THOMSON REUTERS ENDNOTE

[ICAMS-2017: March, 17]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

FATIGUE AND THERMAL ANALYSIS OF ARC WELDED JOINTS IN CYLINDRICAL MILD STEEL SPECIMENS

Nethri Rammohan*[1], Sampath S S[2], Chithirai Pon Selvan M[3]

*[1]Post Graduate Student of Manufacturing Engineering & Technology, Manipal University, Dubai
[2]Assistant Professor, Manipal University, Dubai, UAE
[3]Associate Professor, Amity University, Dubai, UAE

ABSTRACT

In the present study, a weld in mild steel material of circular cross-section is subjected to fatigue loading. The specimen is cut and welded at different points along the gauge length. The number of load cycles the specimen can withstand is determined for different load conditions at different weld positions and S-N curves are plotted for every load condition. The graphs which are plotted are compared with the S-N curves of the standard experiment. A thermal analysis is also carried out to identify the point concentration of temperature and to understand the distribution of temperature along the specimen over a certain time period by considering steady state and transient conditions. Nodal Temperature over Time period graphs are plotted to get a better understanding of the temperature distribution. The high temperature zones around the weld bead are predicted.

KEYWORDS: Fatigue, S-N graph, Arc welding, Steady-state, Transient

INTRODUCTION

Welding is one of the most commonly used joining methods. A very vast majority of the failure under fatigue takes place at the vicinity of welded joints due to loading. Fatigue occurs when there is a repeated fluctuating loads acting on the metal [3]. The failure which takes place is at the lower load than the required to cause the failure. The damage due to fatigue begins with the formation and propagation of micro cracks. There will be stress concentration at this region which leads to fatigue. Another reason is the heat addition and cooling of the parts during the welding process [4]. The material which is close to the weld metal is heated to almost the melting point; high temperature influences the grain growth. The microstructure thus influences the mechanical properties such as strength and toughness [2]. Steel is widely used in many engineering applications since it gives good mechanical and chemical properties. In the present work fatigue analysis is carried out for butt welded mild steel material [3].The fatigue failure takes place in the material which begins with the crack initiation where the welded structure undergoes repeated loading generate a small crack in the weak areas. The crack starts to propagate when the load cycle repeats again. This leads to ultimate failure when the crack has grown extensively and the material cannot withstand the load anymore [4]. There are various methods of reducing fatigue in the welded joints; some of them are by modifying weld geometry and rendering the surface smooth to reduce stress concentration factors such or dents etc. This enhances the fatigue life [5]. With the determination of crack growth, engineers can schedule inspection accordingly and estimate the fatigue life with respect to the load acting. Hence the parts can be replaced before the failure happens. Also being able to predict the path of crack helps the designer to provide an adequate geometrical tolerance to increase part life [7]. High temperatures introduce residual stresses in the structure reducing the fatigue life [16]. Predicting the peak temperature at the weld area helps provides a better understanding of the thermal stresses and its effect on the fatigue life [16, 17]. Current work involves in preparing specimens according to the standard dimensions. It is cut and welded at different points along the length. A fatigue test is carried out to determine the life of the specimen before undergoing failure. A thermal analysis is also carried using steady state and transient boundary conditions.

RELATED STUDY

Trufyakov et al. (1993) [1] conducted an experimental study to identify the effects of residual tensile stresses that are formed during the process the process of welding, on the fatigue life of the welded joints. A quantitative method was developed to study the effect of residual tensile stresses on the cyclic endurance of weld joint. It was noted that residual stresses affected the fatigue strength of the weld joints to a certain degree under certain conditions. A method of ultrasonic peening was used in order improve the fatigue strength of the weld joints. Ultrasonic peening improved the cyclic life of the welded joints by 5-10% and increased the fatigue limit 50-200% by inducing high residual compressive stresses in the work-piece. A quantitative method to compute the effect of the fatigue improvement process was also developed in the study. Dr. Ali Sadiq Yasir (2012) [2] studied the effect of welding locations on the fatigue strength of a steel shaft, in order to find the best location for the weld joint. Electric arc welding method was used to make the weld joints. Each of the steel shaft specimen was cut and welded at X/L=0.25, X/L=0.5 and X/L=0.75 and the subjected to fatigue test (where, 'X' is the distance of the between the center of the weld point and free end of the shaft. 'L' is the total length of the shaft). On comparison to the fatigue of an un-welded specimen, the fatigue life was decreased by 0.25% when X/L = 0.25. The fatigue life was decreased by around 40% and 84% when X/L= 0.5 and X/L = 0.75 respectively. Thus was concluded by the study that fatigue life is maximum when X/L = 0.25. Gonzalez et al. [3] investigated the dynamic response of fatigue damaged AISI 1018 steel welded joints which were subjected impact loading. The dynamic testing was done using a Tensile Hopkinson Bar apparatus. The failure modes were also studied about. The specimens had undergone previous fatigue cycles. It was noted that the yield stress of the weld material was found to be less than that of base metal, in both the quasi-static tension test and dynamic tension tests. Telsang and Patil (2013) [4] conducted an experimental investigation on butt welded joints in grade 2 steel. Fatigue analysis was carried out using a fatigue testing machine as well as Linear Elastic Fracture Mechanics (LEFM). The results from the LEFM were in compliance with the results obtained by plotting an S-N curve extracted from the experimental procedure. The Crack length was monitored using compliance method and it was found that the crack length increased as the number of load cycles increased. Karajagi and Ambhore (2015) [5] conducted a review study to predict the fatigue strength of welded joints by the application of fracture mechanics. Three fatigue life assessment methods were reviewed: Nominal Stress approach, Hot Spot Stress Approach and Effective Notch Stress Approach. Their advantages and disadvantages were reviewed. Their compliance with the actual test results were also reviewed and summarized. Zoran D. Perović (2011) [6] carried out an assessment to determine the benefits of modification in weld geometry. The dependence of stress concentration factors on weld toe radius was found using FEA photoelasticity method for various types of weld joints. Empirical formulae were used to determine the theoretical stress concentration factors, hardness at the heated affected zone near the weld toe and the fatigue stress concentration factors for welds before and after geometry modifications. The results obtained from the empirical formulae were in agreement with the experimental results obtained from literature study. It was noted that the increase in fatigue strength can be attributed to in the weld toe radius. Marin et al (2009) [7] discusses an alternative method of fatigue assessment based on structural stress definition. Due to the limitations in nominal approach, hot spot stress and effective notch approach [5, 7] the structural stress definition is implemented as it couples well with finite element modeling. The approach was found to be successful in the post-processor of the FEA software. Therefore, predicting the fatigue life. The method also had the advantage of being mesh insensitive and provided accurate crack location. Bansode and Misal (2012) [8] carried out a comparative study on a mild steel plate to determine the fatigue life using the S-N curve approach. The S-N curve was experimentally determined by subjecting a ASTM standard test specimen to the Fatigue testing machine. The stress-life curve of the specimen was also determined using Finite Element Analysis software by performing a non-linear structural analysis on a 3D finite element model of the standard specimen. The results were found to be in close compliance. The design of the specimen was also found to be suitable. Lambertsen et al. (2013) [9] Investigated the fatigue behavior of laser welded T-Joints made from stainless steel AISI304. The different kinds of specimens were subjected to one-dimensional cyclic loading. Non-welded specimens were used to study the influence of heat and surface effects on the fatigue life by subjecting them to plasma cutter and comparing the results to mill-cut specimens. The fatigue life from the experiments was compared to the fatigue life calculated by applying the guidelines in the standards design codes. Significant differences were found and was thus concluded that the fatigue life assessment according to the mentioned standards was not accurate. Yildirim and Marquis (2012) [10] presents a comprehensive evaluation of all published data available on High Frequency Mechanical Impact (HFMI) treated welds. Post welding treatments are found to improve the yield strength of the weld thus improving the fatigue strength of the weld as well [1, 10]. Existing experimental results from butt, transverse and longitudinal weld which had undergone HFMI were reviewed. From the results, it was observed that there was significant improvement in the fatigue strength as the yield strength improved. Baptista et al. [11] presented a study on the experimental and numerical analysis of various fatigue life improvement techniques in the welded joints of stainless steels [10, 11]. Duplex S31803 and Austenitic 304L were two types of stainless steel that were considered for the tests. The fatigue behavior of the specimens was studied based on their

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

reaction to the two different environments as well as the 3 fatigue life improvement techniques such as: toe grinding, hammer peening and PPAW dressing. The results were compared and it was found that the hammer peening technique is more effective for higher loads testing conditions, while the weld toe burr grinding is more effective for lower loading conditions. Ghosh and Pal (2014) [12] performed an experimental study on the fatigue analysis of face to face T-Joint in mild steel using structural Hot Spot Stress method [5, 12] using finite element analysis. For the Finite element analysis, a solid T-Joint and a shell T-Joint were considered to undergo repeated cyclic loading. From the analysis it was observed that shell T-Joint can withstand more fatigue stress than the Solid T-Joint at the weld spot. Therefore concluding that for heavy structures, shell models are preferred over solid joints. Michalec et al. (2012) [13] studied the effect of nitro-oxidation on laser beam welded joints in thin Low carbon steel DC 01 (EN 10130-91) sheets. Nitro-oxidation is a method used to enhance the mechanical properties of sheet metal surfaces. Welded and non-welded sheets were treated by nitro-oxidation and their results were compared. The fatigue strength in un-welded sheets was found to increase by two times. Whereas, the fatigue life of nitro-oxidized welded joints did improve, but was not as significant as the improvement in un-welded specimens, which can be attributed to presence of pores in the weld bead. Gadde and murali (2015) [14] discusses the structural and fatigue analysis of three different kinds of weld: Tee Joints, Lap joint and butt joint. The structural analysis was done using Finite element analysis. The stress distribution in all the three weld joints was observed. Fatigue analysis was also carried out using finite element analysis. Based on the results it was concluded that: The Tee joint produced more stress under loading thus failing before the other two joints and the fatigue life was the least for the butt joint. Goes at al. (2011) [15] presented a practical approach to compute the fatigue life of seam-welded joints under combined cyclic loading. Fatigue analysis was carried out experimentally via hot spot stress approach in finite element analysis software [5, 12, 15]. The analysis results and the experimental results were in compliance. The designed FE model was found to be a practical in the case of combined load fatigue test. Pandi and Kannan (2014) [16] conducted a thermo-mechanical analysis on a butt welded aluminium alloy plate by using the FEM software ABAQUS. The study was done to understand the formation of residual stresses in aluminium alloys and also study the various weld parameters such as welding speed, heat input etc. A Gaussian mathematical model is used to understand the temperature distribution, for the finite element analysis. It was found that as the welding speed increased, the heat absorbed by the plate decreased. Karunakaran and Balasubramanian (2013) [17] conducted an experimental study on the temperature profile created during the welding of aircraft grade aluminium alloy using Pulsed Current Gas Tungsten Arc Welding. The transient thermal analysis was carried out using Finite Element Analysis to attain the temperature distribution around the weld bead. The temperature is also measured experimentally using thermocouples at the weld bead. The FEA results were found to be in great compliance with the experimental results. The FEA results were able to predict the peak temperature at the weld bead.

METHODOLOGY

Figure 1 shows the steps involved in completing the entire process. Initially, the problem was identified and a problem statement was created. Then, a literature survey was carried out to review all existing studies on the problem at hand. Once all the literature for the study has been procured and studied, the standard fatigue testing specimen is machined using the lathe machine. The mild steel specimen is then cut and welded at various locations along its length. Then, the specimen undergoes fatigue testing in a cantilever fatigue testing machine.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

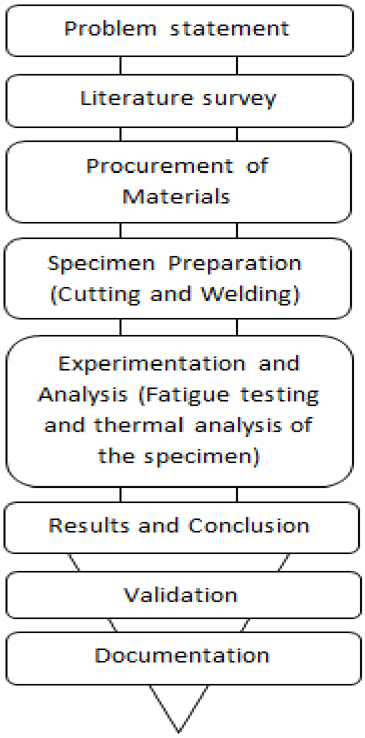

Figure 1. The Methodology followed in the Fatigue and Thermal Analysis of the Mild Steel Specimen

The results are tabulated and discussed. An S-N curve is then plotted based on the results. The results are also validated by comparison with the results derived during the literature review.

The specimen is clamped at one end and concentrated force **F** acts at the free end of the specimen (Cantilever beam). This concentrated point load induces a bending moment $\mathbf{M_b}$ on the specimen. Figure 2, represents the required dimensions of the specimen. The length of the arm of the specimen 'L' = 105mm. As the specimen is rotating an alternating bending stress is constantly acting on the specimen. The Maximum stress always acts on the shoulder of the stepped specimen. The bending moment is calculated using the following formula:

$$\mathbf{M_b = F\ L} \quad \ldots\ldots (1)$$

Where,
F = concentrated bending load
L = Gauge Length (length of the arm of the specimen)
The section modulus 'Z' of the specimen is calculated using the following formula:

$$\mathbf{Z} = \frac{\pi d^3}{32} \quad \ldots\ldots (2)$$

Where,
d = Diameter of the arm of the specimen

Finally, the alternating bending stress for load F is calculated using the below equation:

$$\sigma_a = \frac{M_b}{Z} \quad \ldots\ldots (3)$$

Thus, the stress amplitude for all the loads is found. Once, the fatigue analysis is over, A 3D finite element model of all the specimens are created using ANSYS APDL 15.0. Then a thermal analysis is carried out on all the 3D models, considering the steady state and transient conditions using the same software. This is done to study the distribution of temperature along the specimen. The areas of high temperature around the weld bead are identified. The variations of Nodal Temperatures in the specimen over a certain time period are calculated and graphs are plotted.

FATIGUE TESTING EXPERIMENTATION

Figure 2 represents the mild steel specimen prepared, based on the dimensions of the standard fatigue testing specimen required by the particular fatigue testing machine. 24 identical specimens were prepared by lathe machine. The length of the shoulder of the specimen is 40mm. The length of the arm of the specimen is 105mm. The 24 specimens were divided into 4 batches, with each batch comprising of 6 specimens. The first batch of 6 specimens was cut identically at a length of 0.5 times the total gauge length from the shoulder [2]. Then the specimens were welded at the point of cutting, using electric arc welding. A mild steel filler electrode is used for welding the specimens after cutting. Figure 3 shows a sample of the first batch of specimens cut and welded. Similarly, the second batch of 3 specimens is cut and welded at a distance of 0.25 times the total gauge length from the shoulder [2]. Figure 4 shows a sample from the second batch of specimens. The third batch of specimens is cut at 0.75 times the entire gauge length (L = length of the arm of the specimen) from the shoulder of the specimen [2]. Figure 5 shows a sample from the third batch of cut and welded specimens. The fourth batch is left uncut and un-welded [2]. Each specimen is cut and welded by leaving a gap of 2mm between the two pieces. Figure 6 shows a sample from the fourth batch of specimens. Before welding, the circular edge at the point of cutting chamfered by an angle of 45 degrees in order to produce a double V butt welded joint.

Once the specimens have been cut and welded. The specimens are to undergo fatigue testing. Figure 7 shows the fatigue testing machine in which the specimens were tested. The first batch of specimens is prepared. The fatigue testing machine consists of cantilever loading with a maximum force of 300N. Each specimen from the first batch is tested at different load: 120N, 140N, 150N, 160N, 180N and 200N. The No of cycles each of the specimens can withstand before complete fracture is noted down. The stresses are calculated. The S-N curve is plotted for each load. Similarly, the process is repeated from the rest of the batches of the specimen, at the same loads from the first batch. The point of fracture for each specimen is noted. The Stress Vs Number of Cycles (S-N) curves plotted for all the loads and weld positions are compared and studies. The results are plotted and discussed.

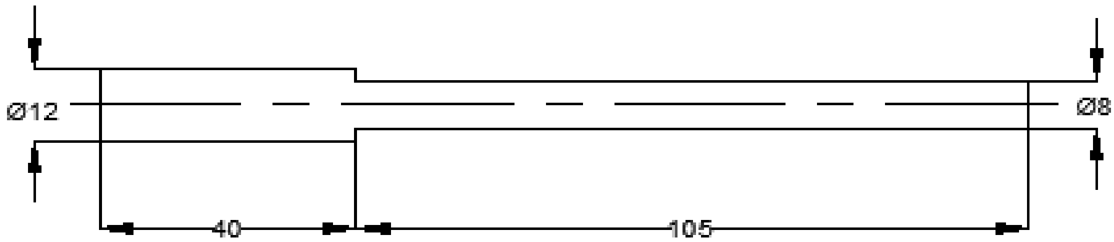

Figure 2: The Standard fatigue testing specimen with dimensions required by the Fatigue Testing Machine.

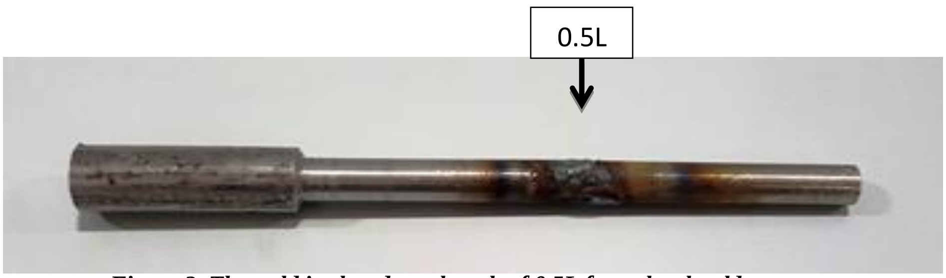

Figure 3. The weld is placed at a length of 0.5L from the shoulder.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Figure 4. The weld is placed at a length of 0.25L from the shoulder.

Figure 5. The weld is placed at a length of 0.75L from the shoulder.

Figure 6. The specimen is Un-cut and Un-Welded.

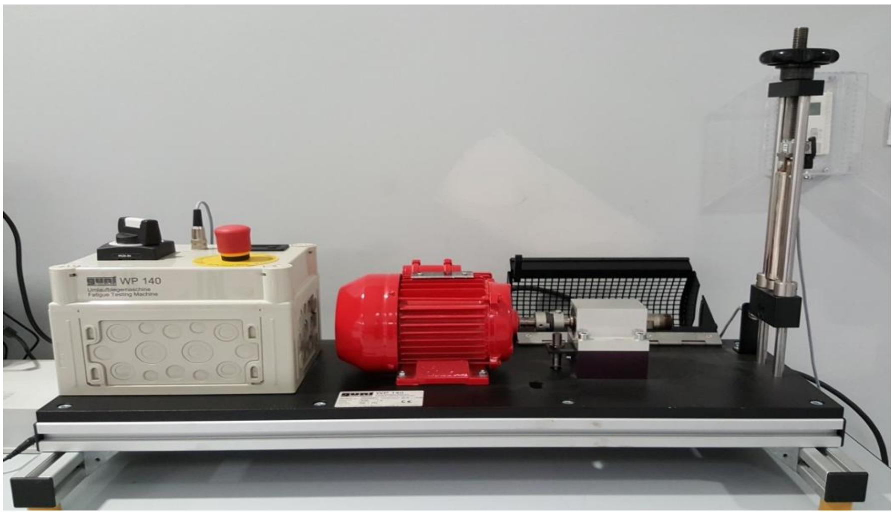

Figure 7. Fatigue Testing Machine

RESULTS AND DISCUSSION

Figure 8 shows the S-N curve for the specimen where the weld is placed at 0.5L. Similarly Figure 9, Figure 10, and Figure 11 represent the S-N curves plotted for the specimens where the weld is placed at 0.25L, 0.75L and un-welded specimen respectively. Using the equations 1, 2 and 3 the stress amplitude for each of the Loads: 120N, 140N, 150N, 160N, 180N, 200N, are found. Once the fatigue testing is carried out for all the 24 specimens, the number of cycles the specimens can withstand before complete fracture is found and tabulated.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Table 1, shows the number of cycles for all specimens at various loads, and the stress amplitude corresponding to those loads. It has been noticed from the results, that the Un-welded specimens can withstand the most number of cycles at every specified load. This is due to the lack of stress concentrators such as dents and air pores, which are otherwise found in weld joints. For the weld located at 0.75L, the specimen undergoes 33840 cycles under a stress of 248.857 MPa (120N). There is decrease of around 25% in the number of cycles when a weld is introduced at 0.75L. As the load increased to 200N, there is a steady decrease of around 68% in the number of cycles compared to the number of cycles the un-welded specimen undergoes at 200N. It was all noticed, that for all specimen welded at 0.75L, the fracture took place at the step between the shoulder and arm of the specimen and not at the weld joint (0.75l).

When the weld is located at 0.5L, the number of cycles they undergo before complete fracture has been tabulated in table 1. At 120N, there is a decrease of 60% in the number of load cycles the specimen can withstand with respect to the un-welded specimen. With loads ranging from 140N to 200N It is seen that there around an 90% decrease in the number of load cycles the specimen can withstand in comparison to the un-welded specimen for the same loads. It was also noted that in all the specimens, the ultimate fracture took place at the step between shoulder and the arm of the specimen (similar to the previous case of specimens; 0.5L).

When, the weld is located at 0.25L, there is almost similar decrease of around 75% in the number of cycles the specimen can withstand under all the specified loads, with respect to the number of the cycles the un-welded specimen can withstand for all the 6 different loads specified. However, it has been noted that the specimen undergoes fracture at 0.25L (weld joint) under the loads of 120N and 200N. Whereas for 140N, 150N, 160N and 180N the specimen fractures at the stepped part similar to the previous two cases. The reason for the fracture at the weld point can be attributed to the lower strength of the two particular welds. The factors for the lower strength may be due to the presence of larger air pores and deeper dents in the two weld specimens. Extremely high temperatures can also contribute to the hardening of the specimen thus rendering the weld joint extremely brittle.

Table 1: The Number of Cycles for each specimen at Various Loads

LOAD (In N)	STRESS (in MPa)	Number of Cycles the Specimen undergoes before Complete fracture For the corresponding Loads			
		Weld Located at 0.25L	Weld located at 0.5L	Weld located at 0.75L	Un-welded Specimen
120	248.857	15816	20128	38840	50990
140	290.335	10780	9568	29077	40132
150	311.072	8261	4269	22600	34552
160	331.809	7644	3518	20300	32456
180	373.286	6408	1989	14608	28263
200	414.762	5172	460	7814	24070

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

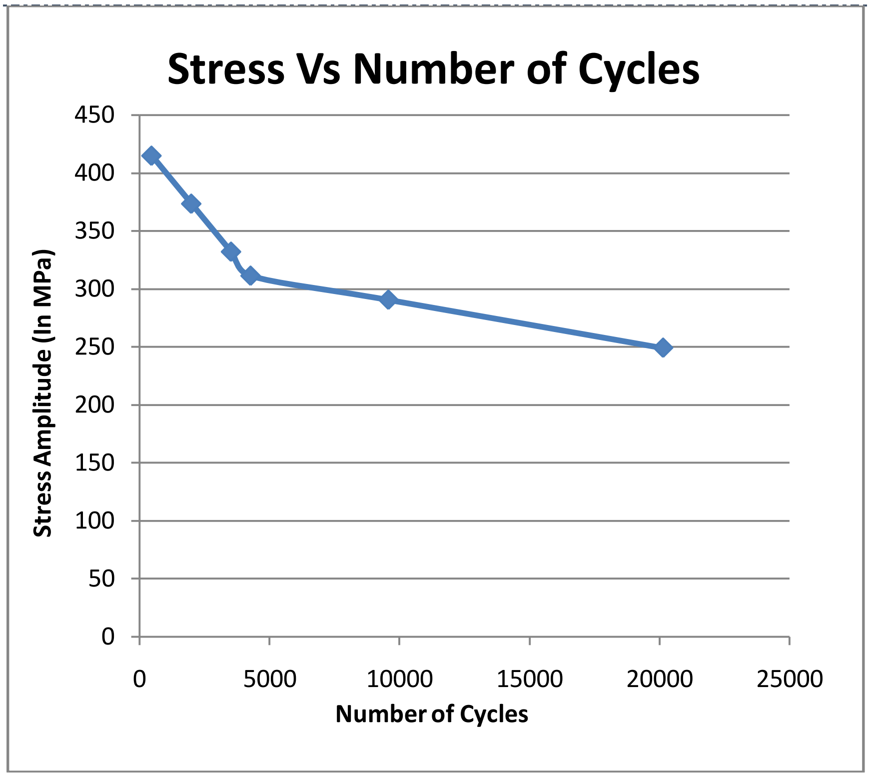

Figure 8. Stress Vs Number of cycles curve for the Weld located at 0.5L

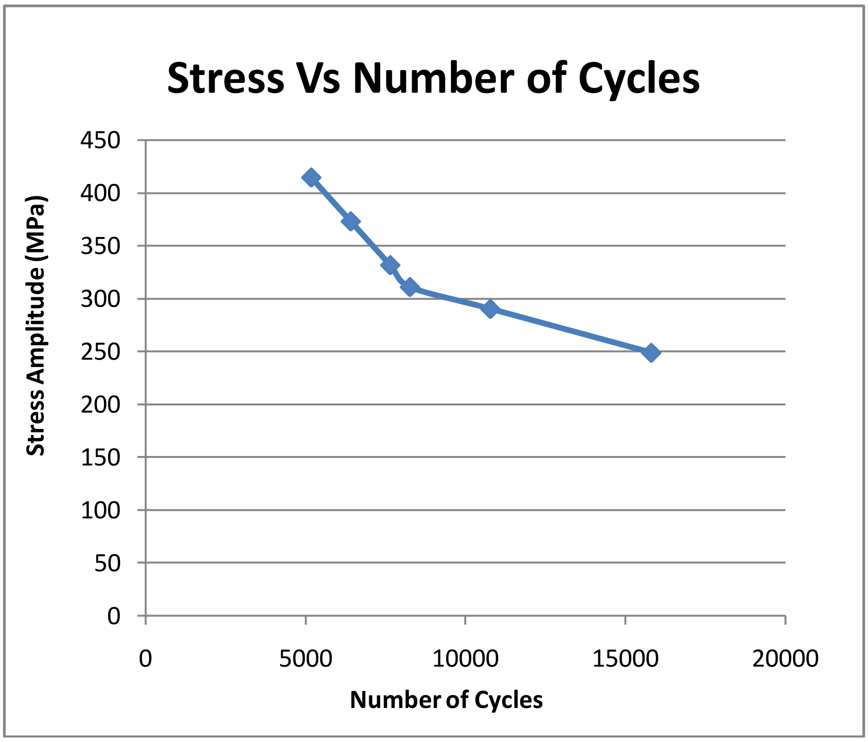

Figure 9. Stress Vs Number of Cycles for Weld Located at 0.25L

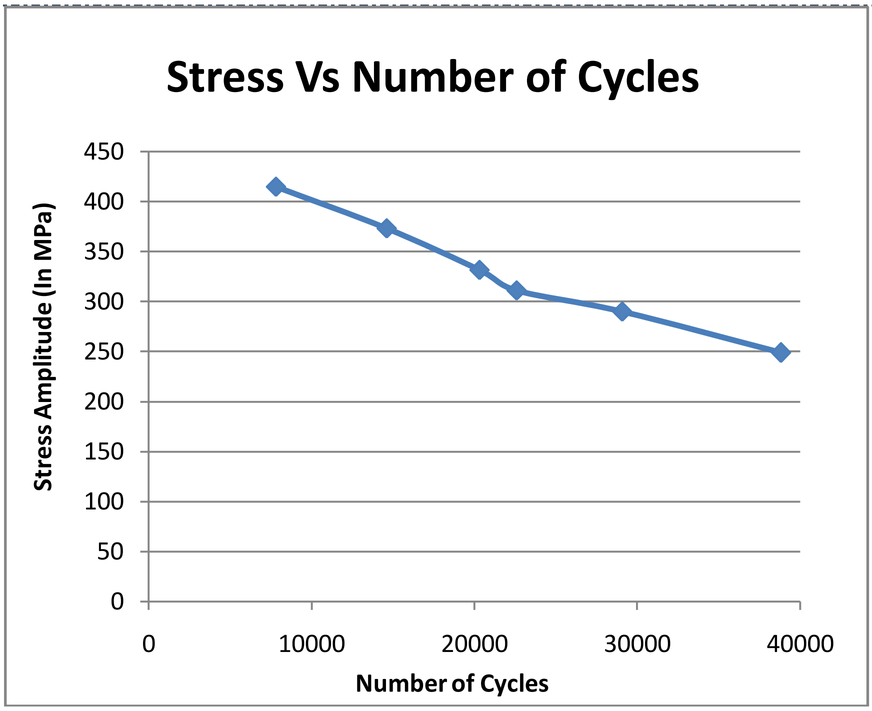

Figure 10. Stress Vs Number of Cycles for Weld Located at 0.75L

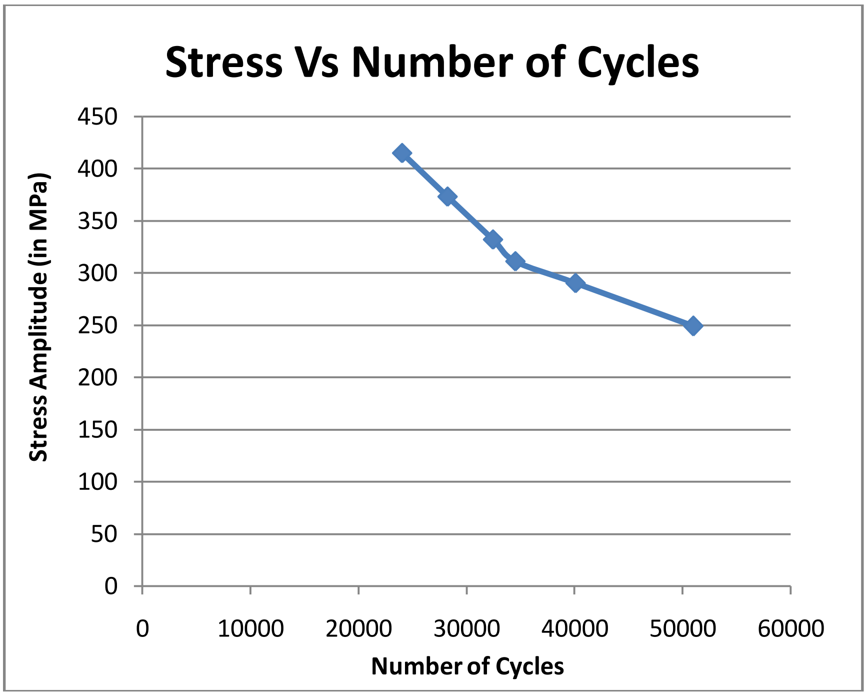

Figure 11. Stress Vs Number for The uncut and un-welded specimen

Three dimensional models of the specimens with welds located at 0.25L, 0.5L and 0.75L were modeled using ANSYS APDL 15.0. Thermal analysis is carried on the model, to find out the nodal temperature distribution. The analysis is carried out for both steady state and transient conditions. The Nodal temperature over Time Period graph is plotted using the same software, and the results are obtained for all the 3 cases. The arc welding melts the filler material at temperature of around 2800 K to 3500 K. The temperature for the particular arc welding equipment is 3273 K.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Figure 12, represents the temperature distribution along the specimen when the weld is located at 0.5L, when a steady state thermal analysis is carried out using Finite Element Analysis. The maximum temperature is 3273 K which is imparted to the weld joint during the welding process and the minimum temperature at the ends of the specimen being 884.081 K. Both conduction by temperature and convection by free air were considered while setting the boundary conditions for the FEM analysis. Figure 13, shows the temperature distribution for the same specimen, under transient conditions. The diagram represents the distribution of temperature after 30 seconds of the application of heat. It is observed that the minimum temperature has decreased to 304.281 K after 30 seconds, that attributing to the dissipation of heat from the specimen. The peak temperature at the weld bead however remains the same. The HAZ can be identified from the figures 12 and 13. Figure 14, shows the nodal temperature variation over a time period of 3000 seconds. A random node along the specimen is selected to understand the change in the temperature at that particular node over the given time period. At the selected node, the temperature attains a steady state at the value of around 2800 K, which occurs at a time period of 400 seconds.

Similarly, figure 15 represents the steady state temperature distribution for weld located at 0.25L. Figure 16 shows the transient temperature distribution for the weld located at 0.25L after a time period of 30 seconds. The minimum temperature at the ends of the specimen attains a value of 331.443 K over a time period of 30 seconds. Figure 17 shows the temperature variation at a particular node over a time period of 3000 seconds. In this case, a node was randomly selected from the model to plot the Nodal temperature Vs Time graph. It is noted, that temperature variation attains a steady state at a temperature of around 2000 K, after a time period of 400 seconds.

Figure 18 represents the steady state temperature distribution for weld located at 0.75L. Figure 19 shows the transient temperature distribution for the weld located at 0.75L after a time period of 30 seconds. In the steady state the minimum temperature is 597.47 K. On transient analysis over a time of 30 seconds, the minimum temperature at the shoulder of the specimen reduces to 298 K, thus attaining the ambient temperature conditions. As the weld is located at 0.75, Figure 20 shows the temperature variation at a particular node over a time period of 3000 seconds. In this case, a node was randomly selected from the model to plot the Nodal temperature Vs Time graph. It is noted, that temperature variation attains a steady state at a temperature of around 1800 K, after a time period of around 300 seconds.

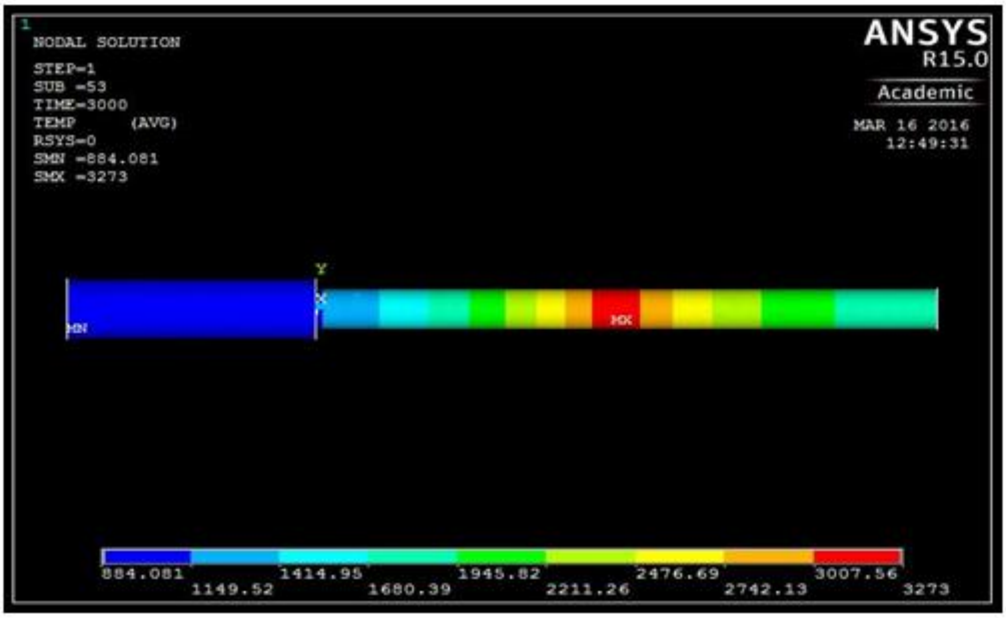

Figure 12. Temperature Distribution (Steady State) for weld at 0.5L

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

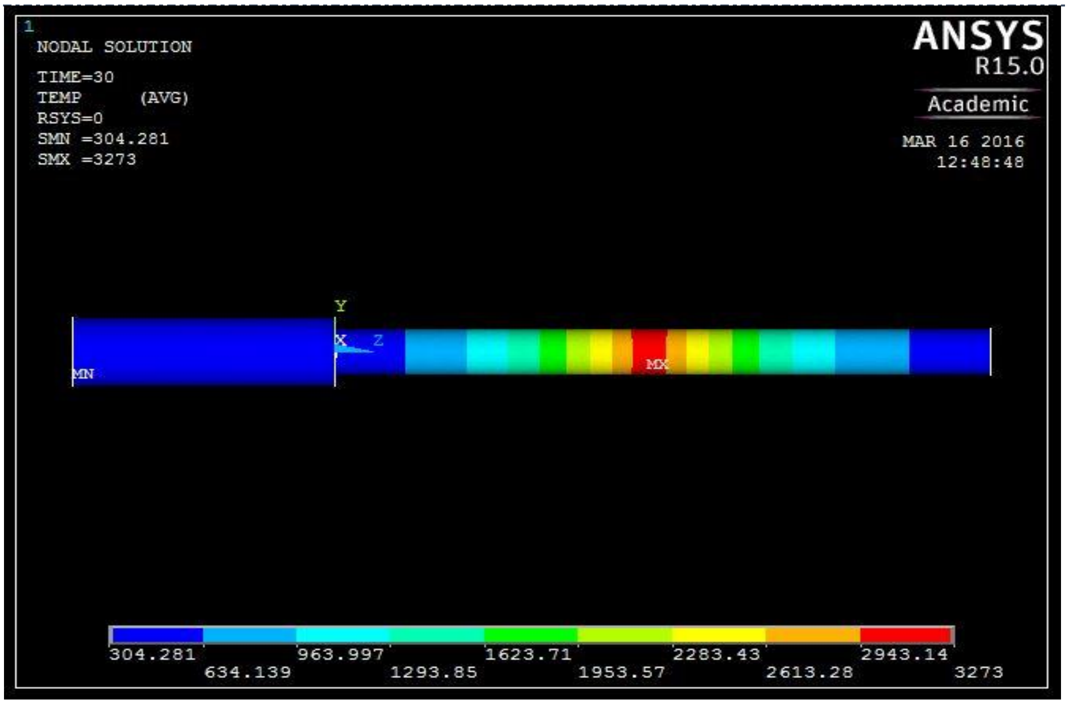

Figure 13. Temperature Distribution after 30 seconds (Transient) for weld at 0.5L

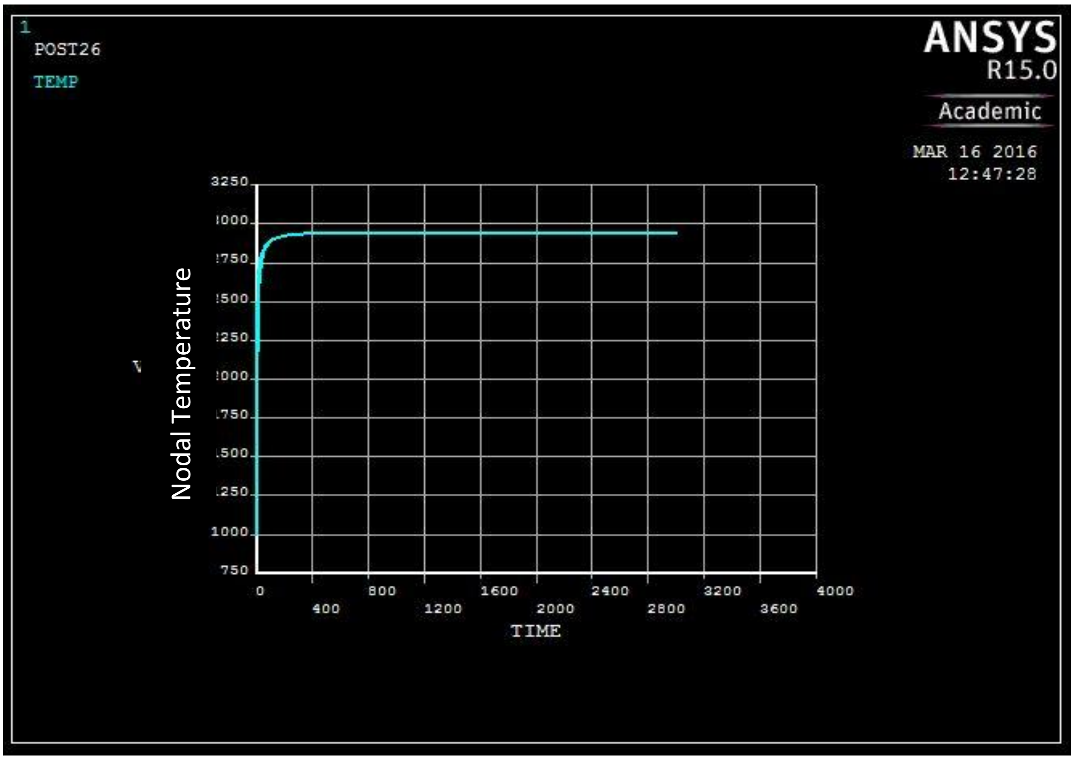

Figure 14. The Nodal Temperature Vs Time Graph for Weld at 0.5L

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

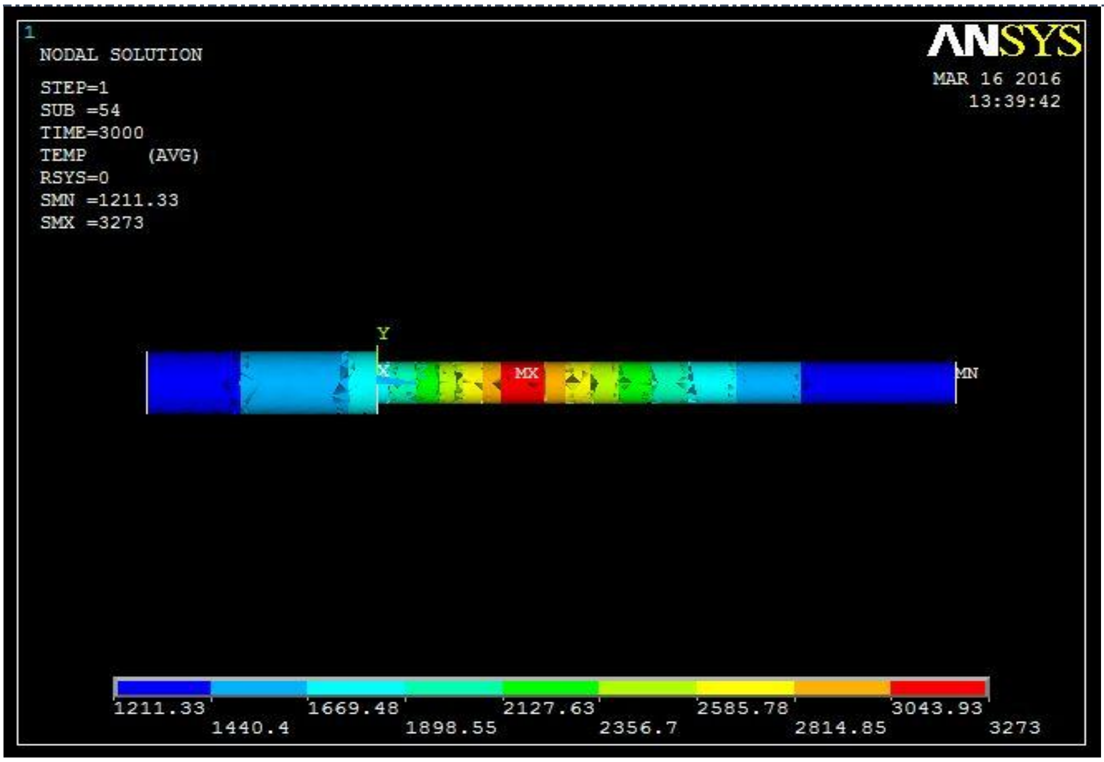

Figure 15. Temperature Distribution (Steady State) for Weld at 0.25L

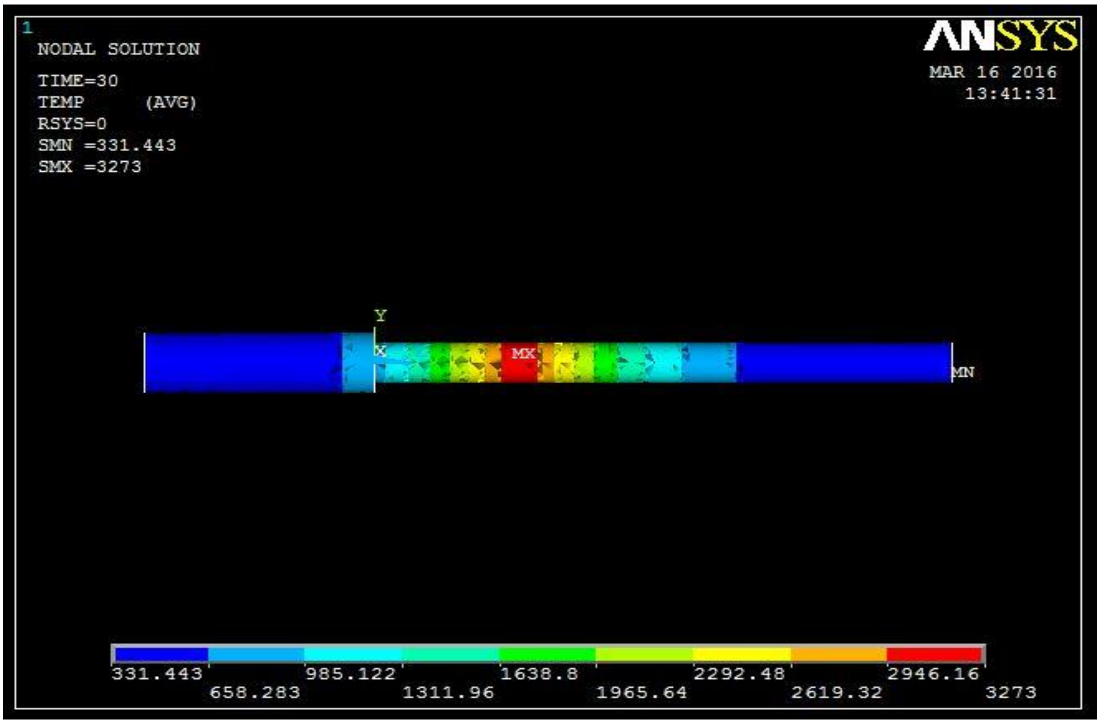

Figure 16. Temperature Distribution after 30 seconds (Transient) for Weld at 0.25L

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

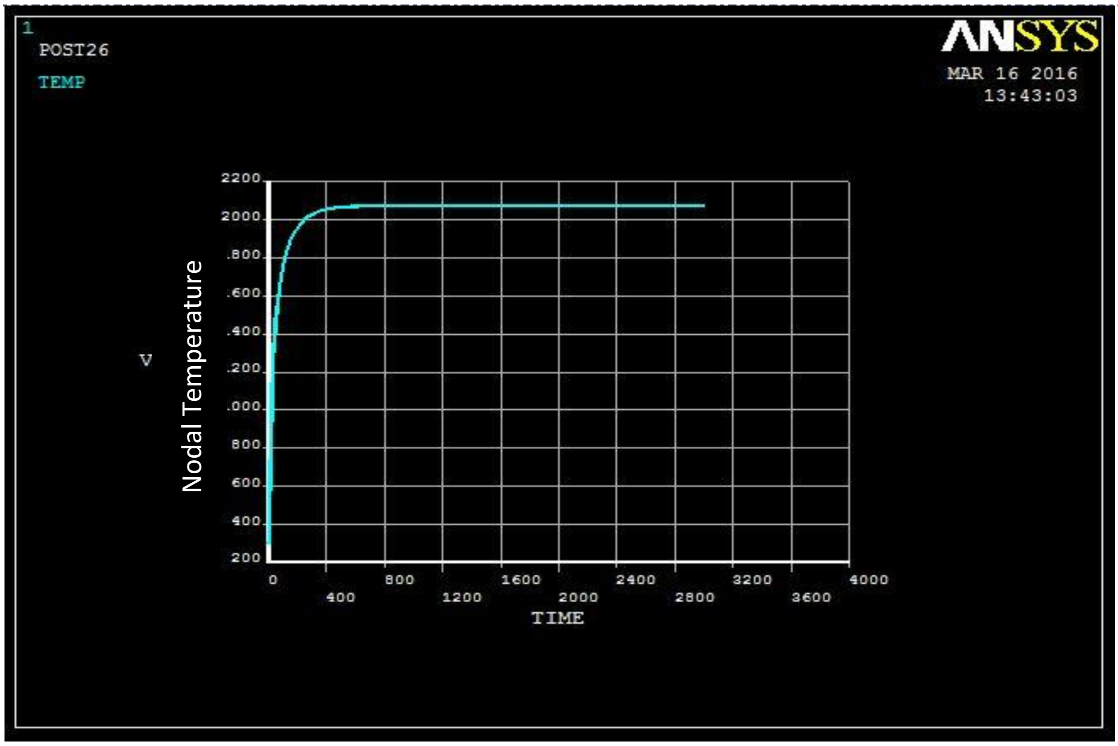

Figure 17. Nodal Temperature Vs Time For weld at 0.25L

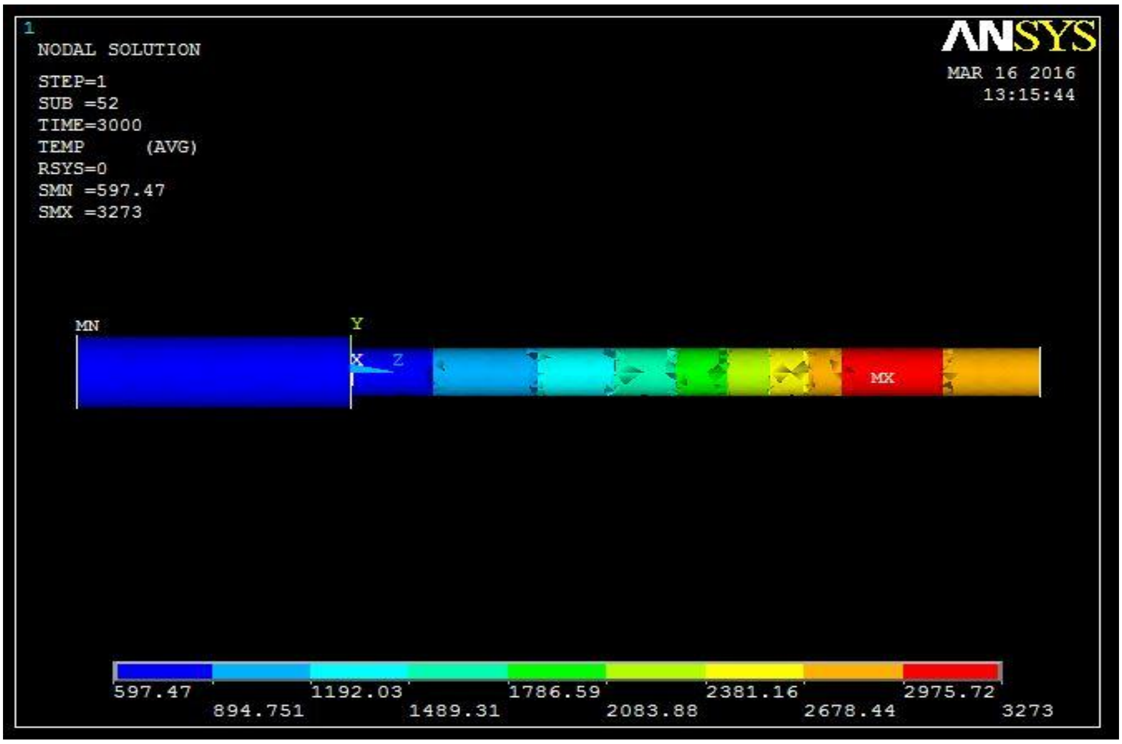

Figure 18. Temperature Distribution (Steady State) for Weld at 0.75L

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

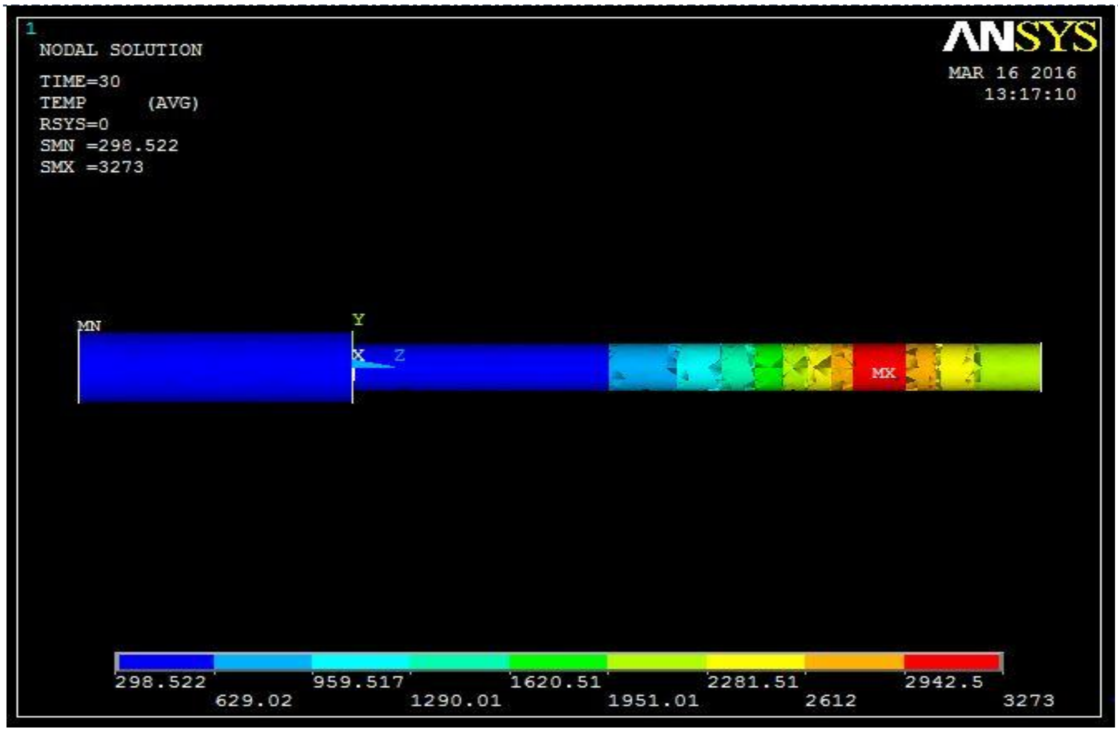

Figure 19. Temperature Distribution after 30 Seconds (Transient) for Weld at 0.75L

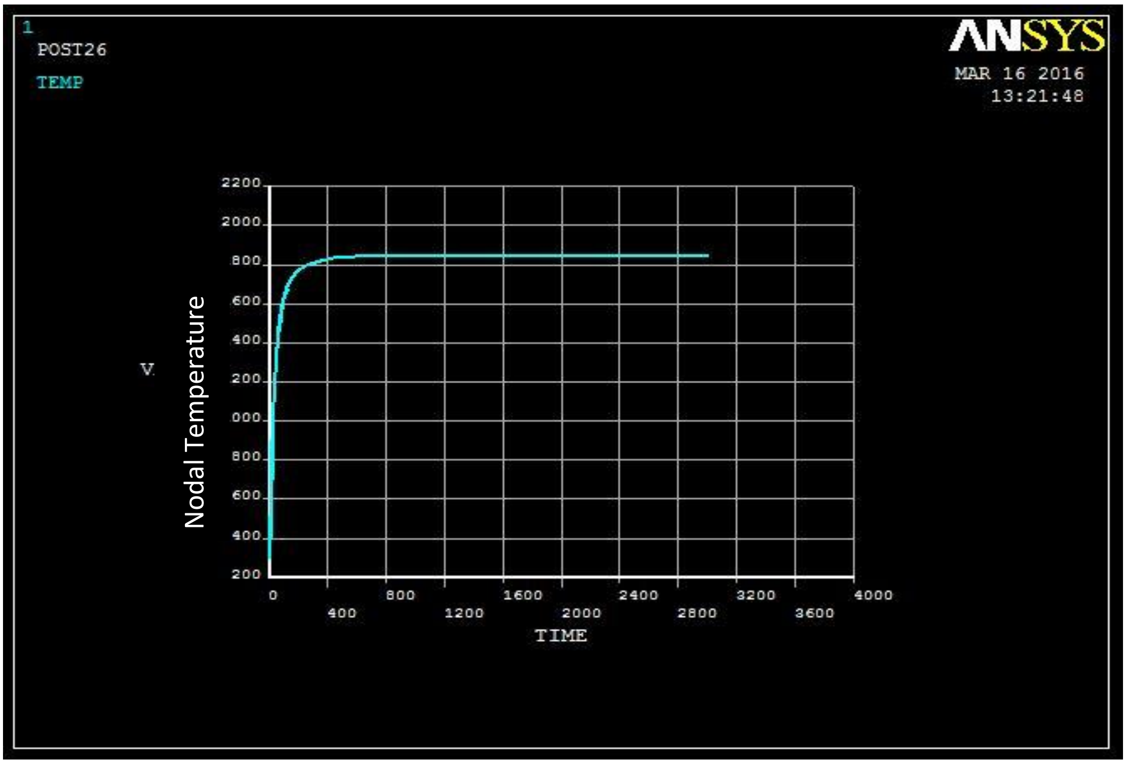

Figure 20. Nodal Temperature Vs Time for Weld at 0.75L

CONCLUSION

It was observed from the experimental fatigue analysis that, on the introduction of a weld in the specimen, the number of load cycles that the specimen can withstand before fracture will significantly decrease, compared to the number of cycles the un-welded specimen can withstand until fracture. It was noted that the appropriate location for the weld to be placed along the specimen was at 0.75L, which is the closest to the point where the load acts. As, the specimen underwent the most number of load cycles before fracture. Therefore it is understood that the specimen with weld located at 0.75L will have the highest fatigue life after the un-welded specimen. This particular conclusion has been in compliance with the conclusions from the existing literature on weld location. However, it was found that the specimen with weld at 0.25L could withstand more number of cycles at all given loads, compared to the specimen with weld at 0.5L. Therefore, this experimental finding has not been in compliance with the results from existing literature. The point of fracture was found to vary in the case of specimens with weld at 0.25L. This inconsistent factor can be attributed to the low strength of the welds. The presence of larger air pores and the occurring of dents near the weld area while machining can be concluded as huge contributing factors for the fracturing at weld joints. The hardening of the filler material due to minor difference in the extreme temperatures provided during welding can also be concluded as a contributing factor.

The high temperature areas and peak temperature surrounding the weld joint can be predicted by created an FEA model and carrying out steady state and transient thermal analysis on the model. The models were considered to undergo conduction by temperature difference and convection by free air. The temperature present at every node along the entire specimen can be predicted. The transient analysis provides the temperature distribution over a certain time period. The nodal temperature variations over a considerable time period were predicted using transient methods. Thermal stresses are also introduced into the specimen during the welding process, which can contribute to the decrease in the fatigue life of the specimen. From the temperature profiles, the maximum and minimum temperature points were found.

Further validation for the thermal analysis can be carried out by finding the temperatures along the specimen practically by using thermocouple sensors. The fatigue and thermal analysis helps in predicting the life of a particular structure, thus making various activities cost effective and safe. Future studies can be made to understand the exact welding parameters on which the thermo-mechanical properties of the weld can depend on.

NOMENCLATURE

$M_{b=}$ Bending moment, N-m
F = concentrated bending load, N,
L = Gauge Length (length of the arm of the specimen), mm
Z= Section modulus, mm^3
d= diameter of the specimen, mm
σ_a = Alternating stress, Pa

REFERENCES

[1] *V.I. Trufyakovi, P.P. Mikheev, Yu. F. Kudryavtsevi and D.N. Reznik, "Fatigue Endurance of Welded Joints, Residual Stresses and Fatigue Improvement Treatments," Ship Structures Symposium, Virginia, November 16-17, 1993*
[2] *Dr.Ali Sadiq Yasir, "Study the Effect of Welding Joint Location on the Fatigue Strength and Fatigue Life for Steel Weldment," Asian Transactions on Engineering, Vol. 2, Issue 4, pp 1-13, 2012*
[3] *C. Rubio-Gonzalez, E. Miranda-Paniagua and G. Mesmacque, "Effect Of Fatigue Damage On The Dynamic Tensile Behavior Of Carbon Steel Welded Joints,"*
[4] *Prof. M. T. Telsang and Mr. Rajesh M. Patil, "Fatigue Analysis Of Butt Welded Joint Using LEFM – Experimental Investigation," International Journal of Engineering Research & Technology, Vol. 2, Issue 6, pp 2278-2283, 2013*
[5] *Tabassum Karajagi and Nitin Ambhore, "Review of Fatigue Analysis of Welded Joints," International Journal of Current Engineering and Technology, Vol.5, No.3, pp 2074-2077, 2015*
[6] *Zoran D. Perović, "The Weld Profile Effect On Stress Concentration Factors In Weldments," 15th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 2011, Prague, Czech Republic, pp 977-980, September 12-18, 2011*
[7] *T. Marin and G. Nicoletto, "Fatigue design of welded joints using the finite element method and the 2007 ASME Div. 2 Master curve," Frattura ed Integrità Strutturale, Vol. 9, pp 76-84, 2009*
[8] *Vinod M. Bansode & N.D.Misal, "Fatigue Life Estimation Of A Butt Welded Joint By S-N Approach," International Journal of Applied Research in Mechanical Engineering, Vol. 2, Issue 2, 2012*

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

[9] *Søren Heide Lambertsen, Lars Damkilde, Anders Schmidt Kristensen and Ronnie Refstrup Pedersen, "Estimation of Fatigue Life of Laser Welded AISI304 Stainless Steel T-Joint Based on Experiments and Recommendations in Design Codes," World Journal of Mechanics, Vol. 3, 178-183, 2013*

[10] *Halid Can Yildirim and Gary B. Marquis, "Fatigue strength improvement factors for high strength steel welded joints treated by high frequency mechanical impact," International Journal of Fatigue, 2012*

[11] *Baptista R., Infante V. And Branco, C.M., "Experimental and Numerical Analysis of Fatigue Life Improvement Techniques in Welded Joints of Stainless Steels,"*

[12] *Arka Ghosh and Manoj Kumar Pal, "Fatigue Analysis Of Face-To-Face T-Joints In Mild Steel Using Structural Hot Spot Stress Method," Proceedings of SARC-IRF International Conference, 12th April-2014, New Delhi, India, pp 74-76*

[13] *Ivan Michalec, Milan Marônek, Jozef Bárta and František Nový, "Weld Joints Fatigue Properties Of Thin Carbon Steel Sheet Treated By Nitrooxidation," Tehnički vjesnik 19, Vol. 1, pp 65-69, 2012*

[14] *Anil Kumar Gadde and J. Venu Murali, "Fatigue analysis of welded joints," International Journal of Applied Research, Vol. 1, Issue 2, pp 37-39, 2015*

[15] *K.C.Goes, G.F. Batalha, M.V. Pereira and A.F. Camarao, "Practical methodology to evaluate the fatigue life of seam welded joints," Journal of Achievements in Materials and Manufacturing Engineering, Vol. 49, Issue 1, pp 35-41, 2011*

[16] *M. Pal Pandi and Dr. R. Kannan, "Thermal Analysis on Butt Welded Aluminium Alloy AA7075 Plate Using FEM," International Journal of Engineering Research, Vol. 3, Issue 2, pp 116-120, 2014*

[17] *N. Karunakaran and V. Balasubramanian, "Transient Three Dimensional FE Modeling for Thermal Analysis of Pulsed Current Gas Tungsten Arc Welding of Aluminum Alloy," International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol. 7, No. 3, pp 484-491, 2013*