Variation of Friction Stir Welding Chisel Radius Pin on Tensile Strength of Aluminum 6061

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Abstract.
Aluminum 6061 is a material that is widely used in the railway manufacturing industry. Friction Stir Welding (FSW) is a solid-state welding method without the addition of filler metal. FSW utilizes heat between the rotating tool and the gripped workpiece so that the heat generated is soften and melt the base metal. This study aims to make a friction stir welding chisel with a variation of pin radius (3 mm, 4 mm, 5 mm) and determine the tensile strength of the FSW welded joint. From the results of tests carried out after the welding process, it could be concluded that the best connection quality obtained from the welding process was 3 mm with an average tensile strength value of 210,056 Mpa, while the lowest average tensile strength was obtained on welding results using a pin radius variation of 5 mm with tensile strength value of 146,356 MPa. This was due to weld flash which could cause a decrease in tensile strength when using a 3 mm pin variation less than using a 4 mm and 5 mm pin variation.

Keywords: Aluminium 6061, Friction Stir Welding, Tensile Strength, Pin Radius.

1 Introduction

Trains are a mode of mass transportation that has many advantages compared to other modes of land transportation. Some of the advantages of trains are that they have the ability to transport passengers and goods in bulk, do not require a lot of space, save energy, have low pollution levels and have a high safety factor. When making trains, it is hoped that the train will have strong construction considering its function as mass transportation. Of the several existing manufacturing processes, one of the manufacturing processes for making trains is the process of making a train frame (carbody). In the process of making a train frame, a connection process is required by welding.
As the world of technology develops, a welding technique using the friction method has been developed, one of which is friction stir welding (FSW). The FSW method has several advantages, including being energy efficient and environmentally friendly, avoiding porosity defects, not requiring filler metal and can be used to connect materials with different characteristics. FSW has many uses or applications, namely in the automotive, shipping, railway and other industries. FSW is classified as a type of solid-state welding where the welding process does not require any additional materials or filler

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metal. In addition, the FSW process involves very little heat input compared to other conventional welding so that it can reduce distortion in each process [1]. The working principle of friction stir welding is to carry out a joining process with the help of the main component, namely a tool consisting of a pin and a shoulder, then the pin will penetrate into the workpiece material and rotate on the sides of the specimen and run from the front to the back. to make a connection [2].

In previous research, a study was carried out on "Analysis of the Effect of Different Diameters of Pin Tools on Tensile, Impact and Micrographic Strength in Aluminum 6061 Using the Friction Stir Welding (FSW) Welding Method" [3] where in this research the welding process used a variation of pin radius of 6 mm, 7 mm, and 8 mm. The results of this research showed that the results of tensile and impact tests on a tool diameter of 8 mm had better levels of tensile strength, strain and impact tests than using pin diameters of 6 mm and 7 mm. The tensile strength obtained from each welding process using a variety of pin radius (6 mm, 7 mm, 8 mm) is 85.82 Mpa, 89.90 Mpa and 143.17 Mpa. The strains resulting from each welding process using various pin radii (6 mm, 7 mm, 8 mm) obtained strains of 10.89%, 11.47% and 13.71%. Meanwhile, for the impact test carried out on each specimen that had undergone a welding process with a variation of pin radius (6 mm, 7 mm, 8 mm), the impact test strength was 0.37 J, 0.38 J and 0.46 respectively. A. Apart from that, changes in the microstructure also occur which affect the mechanical properties. The highest level of density is obtained from using a pin diameter of 8 mm.

In another research on "The Effect of Feed Rate on Tensile Testing and Microstructure of 7075 Aluminum Joints Using the Friction Stir Welding Method" [5] where the research aims to determine the effect of feed rate on tensile tests and microstructure of 7075 aluminum joints. using the friction stir welding method. The friction stir welding method is a solid-state type method so no additional material is needed to connect the two materials. The principle of friction stir welding itself is to utilize the frictional force between the metals to be joined and the welding tool. The welding tool will move rotationally and penetrate into the area to be joined and moved translationally or transversely from the front to the back of the workpiece. In this research, feed rate variations of 24 mm/minute, 42 mm/minute and 55 mm/minute were used to determine the effect on tensile strength and microstructure. Data obtained after the welding process using several feed rate variations obtained the highest tensile test results using a feed rate variation of 55 mm/minute, namely 219.32 Mpa. Meanwhile, in microstructure testing, high density and small structure were obtained when using a feed rate variation of 24 mm/minute.

Therefore, in this research, several modifications were made to differentiate it from previous research, which used pin radius variations of 3 mm, 4 mm and 5 mm with friction stir welding tool material, namely high speed steel (HSS). Meanwhile, the fixed parameters used in this research are the use of spindle rotation speed, plunge depth, inclination angle and feed rate. After the welding process is carried out, a tensile test will be carried out to determine the mechanical properties of each 6061 aluminum welding joint.

2 Method

The method used in this research generally uses experimental methods. The initial stage in this research was to create a geometric design to make friction stir welding chisels using Solidworks software. After making the friction stir welding tool, the welding process is carried out using the friction stir welding method using a variety of planned pin radii (3 mm, 4 mm and 5 mm). The final stage is that a tensile test is carried out and an analysis is carried out regarding the test results that have been obtained.

3 Results

At this stage, friction stir welding chisels were made using HSS material with a length of 100 mm and a diameter of 16 mm. The manufacture of friction stir welding chisels is carried out using a turning process. Turning is carried out to shape the friction stir welding tool to suit the desired size and shape.

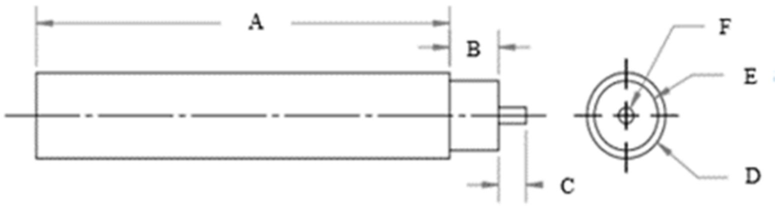

Fig. 1. Friction stir welding tool sketch

Information
Pin Material : HSS
Tools Length (A) : 84.4 mm
Shoulder Length (B) : 10 mm
Pin Length (C) : 5.6 mm
Tool Diameter (D) : 16 mm
Shoulder Diameter (E) : 13 mm
Pin Diameter (F) : 3, 4, 5 mm

The turning process carried out in this process uses a tungsten carbide tip chisel because the material of the HSS workpiece has a high level of hardness. The friction stir welding chisels made have a tool diameter of 16 mm, shoulder diameter of 13 mm, and pin diameters of 3 mm, 4 mm and 5 mm respectively.

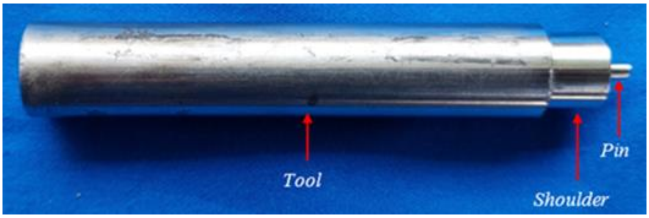

Fig. 2. Results of making friction stir welding chisels

The material used in this research is 6061 series aluminum plate model with an aluminum thickness of 6 mm. The first process for making the workpiece is cutting the plate using a cutting grinder with a size of 100 mm x 90 mm. In this stage, 9 pairs of test specimens are required, which are divided into 3 pairs of specimens for welding using a friction stir welding chisel with a pin radius of 3 mm, 3 pairs of specimens for welding with a pin radius of 4 mm and 3 pairs of specimens for welding. welding with a pin radius of 5 mm.

The welding process in friction stir welding is carried out using a milling or milling machine. The first step before starting the welding process is to set the arbor angle to 3°. Then clamp the workpiece to be welded so that during the welding process the workpiece does not shift, resulting in failure in the welding process. After that, the friction stir welding tool is installed on the milling machine. Then set the rotation on the milling machine to 1130 rpm and the feed rate to 20 mm/minute.

The next step is to turn on the milling machine and start the welding process by penetrating the workpiece joint area. After the pin has sunk into the workpiece, automatically turn on the milling machine's feed rate to move the friction stir welding tool from front to back. The rotary movement of the friction stir welding tool which is in direct contact with the workpiece will produce heat which causes the workpiece to melt. When it melts, the workpieces will fuse with each other.

Fig. 3. Friction stir welding process

Specimens that have been welded using the friction stir welding method according to variations in pin radius (3 mm, 4 mm, 5 mm) will then be subjected to a tensile test to determine the mechanical properties of the specimen. Tensile testing was carried out using a Tarno Grocki universal tensile testing machine with a capacity of 10 tons. The specimen to be subjected to tensile testing is placed on a plate and then locked or gripped so that the specimen does not move when the tensile test is carried out. After the specimen is gripped firmly, turn on the tensile testing machine so that the machine pulls the specimen until it breaks (fracture). From the tensile testing process that has been carried out, the stress and strain values are obtained as follows:

Table 1. Data from tensile testing results

Specimen	ΔL	Strain (mm)	Tensile Strength (Mpa)	Average (Mpa)
A1	6,36	0,08	203,603	210,056
A2	6,15	0,08	211,477	
A3	6,58	0,08	215,088	
B1	5,93	0,07	205,696	
B2	7,68	0,10	160,282	190,958
B3	5,71	0,07	206,895	
C1	4,83	0,06	167,581	
C2	4,61	0,06	195,232	146,356
C3	5,71	0,07	76,256	

Information:

- A1 = Tensile test specimen resulting from welding with a pin radius variation of 3 mm in the first repetition.
- A2 = Tensile test specimen resulting from welding with a pin radius variation of 3 mm in the second repetition.
- A3 = Tensile test specimen resulting from welding with a pin radius variation of 3 mm in the third repetition.
- B1 = Tensile test specimen resulting from welding with a pin radius variation of 4 mm in the first repetition.
- B2 = Tensile test specimen resulting from welding with a pin radius variation of 4 mm in the second repetition.
- B3 = Tensile test specimen resulting from welding with a pin radius variation of 4 mm in the third repetition.
- C1 = Tensile test specimen resulting from welding with a pin radius variation of 5 mm in the first repetition.
- C2 = Tensile test specimen resulting from welding with a pin radius variation of 5 mm in the second repetition.
- C3 = Tensile test specimen resulting from welding with a pin radius variation of 5 mm in the third repetition.

From the results of the tensile strength analysis of each specimen, it can be concluded that variations in the pin radius have an effect on the mechanical properties of the welded joint. The larger the diameter used in the friction stir welding process, the lower the tensile strength value of the welded joint. This is due to the large volume of the tool pin being submerged below the surface of the material, resulting in the extrusion of soft material coming out of the surface around the tool shoulder [4]. The part of the soft material that comes out on the surface around the tool shoulder is called the weld flash. Apart from the volume of the pin immersed in the material, the depth of tool penetration also influences the amount of weld flash that comes out on the surface of the material. This is because the deeper the immersion of the pin tool will result in more pressure so that the soft material due to heat from the welding process will come out to the surface [12].

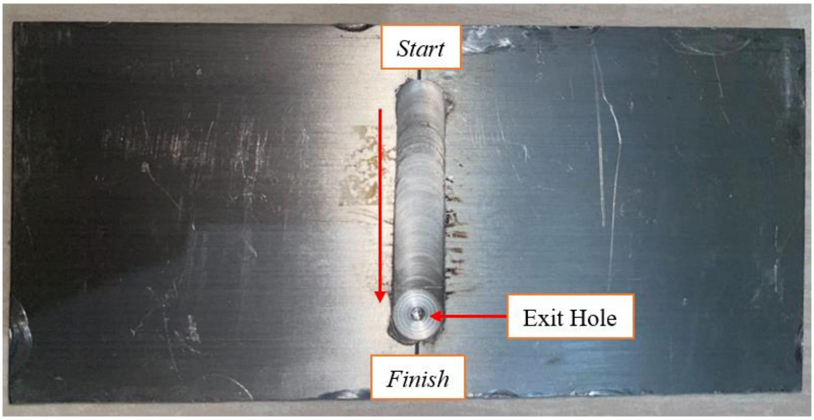

Fig. 4. Welding Results with Pin Radius Variations of 3 mm

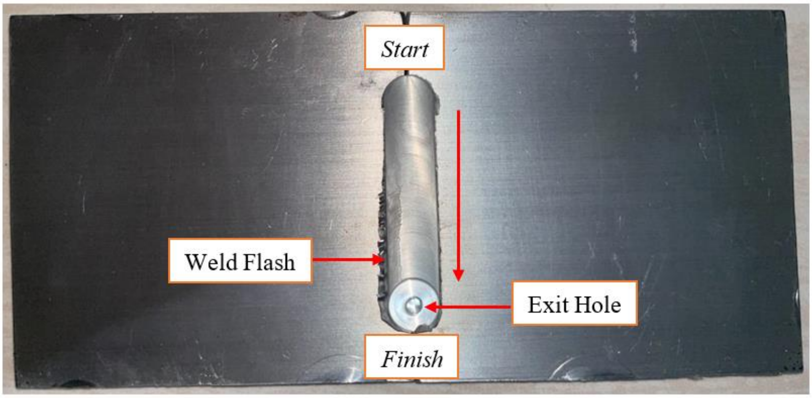

Fig. 5. Welding Results with Pin Radius Variations of 4 mm

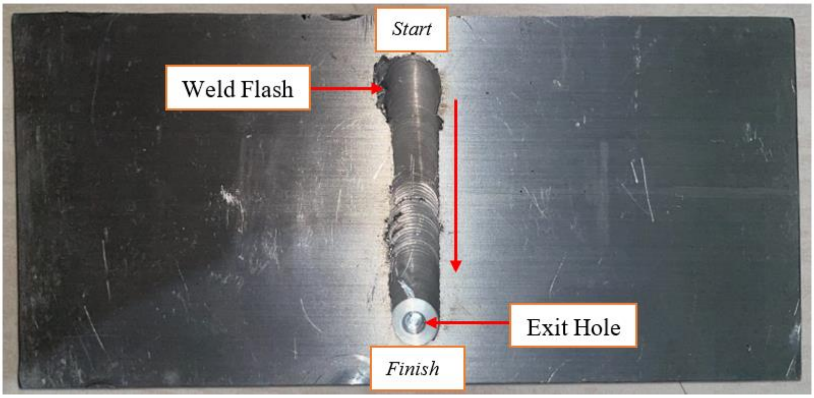

Fig. 6. Welding Results with Pin Radius Variations of 5 mm

It can be seen from the welding results with variations in pin radius that the smaller the pin radius used, the less weld flash is produced. It can also be seen that in the welding area with a smaller pin radius variation, it can produce better welding results than welding results with a larger pin radius variation. Apart from the pin, the shoulder also influences the welding results. Material flow that does not receive pressure from the shoulder will result in the formation of weld flash which can result in the cross-sectional area of the joint being reduced thereby affecting the strength of the joint [9].

4 Conclusion

From the results of the research that has been carried out, it can be concluded that the turning process for friction stir welding chisels begins with setting the lathe machine (setting the spindle rotation, headstock position, tailstock position, workpiece gripper and tool holder) then determining the type of cutting and continuing with the process. lathing according to working drawings. After the turning process is complete, the final step is to check the turning results based on the working drawings. The welding process using the friction stir welding method using a pin radius variation of 3 mm produces the highest average tensile strength value of 210.056 Mpa compared to the welding process using a variation of pin radius 4 mm and 5 mm which obtains an average tensile strength value of 190.958 Mpa and 146,356 Mpa. This is caused by extrusion of soft material due to the volume of the pin being submerged below the surface of the material which can cause weld flash which can affect the tensile strength value of the test object.

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