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Influence of Flywheel for Drive System of Rotary Friction Welding and Chamfer Angle Variations Forging to Welding Strength

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ABSTRACT

The purpose of this paper is to study a flywheel addition on rotary friction welding drive system, which to analyzing between chamfers angle variations and tensile strength. The flywheel addition performed as energy storage that was functioned to stores energy when supply exceeds demand and release it when supply was smaller than need. In this paper was conducted an experimental study to analyze the influence of flywheel addition mass to drive system of rotary friction welding. The test specimens were given chamfer variations and the forging surface was constant at 4 mm with variations of chamfer angle of 30^O, 45^O, and 60^O. From the tests were carried out mass of flywheel and chamfer angle that affected on process and results of welding. The results of the test were obtained highest value of tensile strength at specimens that used flywheel 3 with a chamfer angle of 45^O, which has a value of 554.1 Mpa.

KEY WORDS: Friction Welding, Flywheel, Chamfer, Tensile Strength

NOMENCLATURE

σ	Tensile strength (MPa)
F	Maximum load at test time (N)
A_o	Area of initial cross-section (mm^2)
ε	Strain (%)
l	Extension (mm)
lo	Initial length (mm)
E	Modulus of elasticity (N/mm^2)
σ	Tensile strength (N/mm^2)

1.0 INTRODUCTION

The welding process is the process of joining two metals by utilizing heat energy as the main process in the process of metal connection and heat source in the welding process comes from other energy changes. Some types of energy which can be converted into heat energy is mechanical energy, like friction energy, impulse energy, and others. Along with the times welding technology has undergone many developments. With new methods in the connection process material is an indication of developments in welding technology, one of them is friction welding. This friction welding was first discovered by a Soviet engineer Al Chudikov in 1956. Friction welding is welding without using welding wires or electrodes so that it can be ascertained that the connection is obtained between the two welded material is a homogeneous connection. In addition, connecting the shaft with this process can minimize the shift of the axis from the welded material (Suratman ,2001).

Flywheel is a component of a machine that is capable of storing kinetic energy from the rotational motion of the crankshaft and aims to produce a stable engine speed. Flywheel or flywheel is connected to the crankshaft end of a machine that receives rotational power from the piston during the step of the effort, which will then decrease due to other steps, inertia loss, and also due to friction. Flywheel functions as an energy storage barn, which stores energy when the supply exceeds the need and releases it when the supply is smaller which needs are also useful as controls for speed fluctuations and is able to make the crankshaft rotate continuously and continuously and cause the machine to operate gently (Adin Putra Rachmawan,dkk,2014).

To optimize the rotary friction welding machine, it is necessary to add flywheel to reduce the shock load that occurs in the electric motor of the rotary friction welding machine which aims to minimize damage to the electric motor. Optimizing this rotary friction welding machine in addition to minimizing the damage to the motor also aims to get a more stable engine rotation, it is necessary to do research on the rotary friction welding machine with the addition of flywheel (Erikson Siregar,2018).

In previous research (P Partomuan, 2012) Research has been carried out on the effect of variations in the shape of the surface forging rotary friction welding joints on mild steel steel tensile strength. From the research it was found that the tensile strength in welding mild steel friction with the same forging diameter (the length of the chamfer angle varies) for all angles of chamfer, the value of the tensile strength of mild steel steel increases with the greater angle of the chamfer given and also with the same length of chamfer (forging diameter varies) for all angles of chamfer, the value of the tensile strength of mild steel steel increases as the chamfer angle is reduced.

Addition to (P Partomuan, 2012), (Erikson siregar, 2018) conduct research to determine the effect of the addition of flywheel on the rotary friction welding machine driving system for mild steel steel tensile strength. In research this uses three flywheels with a diameter of 250 mm, each 10 mm thick, 20 mm, dan 30 mm, from the test obtained the value of the average tensile strength at each flywheel that is 492,188 MPa, 515,288 MPa, 531.79 MPa

2.0 FUNDAMENTAL THEORY

2.1 Types of friction welding

Friction welds are divided into three types of processes:

1.Rotary friction welding (RFW), in this friction welding specimen is cylindrical, one of the specimens moves rotation and the other is silent, then is subjected to axial load, as shown in Figure 1

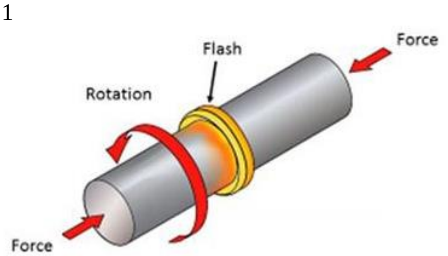

Figure 1 *Rotary Friction welding* (Twi Group Websites, The Welding Institute)

2.Linear friction welding (LFW), this welding difference by welding rotary friction welding is, in this welding heat is generated from the linear motion of one workpiece against another workpiece, as shown in figure 2.

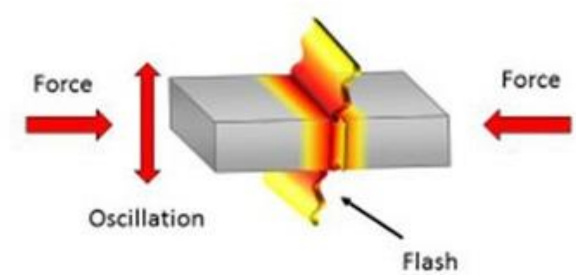

Figure 2 *linear friction welding*, (Twi Group Websites, The Welding Institute)

3.Friction stir welding (FSW), in this welding the heat used to melt the working metal is produced from the friction between a rotating object (Pin) with a stationary object (workpiece), a sheet-shaped workpiece. The pin is rotated at a constant speed touched onto the gripped plate

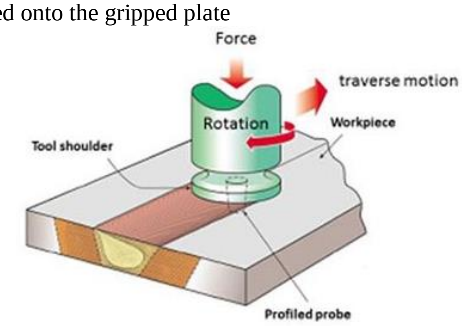

Figure 3 *Friction Stir Welding* (Twi Group Websites, The Welding Institute)

2.2 Inertia Drive Welding

In this test using the inertia drive welding process where the rotary friction welding machine is given the addition of flywheel which functions as an energy storage barn, which one stores energy when supply exceeds demand and releases it when supply smaller than the requirement which is also useful as a control from the occurrence of a speed fluctuation. The difference in the friction welding machine at the University of Riau production laboratory, where the flywheel is located on the transmission shaft connected to belting.

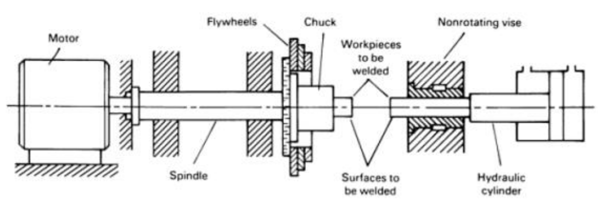

Figure 4 inertial drive welding (ASM Handbook Vol 12, 1996)

Friction welding method with inertia drive welding using which machine the spindle is given a flywheel as a power storage. Flywheel in this process as a controller of heat input in the connection area. For that moment the flywheel inertia is very important to be taken into account. For this reason the flywheel is

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designed to be able to increase or decrease its mass. The amount of energy stored in the flywheel is controlled by speed. Axial pressure is given constantly during the process. It can also be done at the end of the process of further pressure friction.

2.3 *Flywheel*

Flywheel or flywheel is a wheel that is used to reduce changes in rotation speed by utilizing round inertia (moment of inertia). Because of the nature of this inertia the flywheel can store mechanical energy for a short time. Flywheel is used to make the torque produced by the motor to be more stable.

Flywheel or commonly called flywheel is a component of a machine that is capable of storing kinetic energy from the rotation motion of the crankshaft and aims to produce a stable engine speed. Flywheel functions as an energy storage barn, which stores energy when supply exceeds demand and release it when the supply is smaller than the need which is also useful as a control of occurrence a speed fluctuation and is able to make the crankshaft rotate continuously and continuously and result in the machine operating gently (Adin Putra Rachmawan dkk, 2014).

According to R.S Khurmi dan J.K. Gupta (2005), a flywheel used in the engine functions as a reservoir that can store energy during the period when the energy supply is excessive and is redistributed during the period required energy from supply is needed. So, the flywheel is a rotating mass that is used as a power storage in the engine. The power stored in the flywheel is kinetic power. As we know is a component found in all four-wheeled vehicles, is a disk which, because of its weight, can withstand a drastic change in speed so that the rotation of the engine shaft becomes smoother. Figure 5 examples of application of a flywheel on a rotary friction welding machine in the University of Riau mechanical engineering laboratory.

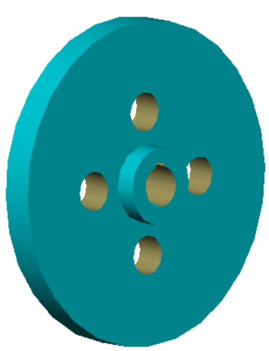

Figure 5 *Flywheel* (Erikson siregar,2018)

2.4 Carbon steel

Carbon steel is a metal material formed from the main elements Fe and the second element that influences its properties is carbon, while other elements influence according to the process. Carbon steel is one of the most important types of metal alloy carbon iron with a weight percentage of carbon up to 2.11%. Carbon steel has levels C to 1.2% and Mn 0.30%-0.95%. The maximum percentage elements besides steel are as follows: 0.60% Silicon, 0.60% Copper (Baumer, B.M.J. 1994).

In this test using a mildsteel steel specimen with a diameter of 8 mm with a length of 90 mm, one of which was given a chamfer angle.

a. Mild steel

The carbon content in this steel is between 0.25 to 0.55%. This type of steel can be tempered, can be welded and is easy to work on fine machining processes.

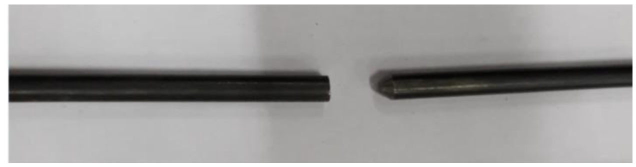

Figure 6 mild steel test specimen

2.5 Tensile Test

Tensile Test is one of the mechanical tests performed on a material by applying a tensile load to the material. So that will be obtained the mechanical properties of the material. The experimental tool for this tensile test should have a strong grip. The curve below shows the relationship between the pulling force and the length change.

Tensile tests performed on a material can provide a relatively complete explanation of the material's behavior to mechanical loading. The information obtained is in the tensile tensile strength testing which is continuously given and gradually increases, along with the observation of the extension experienced by the specimen. Then the voltage and strain curves can be generated

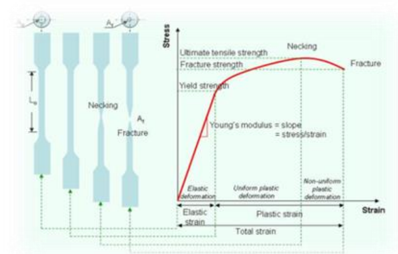

Figure 7 Tensile relationship curve with length changes (Rahayu, 2012).

3.0 Metodology

3.1 Stage of Making Chamfer Angle On Mild Steel

This stage is the stage for making chamfer angle specimens in mild steel which will be connected by using friction welding, the process of making chamfer angles is done using a lathe. The chamfer angle that will be made is 30°, 45°, 60°. The following is a picture of the test specimen with chamfer and without chamfer:

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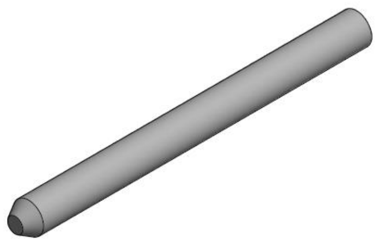

Figure 8 Chamfer angle 30°

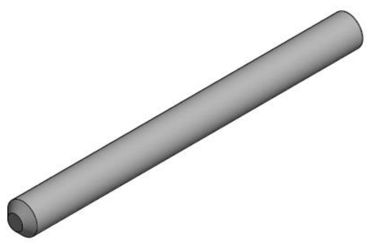

Figure 9 Chamfer angle 45°

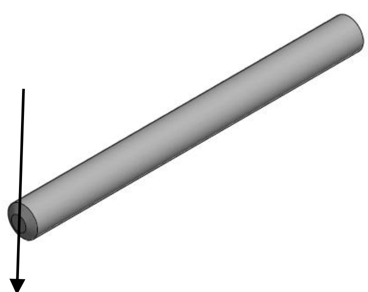

Figure 10 Chamfer angle 60°

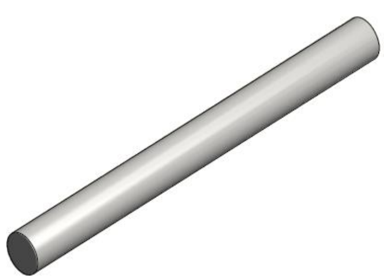

Figure 11 test specimens without chamfer

3.2 Set Up Testing Of Rotary Friction Welding

The rotary friction welding machine set up is shown in Figure as follows:

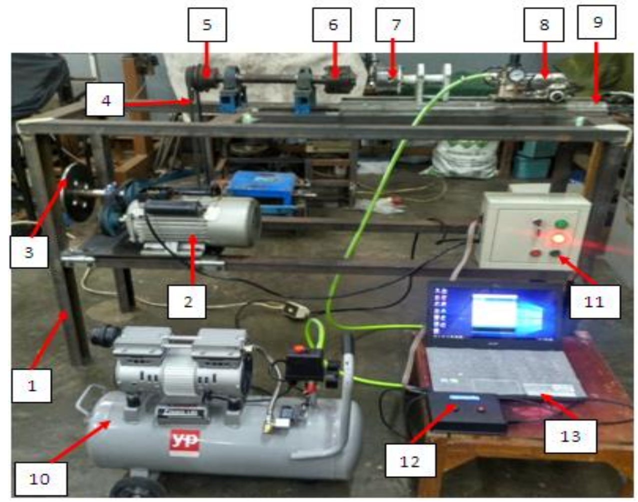

Figure 12 Set Up Rotary Friction Welding (Erikson Siregar,2018)

Caption

No	Nama Bagian	Jumlah
1	Rotary Friction Welding Machine Frame	1
2	Elektro Motor	1
3	*Flywheel*	3
4	*V-belt*	1
5	*Graded Pulley*	2
6	*Head stock*	1
7	*Tail Stock*	1
8	*Pneumatic System* dan *Pressure Gauge*	1
9	*Rail Tail Stock*	2
10	Compressor	1
11	*Control Unit*	1
12	*Display Data Loger*	1
13	Laptop	1

3.3 Data Retrieval Phase Rotary friction welding

This stage is taking friction welding data, Testing of rotary friction welding tools is done by welding 27 pieces of Mild Steel which have been given chamfer angle, divided into three testing groups each of 9 welding specimens including the chamfer angle 30^O, 45^O and 60^O using flywheel 1, flywheel 2, and flywheel 3. The data set in the testing procedure is 4 bar friction pressure data, forging pressure 6 bars and forging time 3 seconds. While the data taken during testing is the initial rotation of data, initial lap time, rotation friction, time of friction, forging rotation, flywheel time stops, the specimen heat drop time after welding, change in specimen length, and electric motor power during the welding process.

The data taken during the friction welding process are:

a. Initial lap time

The data obtained in this test is in the form of an initial lap time, where to determine the initial rotation and rotation

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speed of the shaft using a tachometer and stopwatch. Tachometer sensor is directed at the transmission shaft, from the tachometer is obtained the number of rotations in the form of rpm to know the rotation of a constant electric motor is used stopwatch.

b. Constant rotation time of the electric motor
Retrieval of the constant rotation time data of the electric motor also uses a stopwatch and tachometer, constant rotation of an electric motor can be known through a tachometer, The stopwatch calculates the time during which the round occurs.

c. Friction pressure
In pneumatic friction pressure data collection, 4 bar pressure is applied after constant rotation is obtained. In these conditions there is friction pressure until the chamfer runs out and the specimen begins to melt due to the friction force that occurs. The data taken is the time needed to spend the chamfer to forging, the length of time to spend chamfer is recorded using the stopwatch.

d. Forging pressure
Forging pressure is carried out after the process of frictional pressure until melting occurs on the specimen, Forging process is given a pressure of 6 bars on pneumatic.

e. Forging pressure time
After the forging pressure is given at 6 bars then the forging or forging is given for 3 seconds.

f. The flywheel time stops
After the forging process is completed for 3 seconds, the next step is to turn off the electric motor through the Arduino panel, and the time the flywheel stops is recorded using the stopwatch.

g. Time reduction in heat after the welding process.
After the time the flywheel stops is obtained, then the specimen is left idle during the forging process, and the heat down time is recorded using the stopwatch.

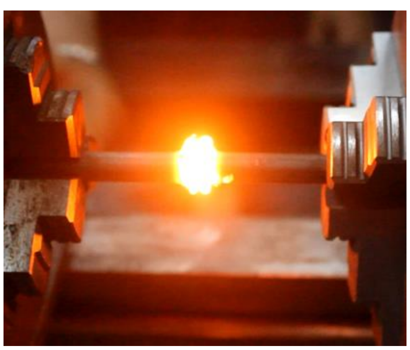

Figure 13 Rotary Friction Welding Process

3.4 Stages of Tensile Test Data Retrieval

This stage is the stage for doing the final data retrieval, data retrieval carried out among them is do a tensile test of 9 specimens that have been previously welding. Specimen testing was carried out using ASTM E8-M standard.

Figure 14 Tensile Test Specimens

After the specimen has been formed into the ASTM-E8M standard form the next step is to do tensile testing using *Universal Testing Machine* to find out the maximum tensile force on the friction weld joint mild steel which will be used to calculate Ultimate Tensile Strengh on Mild Steel steel rotary friction welds.

Figure 15 Tensile Testing Process

After testing the tensile of the 9 specimens, the tensile strength of each specimen was obtained, The results of the tensile test specimen can be seen in Figure 16:

Figure 16 Tensile Testing Results

4.0. RESULT AND DISCUSSION

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4.1Testing Results

1. Electric Motor Rotation

From the tests carried out obtained the value of the rotation of the electric motor at the time of welding for three stages, namely the initial rotation which is the motor rotation when before being given pressure on the specimen, friction rotation which is an electric motor rotation when the specimen is given a pneumatic friction pressure of 4 bars, while the forging round is the rotation of the electric motor when the forging process occurs when the specimen is given additional pressure to 6 bars through pneumatics. Following is a graph of the average rotation of the electric motor when testing using flywheel 1, flywheel 2, and flywheel 3.

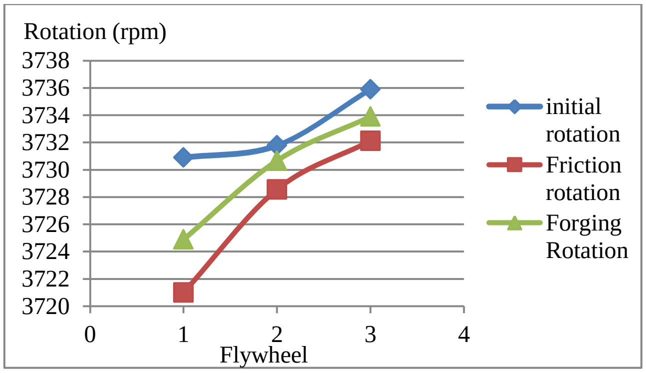

Figure 17 Graph of average motor rotation

The results of the test obtained the value of the initial rotation of the electric motor at the time of testing with the highest initial rotation average value at flywheel 3 which is 3735.8 rpm and the lowest initial rotation value at flywheel 1 3730.8 rpm, For the average rotation value when the highest friction is obtained at flywheel 3 with a value of 3732.1 rpm and the lowest friction value at the flywheel 1 with a value of 3721 rpm. Whereas for the average value of motor rotation during the forging process, the highest average rotation value obtained at flywheel 3 is 3733.8 rpm and the lowest is at flywheel 1 with a value of 3724.8 rpm

2. Friction Time

Friction time is the time needed for the specimen to friction until the specimen material begins to glow when welding, below is a graph of friction time at 4 bar pneumatic pressure when testing.

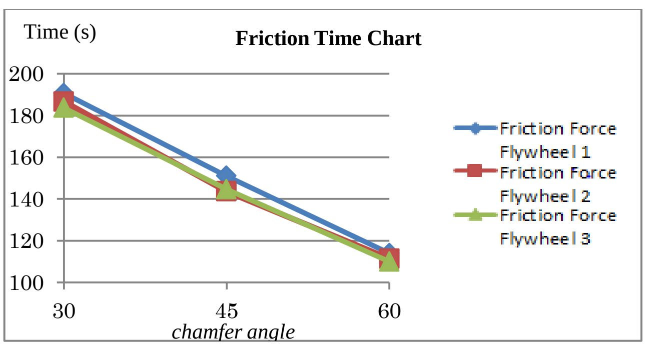

Figure 18 Average friction time chart

From the graph in Figure 18, the average friction time of each flywheel is obtained with variations in chamfer angle. The lowest friction time is obtained at flywheel 3 with a chamfer angle of 60° with a friction time of 110 seconds and the longest friction time on the flywheel 1 angle of chamfer 30° is 190 seconds. From these data it is known that at an angle of 30° with flywheel 1 requires a longer friction time to reach the melting point of the material while at flywheel 3 with an angle of 60° the friction time needed to reach the melting point of Mild Steel material is relatively shorter than in the flywheel 1 and flywheel 2 with each chamfer angle.

3. The Flywheel Time Stops

The flywheel time stops is the time it takes for the flywheel to stop spinning after the electric motor is off, Time data is obtained through observation using a stopwatch.

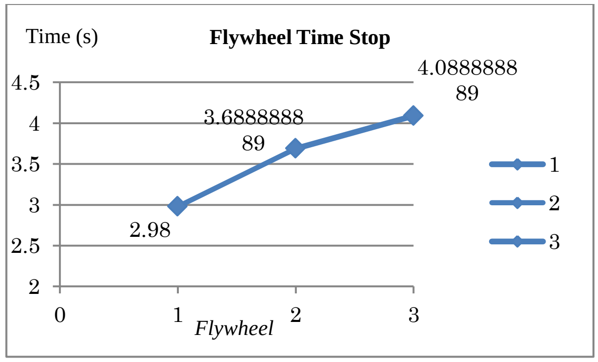

Figure 19 Stop Time Flywheel Chart

From the graph of the average time the flywheel stops in Figure 4.56, the flywheel 3 has a longer stop time of 4.08 seconds while flywheel 1 is the fastest flywheel that stops with 2.98 seconds. From the stop flywheel time data, it is known that the flywheel 3 is the flywheel that stops the longest than the flywheel 1 and flywheel 2, then flywheel 3 is a flywheel that can save welding energy better than flywheel 1 and flywheel 2.

4. Specimen Length Changes

Specimen length changes are changes in length of the specimen before welding and after welding, Specimen material before welding has a dimension of 180 mm in length with a diameter of 8 mm.

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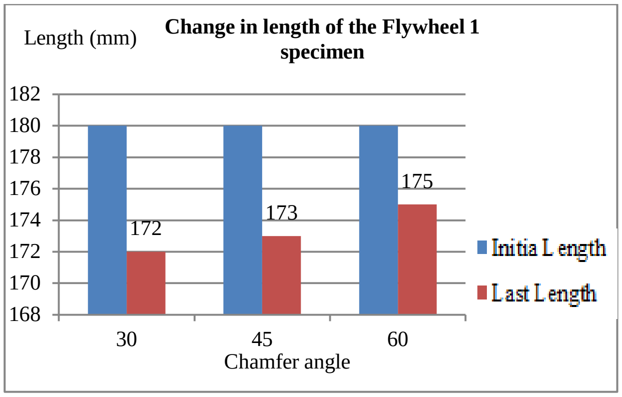

Figure 20 Graph of changes in flywheel specimen length 1

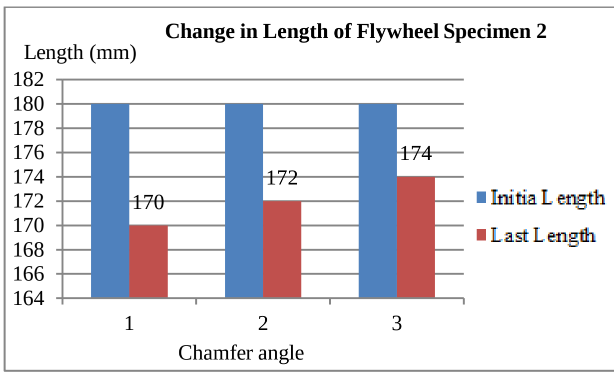

Figure 21 Graph of changes in flywheel specimen length 2

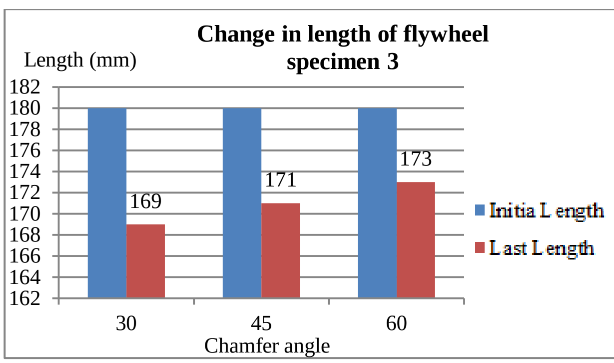

Figure 22 Graph of changes in flywheel specimen length 3

The graphs in Figures 20, 21, and 22 are the average graphs of each flywheel with variations in chamfer angles, from the graph above, the initial specimens were 180 mm each and when welding was done each specimen underwent a long change in which the flywheel 3 with the chamfer angle of 30° having the most length reduction of 11 mm while the flywheel 1 with a chamfer angle of 60° the lowest length reduction is 5 mm.

5. Time Welding Energy

The following is a graph of time welding energy from one of the tests when welding is obtained through the Arduino program.

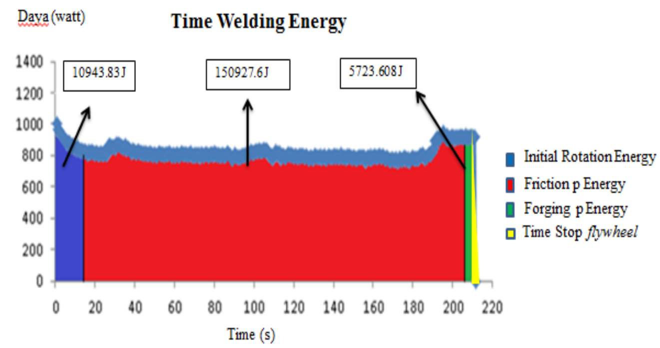

Figure 23 graph of Time Welding Energy

From the graphic above, it can be seen that the motor power increased when given friction pressure and increase again when given pressure forging resulting from increasing frictional force because of the increase in pressure given through pneumatics.

6. Tensile strength test results

Tensile testing is carried out to determine the maximum tensile strength value of welded specimens from rotary friction welding tools. The following data from the tensile test are shown in tables 1, 2 and 3, respectively

Table 1 Test results of tensile test specimens using flywheel 1

hamfer angle	Area (mm²)	Max. Force (N)	0.2 % Y.S. (N/mm²)	Yield Strength (N/mm²)	Tensile Strength (Mpa)	Elongation %
30	27.34	11851.7	391.56	203.6	433.5	9.35
45	28.27	15431.9	391.56	433	545.79	9.35
60	29.22	14600.1	391.56	400.02	499.58	9.08

Table 2 Test results of tensile test specimens using flywheel 2

Chamfer angle	Area (mm²)	Max. Force (N)	0.2 % Y.S. (N/mm²)	Yield Strength (N/mm²)	Tensile Strength (Mpa)	Elongation %
30	28.75	14200	391.56	404.44	493.95	9.35
45	28.274	13793	391.56	411.67	487.83	9.35
60	27.34	14781.5	391.56	424.89	540.66	9.35

Table 3 Test results of tensile test specimens using flywheel 3

Angle	Area (mm²)	Max. Force (N)	0.2 % Y.S. (N/mm²)	Yield Strength (N/mm²)	Tensile Strength (Mpa)	Elongation %
30	28.75	12746.5	391.56	418.58	443.39	9.35
45	28.748	15938	391.56	428.76	554.1	9.35
60	27.34	14872.8	391.56	413.06	544	9.35

The following graph is a graph showing the maximum tensile strength of all three flywheels with variations in chamfer angles

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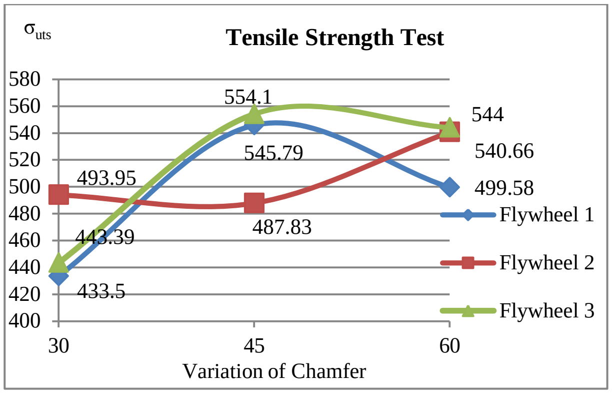

Figure 24 Graph of the maximum tensile strength of all three flywheels with variations in chamfer angle

From the tensile strength graph in Figure 24 it is known the maximum tensile strength values in each flywheel with variations in the chamfer angle, From this data, it is found that the highest maximum tensile strength value in the welded specimen uses a flywheel 3 with a 45° chamfer angle which has a value of 554.1 Mpa. While the lowest tensile strength values obtained in the welded specimens using flywheel 1 with an angle of 30° chamfer which has a value of 433.5 Mpa.

From these data it is known that mass variations in the flywheel and chamfer angle affect the value of the maximum tensile strength of the welding results, this is because the mass variations on the flywheel affect the welding process where as is known, each flywheel has the ability to increase rotation and withstand shock loads when welding, thus affecting the welding process., On flywheel 3 which has a longer flywheel stop time compared to flywheel 2 and flywheel 1 so that when the electric motor is off, the flywheel still rotates longer to do welding so that the forging process on the specimen is longer than testing using flywheel 1 and flywheel 2. Then the chamfer angle variation also affects the welding results, from the three variations of the chamfer angle given to the specimen friction surface, can be analyzed that at an angle of 45° is the ideal chamfer angle for use in test specimens where at the angle of 45° the chamfer has the highest tensile strength compared to the other chamfer angle which is used as the comparison angle in this study is 30° and 60o angles.

5.0. CONCLUSIONS

The highest tensile strength value on welded specimens using flywheel 3 with a 45° chamfer angle which has a value of 554.1 Mpa while the lowest tensile strength value is obtained in the welded specimen using a flywheel 1 with a chamfer angle of 30° which has a value of 433.5 Mpa. From the tests that have been carried out, flywheel 3 has an initial rotation, friction rotation, forging rotation, friction time, stop flywheel time which is better compared to flywheel 1 and flywheel 2.

From the data obtained through the Arduino program in each test with 27 samples that have been carried out, it is known that the motor power will increase when given friction pressure and forging pressure, From the graph of electric motor power, it was found that the test using flywheel 1 experienced a higher power increase when given friction and forging pressure while the lowest power increase was at flywheel 3 , this is due to the difference in mass of each flywheel, Flywheel 3 with a mass of 11.017 kg has the ability to withstand shock loads better than flywheel 1 3,8836 kg and flywheel 2 7,4502 kg, resulting in a faster and more valuable welding process better tensile strength. From the testing carried out by the masses from the flywheel affecting the welding process and results.

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