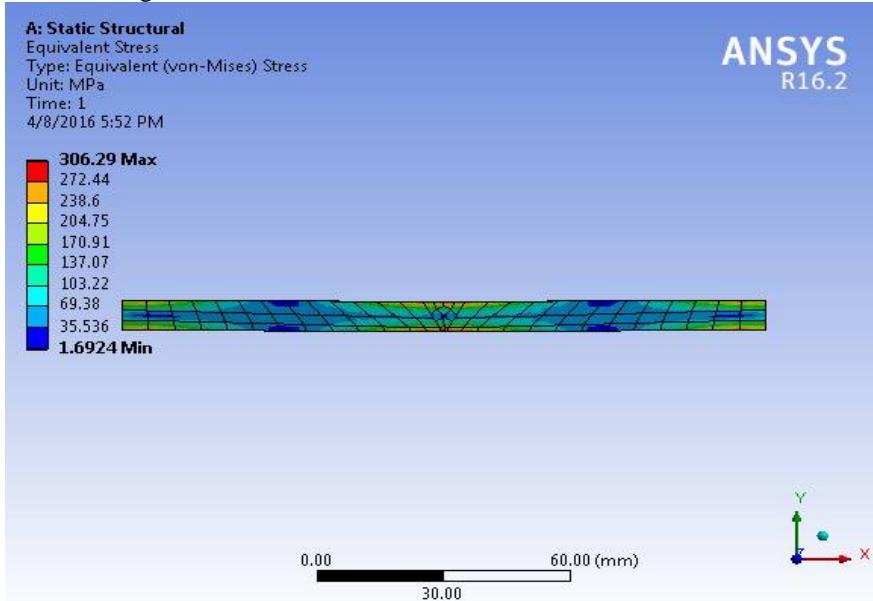


Fig 3 von-mises stress

The value of von-mises stresses developed in the welded joint in the model is 306 MPa of the tensile nature and 169 MPa of the compressive nature. The maximum tensile stress is located at the centre of the welded joint and is much localised.(fig 3)

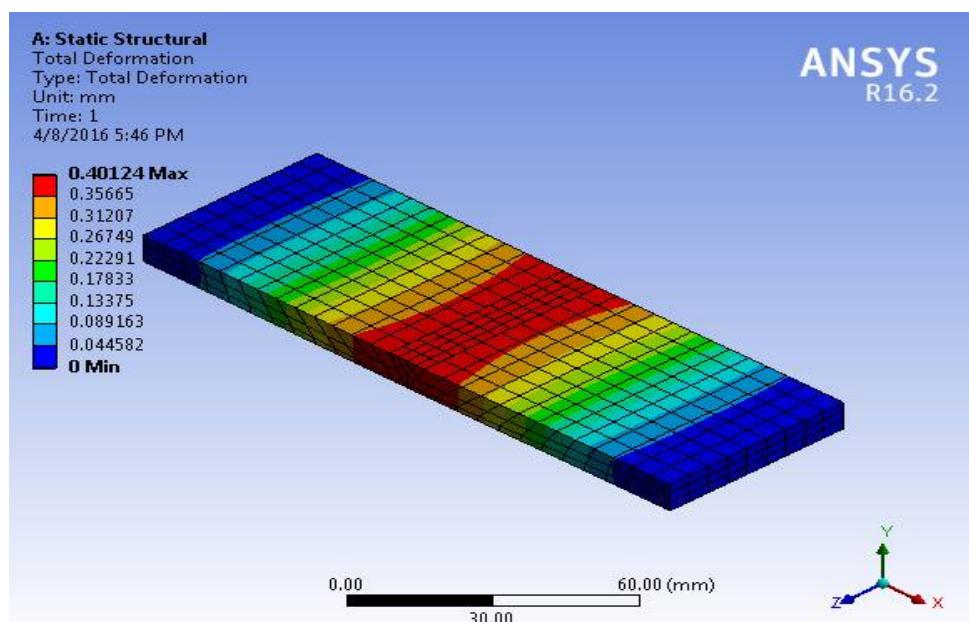


Fig 4 Total deformation

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

The total deformation result shows that tensile value in the weld joint to be 410 Mpa then the weld zone to be deformed. The total stress occurred in the center line of the weld joint (fig 4)

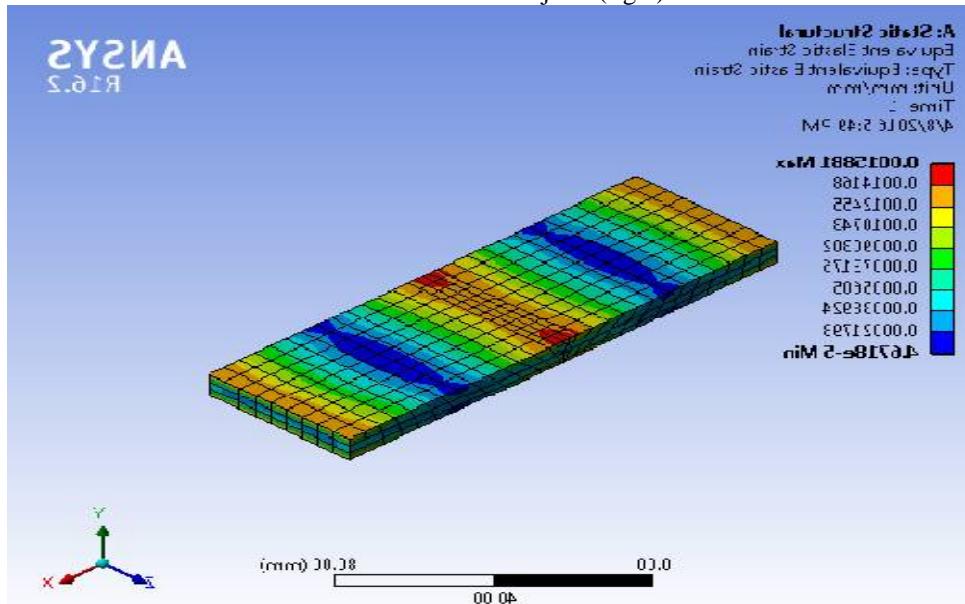


Fig 5 Equivalent elastic strain

The analysis of strain which is a parameter in deciding the susceptibility of stress corrosion cracking is discussed in the next paragraph. In line with the stresses the contour of equivalent strain also depicts that a maximum strain of 0.001 m/m is also located in the weld interface on the IS 2062 mild steel side. This means that this interface has the highest deformation.

### III. Tensile Test



Fig 6 Tensile test specimen

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

Tensile testing was carried out using Universal Testing Machine of 400 KN capacity and the geometry of the test specimen is as shown in Fig. 1. Mechanical proprieties of GTAW welded dissimilar welds of stainless steel and mild steel after tensile test are tabulated in respectively. Tensile strengths of welded test samples vary from 394 to 457 MPa depending upon the welding conditions. All the specimens broke in the weld region and parentage of elongation measured across the weldment using an extensometer show ductility ranging from 4.9% to 6.6%. The variation of average values of ultimate tensile value, yield strength and percentage elongation for each test sample has been plotted in Figure 3 and 4 respectively for GTAW welded joints.

1. Tungsten Inert Gas Welding is more suitable than other welding process, and welding for dissimilar metal welding of mild steel and stainless steel(fig 6) TIG welding process provides better strength. It may be because of less porosity in dissimilar metal welds during TIG welding and carbon precipitation which comes out due to welding is also less. The low percentage of free carbon allows the product (welded stainless steel with mild steel) better corrosion resistivity, ductility and strength.
2. The main advantage of TIG which reduces welding developing cracks and pores on the surface of material.
3. The percentage dilution in stainless steel is higher in TIG welded dissimilar joints which may be the reason of chromium loss due carbon precipitation in the joints and higher corrosion resistance.
4. The dissimilar metal joint of AISI 316L and mild steel has the best ductility for both TIG and also in other welding processes.
5. The yield strength of dissimilar joint of IS2062 and mild steel is best for both TIG and welding process.
6. The dissimilar metal joint of AISI 304 and mild steel has poor ultimate tensile stress for both TIG and welding processes.(Table1)

Table 1 Tensile test values of Dissimilar metal welded joints (AISI 316L & IS 2062)

Stress(Mpa)	Strain(%)	Force(N)	Position(mm)	Time(sec)
0	0	0	0	0.109
36.6	1.16	878	0.347	21
69	2.37	1660	0.71	42.8
128	3.58	3060	1.07	64.5
187	4.79	4480	1.44	86.3
243	5.99	5840	1.8	108
279	7.2	6690	2.16	130
298	8.41	7150	2.52	152
314	9.62	7540	2.89	173
328	10.8	7860	3.25	195
339	12	8140	3.61	217
349	13.3	8380	3.98	239
357	14.5	8580	4.34	260
364	15.7	8740	4.7	282
369	16.9	8860	5.60	304

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

372	19.3	8920	5.79	347
366	20.5	8780	6.15	369
352	21.7	8450	6.51	391
328	22.9	7870	6.88	413
287	24.1	6880	7.24	435

IV. Bend Test: Bend test is a simple and inexpensive test that can be used to evaluate both ductility and soundness of metal joints. The strain applied to the specimen depends on the diameter of the former around which the coupon is bent and this related to the thickness of the coupon 't', normally expressed as a multiple of 't' eg 3t, 4t etc. The former diameter is specified in the test standard and with the strength and ductility of the material - the former diameter for a low ductility material such as a fully hard aluminium alloy may be as large as 8t.

In cutting the coupon from the test weld the effect of the cutting must not be allowed to affect the result. Thus it is necessary to remove any HAZ from flame cutting or work hardened metal if the sample is sheared. It is normal to machine or grind flat the face and root of a weld bend

test coupon to reduce the stress raising that these would have. Sharp corners can cause premature failure and should be rounded off to a maximum radius of 3mm.



Fig 7 Face bent of weld joint



Fig 8 Root bend of weld joint

### V. CONCLUSION

In this Experimental work presents a study of mechanical properties in a dissimilar welding joint between IS 2062GrC mild steel and AISI 316L stainless steel, using AISI 309L filler rod. It increases the weld zone strength has been discussed. From the results above that arrive the following conclusions

- The hardness survey revealed how the weld zone strength is increased as a result of base metal dilution. In addition, the HAZ of solutionized 316L will increase in strength.
- The weld tensile test indicated that a AISI 316L and IS 2062C dissimilar metal with AISI 309L as filler using GTAW process can be performed as a strength of 372 Mpa, normal tensile yield strength of MS about 200Mpa. It indicates it would increase the total yield strength of specimen.
- Electron microscope shows the change of metal migration towards base metal. On studying fusion zone and HAZ of mild steel, Stainless steel on using AISI 309L have higher dilution of base metals in weld area. Hence, the welded area strength is better.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

- The bend test of AISI 316L and AISI 2062C dissimilar metal with AISI 309L as filler rod. Is haven't any visual defect, when using (4T -180 degree) bending angle. It shows, had better bending behavior.

### REFERENCES

- [1]Chengwu Yao, Binshi Xu, Xiancheng Zhang, Jian, Huang, Jun Fu and Yixiong Wu "Interface microstructure and mechanical properties of laser welding copper-steel dissimilar joint" Optics and Lasers in Engineering, Vol. 47, 2009, PP 807–814.
- [2] Wen-chun Jiang and Xue-wei Guan "A study of the residual stress and deformation in the welding between half-pipe jacket and shell" Materials and Design, Vol. 43, 2013, PP 213-219.
- [3] Man Gyun Na, Jin Weon Kim and Dong Hyuk Lim "Prediction of Residual Stress for dissimilar metals welding at nuclear plants using Fuzzy Neural Network Models" Nuclear Engineering and Technology, Vol. 39, 2007, PP 337- 348.
- [4] M.M.A. Khan, L. Romoli, M. Fiaschi, G. Dini and F. Sarri "Laser beam welding of dissimilar stainless steels in a fillet joint configuration" Journal of Materials Processing Technology, Vol. 212, 2012, PP 856-867.
- [5] Yoshiya Sultoh and Kabushiki Kaisha Toshiba "Joined structure of dissimilar metallic materials" Patent Publication Number, EP0923145A2, 1999.
- [6] P. Delphin, I. Sattari-Far and B. Brickstad "Effect of thermal and weld induced residual stresses on the j-integral and ctod in elastic-plastic fracture analyses" Final Report Vol. SINTAP/SAQ/03, 1998, PP 1-47.
- [7] T.A. Mai and A.C. Spowage "Characterization of dissimilar joints in laser welding of steel-kovar, copper-steel and copper-aluminium" Materials Science and Engineering, Vol. 374, 2004, PP 224-233.