ANALYSIS OF RESIDUAL STRESSES IN A DISSIMILAR METAL WELDED JOINT

B.SURYAM,
13671D0409, M.Tech (CAD/CAM),
Department of Mechanical
J.B. Institute of Engineering & Technology

G. GOPAL KRISHNA,
ME (Ph.D), Associate Professor,
Department of Mechanical, J.B. Institute of Engg. & Tech.
Email: krishanas@gmail.com

ABSTRACT

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.

In this project we are going to study of changing properties of two dissimilar metals while welding and also analyze the distribution of the residual stress, thermal and structural defects in weld joints by means of finite element method (FEM) using ANSYS and ABAQUS software's.

In this process we are going to simulate the welding process of two dissimilar metals (stainless steel with copper), because of this complex welding process. Predicting residual stresses becomes a very difficult challenge.

Recently, a number of numerical models based on thermal elastic plastic finite element method have been used to predict residual stresses in dissimilar metal weld joints. It has been recognized that residual stresses in a welded structure are the product of its entire history. Therefore, when numerical simulation technology is used to obtain residual stresses, the result would be less accurate.

In the present work, an attempt is made to predict residual stresses in dissimilar metals by means of an improved computational procedure. With using the computational procedure, the variations of the stress status in welding processes are investigated. In addition, the numerical results are compared with the theoretical data and the usefulness of the computational procedure is verified.

INTRODUCTION

Welding represents one of the most complex manufacturing processing terms of number of variables involved and factors contributing to the final output or response. Welding has been used in the fabrication of structures ranging from conventional industrial applications to high-tech engineering applications in aeronautical, nuclear, aerospace, marine and high-pressure vessel applications. Compared to mechanical joining methods, welding method offers some significant advantages including flexibility of design, improved structural integrity and weight & cost savings.

A wide range of similar and dissimilar metals can be joined by various welding processes. Dissimilar metals welding include relatively more difficulties than that of welding similar metals. This is due the variation in physical and thermal properties of the metals. In the present scenario demand of the joining of dissimilar materials continuously increases due to their advantages, which can produce very narrow heat affected zone (HAZ), low residual stress, and small welding defects. Welding of stainless steel 304L with pure copper includes a large variation in considering the parameters. In Power generation industries the copper and steel joint have been widely been used due to their high electrical conductivity and stiffness. The demand for producing joints of dissimilar materials is continuously increasing due to their advantages, which can provide appropriate mechanical properties and good cost reduction.

TIG or GTAW welding is one of the most common welding used in several industries for welding various metals. It is an economical a high productivity process. This process can be used for welding both similar and dissimilar metals and the parameters can be varied and controlled depending on the requirements.

The use of optimization of the parameters has improved as the design and the process parameters can be estimated without any difficulties. The optimization of process parameters can improve quality of the product and minimize the cost of performing lot of experiments and also reduces the wastage of the resources. The optimal combination of the process parameters can be predicted. This project deals with the optimum parameters that are required to obtain a proper weld and hardness. The optimization is processed using ABAQUS software and then experimental procedure is carried. The main parameters considered are the voltage, current, temperature and the filler material to be used.

This thesis mainly addresses about the investigation of process parameters that result in proper welds and the simulation of temperature distribution, heat flux distribution and direction of distortion of the base metals after welding. However any welding process induces the stresses in base metals and leads to distortion. This can be observed in simulation and can be minimized by using proper techniques.

LITARETURE SURVEY

M. Audronis and J. Bendikas[1] concluded that Welding deformations are often calculated using analytical approaches or finite element analysis. In this article the methodologies of Okerblom,

Walter, Horst Pflug, Sparagen–Ettinger, [2] Blodgett and finite element analysis, were applied to calculate deformations. The experimental study of deformations was made using austenitic stainless steel X8CrNiTi 18-10. The results of analytic analysis were compared with the results of the experimental

Dean Deng [3] concluded that Dissimilar metal weld joints are widely used in the nuclear power plants to connect the ferritin steel components and the austenitic steel piping systems. Because the manufacturing processes are considerably complicated, it is difficult to accurately predict residual stresses in dissimilar metal weld joints by numerical simulation technology. In this study, a simplification methodology has been developed to compute residual stresses

June-soo Park, [4] Ha-cheol Song concluded that this study is concerned with the stress analysis and fracture mechanics evaluation for a sub-critical crack in the dissimilar metal weld (DMW). The DMW considered herein is a transition joint of the ferritic nozzleto austenitic safe-end using the Inconel A 82/182 buttering and weld deposit. Weld residual stresses in the DMW nozzle are computed by non-linear thermal elasto-plastic analysis using the axisymmetric finite element (FE) model

R.L. Smith & G.E. [5] Sandland, concluded that Before undertaking to coninience an investigation of this description, it is, of course, most desirable that the term "hardness" should be clearly understood and well defined. Unfortunately, up to the present, there is no universally approved or standardized quantitative definition for "hardness," and it therefore follows that until the arrival of this definition, all investigations in search of accurate methods for hardness testing will be done

MR.MIRSADATALI, DR.CH.SRINIVASARAO, [6] concluded that the dissimilarity of the metals may arise due to the difference in chemical composition. The chemical composition of the steel affects weld ability and the mechanical properties of the welded joint. During the reclamation and repair work of structural and machine components the difference in chemical composition of the material to be welded is very much pronounced. These differences in chemical composition arise due to age.

THEORITICAL ANALYSIS

In other word 'welding' is define the joining of two or more surface under the influence of heat, so the product shall be nearly homogeneous union as possible. There are so many types of welding process to weld metal or non-metals are given below.

Welding

Welding is a fabrication process that joins materials, usually metals, thermoplastics, by causing coalescence. This is often done by melting the pieces and adding a filler material to form a pool of molten material that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. In this process the joining metals or non-metals can melt by the help of thermal source like a gas flame or electric arc or laser and then using filler metal. Welding is generally two types

i) Conventional

ii) Nonconventional

Conventional is again sub-classified into several types such as shielded metal arc welding, gas metal arc welding, plasma arc welding, TIG welding etc.

TIG Welding

Principle of TIG welding

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by a shielding gas and a filler metal is normally used.

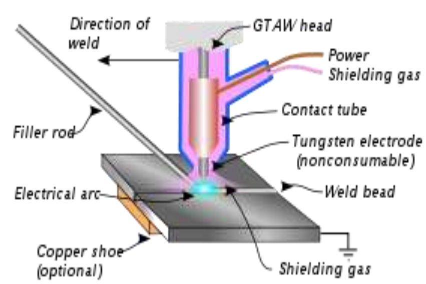


Figure: GTAW weld area

The equipment required for the gas tungsten arc welding operation includes a welding torch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

Welding torch

GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. Air cooling systems are most often used for low-current operations (up to about 200 A), while water cooling is required for high-current welding (up to about 600 A). The torches are connected with cables to the power supply and with hoses to the shielding gas source and where used, the water supply. The internal metal parts of a torch are made of hard alloys of copper or brass in order to transmit current and heat effectively. The size of the welding torch nozzle depends on the amount of shielded area desired. The size of the gas nozzle will depend upon the diameter of the electrode. The nozzle must be heat resistant and thus is normally made of alumina or a ceramic material.

Figure GTAW power supply

Figure GTAW torch with various electrodes, cups, collets and gas diffusers

SIMULATION TECHNIQUES

Simulation is the imitation of the operation of a real-world process or system over time. It includes the development of the model. This model represents the key characteristics or behaviors of the selected physical or abstract system or process. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation of welding can be obtained by the numerical methods in which finite element analysis is the most common simulation technique.

The finite element analysis (FEA) is used for finding approximate solutions. FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. In welding the temperature distribution, residual stresses, heat flux variations, distortion and several other effects can be predicted without conducting any experiments. However, the simulation of the welding process includes several complications such as the interaction between the weld pool and the base metals, temperatures that vary with time, weld speed, properties of the weld pool etc. The solutions obtained through the analysis are optimum.

Introduction to FEA

The finite element method has been presented in 1956 by Turner,Clough, Martin and Top. The finite element method was initially developed for structural mechanics but later on it was applied to heat transfer, fracture mechanics, flow and coupled field problems. The basic purpose for finite element method is to optimize the complications and find the appropriate solutions to the problems. This method is widely applied in various fields like structural analysis, heat analysis, etc. In this modeling is relatively easy to that of CAD technologies. The overall structure is sub divided into small structures called elements. Then the appropriate load conditions and properties of the model are to be assigned.

To predict the behavior of structure three methods have to be adopted such as analytical, experimental and numerical methods. The analytical method is used for the regular sections of known geometric entities or primitives where the component geometry is expressed mathematically. The solution obtained by analytical method is exact and takes less time. This method cannot be used for irregular sections and the shapes that require very complex mathematical equations. On the other hand the experimental method is used for finding the unknown parameters of interest. But the experimentation requires testing equipment and a specimen for each behavior of requirement. This in turn, requires a high initial investment to procure the equipment and to prepare the specimens. There are many numerical schemes such as finite difference methods; finite element method, etc. are used to estimate the approximate solutions of acceptably tolerance.

EXPERIMENTAL ANALYSIS

Processing is normally carried out at room temperature in a clean environment. Appropriate fix Turing is needed to ensure that the parts do not move relatively to one another welding to prevent misalignment and the formation of gap. Molten weld metals are protected from environmental contamination by a quiescent blanket of inert shielding gas such as argon.

Process gas

Gases are used in welding because of three main functions

(1) Shielding

(2) Protection of optics

Shielding of the molten weld pool prevent oxidation and contamination, which could lead to porosity and embrittlement. Both the weld bead face and root face required shielding. Plasma is caused by ionization of ejected metal vapor and of the shielded gas.

Joint Preparation

The weld joint of the two metals should be properly made. A grove angle of 60^0 is to be prepared. The finishing of the faces should be done. Prior to joining materials should be cleaned thoroughly. If the component contains residual from prior processing, they are often baked to remove moisture and contaminants. Surface are abutting edges should be as smooth as possible to avoid welding imperfections the mechanical properties of base materials should be measured to establish a baseline against which the properties of the welded joint can be compared.

Featuring

Accurate featuring is necessary in welding. Gap along the joint line should be maintained constant. Joint parts may be fixture in a frame to avoid angular and bending shrinkage. Clamps are also used as fixture in order to avoid relative motion between the base metals.

Specifications

The process parameters of the T.I.G welding we used are

Process	GTAW
Diameter	1.6-2.0
Type polarity	DCEN
Amp range	100-150
Volt range	11-14
Travel speed range	40-1400 mm/min
Shielding gas	Argon
Flow rate	5-12 pm

Filler material is used according to the base metals which are welded. Filler metal will one of the base material type in case of dissimilar welding. Nickel is rarely used filler for dissimilar metals. The soluble metal with both the base metals can be used. Buttering or layering of the common alloy of the both base metals is also done.

Experimental procedures

In this investigation it consists of the welding of copper with stainless steel304.

Table: Composition of copper

Material	C	Si	Cu
Copper	3.88	0.82	95.29

The successful weld joint was obtained after several trials. The main problem is copper doesn't melt easily due toits high thermal conductivity which results in the fast dissipation of heat input than that of the stainless steel.

But finally after 3 trials we could weld the two dissimilar nonferrous and ferrous metals successfully by arranging the backup plates which restricted the heat dissipation and allowed the copper to melt and forma weld pool with stainless steel.Thereby an alloy of copper stainless steel is formed and finally joined both metals

SIMULATION OF PROBLEM

Welding of copper and stainless steel is a complex procedure and involves critical parameters to be considered. The input parameters are obtained from the experimental procedure. Residual stresses are induced in the metals and which may lead to cause a metal part suddenly split into two or more pieces after it has been resting on a floor or table without any external load being applied.

Residual stresses lead to distortion in the welded joints. This has to be controlled in order to avoid distortion. This can be reduced by clamping or by providing proper fixtures while welding. In this project, the base metals are clamped using c-clamps during welding which reduces the distortion to some extent.

The main parameters required are

- Dimensions of the weld plates
- Material properties
- Groove angle between the plates
- Weld temperature
- Ambient temperature
- Interaction properties between the metals

Butt Weld Modeling

The weld plate of dimensions (130* 75*6.5) mm is created. Divide the plate in two parts by partitioning or by using a cutting plane exactly at the midpoint of the length. Define the materials pure copper and stainless steel 304 with the properties density, thermal conductivity, specific heat capacity, young's modulus and poison's ratio.

The properties of the metal are tabulated below

TABLE – Properties of the metal

Metal	Copper	Stainless steel
Thermal conductivity	401	16
Specific heat	390	510
Density	8940	7500
Young's modulus	118	180
Poison's ratio	0.34	0.28

Define the sections with solid homogeneous type of materials copper and stainless steel. Assign these sections to the parts of the model that are to be required to assign the properties. The parts are to be assembled to in order to globalize the coordinates. To assemble the parts create an instance with dependent type i.e. mesh on the part.

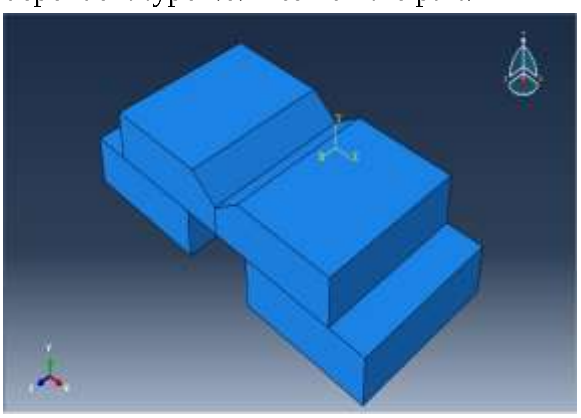


Figure- Pre-Requisites of Model

Step and interaction

Heat transfer step and thermal analysis step is to be created in order to conduct heat analysis. The step should be solid homogeneous type. The interactions are to be created at the weld pool and between the surface and the surroundings.

Load and boundary conditions

The boundary conditions given are the ambient temperatures to the extreme surfaces. The constant boundary temperature is to be assigned. Thermal load is applied on the weld joint in the form of surface heat flux. The boundary temperature given is 27^0C. The thermal load applied is3100KJ.

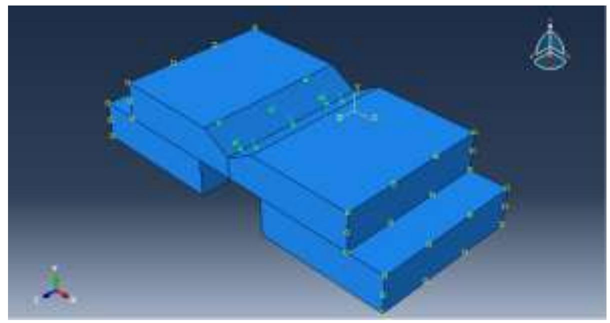


Figure: Load and boundary conditions

Meshing

The mesh tool is used and the meshing of the part is done by selecting TET element type. The size of the mesh i.e. the number of seeds the part is to be divided is to be mentioned. Then adjust the seed size and mesh the parts. Meshing of the part is done after applying the loads over the part.

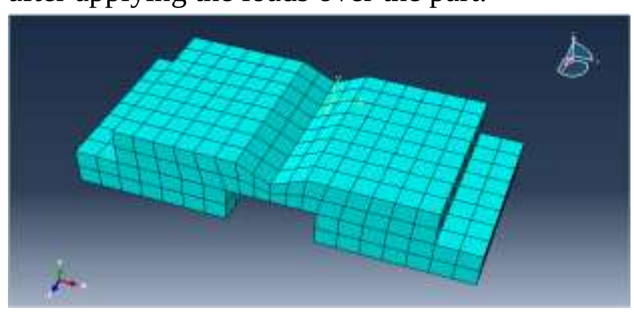


Figure: Meshing

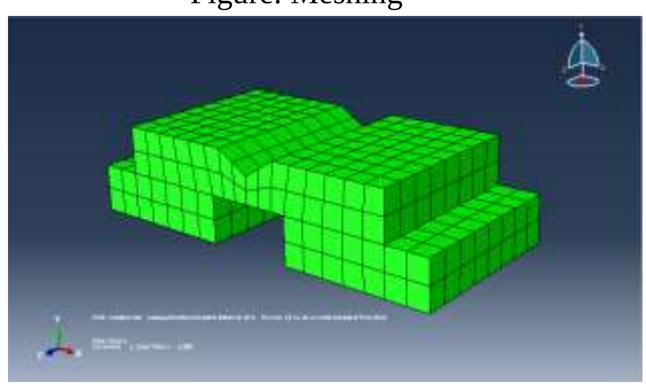


Figure: Execution of the input values

RESULTS AND DISCUSSION

- Finally, copper and stainless steel got welded and the hardness, toughness, Universal Tensile strength of the weld joint is higher than that of brazing joint. Using vicker's hardness test, izod impact test and universal tensile strength

Vicker's Hardness Test

The Vickers hardness test was developed in 1921 by Robert L. Smith and George E. Sandland at Vickers Ltd as an alternative to the Brinell method to measure the hardness of materials. The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source.

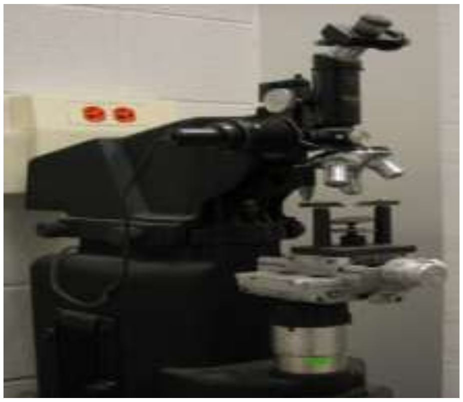


Figure Vicker's Hardness Test Machine

When doing the hardness tests the minimum distance between indentations and the distance from the indentation to the edge of the specimen must be taken into account to avoid interaction between the work-hardened regions and effects of the edge. This minimum distances are different for ISO 6507-1 and ASTM E384 standards.

Experimental results

The welding of stainless steel and copper is successfully carried out by using the backing plates. In order to calculate the hardness and strength of the weld joint and to observe the metals in the alloy of the weld joint, hardness tests and chemical tests were conducted on both the welded joint and brazed joint.

Standard	Distance between indentations	Distance from the center of the indentation to the edge of the specimen
ISO 6507-1	> 3·d for steel and copper alloys and > 6·d for light metals	2.5·d for steel and copper alloys and > 3·d for light metals
ASTM E384	2.5·d	2.5·d

Figure: A sample of welded joint for testing

According to the Vickers hardness test conducted on the brazing sample under

Test procedure IS 1501-2002
Indenter diamond
Load applied 10 kgs

The hardness at three different places on Brazing jointas shown in the below table

Table Hardness for brazing joint

Number of impressions	Hardness at that particular Point(Pascal)
First	159
Second	[illegible]
Third	[illegible]
Average	[illegible]

The hardness at three different places on Welding jointas shown in the below table

Simulated results

The nodal distribution on the plates, heat flux vectors and the direction in which the distortion takes place are observed in ABAQUS.

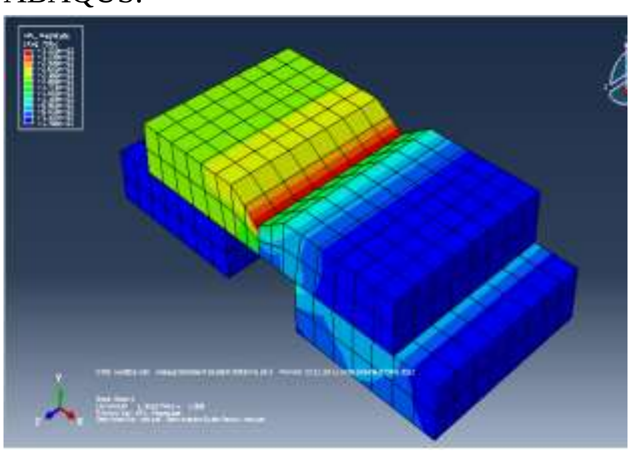


Figure Effect of Heat Flux Vectors with Backing Plates

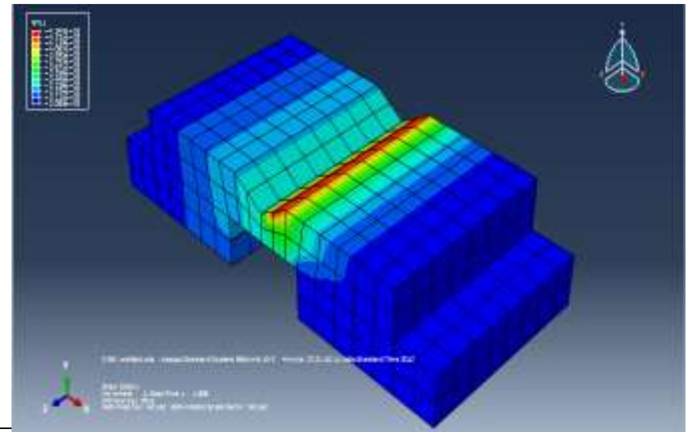


Figure Effect of Nodal Temperature Distribution with backing plates

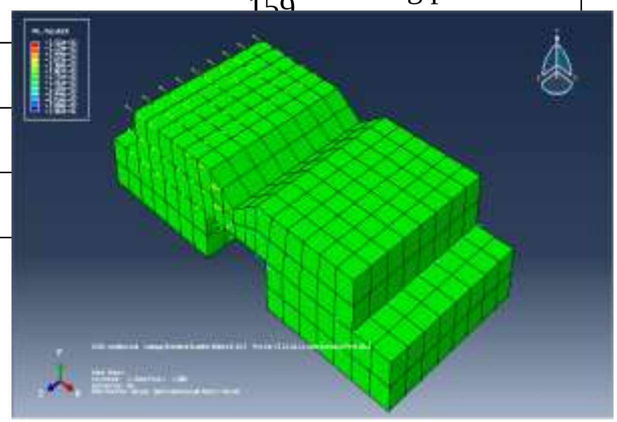
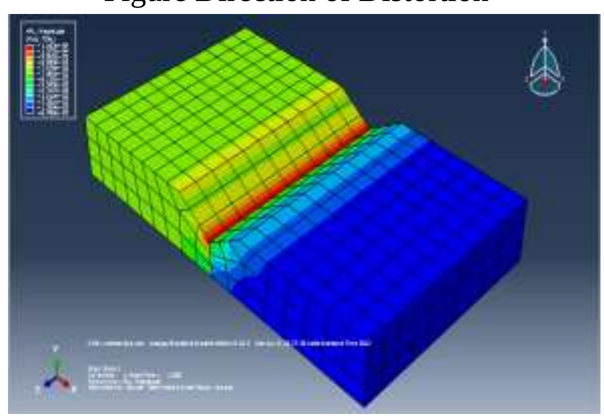


Figure Direction of Distortion



CONCLUSION

- By using some basic principles of heat transfer in the composite walls the heat transferred from copper is restricted by arranging the backing plates.
- Finally, copper and stainless steel got welded and the hardness, toughness,

Universal Tensile strength of the weld joint is higher than that of brazing joint.

- The hardness obtained for the weld joint is 201.00 Pascal
- The toughness obtained for the weld joint is 68 J/m^2
- Universal Tensile strength obtained for the weld joint 310 MPa
- The FEA model is simulated in ABAQUS were the heat transferred is been analyzed on the weld bead formed

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