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MEASUREMENT OF RESIDUAL STRESS DISTRIBUTION AND FATIGUE LIFE ASSESSMENT OF SIMILAR AND DISSIMILAR BUTT WELDED JOINT

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ABSTRACT
The welding process induces residual tensile stress that is detrimental to fatigue life. Tensile stresses act to stretch or pull apart the surface of the material. With enough load cycles at a high enough tensile stress, a crack is initiated. Significant improvement in fatigue life can be obtained by modifying the residual stress level in the material. The intent of this work is to measure the residual stress distribution and fatigue life assessment of butt welded joint with similar (M.S and M.S) and dissimilar (SS304L and M.S IS 2062) materials. The residual stress level in these joints is evaluated accurately by X-ray diffraction, before and after the surface modification. The surface modification method employed is shot peening, which is simple and yet effective to improve the fatigue life of the joint. In this study an experiment was carried out into the effect of shot peening upon improvement in the fatigue strength, which validates the FEA static structural analysis carried out for the joint.

KeyWords: *Similar and Dissimilar joints*

I. INTRODUCTION

Welding process is an integral part of any mechanical industry. Most industrial machines and the structures that support them are subjected to fluctuating loads over their lifetimes, even if nothing more than the cyclic loading associated with starting and stopping. The vast majority of these machines are assembled, at least in part by welding, which means that their welded joints must sustain those changing loads over the life of the machine. In steam generating power stations, the parts of boilers that are subjected to lower temperatures as in the primary boiler tubes and heat exchangers are made of mild steel for economic reasons. Other parts, such as the final stages of the super heaters and repeaters operating at higher temperatures where increased creep strength and resistance to oxidation are required, are constructed with austenitic stainless steels. Therefore, transition welds are needed between the two classes of materials. Dissimilar metal weld is also used to analysis of strength of joint. Because of due to residual stress induces in the weld. We can find the amount of residual stress in two different metals [4].

Welding process induces residual stress that is detrimental to fatigue life.[1] Residual stresses in welded joints primarily develop due to differential weld thermal cycle (heating, peak temperature and cooling at the any moment during welding) experienced by the weld metal and region closed to fusion boundary which is the heat affected zone. Type and magnitude of the residual stresses vary continuously during different stages of welding (heating and cooling). During heating primarily compressive residual stress is developed in the region of base metal which is being heated for melting due to thermal expansion and the same thermal expansion is restricted by the low temperature surrounding base metal. After attaining a peak value, the compressive residual stress gradually decreases owing to softening of metal being hea ted. Compressive residual stress near the surfaces eventually reduces to zero as soon as the melting starts and a reverse trend is observed during cooling stage of the welding. During cooling as metal starts to shrink, tensile residual stresses develop and their magnitude keeps on increasing until room temperature is attained. Tensile residual stress act to stretch or pull apart the surface of the material. With enough load cycles and high enough tensile stress, a metal surface will initiate crack [1]. It is well known that when a component fails in fatigue, the failure location is usually the welded zone. Residual stress directly affects a components fatigue life [6]. High tensile weld residual stress is one important factor contributing to fatigue crack development even under reversal or compressive cyclic loadings. A compressive stress induced by post-weld treatment is beneficial by eliminating the tensile residual stresses and generating compressive residual stresses, which improves fatigue strength of welded structures [5]. Shot peening, Hammer peening and Heat treatment are some of the few methods used in eliminating the residual tensile stress. Shot peening method, which requires simple equipment and treatment, is extensively employed as a method to improve fatigue strength and to reduce the tensile stress in the component.The residual stress distribution in the similar and dissimilar joints is measured before and after the surface enhancement process using an X-ray diffraction equipment. Fatigue Analysis is carried out to predict the fatigue life of the joints by a commercial available software called ANSYS Workbench version 14.0. The fatigue life of the joints is determined experimentally with the help of fatigue testing machine TM7001.

II. EXPIREMENTAL DETAILS

In this work, dumbbell specimens were prepared with ASTM E647 specifications. IS 2062 plate and stainless steel 304l plate of 4 mm × width 20 mm × length 110 mm were subjected to bead-on-plate welding under the following welding condition: welding current 180 A, arc voltage 21 V, welding speed 1100 mm/min and weld width 3 to 4 mm, While the plate was restrained and continued to restrained for 30 minutes, following the completion of welding. Two plates of size 110x20x4 mm is taken for welding and single V-joint with bevel angle 35 degrees, root face 3 mm are prepared. The plate is butt-welded by shielded metal arc welding process with E-6013 electrode. Butt weld joint is prepared with good surface finishing conditions and with an electrode specification E-6013. Then milling of the plates as per specimen diagram is given below. Figure1 explains the geometry details of Dumbbell Specimen for Experimental Testing. Table1 and Table 2, gives the material chemical composition. Table 5 and Table 6 gives the material properties of the materials.

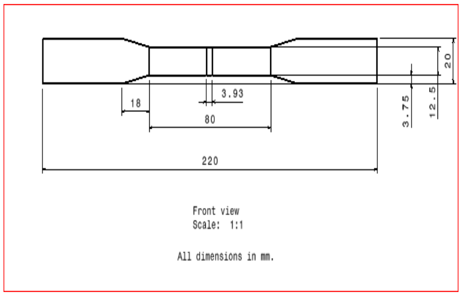

Figure1: Specimen Dimensions

Table1: Chemical Composition of IS2062 in % weigh

C	Mn	Si	P	S	Fe
0.05-0.18	0.7-0.9	0.40	0.04	0.04	Balance

Table2: Mechanical Properties of IS2062

Cycles	Stress MPa	Properties	Quantity
10	407.5	ρ	7800kg/m^3
20	407.4	E	200GPa
50	407.3	υ	0.3
100	407.2	σ_Y	250MPa

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200	407.1	σ_t	345MPa
2000	407		
10000	406.9		
20000	406		
100000	402		
200000	397		
1000000	356		

Table3: Chemical Composition of SS 304 in % weight

C	Mn	Si	P	S	Cr
<0.03	<2	<0.75	0.045	<0.03	18-20
Ni	N	Fe			
8-12	<0.1	Balance			

Table 4:Mechanical Properties of SS 304L

Stress	Cycles MPa	Properties	Quantity
10	562.5	P	7600kg/m^3
20	562.4	E	189GPa
50	562.3	υ	0.33
100	562.2	σ_Y	170MPa
200	562.1	σ_t	480MPa
2000	562		
10000	561		
20000	560		
100000	551		
200000	540		
100000	455		

III. RESIDUAL STRESS MEASURMENT

The atomic planes of a crystal cause an incident beam of X-rays to interfere with one another as they leave the crystal. The phenomenon is called X-ray diffraction. The X-ray method is a non-destructive technique for the measurement of residual stress, the resulting elastic strains cause the atomic planes in the metallic crystal structure to change their

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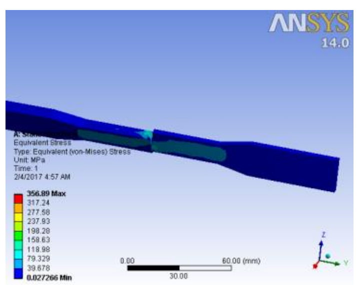
spacing. X-ray diffraction can directly measure this inter-planar atomic spacing; from this quantity, the total stress on the metal can then be obtained. In this project work, we are using a non-destructive technique of X-ray diffraction type to measure residual stress in the given specimens. The residual stress values are given in table 3.

Table3. Residual Stress distribution in Psi

Specimen	Before shoot peening	After shoot peening
IS2062-IS2062	4	-186
IS2062-SS304L	3.75	-190

IV. FEA MODELS

Vinod M. Bansode et al. [7] investigated about the failure analysis based on stress life approach, which is useful for predicting the life time of weld in the structure. In this project the fatigue life of the similar and dissimilar butt welded joint, before and after the surface modification is estimated with the FEA software ANSYS 14. Linear static structural analysis is carried out for the four conditions. The model is generated and assembled using CATIA V5. The generated model is imported to ANSYS 14 through .igs format. The residual stress values obtained from XRD is converted into force and its components are applied on the appropriate surface of the span length. One end of the structure is fixed and a counter clockwise moment is applied on the other side of the specimen to establish a twisting action. The Von-Misses stress distribution, Fatigue Life and safety of the structure is determined for different moments. Figure:2. Shows the Von-Misses stress distribution in the joints. Graph:1 Shows the relation between load versus Von-Misses stress distribution. Graph:2 Shows the relation between load versus life. Graph:3 Shows the relation between load versus safety of the structure.



IS2062:IS2062 joint at 1.4N tensile residual stress.

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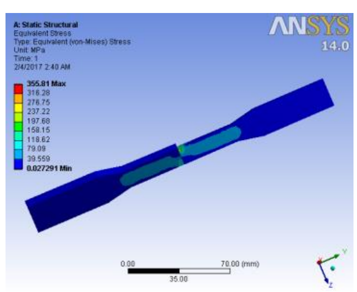

IS2062:IS2062 joint at 645N compressive residual stress

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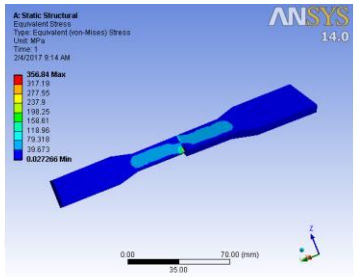
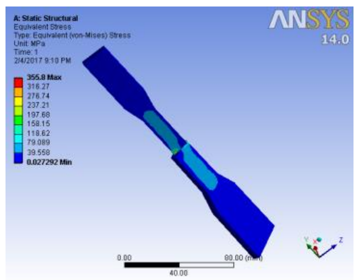


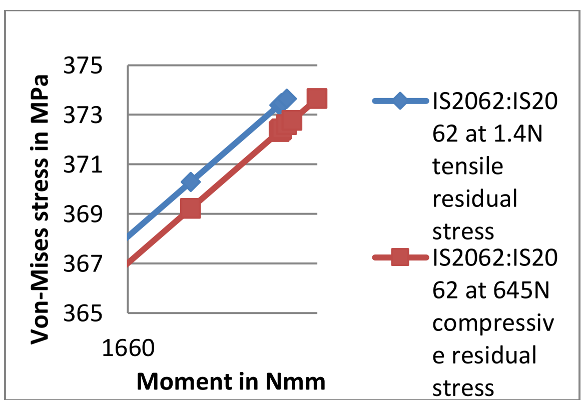
SS304l:IS2062 joint at 1.3N tensile residual stress.



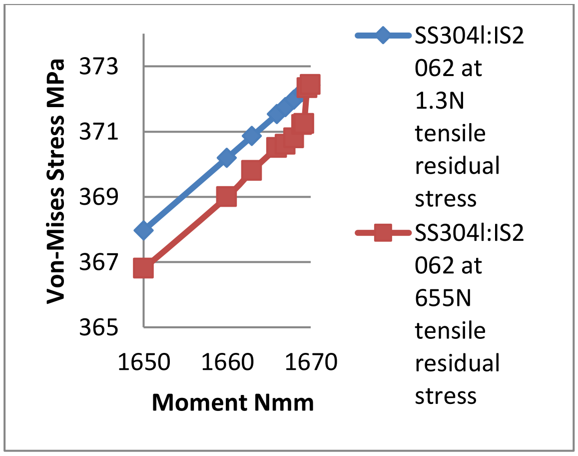
SS304l:IS2062 joint at 655N compressive residual stress.

Figure2: Shows the Von-Misses stress distribution in joints before and after surface enhancement at 1600Nmm.

Graph1: Von-Mises Stress distribution versus Moment.

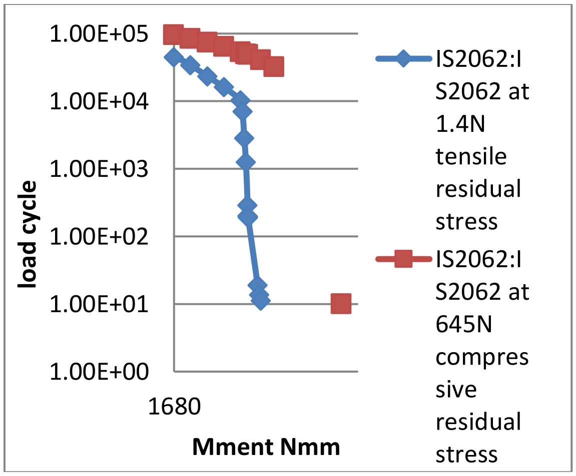


IS2062:IS2062 butt welded joint

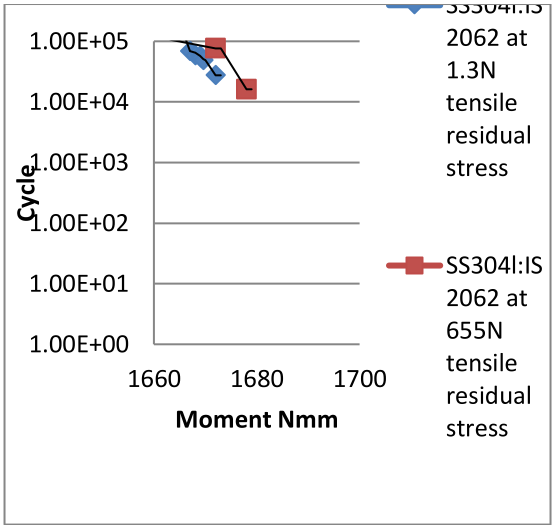


SS304l:IS2062 butt welded joint

Graph2: Cycles versus Moment.

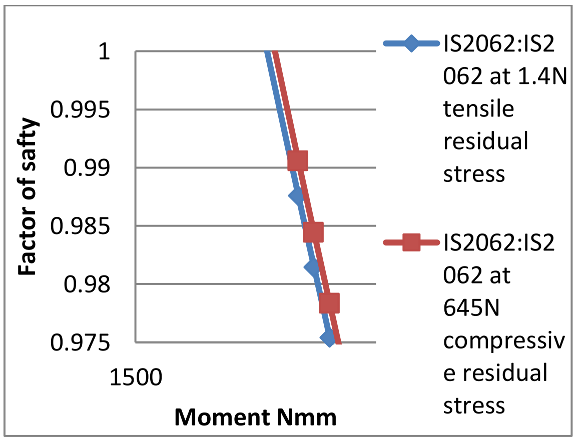


IS2062:IS2062 butt welded joint



SS304l:IS2062 butt welded joint

Graph3: Safety versus Moment.



IS2062:IS2062 butt welded joint

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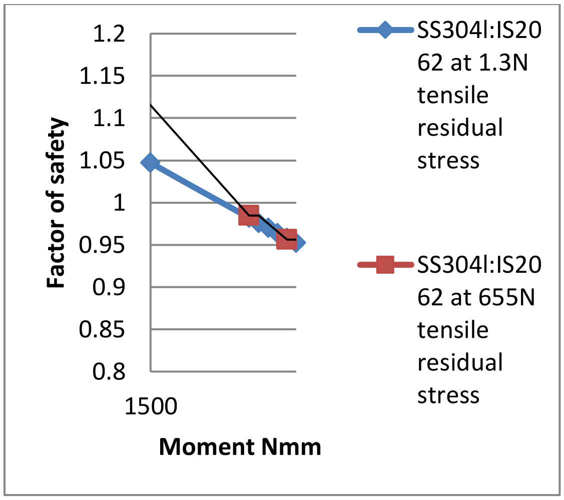

SS304l:IS2062 butt welded joint

V. FATIGUE TEST

Rotating fatigue testing machine TM7001 is employed to carry out the fatigue analysis. The fatigue specimen is gripped on to a motor at one end to provide the rotational motion whereas the other end is attached to a bearing and also subjected to a load or stress. When the specimen is rotated about the longitudinal axis, the upper and the lower parts of the specimen gauge length are subjected to tensile and compressive stresses respectively. Therefore, stress varies sinusoidal at any point on the specimen surface. The test proceeds until specimen failure takes place. The number of cycle for which the specimen withstands without any failure is noted down. This cycle is known as fatigue strength of given specimen. The revolution counter is used to obtain the number of cycles to failures corresponding to the stress applied increasing of the load applied to the fatigue specimen results in a reduction in number of cycles to failure. The fatigue test is normally conducted using eight specimens in order to provide sufficient information for the interpretation of fatigue behaviour of the tested material. High applied cyclic stress results in a low number of cycles to failure. As the cyclic stresses reduces, the number of cycles to failure increases. At the fatigue endurance limit, there will be a certain value of the cyclic stress where specimen failure will not occur. This cyclic stress level is called the fatigue strength. The specimen is rotated at 2500 rpm. The average of the eight results obtained is tabulated in Table 5.

Table5: Fatigue Fracture Life before and after shot peening.

Joint	Load (N)	Before Shot Peening	After Shot Peening
IS2062:IS2062	25	35475	49942
SS304L:IS2062	25	45372	61266

VI. ROCKWELL HARDNESS TEST

Rockwell hardness tester presents direct reading of hardness number on a dial provided with the machine. In this project work we are measuring the hardness on steel surface. So, scale used in this case is ‘A’. Diamond indenter is used and dial used is black. During the experiment first the specimen is placed on the anvil surface. Then the indenter ball makes contact with specimen surface. Load lever is released and is applied for minimum 15 second. Load of 60 kgf is applied by means of the leaver. The readings are tabulated in Table6.

Table6: Experimental result of Rockwell Hardness Number (HCR) on the heat affected zone in the specimens before and after shot peening.

Joint	Load (Kgf)	Before Shot Peening HCR	After Shot Peening HCR
IS2062:IS2062	60	52	63
SS304L:IS2062	60	57	65

VII. CONCLUSION

The Fatigue life of the similar and dissimilar but welded joints is estimated by FEA and experimentally. The results indicated the following:-

- From FEA the Von-MIses stress distribution values for the same loading condition before and after shot peening is reduced by 0.36% in IS2062:IS2062 joint and by 0.30% in SS304L:IS2062.
- From FEA the Life cycle before failure values for the same loading condition before and after shot peening is increased by 3.9872% in IS2062:IS2062 joint and by 5.845% in SS304L:IS2062.
- From FEA the Safety of the structure for the same loading condition before and after shot peening is increased by 2.33% in IS2062:IS2062 joint and by 2.30 %in SS304L:IS2062.
- The Rockwell Hardness Number of the structure before and after shot peening is increased by 21.15% in IS2062:IS2062 joint and by 14.035% in SS304L:IS2062 joint.
- Experimental Fatigue Fracture life of the structure before and after shot peening is increased by 40.78% in IS2062:IS2062 joint and by 35% in SS304L:IS2062 joint.

Stress state of the structure, Material Surface Hardness and Fatigue Fracture Life are some of the parameters which determine the fatigue life of a structure. From the results obtained the stress levels are decreased, surface hardness is increased and the safety factor of the structure is increased after the shot peening.

VIII. SCOPE FOR FUTURE WORK

Here, are few research work projecting as scope for future research to improve welded joint fatigue life.

- Improvement of fatigue strength of welded joint by using other surface enhancement process like burnishing process, surface grindings process, heat treatment process can be carried out and compare the fatigue strength obtained from the above mention process.
- Improvement of the surface hardness and fatigue strength of welded joints by surface modification process such as shot peening process by using different shot material by varying peening condition.
- Determination of residual stress in various welded joint and welding process.
- Measurement and modification of residual stress by using the different material which is joined by different welding process.
- A more approximate result can be estimated if Material and Displacement Non linearity is considered and Material S-N data is interpolated using an exponential function.

IX. ACKNOWLEDGEMENT

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