UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

PROCESS-PROPERTIES RELATIONSHIP OF MILD STEEL ORBITAL WELDING

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PROCESS-PROPERTIES RELATIONSHIP OF MILD STEEL ORBITAL WELDING

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DECLARATION

I declare that his project entitled "Process-Properties Relationship on Mild Steel Orbital Welding" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : NOR SAFURA BINTI NORDIN

Date : 9 SEPTEMBER 2014

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (Manufacturing System Engineering).

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LIST OF SYMBOLS

CO_2	-	Carbon dioxide
mm	-	Millimetre
%	-	Percent
min	-	Minutes
A	-	Ampere
V	-	Volt
cm	-	Centimetre
°	-	Degree
HB	-	Brinell hardness
kN	-	kilo Newton
MPa	-	Mega pascal
m	-	Meter
S/N	-	Signal-to-noise
F	-	Force
HV	-	Vickers hardness
rpm	-	Rotation per minute

LIST OF ABBREVIATIONS

MIG	Metal Inert Gas
UTM	Universal Tensile Machine
SMAW	Shielded Metal Arc Welding
ASME	American Society of Mechanical Engineering
AWS	American Welding Society
ISO	International Organization for Standardization
EDM	Electrical Discharge Machining

CHAPTER 1

INTRODUCTION

1.1 Introduction

Lightweight products become a trend nowadays. The same trend influenced auto manufacturing field which is increasingly turning to lightweight parts. Every gram saved not only can makes cars eco-friendlier by reduces CO_2 emissions but also can reduce the cost. ThyssenKrupp Company (2010) under the name "InCar" has developed solutions for car's weight reduction, cost-efficient and safety. One small part of the solution is by optimizing wall thickness of tube used in car system includes exhaust system and car seats. ThyssenKrupp (2010) discover that optimizing wall thickness can be done by using tube of different thickness for different working loads. Thinner tube can be used in parts with low working loads and thicker tube for high working loads parts despite of using the same wall thickness without considering the working loads. For this operation, ThyssenKrupp (2010) and WISCO Tailored Blank Company (2013) states that orbital welding is a very ideal process to joint tubes with dissimilar thickness.

Fronius International (2010), one of welding company in Austria states that whenever high quality results of joining tubes welding are required, orbital welding will be the first choice. Orbital welding got its name by its own feature which can weld in circular around the work piece. Orbital welding not only gives benefit in terms of light weight and reduces cost. WISCO Tailored Blank Company (2013) has list more advantageous of orbital welding includes save in material and necessary process step, improve functions and can also allow freedom in shaping. Tubes with different diameters, wall thicknesses or even different materials can be combined in an individual tailored orbital tube.

Mild steel, which also known as low carbon steel has been used widely in different industries especially in automotive industries. The weld ability and properties of mild steel made it suitable to be used widely in fabrication of automobile chassis and bodies (Bahman and Alialhosseini, 2010). Mild steel will be used as weld specimen in this experiment because it is the most common form of steel with affordable price while the material properties are acceptable for various applications (Tewari et. al, 2010).

In order to obtain good weld, process parameters such as welding current and welding speed become very crucial as it influenced the mechanical properties the most based on the literature review. Hence, this study is proposed to correlate process variables with mechanical properties of dissimilar thickness mild steel weld pipe.

Yapp and Blackman (2004) stated that metal inert gas (MIG) welding which also known as gas metal arc welding (GMAW) process is widely used for large diameter transmission pipelines compared to other processes. MIG welding techniques comprise a group of welding processes where the arc, the molten metal and the surrounding area are protected from atmospheric contamination by a stream of gas or a mixture of gases that is fed through the welding torch. Therefore, MIG welding will be used as a welding process in this study.

1.2 Problem Statement

Lightweight automobiles becomes trend nowadays which can profit manufacturers by saving cost and indirectly makes cars eco-friendlier by reduces the emissions of CO_2 (ThyssenKrupp, 2010). ThyssenKrupp (2010) and WISCO (2013) has found that varying wall thickness of tube used in exhaust system or in chassis depending on their workloads can help to reduce overall weight of the car. Arunkumar et. al. (2012) and Olawale et. al. (2012) found that process parameters give great influences to mechanical behaviour of the welded pipe. Studies might have done by manufacturers but detailed studies are not disclosed to public review and not all types of material available are covered.

Thus, this study focus on understanding the effect of the process parameters on the tensile strength and the micro hardness of dissimilar thickness weld tube. The variables parameters tested are welding current and jig rotational speed. MIG welding was used as welding process and the material used in this study were two dissimilar thickness mild steel tubes. The Universal Tensile Machine (UTM) was used to test the tensile properties of the welded tubes.

1.3 Objectives

The objectives of this project are as follow:

i. To study the effect of welding current and jig rotational speed to the mechanical properties of dissimilar inner tube diameter of mild steel by MIG orbital welding.
ii. To develop and verify the empirical mathematical model.
iii. To suggest the optimum set of parameter.

1.4 Significance of Study

There are a few of previous studies which have investigated about the welding parameters effect to the mechanical properties of weld material. However, all the studies are limited to welding of steel sheets which may have different thicknesses and materials, and of pipes with different materials. Manufacturers may have done the study about welding pipes of different thicknesses but it is not available for public view.

The study was aimed to the evaluation of the welding current and jig rotational speed effect on tensile properties of welded tubes of different thicknesses joints in order to produce of a high strength and tempered steel. The lightweight strategy can be used for cars such as go-kart and also for gas pipes which can helps to produce lighter product hence lead to cost reduction.

1.5 Scopes and Limitations

Due to various limiting factors of time, money, and resources, the scope of this research was limited by the following characteristics:

i. Testing only will be held on 26.70 mm diameter of mild steel tubes having 2.87 mm and 3.90 mm thicknesses respectively. Other materials and thickness ratio may yield different results.
ii. The creation of the weld was limited to MIG orbital welding. Other welding processes may yield different results.
iii. Due to machine restrictions, the only possible manipulated welding parameters are welding current and jig rotational speed.

1.6 Research planning

Research planning is outlined in a Gantt chart as in Appendix A.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Pipes and tubes welding are widely used in most of engineering application. Increasing demand leads to the development of various automatic welding processes and it keeps developing in order to get better quality of welding, better speed, less mistakes and minimum cost. Development of orbital welding put it in their own class as by employing variety of automated features, it able to helps to maximize the productivity and make the process easier (Hamidreza, 2012).

In present, orbital welding system become more reliable as it offer computer controls which store welding parameters for various applications in memory and able to called up anytime needed for specific application (Pro-Fusion, 2014). Hence, the systems were built from the skills of a certified welder, producing enormous numbers of identical welds and leaving significantly less room for error or defects (Pro-Fusion, 2014) (Bernard and Jack, 1999).

2.2 Tailored orbital welding

A conglomerate company in German, ThyssenKrupp (2010), is one of automotive companies which have widely implementing the tailored orbital application for their product. The specialities of tailored orbital welding which are of its capability to join, up to five tubes together and each individual tube can has different materials, different diameters, wall thicknesses and even different coatings (Tubefirst, 2010). The application can be seen for example in car seats, exhaust systems, cockpit support tubes and chassis parts.

One of the success stories of tailored orbital welding by ThyssenKrupp is they has successfully developed a tailored orbital alternative for a rear seat back reinforcement made from conventional tube (Tubefirst, 2010). The structure is made from a tube of uniform wall thickness which determined by the highest loads occurring in the part. The new solution successfully reduces weight by around a kilogram because the part made form a tailored orbital of different wall thickness. In other cases, tailored orbital for shock absorber reservoir tubes claimed weight reductions of up to 30 % (Tubefirst, 2010).

Figure 2.1 explains the comparison of stress distribution in three different tubes (InCar, 2014). One tube has constant wall thickness of 3.0 mm, taking the minimum thickness needed to accommodate highest work load and standardize the thickness along the tube. Another tube is taking average thickness needed to accommodate the work load and the other tube has stress optimized wall thickness. It can be seen that the stress distribution in stress optimized wall thickness are more stable than the other two tubes.

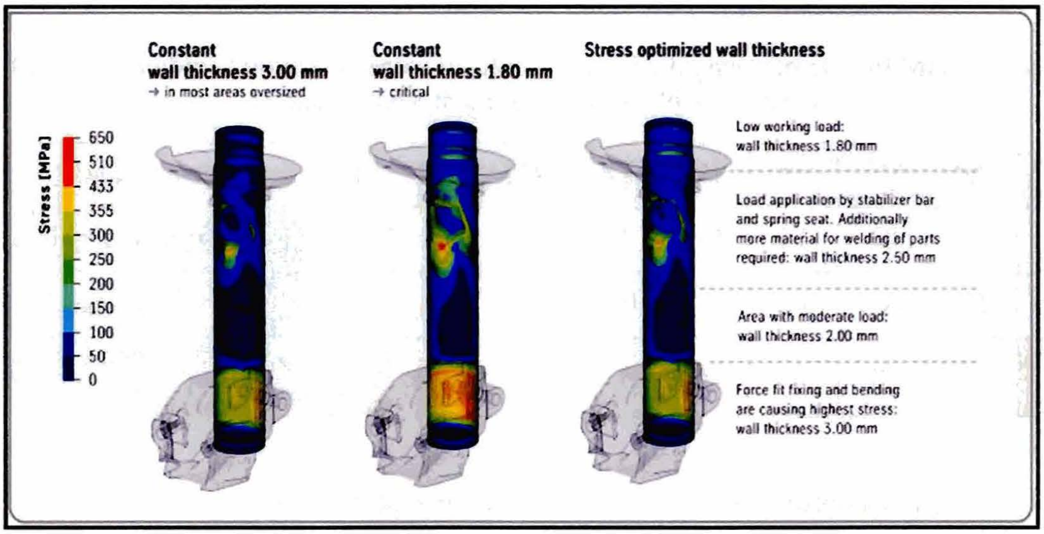


Figure 2.1: Varying stress levels of different tube variants (InCar, 2014).

Tailored orbital can be fabricated just like conventional straight-seam welded tubes (Tubefirst, 2010). It helps to optimize production processes as it helps to reduce overall part weight, improve functionality, reduce costs and allow great forming freedom. However, there are very limited sources on the process of welding dissimilar tube thicknesses available for public view. Hence, this study is proposed.

2.3 Dissimilar thickness welding

Example of conventional solution which used uniform wall thickness can be seen in go-kart. Pilana (2011) used maximum workload to determine the shaft and chassis tube size, while he redesigned a go-kart for his study. From calculation, he found that the maximum combine normal stress for middle floor tube is 139 MPa (refer Table 2.1), so he used 27 mm diameter tubes having 2.5 mm thickness, which has an allowable stress of 166.7 MPa.

However, despite of using uniform wall thickness, the best solution with minimum cost can be gained by optimizing the wall thickness to its respective workloads (InCar, 2014).

Table 2.1: Combined normal stresses for floor tube. The highest stress, 139 MPa, is used to set the suitable thickness of tube (Pilana, 2011)

Tube locations	N1	N2	N3	N4	N5	N6	N7	N8	N9
Bending moments (Nm)	148	37	18	32	141	32	18	37	148
Axial force (N)	82	82	500	500	82	500	500	82	82
Combine normal stresses (MPa)	139	35	19	33	132	33	19	35	139

Welding two dissimilar thicknesses of steel needs few considerations, differ from normal welding. Tricia (n.d.) highlighted the need of controlling welding parameters so that the thicker piece receive enough heat to joint with the thinner piece without causing the thinner piece to warp or burn at the same time. Therefore, she suggest to set the welding current which suit the thicker piece so that it is sufficient to melt and joint both pieces. In order to avoid over penetrated on thinner piece, a winding motion is suggested instead of straight line travelling.

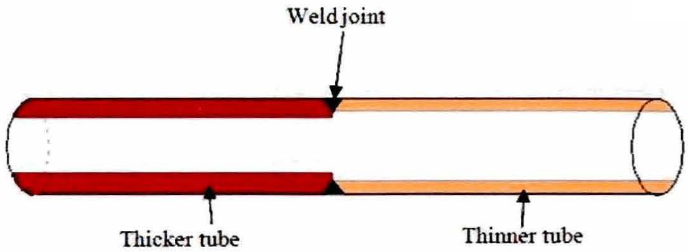


Figure 2.2: Dissimilar inner diameter tubes joint.

2.4 Heat sources of welding

There are several processes available for joining pipe and those which widely used in orbital welding includes shielded metal arc welding (SMAW) and MIG processes. Quality weld and penetration bead are the important requirement in determining which welding process is to be used (Spiller, 1991).

2.4.1 Shielded Metal Arc Welding (SMAW)

The effect of welding parameters on 5mm thickness mild steel sheet using SMAW has been studied by Singh et. al. (2012). The manipulated welding parameters are welding speeds of 40, 60 and 80 mm/min, welding current of 90, 95, 100, 105 and 100 Ampere (A) and arc voltage of 20, 21, 22, 23 and 24 Volt (V). The effects of these parameters on welding penetration were investigated and found that the depth of penetration increased by increasing in welding current and the penetration decreased by increasing in welding speed and arc voltage. Singh et. al. (2012) also found that a strong joint of mild steel was produced by using SMAW technique.

The other similar studies were conducted by Olawale et. al. (2012) but in their study, the material used is low carbon steel round bars of 12 mm diameter and 50 mm length and the impact investigated were tensile strength and hardness. The process parameters used are welding currents of 100 A, 120 A and 140 A with terminal voltage 80 V. They found increase in welding current led to an increase in hardness and ultimate tensile strength values but reduces in impact strength.

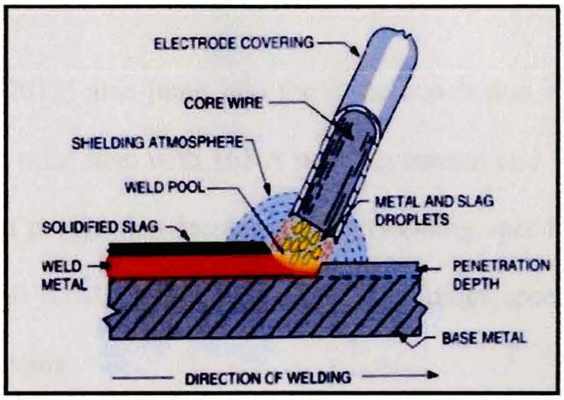


Figure 2.3: Shielded metal arc welding process (Gurpreet, S.S. et.al., 2012)

2.4.2 Metal Inert Gas (MIG) welding

The effect of process parameters on welding penetration by using MIG welding was studied by Lian (2012). The weld specimen used is 2.5 mm thickness of Stainless Steel tube. The manipulated variables parameters used in this experiment are arc voltage, welding current and welding speed. The arc voltages used were 14, 16 and 18 V, welding currents of 95, 105 and 115 A, and the welding speeds of 10, 30 and 50 cm/min. He founds that the significant parameter that influence welding penetration and welding geometry is welding speed followed by welding current and welding voltage. Increasing in welding current and welding voltage increased in penetration. However, increasing in welding speed decreased the penetration.

Similar study but using 50 mm x 40 mm x 6 mm mild steel sheet as weld specimen was conducted by Tewari et. al. (2010). In their study, welding speed was the only manipulated welding parameters while welding current and arc voltage were leaved constant, 105 A and 24 V respectively. They found that increasing in welding speed increased the depth of penetration. The optimum value to obtain maximum penetration was when the welding speed was 110.39 mm/min because after that increasing in welding speed only makes the depth of penetration decreased gradually.

Abbasi et. al. (2012) also jump into the same conclusion when dealing with 144 mm x 31 mm x 10 mm mild steel with 165 A welding current and 16 V arc voltage. They found that the depth of penetration increases when welding speed is increased up to an optimum value of 1450 mm/min and beyond that optimum speed value, the depth of penetration starts decreasing.

Karadeniz et. al. (2007) also used MIG welding in their experiment with the process parameters chose were welding current of 95, 105 and 115 A, arc voltage of 22, 24 and 26 V and the welding speeds of 40, 60 and 80 cm/min. The specimen material used in this experiment is Erdemir 6842 steel of 2.5 mm thickness. As a result, they found that increasing in welding current and arc voltage result in increasing in depth of penetration.

2.5 Pipe welding positions

The designations for the position of the tube to be welded are specified by the ASME code, section IX and the European Standards EN 287/ EN ISO 6947 (Fronius, 2010). Figure 2.4 shows numerous pipe positions. For AWS 1G/ ISO PA, pipe rotates with axis horizontal and the welding direction is down hand. For AWS 2G/ISO PC, pipe fixed with axis vertical and the welding direction is horizontal-vertical. For AWS 6G/ISO H-LO45, pipe fixed with axis under 45 angles and welding upwards.

Figure 2.4: Pipe welding positions (Fronius, 2010)

Li et. al. (2013), stated that 5G position is the most difficult welding position to deal with despite of it widely usage for pipe welding and when welding around the pipe joint circumference, several common welding positions or their combinations are encountered. In the other side, 1G position can produces high quality and quantity of welds consistently. These advantageous make most of industry using is as the standard practise (Weidner, 2005).

2.6 Weld joint preparation

Welding joint is one of the important measures in orbital welding. Accurate joint preparation and specific groove shape, both of which are time consuming and costly, are crucial in order to produce the required joint penetration as existing automatic orbital welding systems use pre-programmed welding parameters per welding position (Li et. al., 2013). The standard welding joint used for tubes is a V-groove with a gap (refer Figure 2.4).

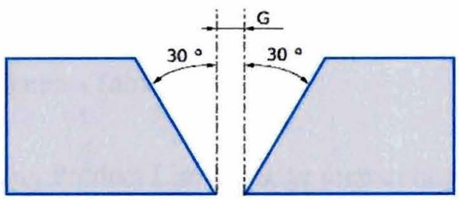


Figure 2.5: Tube end preparation commonly used for manual tube welding (Fronius, 2010).

To get desired uniform penetration, Fronius (2010) suggest to use J-groove with a collar of the width L and the thickness T (refer Figure 2.5). The recommendation is as in the Table 2.2 below:

Table 2.2: Dimension for J-groove (Fronius, 2010)

Tube range (mm)	**Angle (°)**	**Collar (mm)**	
Wall thickness (mm)	A	T	L
$3 < E \leq 6$	30°	1	2
$E \leq 6$		1, 5	2
$10 \leq E \leq 15$	20°		

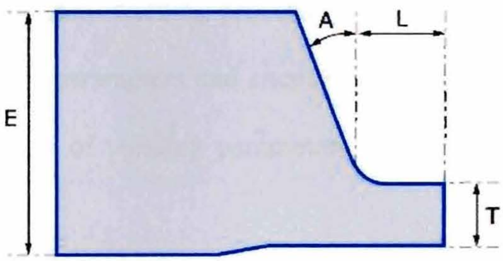
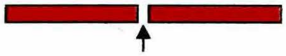


Figure 2.6: J-groove (Fronius, 2010)

Kumar et. al. (2013) have done study about the effect of bevel angle to the tensile strength of welded IS 2062 mild steel. They found that as the bevel angle increases from 15° to 45°, the tensile strength also increases.

Murex Welding Product Limited in its handbook has listed suitable edge preparation for relative thickness (Table 2.3).

Table 2.3: Murex Welding Product Limited edge preparation standard (Murex, n.d.)

Thickness of metal (mm)	**Diameter of welding rod (mm)**	**Edge preparation**
0.914 ~ 3.175	1.588 ~ 3.175	 0.794 ~ 3.175 (mm)
3.175 ~ 4.763	3.175 ~ 3.969	80° V-groove:  1.588 ~ 3.175 (mm)

2.7 Welding parameters

Welding input parameters play a very significant role in determining the quality of weld joint. The mechanical properties, weld-beam geometry and distortion are usually used to define the joint quality. Any welding process generally aims to obtain a welded joint with the desired weld-bead parameters and excellent properties with minimum distortion. Hence, a good combination of welding parameters is crucial in order to obtain a good quality of weld joint.

2.7.1 Weld current

Pro-Fusion (2014) stated the general guidelines for weld current as 1 average current per 0.001 inch wall thickness as a starting point if the material is stainless steel. For example, if the wall tube is 0.050 inches, the average weld current should be 50 A in the