Investigation of Residual Stresses and Its Effect on Mechanical Behaviour of AISI310

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Abstract* - Welding is the most preferred fabrication method in ship, aircraft, automotive and bridge building industries. As a result residual stresses are developed in welded joints. Residual stresses are 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 i.e. heat affected zone. It causes brittle fracture and corrosion cracking, reduce the buckling strength and fatigue life. So it is important, therefore, to understand the distribution of residual stresses on the surface of the welded components in and near the welding zone. This paper presents a method to model mechanical behaviour of weld joint in the presence of residual stresses using deformation theory of plasticity. Residual stresses are estimated numerically and values are assigned as an initial stress in finite element model of weld joint. The weldment specimen model is subjected to static loading and effect of residual stress on local yielding is investigated. ANSYS is used for this purpose. The response of weld joint to monotonically increasing tensile load is determined experimentally by conducting transverse and longitudinal tension tests to validate simulation model.

Keywords: Welding, FEA, Residual stresses, Tension test.

I. INTRODUCTION

The manufacturing technology primarily involves sizing, shaping and imparting desired combination of the properties to the material so that component or engineering system being produced can perform the indented function in its expected life. Manufacturing processes have been developed in a wide range, in order to produce the engineering components of very simple to complex geometrics of different physical, chemical, mechanical and dimensional properties. There are four basic manufacturing processes i.e. casting, forming, machining and joining/welding. Selection of manufacturing process is depending upon complexity of geometry of the component and the number of units to be produced, properties of the materials etc. During manufacturing, it frequently requires joining of the components to get the desired shape. Three joining techniques namely mechanical joint (nuts, bolts, and rivets), adhesive joint (epoxy resin) and welding are commonly used for manufacturing. Welding is one of the most commonly used fabrication techniques for manufacturing engineering components for different sectors. Welding is a process of joining metallic or other components with or without application of heat, with or without pressure, with or without filler metal in which coalescence of the joining materials/components occur. Welding differs from other joining processes in that the joint created by welding is very strong and permanent. Parts that have been welded together cannot be easily separated. Welding is fast and is one of the most economical ways to join metal together permanently. There are as many as 94 different types of welding processes recognized by the AWS (American welding society) that use different sources of energy to join metals. Though there are a number of well established welding processes, arc welding is still the most popular welding process. These processes are mainly shielded metal arc welding (SMAW), submerged arc welding (SAW), tungsten inert gas welding (TIG), metal inert gas welding (MIG) and flux core arc welding (FCAW).Several situations arise in industrial practice which call for joining of materials. The materials employed are location dependent in the same structure for effective and economical utilization of the special properties of each material. Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the work pieces to form a bond between them, without melting the work pieces. Only in this way can the designer use most suitable materials for each part of a given structure. It is well known that the welding process relies on an intensely localized heat input generate undesired residual stresses and deformations in welded structures, especially in the case of thin plates. Therefore, estimating the magnitude of welding deformations and characterizing the effects of the welding conditions are being necessary. Due to modern computing facilities, the finite element (FE) technique has became an effective method for prediction and assessment of welding residual stress and distortions . However, the welding deformations are various with production variations such as dimension, welding materials and welding process parameters. Therefore, rapidly and accurately predicting welding induced distortion for real engineering applications is more challenging.

II. LITERATURE REVIEW

1.Jamal Jalal Dawood, Atul Sitarm Padalkar.

This paper presents a method to model mechanical behaviour of weld joint in the presence of residual stresses using deformation theory of plasticity. Residual stresses are estimated numerically and values are assigned as an initial stress in finite element model of weld joint. The weldment specimen model is subjected to static loading and effect of residual stress on local yielding is investigated. Commercially available finite element analysis code ABAQUS is used for this purpose. The response of weld joint to monotonically increasing tensile load is determined experimentally by conducting transverse and longitudinal tension tests to validate simulation model particularly in plastic region. The results show that deformation theory of plasticity can be used to model post yield behaviour of a weld joint. As expected stress-strain behaviour of the weld joint differ marginally from virgin duplex stainless steel alloy. The work presented in this paper will help designer to ensure structural integrity.

2.M.L. Tan, S. Ganguly, P.E. Irving, M.E. Fitzpatrick, X. Zhang, L. Edwards.

The interaction between residual stress and fatigue crack growth rate has been investigated in middle tension and compact tension specimens machined from a variable polarity plasma arc welded aluminium alloy 2024-T3 plate. The specimens were tested at three levels of applied

constant stress intensity factor range. Crack closure was continuously monitored using an eddy current transducer and the residual stresses were measured with neutron diffraction. The effect of the residual stresses on the fatigue crack behaviour was modelled for both specimen geometries using two approaches: a crack closure approach where the effective stress intensity factor was computed; and a residual stress approach where the effect of the residual stresses on the stress ratio was considered. Good correlation between the experimental results and the predictions were found for the effective stress intensity factor approach at a high stress intensity factor range whereas the residual stress approach yielded good predictions at low and moderate stress intensity factor ranges . In particular, the residual stresses accelerated the fatigue crack growth rate in the middle tension specimen whereas they decelerated the growth rate in the compact tension sample, demonstrating the importance of accurately evaluating the residual stresses in welded specimens which will be used to produce damage tolerance design data.

3. Martina Nerádová, Robert Augustin, Pavel Kovačócy

The article presents samples of weld joint of AISI 310 austenitic steel which were subjected to solution annealing at various temperature - time exposures. The objective of the experiment was to determine the annealing temperature so that the steel should not be sensitized. Tendency to inter crystalline corrosion was analysed by means of a corrosion test in 10 % oxalic acid according to ASTM A 262. At the temperatures of 1000 and 1100°C held for 15 min. the steel was not sensitized. At the temperature of 850°C the steel was sensitized, i.e. susceptible to intercrystalline corrosion.

4. George Labeas, Ioannis Diamantakos

Numerous engineering structures operate under the presence of residual stresses resulting from welding or other manufacturing processes. In the present work, the effect of typical residual stress fields on stress intensity factors and crack propagation angle of cracks developing into the residual stress field under mixed mode loading conditions is studied. For the calculations a numerical methodology based on linear elastic finite element analysis is used. The presented results provide a useful tool for an efficient assessment of the influence of residual stress field on the crack evolution behaviour.

5.Sandeep Singh, Dr. Gurbhinder Singh, Sanjeev Kumar, Sharanjeet Singh, Amritpal Singh.

The objective of this research is to study the influence parameters affecting the mechanical property (tensile strength) and optical investigation (SEM & EDAX) of austenitic stainless steel grade (AISI-304L& AISI-310) with Gas Metal Arc Welding (GMAW). The research was applying the different values of wire speed and current for experiment**,** which have following interested parameters: welding current at (180**,** 250 and 320 Amps), welding wire speeds at (2, 3, 5 m/min), shield gas pure CO_2 and (24V)Welding Voltage. The study was done in following aspects: tensile strength and optical investigation. A research study investigate the tensile strength of welding joint is maximum 320.4 N/mm² at wire speed 3m/min and 250 Amps welding current. It has been observed from the SEM analysis that grain of the surface are ultra fine and EDAX analysis conforms the change of chemical composition is small at wire speed 3m/min and 250 Amps welding current.

6. Y. Ohtake, S. Kubo

Welding residual stresses cause buckling or brittle fractures in welded structures so that estimation of residual stress is required to protect the structures. In previous works, an identification method by thermo-elastic boundary element analysis was proposed to estimate the magnitude and the distribution of the residual stress in butt-welded plate from a few measured data. The method can also estimate the maximum stress value at the welding line, where the X-ray diffraction method is inapplicable. The validity of the method was examined using numerical simulations while experiments were not carried out. This paper investigates the effectiveness of the method using experimentally measured stresses in butt-welded plate. The estimated stresses were in good agreement with those measured in the experiments when the measurement points were at suitable locations. The maximum residual stresses were estimated using the stresses measured near the line by the X-ray diffraction method

7.Cristian Simion, Corneliu Manu, Saleh Baset, Julian Millard.

The objective of this paper is to present both a methodology of detailed axisymmetric simulation of a small scale welding test using the ANSYS general purpose finite element computer code and a comparison with test data. To simulate this manufacturing process, an APDL (ANSYS Parametric Design Language) macro was developed and implemented. The methodology implemented deals with the major phenomena of the welding process from transient heat analysis to structural thermal-plastic analysis. The methodology is based on an axis symmetric approach and accounts for nonlinearities due to temperature-dependent thermal and mechanical material properties as well as surface contacts. It predicts, with reasonable accuracy, the real test measurements. CANDU nuclear reactors use horizontal fuel channels housed in a large fabricated horizontal vessel called the calandria vessel. This calandria vessel has two end shields (each consists of double endplates), which provide support for the fuel channels as well as defining the basic reactor geometry. Each pair of double endplates is joined by tubes called lattice tubes. The lattice tubes, which are welded to the endplates, provide passages for the fuel channels and stiffness to the calandria vessel. To ensure that the distortions of the endplates due to welding satisfy the design requirements, small scale and large scale welding tests are performed. The initial small scale welding test consisted of welding a lattice tube to the associated section of an endplate. A larger scale welding test consists of welding a 2x6 array of lattice tubes to assess the accumulated distortion on the end plate. In order to develop a deep understanding of the distortions generated by welding, these welding tests are simulated using detailed finite element analyses. The detailed simulations include heat flow and elastic plastic analysis. Numerical simulations of the complete assembly, using coarse finite element models and elastic-only analyses of the endplate assembly, are also included as part of the design qualification effort.

8. Dragi Stamenković,Ivana Vasović.

In this paper, Manual Metal Arc Welding of carbon steel plates was studied. The finite element analysis of residual stresses in butt welding of two similar plates is performed with the ANSYS software. This analysis includes a finite element model for the thermal and mechanical welding simulation. It also includes a moving heat source, material deposit, temperature dependant material properties, metal plasticity and elasticity, transient heat transfer and mechanical analysis. The welding simulation was considered as a sequential coupled thermo-mechanical analysis and the element birth and death technique was employed for the simulation of filler metal deposition. The residual stress distribution and magnitude in the axial direction was obtained. A good agreement between the computation and experimental results is obtained.

9. Y.Dong,J.K.Hong,C.L.Tsai,P.Dong

Three dimensional Finite Element Modelling of residual stresses in a girth welded pipe is presented in this paper ,with an emphasis on modelling procedure for the global residual stress characteristics. The shell element model with a heat source moving along the circumferential joint is demonstrated to be cost effective and capable of predicting the global residual stress features Transient residual stress behaviours near the weld start and stop locations are discussed The effect of wall thickness and welding speed on residual stresses are also presented in this paper.

10.S.R. Thorat, Dr.Y.R.Kharde, K.C. Bhosale , S.B. Kharde

Fusion welding is a joining process in which the coalescence of metals is accomplished by fusion. Owing to localized heating by the welding process and subsequent rapid cooling, residual stresses can arise in the weld itself and in the base metal. Residual stresses attributed to welding pose significant problems in the accurate fabrication of structures because those stresses heavily induce brittle fracturing and degrade the buckling strength of welded structures. Therefore, estimating the magnitude and distribution of welding residual stresses and characterizing the effects of certain welding conditions on the residual stresses are deemed necessary. The transient temperature distributions and temperature variations of the welded plates during welding were predicted and the fusion zone and heat affected zone were obtained.

*11.Mr.L.SuresKumar,Dr.S.M.Verma,P.Radhakrishna Prasad, P.Kiran kumar Dr.T.Siva Shanker***.**

This Paper discuss about the mechanical properties of austenitic stainless steel for the process of TIG and MIG welding. As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW or MIG welding is used to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embitterment if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc. We used the TIG and MIG process to find out the characteristics of the metal after it is welded .The voltage is taken constant and various characteristics such as strength, hardness, ductility, grain structure, modulus of elasticity, tensile strength breaking point, HAZ are observed in two processes and analyzed and finally concluded.

12. Deepak M.Badgujar, S.P. Shekhawat.

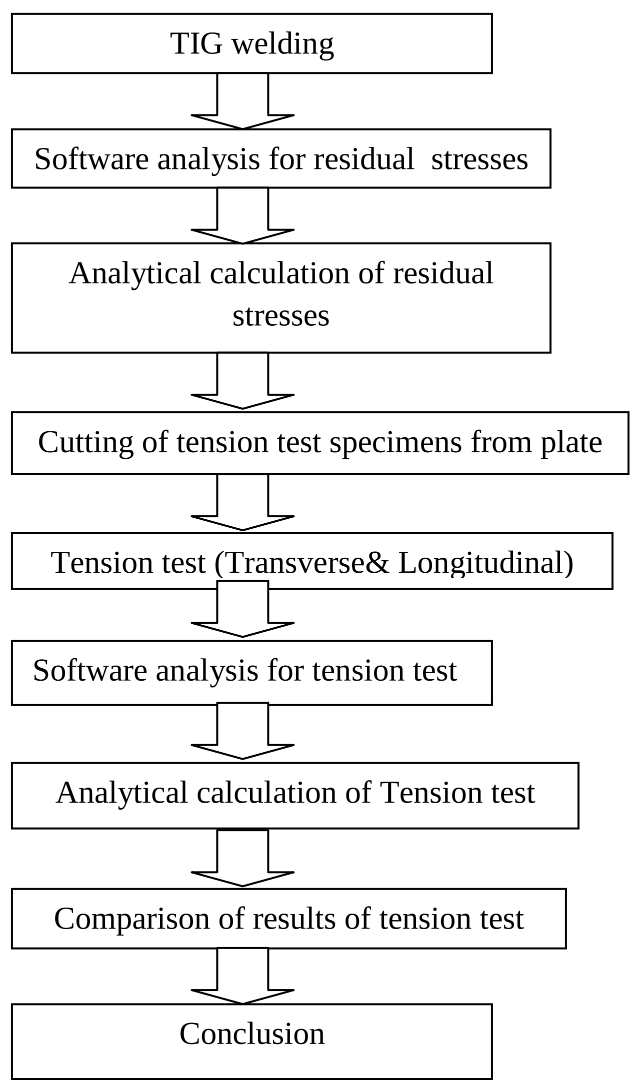
In this paper, the finite element analysis of residual stresses in butt welding of two similar plates is reviewed with the ANSYS software. For this paper work thermal structural direct coupled field analysis is used to simulate welding process. The residual stress distribution and magnitude in the axial direction was obtained. Finite element analysis is the effective method to carry out the stress analysis and to identify the stress gradient in the component. In this project temperature variation and stress, strain characteristics of the butt welded steel plate were studied and results were derived by Finite element analysis and coupled field analysis. This analysis is very useful for the engineers worrying in the field of welding technology and processes. Comparison between experimental residual stresses and FEA residual stresses is done. These results are found to be very much similar.

13. Gurinder Singh Brar.

Welding is one of the most reliable and efficient permanent metal joining process in the industry. When two plates are joined together by welding, a very complex thermal cycle is applied to weldment. Thermal energy applied results in irreversible elastic-plastic deformation and gives rise to residual stresses.

In this paper the finite element analysis was performed to understand the complete nature of residual stresses in manual metal arc welded joint of AISI 304 stainless steel plate. Variation of residual stress in the plates in the heat affected zone was also being studied. The results obtained by finite element method agree well with those from X-ray diffraction method as published in literature for the prediction of residual stresses.

III. Flow chart



IV. CONCLUSION

While studying literatures it is observed that, FEA is an effective method for prediction and assessment of welding residual stress and distortions.Many of the researchers found results of FEA are in good agreement with the measured results for residual stresses. Also it is found that the literature is not enough on TIG welded stainless steel 310.

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