Finite Element Analysis Of Residual Stress In Butt Welding Of Two Similar Plates In Different Material

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Abstract ***Carbon steel and titanium metal matrix composite materials represent a significant metal portion of the aircraft structural, engine components and various auto parts. Residual stresses induced even a normal butt welding of corresponding plates, which is critical due to safety and sustainability concerns. And residual stresses along the weldment area are very difficult to predict unless it destruct or very expensive. This paper presents Metal Arc Welding of carbon steel plates and metal matrix composite plates arestudied. 3d model of corresponding metal plates are created with solidwork 2013 edition software. 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. The study includes a finite element structure for heat (thermal) and structural (mechanical) welding analysis. The welding simulation was considered as a sequential coupled thermo-mechanical analysis was employed for this operation. The residual stress distribution and magnitude in the axial direction .Result and comparison of two plates in same materials on two materials was obtained.***

Keywords: Carbon Steel, Metal Matrix Composite (Ti-6al-4v+12% Tic), Residual Stress, Solid Works, Ansys.

I. INTRODUCTION

Butt welding is a welding technique used to connect parts which are nearly parallel and don't overlap. It can be used to run a processing machine continuously, as opposed to having to restart such machine with a new supply of metals. Butt-welding is an economical and reliable way of joining without using additional components. Usually, a butt-welding joint is made by gradually heating up the two weld ends with a weld plate and then joining them under a specific pressure. This process is very suitable for prefabrication and producing special fittings. Afterward, the material is usually ground down to a smooth finish and either sent on its way to the processing machine, or sold as a completed product.

With arc welding, after the butt weld is complete, the weld itself needs to be struck with a hammer forge to remove slag (a type of waste material) before any subsequent welds can be applied. A joint between two members aligned approximately in the same plane. Butt welding can also be achieved through traditional blow torches in the most common form of butt joints, a process that uses some variety of flux, usually a tin-based solder and precise hand-eye coordination that is common for hand-made boxes of copper , brass, and silver. There are two types of butt welding; one is carried out by smiting and another is carried out by welding two work pieces by non-overlapping. The process consists of two desired strips of metal that are lined with flux that is lightly dried with a blowtorch until it is a sticky consistency, followed by cutting a strip of solder that is generally 20% of the full joint's size. Applying heat gently makes the gel-like flux now appear white and powdery which now is primed to be welded in which the blow torch is arched so that the "heat cone", the bluest and hottest part of the flame, is now directly upon the solder melting the joints together evenly.

Selection Of Materials:

2SELECTIONS OF MATERIALS

2.1 CARBON STEEL

Steel which contains carbon as the main alloying constituent is known as carbon steel. Based on the content of its basic constituent, it can be classified as follows.

- Low or mild steel
- Medium steel
- High content steel
- Ultra-high carbon content steel

Low or mild steel: Mild or low steel contains 0.16-0.29% of carbon. This variety of steel is used for various applications as it is relatively cheap compared to the other types of steel. Mild steel has comparatively lower durability and strength as it contains lesser amount of the main constituent. Used in places when large amount of steel is required, this variety of steel is applicable for various construction purposes.Medium steel: Another notable variety of steel which is quite strong and resistant to wear and tear. It is mainly used for automotive components and large metal structures.High carbon steel: This variety of steel is very strong and is mainly used for manufacturing high-strength wires and springs.Ultra-high steel: These steels are mostly used for non-industrial purposes as it is very hard and strong. It is used to manufacture axles, knives and other hard materials.

I. CARBON STEEL (AISI 1040 STEEL)

Carbon steel has high carbon content and can be hardened by heat treatment followed by quenching and tempering to achieve 150 to 250 ksi tensile strength. Chemical composition of 1040 steel are Iron 98.6-99%, Manganese 0.60-0.90%, Carbon 0.37-0.44, Sulfur <0.05% and Phosphorous <0.04%.Carbon steel is a medium carbon, medium tensile steel supplied as forged or normalized. This steel shows good strength, toughness and wears resistance.Carbon steel is a medium-carbon engineering steel that is suitable for flame or induction hardening. It is a versatile forging material with mechanical properties that are appropriate for a full range of applications. The steel can be readily welded and machined providing correct procedures are followed.

Carbon steel is forged from 2100 – 2300 º F down to a temperature in the range 1600 – 1700 º F (1150*–1280 º C down to 870 – 925 º C.). The actual forging and finishing temperatures will depend on a number of factors, including overall reduction during forging and complexity of part being forged. Experience alone will1040 steel is weldable by all of the welding methods. However with its higher carbon content it is important to use both pre-heat at 300 to 500 F and post-heat at 1100 to 1200 F practice per an approved welding procedure.determine near exact values for these two parameters. In the annealed state the 1040 alloy is readily cold worked by conventional methods. Anneal at 1600 to 1800 F and slow cool in the furnace for a full anneal. A stress relief anneal may be done at 1100 F and a normalizing treatment may be done at 1650 F with slow cooling.

Application

AISI 1040 carbon steel can be used in couplings, crankshafts, and cold headed parts. Carbon Steel can be used in various fields for various purposes. While low carbon steel is used for making fences, The mild carbon steel with "medium" amount of carbon used in it, is best suited and used for constructing bridges and buildings. The high carbon steel is mainly used for wires. The ultra-high carbon steel which is also known as "cast iron" is used in the making of pots and pans

Mechanical and Thermal Properties

Sl.No	Properties	Parameter
1	**Young's modulus**	1.9e+5 MPa
2	**Poisson's ratio**	0.27(no unit)
3	**Density**	7845 kg/m^3
4	**Shear modulus**	74803MPa
5	**Bulk modulus**	1.376e+5MPa

II. METAL MATRIX COMPOSITE (Ti-6Al-4V+12% Tic)

Titanium-based metal composites (TMCs) are showing great potential to replace existing traditional materials in aerospace, automotive, and other high temperature engineering applications. This is due to their excellent mechanical, thermal, and physical properties and improved strength to weight ratio. Weight savings in the aerospace industry results in higher efficiency. Carbon nanotubes (CNTs), because of their low density and high Young's modulus, are considered einforcement for metal matrix composites (MMCs). In the last 20 years extensive research has been carried out to investigate the combination of carbon nanotubes with aluminum, nickel, copper, magnesium, and other metal matrices.

The production techniques such as mechanical alloying through powder metallurgy routes and their effects on the mechanical properties of CNT reinforced TMCs are reviewed in this article. The role of the volume fraction of carbon nanotubes and their dispersion into the metal matrix are highlighted. Governing equations to predict the mechanical and tribological properties of CNT reinforced titanium matrix composites are deduced. With the help of this initial prediction of properties, the optimal processing parameters can be optimized. Successful development of CNT reinforced TMCs would result in better wear and mechanical behavior and enhance their ability to withstand high temperature and structural loading environments

The addition of titanium with titanium carbide has a positive influence on the modified MMCs. It is noticed that the hardness of the substrate increased from 357.30 HV to 541.30 HV for 88%Ti+12%TiC MMC which have the highest hardness value in the Ti+TiC system. Metal injection molding (MIM) was used to fabricate Ti–6Al–4V matrix composites reinforced with 12 vol.%TiC particles (referred to as TMCs) at CANMET Materials Technology Laboratory.

In this method, a mixture of gas atomized Ti and 60Al40V master alloy powders (both with an average size less than 45_m) were mixed with TiC particles (irregular in shape and size ranging from 1 to 10_m) and a wax-based binder in a Tumbler mixer for 30 min followed by hot mixing in a twin-screw extruder at 130 ◦C to produce the feedstockTitanium Matrix Composites (TMC) consist of a titanium metal matrix reinforced with unidirectional continuous SiC fiber. The resulting composite exhibits exceptional mechanical properties, is lightweight, corrosion resistant and able to operate in high-temperature environments. The combination of lightweight and high strength result in weight adjusted (specific) properties unmatched by any other flight-qualified aerospace metallic material.

Sl.no	Properties	Parameter
1 1	**Density**	4.43e-006 kg/m^3
2	**Young's Modulus**	1.14e+008 MPa
3	**Poisson's Ratio**	0.342 (no unit)
4	**Bulk Modulus**	1.2e+008 MPa
5	**Shear Modulus**	4.2e+007 MPa

Advantages

TiC particulate reinforced Ti6Al4V metal matrix composites (Ti6Al4V+12wt.%TiC) have high strength-to-weight ratio and good high temperature properties.

TiC reinforced Ti6Al4V based composites (TiC/Ti6Al4V), and these work has got a remarkable improvement in hardness and tribological properties.

Hardness values of TiC/Ti6Al4V composites maintain at about 345HB which is nearly 70HB higher than that of the titanium alloy.

Applications

Titanium matrix composites , such as the particle reinforced Ti6Al4V+12 wt.% TiC, can be included in this new era opening new perspectives for applications such as sporting goods and aerospace structures. The use of advanced materials is very attractive to material scientists and high-technology industries.

Application of titanium metal matrix composite will be in compressor bladed rings(blings) in which the good longitudinal titanium metal matrix composite properties can be fully exploited while the weakest transverse orientation can be protected.

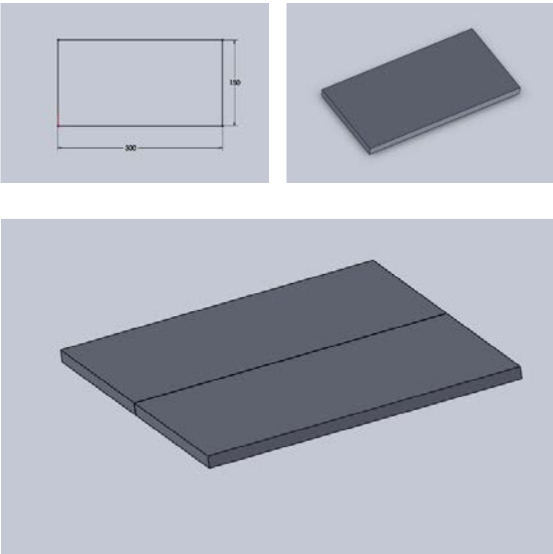
Parameters	Values
Length of plate	300 mm
Width of plate	150 mm
Thickness	12 mm

Aerospace engine and airframe designers are constantly seeking lighter weight high strength materials to reduce weight and improve performance of power plants and aircraft. Titanium metal matrix composites (Ti MMCs) have offered the promise of significant weight savings.

Ti6Al4V+12 wt.%TiC materials which are used for tail rotor for helicopter manufacturing.

Dimension of carbon steel plates and titanium composite plate

SOLID WORKS DRAWINGS



III. METHODOLOGY

MODELING

The butt welding model has been entirely modelled by SOLIDWORKS software. First of all sketch command of the solidworks is opened. Then by using 2d commands sketch is created. Then the 3D model of butt welding plates is created by extrude command in solid works.

TRANSFORMATION OF MODEL

Then the model is converted in to the IGES format which is most suitable and easy access for any other software's. Using the IGES format we can import the butt welding model from solid works to ANSYS. Now we can make static structural analysis and modal analysis.

MESHING

After the complete structure is modeled, butt welding is meshed. This has been done by using ansys workbench software. The last step to be completed before meshing the model is to set the meshing controls, i.e. the element shape, size, the number of divisions per line, etc. Selecting the various parts of the model, one by one finite element mesh is generated. The critical portions are plates with sharp corners, curvature etc. These areas can be remeshed with advance mesh control options. "Smart element sizing" is a meshing feature that creates initial element sizes for free meshing operation. Proper care has to be taken to have the control over the number of elements and hence the number of degrees of freedom associated with the structure. This is done to have acontrol over the solution time. However, no compromise is made on the accuracy of the results.

LOADING

The types of loading that can be applied in a structural analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements

ANALYSIS

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

A transient thermal analysis follows basically the same procedures as a steady-state thermal analysis. The main difference is that most applied loads in a transient analysis are functions of time. To specify time-dependent loads, you first divide the load-versus-time curve into load steps.

INTRODUCTION TO ANSYS

ANSYS is an engineering simulation software provider founded by software engineer John Swanson. It develops general-purpose finite element analysis and computational fluid dynamics software. While ANSYS has developed a range of computer-aided engineering (CAE) products, it is perhaps best known for its ANSYS Mechanical and ANSYS Multi physics products.

ANSYS Mechanical and ANSYS Multi physics software are non exportable analysis tools incorporating pre-processing (geometry creation, meshing), solver and post-processing modules in a graphical user interface. These are general-purpose finite element modeling packages for numerically solving mechanical problems, including static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

ANSYS Mechanical technology incorporates both structural and material non-linearities. ANSYS Multiphysics software includes solvers for thermal, structural, CFD, electromagnetic, and acoustics and can sometimes couple these separate physics together in order to address multidisciplinary applications. ANSYS software can also be used in civil engineering, electrical engineering, physics and chemistry.

ANSYS, Inc. acquired the CFX computational fluid dynamics code in 2003 and Fluent, Inc. in 2006. The CFD packages from ANSYS are used for engineering simulations. In 2008, ANSYS acquired Ansoft Corporation, a leading developer of high-performance electronic design automation (EDA) software, and added a suite of products designed to simulate high-performance electronics designs found in mobile communication and Internet devices, broadband networking components and systems, integrated circuits, printed circuit boards, and electromechanical systems. The acquisition allowed ANSYS to address the continuing convergence of the mechanical and electrical worlds across a whole range of industry sectors.

INTRODUCTION TO FEA

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. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition.In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modelling, and 3-D modelling. While 2-D modelling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modelling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modelling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

IV. SIMULATION

APPROPRIATE ANALYSIS

4.4.1 Static structural analysis

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The types of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)

4.4.2 Thermal analysis

The ANSYS/Multiphysics, ANSYS/Mechanical, ANSYS/Thermal, and ANSYS/FLOTRAN products support transient thermal analysis. Transient thermal analysis determines temperatures and other thermal quantities that vary over time. Engineers commonly use temperatures that a transient thermal analysis calculates as input to structural analyses for thermal stress evaluations. Many heat transfer applications-heat treatment problems, nozzles, engine blocks, piping systems, pressure vessels, etc.-involve transient thermal analyses.

A transient thermal analysis follows basically the same procedures as a steady-state thermal analysis. The main difference is that most applied loads in a transient analysis are functions of time. To specify time-dependent loads, you first divide the load-versus-time curve into load steps. Each "corner" on the load-time curve can be one load step, as shown in the following sketches.

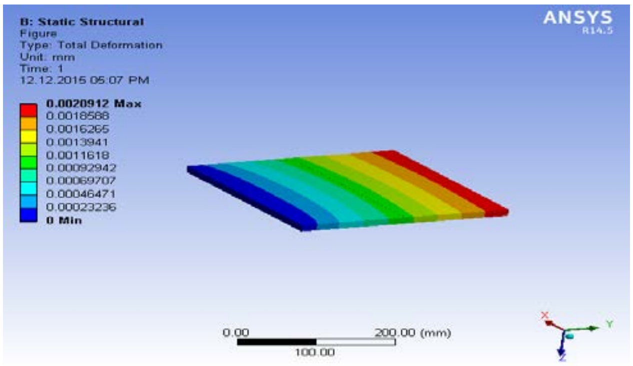
INPUTS

ANALYSIS AND INPUTS PARAMETER

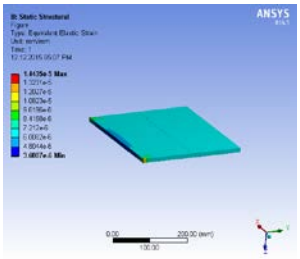
Parameters	Value
Maximum Temperature	1200^0c
Load applied	5000N

I. CARBON STEEL

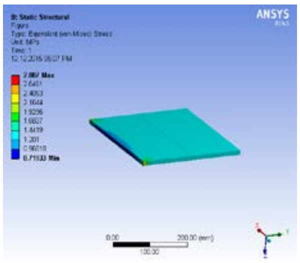
TOTAL DEFORMATION



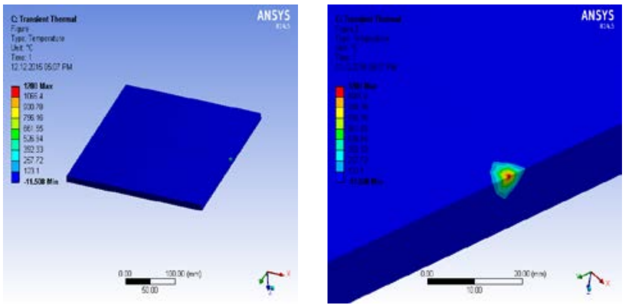
EQUIVALENT STRAIN



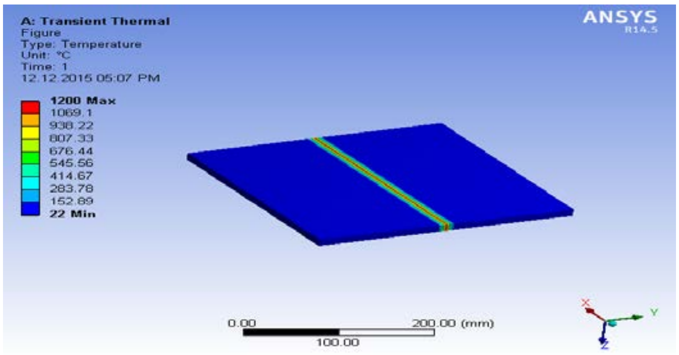
EQUIVALENT STRESS



TEMPERATURE DISTRIBUTION AT START POINT

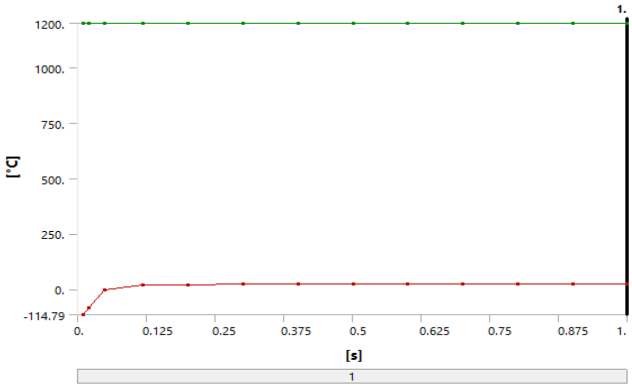


OVERALL TEMPERATURE DISTRIBUTION



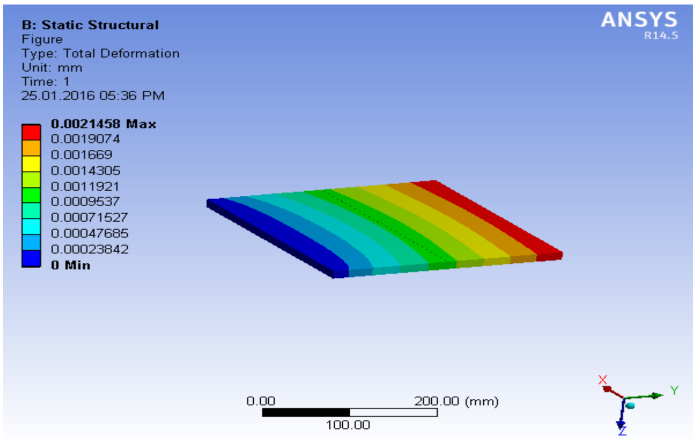
TEMPERATURE DISTRIBUTION

TEMPERATURE VS WELDING SPEED



II METAL MATRIX COMPOSITE

TOTAL DEFORMATION



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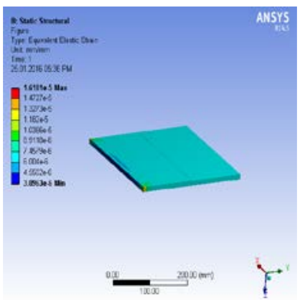
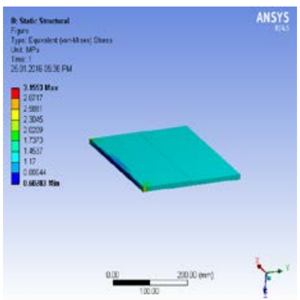
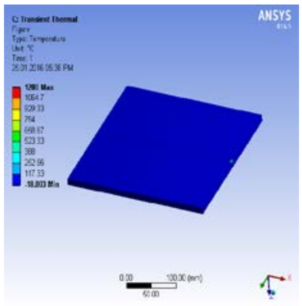
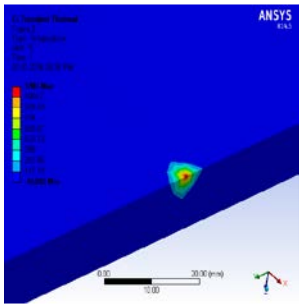


EQUIVALENT STRESS

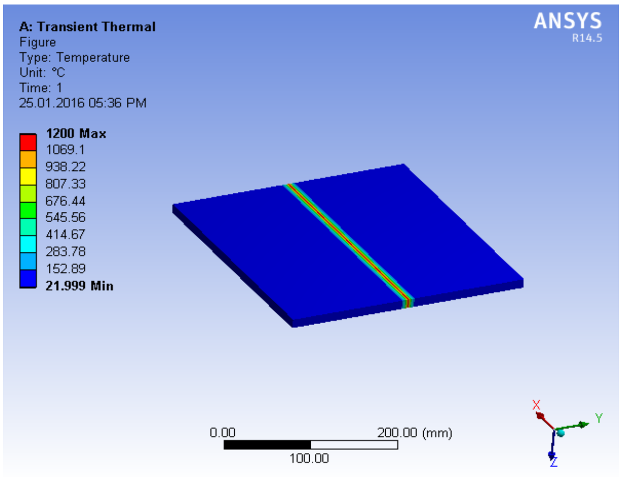


TEMPERATURE DISTRIBUTION AT START POINT



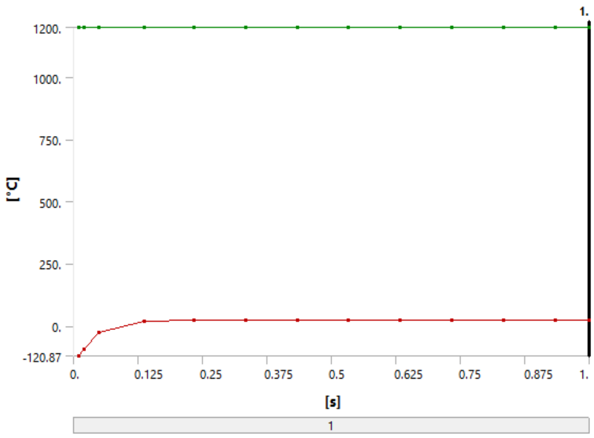


OVERALL TEMPERATURE DISTRIBUTION



TEMPERATURE DISTRIBUTION

TEMPERATURE VS WELDING SPEED



RESULTS AND COMPARISON OF ABOVE MATERIALS FROM FEM

MATERIALS	Total Deformaion (mm)	Max Strain (no unit)	Max Stress (Mpa)	Temperature Distribution (^{0}C)
CARBON STEEL	0.00209	1.44e-5	2.887	1200 to 22
METAL MATRIX COMPOSITE	0.00214	1.61e-5	3.155	1200 to 21.99

CONCLUSION

Analyzing results for weld plates under force and temperature are listed in the Table. Analysis has been carried out by carbon steel and metal matrix composite. The results such as total deformation, equivalent elastic strain, equivalent stress and temperature distribution for each material are determined. Comparing these materials, metal matrix composite has allowable limits compared to the carbon steel material.

The finite element method is an efficient technique in analyzing residual stresses in welding processes. A 3-D finite element welding simulation was carried out assuming welding is carried out by manual metal arc welding. 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 finite element analysis results of the residual stress distributions of two butt welded plates on two materials in the transverse direction are presented. It can be concluded that residual stresses are high in and around the weld zone and it is this zone which needs further investigation. Also it can be concluded that the decreasing of heat input decreases the distribution of residual stresses in the material.

While carrying out this project we are able to study about the 3Dmodelling software (SOLIDWORKS) and Study about the analyzing software (ansys). By using those software we predict residual stresses exhibiting on the area around the weld zone of two similar plates on different materials (carborn steel and titanium +titanium carbide composite) .

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