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Study on MIG and TIG Weldment Behaviour Using Finite Element Approach

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ABSTRACT

Welding production is used in a wide range of industries, including construction, automotive manufacturing, shipbuilding, aerospace, and more. It is a crucial process in creating strong and durable structures and products. Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. The completed welded joint may be referred to as a weldment. Failure of a welded junction happens when it does not satisfy expected strength standards or does not serve the purpose for which it was designed. A number of things, such as improper welding technique, the wrong choice of material, the wrong welding procedure, or subpar quality control during the production process, can lead to welding joint failure. Experimental tests for quality assurance and inspections were applied in aid for spotting potential problems and preventing welding joint failure. The weldments were studied for tensile test and impact test. The research provides discussion on the SolidWorks simulation method on different steel material in terms of quality welding joint. The objective of this study is to investigate the relationship between two types of welding which are MIG and TIG welding and different steel materials involving low carbon steel (LCS), cold-rolled steel (CRS) and hot-rolled steel (HRS) through SolidWorks simulation. The main focus of this study was to propose the best welding joint design with minimal welding defects, for instances, porosity, weld cracks and undercut. This study was designed in order to find out about the performances of various welding types on different steel materials castings in welding production. There were three different weld joint designs proposed in this study based on the previous researches with fixed parameters installed on each design.

1. Introduction

The implementation of good weld joint brought about the fundamental yields in the metal fabrication [1]. Weld joint is referring to the location where two or more pieces of metal or thermoplastic materials are joined together using welding techniques. There are several types of

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weld joints, each designed for specific applications and purposes. Some common types of weld joints including butt joint, lap joint, edge joint, T-joint and corner joint. The completed welded joint can be referred to as a weldment [2]. The components used in frame assembly can vary depending on the application and the desired strength and durability of the structure. In general, the components are joined using a combination of fasteners, adhesives, and welding. The choice of joining method depends on factors such as the materials being used, the load requirements of the structure, and the environmental conditions the structure will be exposed too [3]. The selection of material and welding joints was elaborated by Mehdi Mazar Atabaki *et al.,* [4] as it was among the major factor that contributed to welding defects through the first arc. Composite materials, which are made from a combination of two or more materials, are becoming increasingly popular in frame assembly due to their high strength-to-weight ratio [5].

The welding process introduces complications because of the high temperatures needed. Traditional fatigue analysis is complicated and tedious. It takes too long to perform and there are too many variables to consider. The expansion and contraction of the nearby base metal and the weld metal throughout the heating and cooling cycle of the welding process causes distortion in the weld [1]. Defects in welding can happen on the exterior or inside of the metal being welded. Welding defect, for instance, weld crack, is not accepted almost by all standards in the industry. It can appear on the surface, in the weld metal or the area affected by the intense heat. Most of these problems can be avoided by using the right techniques and properly prepping the materials to be welded [6]. The majority of welding issues can be resolved before the first arc by being more thorough up front [4,7].

Different weldment design would give a different result in terms of the outcomes of the process of welding process. Improper design of weldment design would contribute into several welding defects like weld cracks, porosity, undercut, heat deformation, low fusion and penetration [8]. Such requirements need to be studied and fulfilled to achieve a free welding defect throughout the metal fabrication process. Hence, the optimization of weldment design including the welding types and material specification need to be studied in order to obtain a good quality of frame welding production.

1.1 Welding Distortion

The major reason for distortion in arc welding is the fact that when the weld metal is deposited, it is molten and therefore fully expanded. The molten weld metal will solidify and can only exert contraction forces as it cools. This shrinkage force then acts on the parts to cause movement [9]. The other cause of distortion is expansion and contraction, which always accompanies changes in the temperature of metals. As metals are heated, they expand, and then cool as they contract. Furthermore, the amount metals expand and contract per 1 °C change in temperature is particular to each metal and does not change [10].

The amount which a metal expands or contracts per 1 °C change in temperature, is known as the coefficient of linear expansion. In welding, the situation described is created by the concentrated nature of the heat source, which causes local expansion and contraction as the weld progresses. Local expansion and contraction take place in the parent metal adjacent to the weld. The colder, surrounding mass of metal acts to restrict movement from these forces, as did the vice in the example, and creates distortion [10,11].

1.2 MIG Welding

There are many different types of welding processes, some of which are more commonly used than others. In the refining and petrochemical industries, arc welding is the process that is predominantly used [12]. Arc welding is a process that uses a welding power supply to create an electric arc (for creating heat) between a consumable or non-consumable electrode and the base material to melt metals at the welding point. Metal Inert Gas (MIG) welding is an arc welding process that uses a continuous solid wire electrode heated and fed into the weld pool from a welding gun. The two base materials are melted together forming a join. The gun feeds a shielding gas alongside the electrode helping protect the weld pool from airborne contaminants [13].

MIG welding is carried out on DC electrode (welding wire) positive polarity (DCEP). However, DCEN is used (for higher burn off rate) with certain self-shielding and gas shield cored wires. DC output power sources are of a transformer-rectifier design, with a flat characteristic (constant voltage power source). The most common type of power source used for this process is the switched primary transformer rectifier with constant voltage characteristics from both 3-phase 415V and 1- phase 240V input supplies. The output of direct current after full wave rectification from a 3-phase machine is very smooth [14]. To obtain smooth output after full wave rectification with a 1- phase machine, a large capacitor bank across the output is required. Because of the expense of this, many low cost 1-phase machines omit this component and therefore provide a poorer weld characteristic [15].

1.3 TIG Welding

Gas Tungsten Arc Welding (GTAW) also known as Tungsten Inert Gas welding (TIG) is an electric arc welding process that produces an arc between a non-consumable electrode (tungsten which does not melt due to its high melting point) and the work piece to be welded. The weld is shielded from the atmosphere by a shielding gas that forms an envelope around the weld area. However, a filler metal is usually used in the process [9]. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used [10].

GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. The automatic and manual torches are similar in construction, but the manual torch has a handle while the automatic torch normally comes with a mounting rack. The angle between the centerline of the handle and the centerline of the tungsten electrode, known as the head angle, can be varied on some manual torches according to the preference of the operator [11]. 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.

1.4 Steel Material

Welding is distinct from lower temperature techniques such as brazing and soldering, which do not melt the base metal (parent metal). Knowledge of a material's properties will greatly assist the tradesperson in many ways [10]. It is important to be able to select the most suitable material for a particular application and the correct methods to be employed in using a given material, the correct welding method. A general knowledge of materials can be built up by recognizing the individual characteristics or properties of each one. An obvious example of mass is the comparison of components made from lead being a heavy metal and aluminium being a light metal [11]. Copper and aluminium are good conductors and so need more heat to counteract the loss when heat is conducted away from the weld area. On the other hand, stainless steel is a poor conductor because heat is accumulated and retained at the weld area without much loss. This also contributes to local overheating and distortion [12].

1.5 SolidWorks Simulation

SolidWorks application do provide design analysis through simulation process in the software. It includes a variety area of analysis [16]. There are several analyses can be done through simulation study in SolidWorks software in which involving static analysis, buckling study, study of frequency, thermal study temperature changes Static study provides instruments for the linear stress analysis of static load loaded parts and assemblies [17]. Analysis for stress and displacement are among those studies which are included in the static analysis of the object designed in the SolidWorks software [18]. Test designs using linear materials under steady-state load conditions to quickly analyze and iterate designs based on stress, strain, displacement, and Factor of Safety (FOS) results [19]. A stress analysis result in simulation may be greater than the yield strength. Von Mises and Tresca are applied for ductile materials. Other than that, maximum normal stress is applied for brittle materials. Von Mises is the most widely used for the majority of static stress analysis [20-23].

2. Methodology

This research was focused mainly in the analysis of the weldment joint in order to study the weldment of weld joint of various steel material through TIG and MIG welding process. There were several parameters involved in the analysis of the weldment joint which were obtained from the literature review. The weldment joint was analyses on the stress and displacement study through SolidWorks Software.

2.1 SolidWorks Simulation Analysis

The static study on the design of gating system has been done by using SolidWorks software. There were two components assessed in the static study regarding the designs of the gating system in which include stress analysis and displacement analysis. The stress analysis was applied involving several steps regarding the simulation which consisted of applying design material, the geometry fixture of the part and the force on the design. After that, the design was mesh and the analysis was run in the SolidWorks software to get the result. The mechanical properties of material used in this study involving low carbon steel, hot-rolled steel and cold-rolled steel were classified as shown in Table 1, 2 and 3 respectively.

Table 1
Mechanical properties ASTM A513 Low Carbon Steel

Properties	Value
Elastic Modulus	200000 N/mm^2
Tensile strength	275 N/mm^2
Poisson's ratio	0.88
Shear modulus	35900 N/mm^2

Table 2
Mechanical properties ASTM A1011 Hot-rolled steel

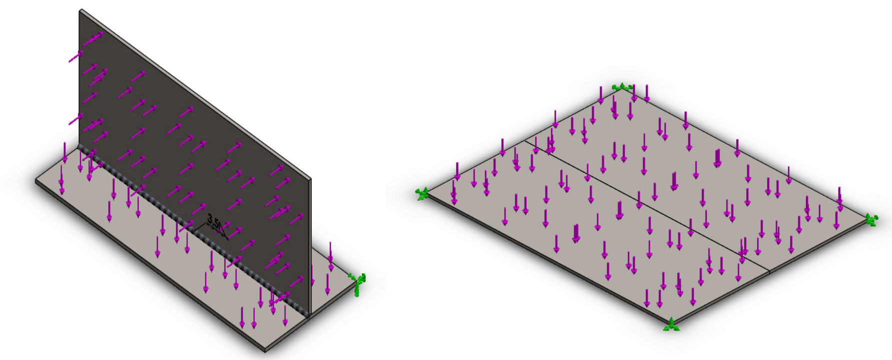
Properties	Value
Elastic Modulus	190000 N/mm^2
Tensile strength	128.005 N/mm^2
Poisson's ratio	0.45
Shear modulus	54000 N/mm^2

Table 3
Mechanical properties ASTM A1008 Cold-rolled steel

Properties	Value
Elastic Modulus	11000 N/mm^2
Tensile strength	221.488 N/mm^2
Poisson's ratio	0.21
Shear modulus	22700 N/mm^2

2.2 Finite Element Method on Stress and Displacement Analysis

The simulation on stress analysis of the gating design can be performed after completing all the part drawing and assemblies involving the weldment joint with accurate dimension through SolidWorks software. The first step of the simulation on stress analysis was selected the simulation properties and clicked on the 'new study' option in the SolidWorks software. The implementation of boundary condition to tell the SolidWorks simulation on how the model behaves in the real world. This is the most essential step in the process which were including in assigning forces, fixed geometry and contact areas on the gating design. The force was applied on the weldment design including the area of contact between T-joint as well as the butt joint. The next step was to get the mesh model of the weldment design. The weldment design was meshed before the simulation analysis was run. Figure 1 shows the mesh analysis consisted of T-joint with TIG fillet weld and Butt joint with TIG fillet weld. Figure 1 (a) shows the mesh structure with TIG welding on T-joint weldment meanwhile Figure 1 (b) refers to TIG welding on butt joint weldment. These processes were done for the MIG welding with different materials involving low carbon steel, hot-rolled steel and cold-rolled steel.



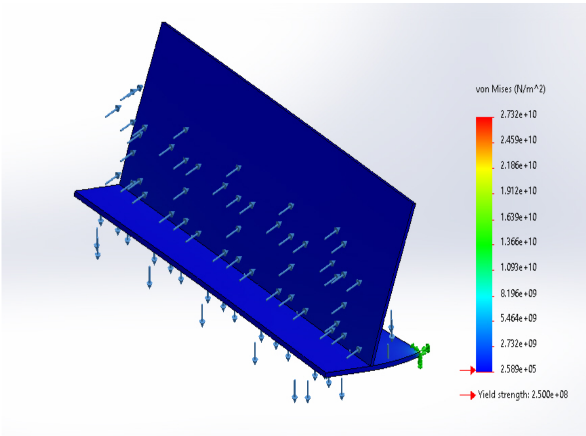
(a) (b)

Fig. 1. Mesh analysis; (a)T-joint joint with TIG fillet weld;(b) Butt joint with TIG fillet weld

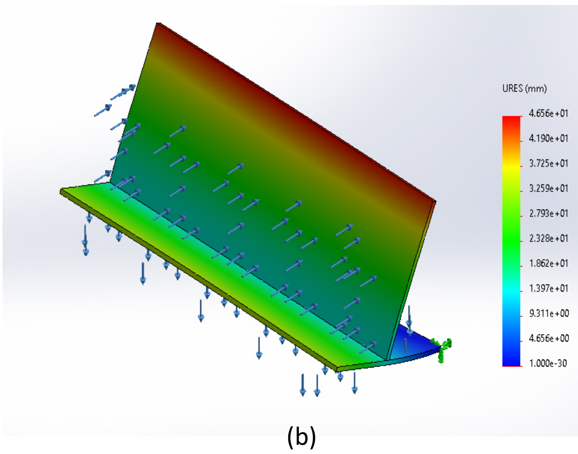
3. Results and Discussion

SolidWorks simulation software was applied in order to analysis the aspects of stress and displacement on the weldment including T-joint and butt joint through Finite Element analysis (FEA) programme. The programme allows the simulation of welded connections using 3D solid or shell models. Previous research study mentioned, for more complex structures, it is suggested to use the shell model to avoid convergence problems. To replicate the geometry of the tested specimens, 3D solid and shell models were used. Models of shells have been created using the centre surfaces of the solids. Figure 2 (a) shows the stress analysis on T-joint weldment meanwhile Figure 2 (b) shows displacement analysis on T-joint weldment.

According to the Figure 2 (a), the highest stress distribution was obviously located on the weld root along the weld joint. The highest displacement distribution was shown at the tip of the weldment as shown in Figure 2 (b). Table 4 shows the minimum value and maximum value of stress and displacement distribution of the T-joint weldment respectively. The maximum amount of stress was valued at 2.732e+10 N/m^2 meanwhile the maximum amount of displacement was valued at 4.656e+01 mm.



(a)



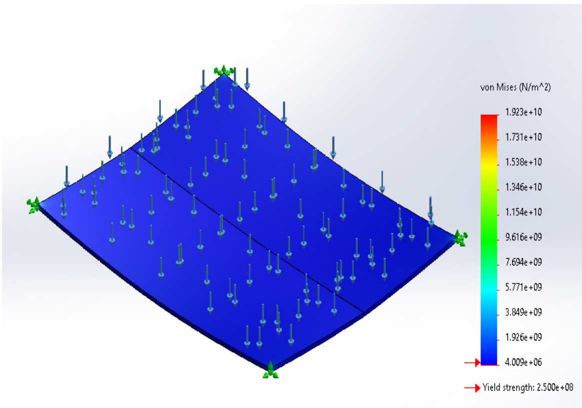
(b)

Fig. 2. SolidWorks simulation; (a)Stress analysis on T-joint weldment; (b) Displacement analysis on T-joint weldment

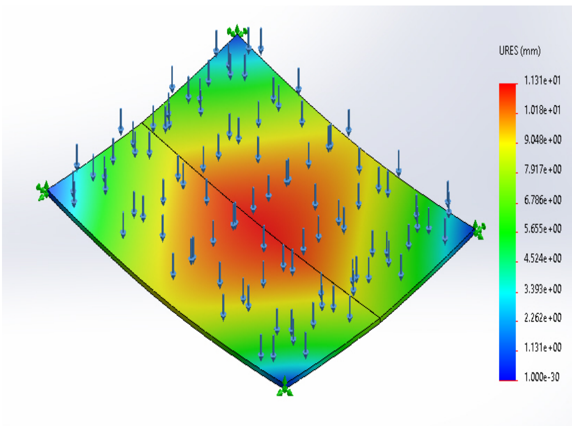
Table 4
SolidWorks simulation result consisting of min and max of stress, displacement of T-joint

Name	Type	Min	Max
Stress1	VON: von Mises Stress	2.589e+05 N/m^2 Node: 47055	2.732e+10 N/m^2 Node: 64
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 1	4.656e+01 mm Node: 47374

Figure 3 (a) highlights the stress analysis on butt-joint weldment meanwhile Figure 3 (b) shows displacement analysis on butt-joint weldment. According to the Figure 3 (a), there was no noticeable maximum stress distribution located at the weld joint. The highest displacement distribution was shown at the middle of the joint as shown in Figure 3 (b). Table 5 shows the minimum value and maximum value of stress and displacement distribution of the butt-joint weldment respectively. The maximum amount of stress was valued at 1.923e+10N/m^2 meanwhile the maximum amount of displacement was valued at 1.131e+01mm.



(a)



(b)

Fig. 3. SolidWorks simulation; (a)Stress analysis on butt joint weldment; (b)Displacement analysis on butt joint weldment

Table 5
SolidWorks simulation result consisting of min and max of stress, displacement of butt-joint

Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.009e+06N/m^2 Node: 75286	1.923e+10N/m^2 Node: 251
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 1	1.131e+01mm Node: 182

4. Conclusions

In conclusion, SolidWorks simulation tool displays its utility for evaluating the strength of welded junctions. These were done through precise computation of weld loads and quick prediction of weld depth requirements or stress levels. The effective weld neck thickness on the materials was 3mm, which was calculated using 3D Solid models with beam elements is quite variable because the model was loaded symmetrically. Additionally, there was a lack of fluidity in the simulation process. As a result, there will be needed a follow up process for experimental test with the specimen of material involving impact test and tensile test for comparison with the FEA analysis model in the SolidWorks simulation. The entire bonded contact has been created as a result of the no penetration contact's faulty operation in SolidWorks mesh object. Hence, series of experiments are needed for verification due to this complicated flow topology.

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