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Effect of Spindle Speed of Bar-Plate Rotary Friction Welding Machine on Joint Interface Area and Hardness Value

Michael Simorangkir [a], Yohanes [a,*] and Muftil Badri [a]

[a)] *Mechanical Engineering Department, Faculty of Engineering, Universitas Riau, Indonesia*

*Corresponding author: yohanes@lecturer.unri.ac.id

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ABSTRACT

This study aims to determine the effect of the rotational speed parameter on the joint interface weld area and the value of hardness on similar materials. Welding parameters used the rotational speed of 2,484 rpm, 2,613 rpm and 4,335 rpm. Test method used in this research was liquid penetrant, macro and micro-observation and hardness test. The results of the liquid penetrant test showed no defects on the surface of the connection. In macro-observation, where there is a fairly large void at rotational speed of 2,484 rpm, which has length is 2,69 mm, then shrinks at 2,613 rpm to 1,52 mm, then at 4,335 rpm there is no visible void. In micro-observations showed that the weld metal area had a finer grain structure than the HAZ (Heat Affected Zone) and base metal areas this affect hardness value. The results of the hardness test are that the higher the rotational speed the higher the hardness value produced.

KEYWORDS: Friction welding, Rotation speed, Macro-observation, Micro-observation, hardness.

1.0 INTRODUCTION

The welding is a metal joining technique by melting some of the parent metal with filler metal or without filler metal [1-3]. One of the welding processes used in the industrial world, especially the manufacturing industry, is friction welding. Friction welding is a method of joining materials that utilizes the heat generated between two materials of different or similar types without the use of added materials or fillers [4-5].

Friction welding is a welding process that makes use of the heat produced by friction. A compressive force brings the surfaces of the two materials to be connected, one spinning and the other stationary, into contact. Friction between the two contact surfaces occurs continuously, causing the heat generated by this continuous friction to rise. A welding process occurs when compressive force and heat are applied to both sides until the meeting of the two materials exceeds the melting point. Friction welding is a solid-state welding method that does not involve the melting of the metal to be connected [6]. Friction welding can be used to connect a range of materials, as long as one of the welded components has some rotational symmetry, the solid surface makes welding easier, and the goal is to produce a good quality welded junction [7].

Rotary friction welding is a process of joining metal materials, which is carried out by rubbing the two metal materials to be joined until the two metals reach a heated state. Hence, the pressing forging is carried out, so that the metal could be connected. The heat that occurs is generated from the ends of the workpieces being rubbed against each other. Friction welding is included in the type of solid-state welding [6].

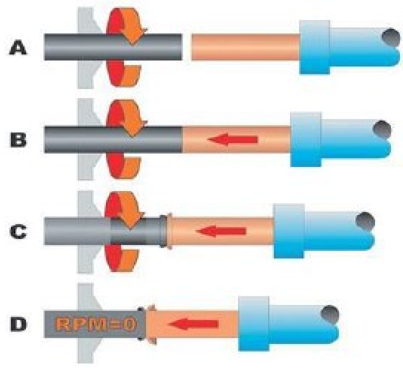

Figure 1: Rotary friction welding [6]

Parameters used in friction welding are rotational speed, friction duration, and axial force (friction and forging) during the welding process.

1. Rotation Speed

The rotation speed greatly affects the welding result, the heat generated from the material on the surface of the workpiece causes plastic deformation, the heat generated by friction in the friction phase, is the main source in the forging stage to prevent the temperature drop between the surfaces [8-10]. So, it can be concluded that the rotational speed greatly

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affects the speed, which the temperature is generated, the higher the rotation speed, the greater the energy produced, so that it requires a greater incubation force as well.

2. Friction Duration

The duration of friction affects the temperature when the friction process takes place until it reaches the forging temperature, so that on the base metal surface a forging surface is formed [11-12]. For a longer duration of friction, the surface area of the forging formed will be even greater, because the heat from friction is a straight ratio with a function of increasing time. Long duration of friction is required if the characteristic of the rotational speed that occurs in welding against the surface is low. This duration in combination with the axial pressure generates heat. Because the friction duration starts at the beginning of the friction process until the forging process occurs. If the speed used is high, the duration needed will be lower.

3. Friction and Forging Pressure

The pressure from the effect varies the speed [13-16], if the applied pressure is excessive it will result in poor welds, so that the center will have a large number of upset welds. Upset welds are similar to flash welding, on the surface of the upset welds, the surface of the workpiece to be welded, is pressed simultaneously with the heating process.

2.0 METODOLOGI

In this research, a summary of the work from start to finish is needed to facilitate this research, it can be seen in the flow of activities as shown in Figure 2.

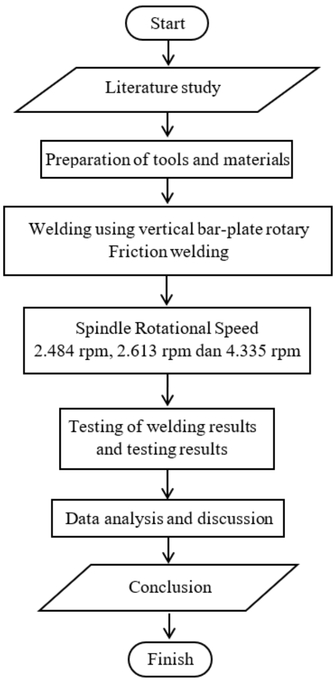

Figure 2: Flow chart of research

2.1 Tools and Materials

The tools and materials used in this research were a Vertical Bar-Plate RFW Machine, optic microscopic, hardness testing machine, caliper, stopwatch. The material used is mild steel AISI 1037.

2.2 Welding Using Vertical Bar-Plate Rotary Friction Welding

In this study, vertical bar-plate friction welding was used on similar steel materials, namely mild steel AISI 1037 with welding parameters, rotation speed of 2,484 rpm, 2,613 rpm and 4,335 rpm, the friction pressure is 0.5 MPa, forging pressure of 0.7 MPa.

Figure 3: Welding result

2.3 Liquid Penetrant Test

The liquid penetrant test is carried out to find open surface defects in the welding results by giving a light-colored liquid on the inspected surface [16]. The steps are as follows:

1. Pre-Cleaning

Pre-cleaning is done by spraying a liquid cleaner on the specimen which serves to clean the surface of the specimen from dirt attached to the specimen.

2. Spraying Penetrant

Spraying penetrant aims for the liquid to propagate into the gaps of imperfect welding.

3. Penetrant Cleaning

The next step is to clean the surface of the object that has been given a liquid penetrant.

4. Giving Developer

Then last step is spraying developer on the surface of the weld joint.

2.4 Macro and Micro Observation

The process of observing the macrostructure is as follows: Prior to macro and micro-observations, the specimens were first cut into 2 parts transversely.

Figure 4: Result of sample cutting

After cutting, then grinding and polishing, the purpose is to flatten the test object using sandpaper, this aims to clarify the structure of the material and also minimize existing scratches.

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The next step is for macro observing the specimen using microscope optic with 5x magnification. After macro obvserving specimen is etched using Nital 2% and then micro obvservation were made using 50x magnification. Macro obeservation is to see the defects that occur and measure the defect length and micro observation is to see the difference of microstructure.

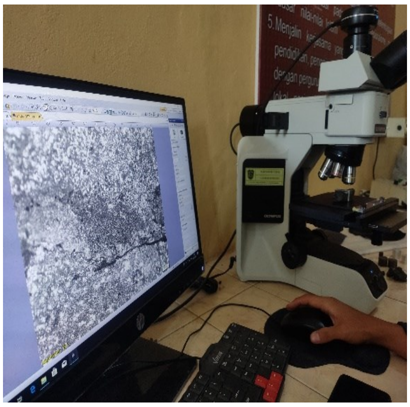

Figure 5: Macro and micro-observation

2.5 Hardness Test

Hardness testing is carried out after the specimen has been observed on macro observations. This hardness test is carried out to determine the hardness value of a test material that has been welded. The hardness test method in this study is the Vickers hardness method [17]. Where the Vickers hardness method uses a diamond pyramid indenter which has a plane angle of opposite (136°), emphasizing the surface of the part to be measured with a loading of 60 kgf, with a distance between test points of 3 mm so as to produce traces that can be measured by an optical microscope lens. The value obtained in the hardness test using the Vickers method has a unit, namely VHN (Vickers Hardness Number).

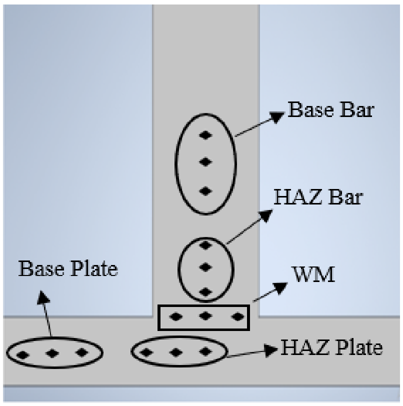

Figure 6: Test sample point

3.0 RESULT AND DISCUSSION

The results obtained from this study are what the effects occur in each variation of the spindle rotational speed and the appropriate variation of the spindle rotational speed on this vertical bar-plate rotary friction welding machine.

3.1 Liquid Penetrant Test Result

From the results of the liquid penetrant test, if there is a red liquid coming out of the surface of the weld joint, it indicates that there were welding defects or cracks and the white color indicated that there were no cracks. It can be seen in Figure 7, the friction welding with the bar-plate method there was no liquid coming out of the weld joint which indicated no cracks were found on the surface.

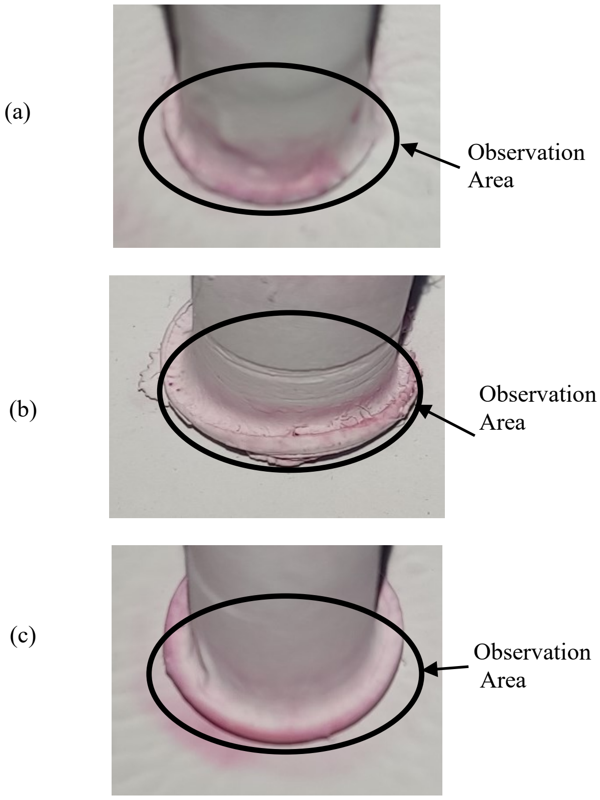

Figure 7: The results of the penetrant test speed of (a). 2,484 rpm, (b). 2,613 rpm. (c). 4,335 rpm

3.2 Macro Observation Result

From the results of macro-observations, in Figure 8 shows the weld joint interface area of the three variations of spindle rotation speed using bar-plate vertical friction welding. It can be seen that welding defects in the form of voids are still found. In the variation of (a) the spindle rotation speed of 2,484 rpm, there is a fairly large void, (b) the spindle rotation speed of 2,613 rpm, the void shrinks, (c) the spindle rotation speed of 4,335 rpm, there is no void. To determine the size of the void, the length of the void is measured using the Olympus Stream software which is integrated with an optical microscope with 5x magnification. Then the microscope images from each observation point are combined as shown in Figure 8.

At the spindle rotational speed of 2,484 rpm there is a void with a fairly large intensity, which has a total length of 2.69 mm where this occurs due to less heat input so that there is a lack of penetration during the welding process, as well as the spindle rotation speed of 2,613 rpm, there are still void. but the intensity of the size of the void has changed compared to the speed of 2,484 rpm where the resulting void is getting smaller, which has a total length of 1.52 mm. Then at the spindle rotation speed of 4,335 rpm the void is no longer visible this is

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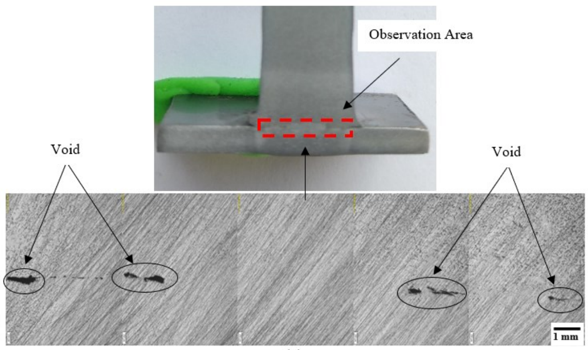
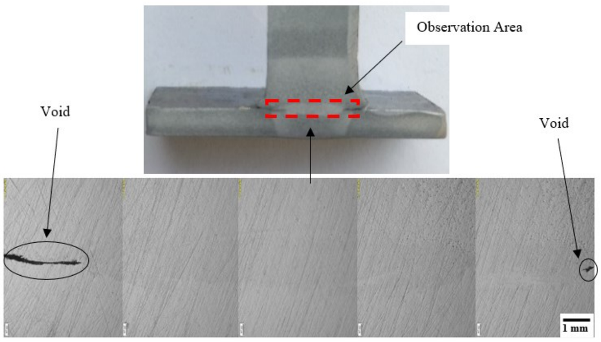
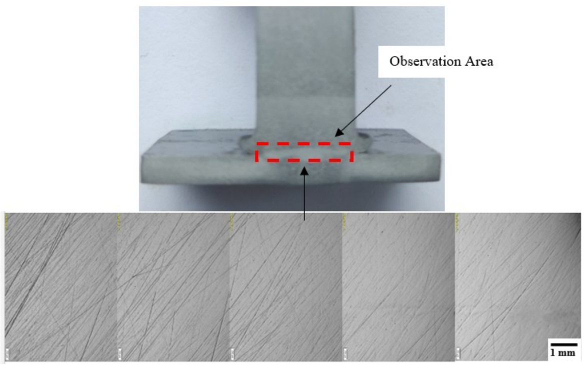
because the heat input provided is greater so that the resulting penetration makes the material blend optimally. These voids arise due to the lack of heat input during the welding process so that it is not sufficient to soften the material. Each variation of the rotational speed given has an influence on the connection interface area where at low speeds there are still voids in the interface area but at high speeds there are no voids. The rotational speed increases the void becomes narrower and there are no voids, this is because heat input is added due to the increase in rotational speed [10].



(a)



(b)

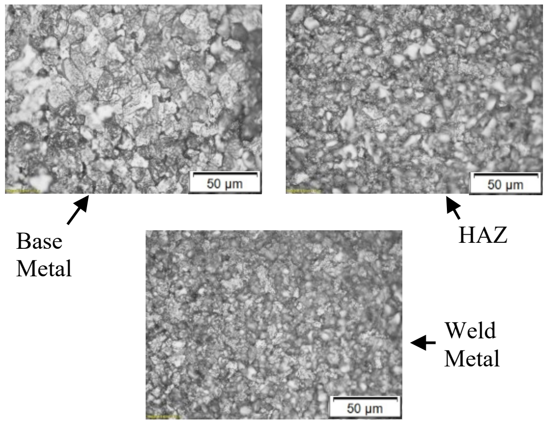


(c)

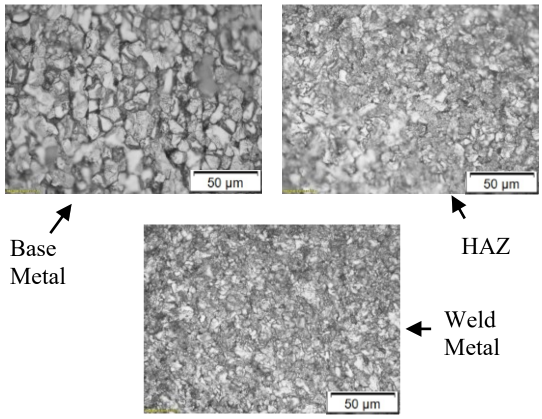
Figure 8: Macrograph of welding joints with rotational speed variations of (a) 2,484 rpm, (b) 2,613 rpm, (c) 4,335 rpm

3.3 Micro Observation Result

Micro-observations were carried out to observe differences in microstructure in the results of vertical bar-plate rotary friction welding using AISI 1037 material.



(a)



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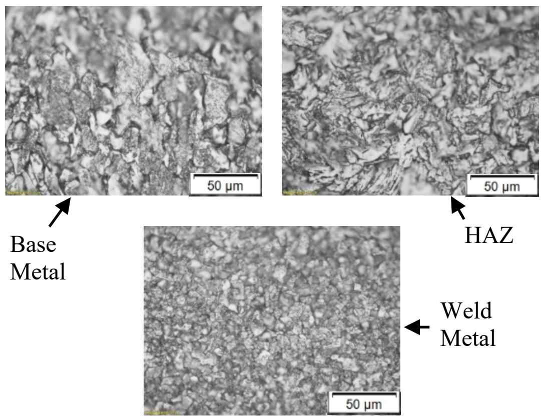

(c)

Figure 9: Observation of microstructure of variation (a) 2,484 rpm, (b) 2,613 rpm, (c) 4,335 rpm

From Figure 9, it can be seen the results of micro-observation of the results of vertical bar-plate rotary friction welding. It can be seen that the weld metal area has a finer grain microstructure than the base metal and HAZ areas, this is because the heat input in the weld metal area is higher than other areas. The fine grain microstructure will cause the mechanical properties (hardness value) to be higher, while the coarse grain microstructure causes the hardness value to be lower.

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3.4 Hardness Test Result

Hardness test using the Vickers method at rotation speed 2,484 rpm, 2,613 rpm and 4,335 rpm on AISI 1037 can be seen in the Figure 10.

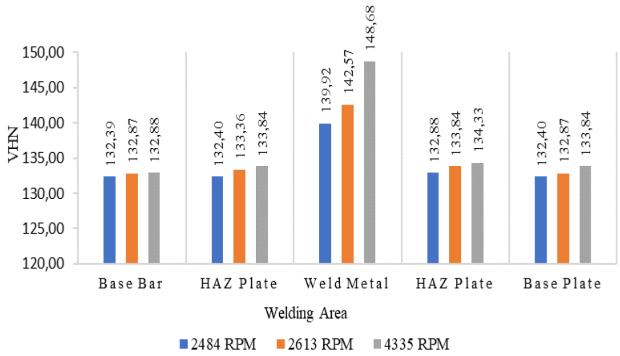

Figure 10: Hardness value chart

Figure 10 shows the hardness value data obtained for each variation of the spindle rotation speed. The hardness value produced in the weld metal at the variation of the spindle rotational speed of 2.484 rpm has an average 139,92 VHN which is the lowest value, then the variation of the spindle speed of 2.613 rpm has an average of 142,57 VHN, then the variation of the spindle speed rotational speed 4.335 rpm produced an average 148,68 VHN, which is the highest value.

It can be seen that each region has a different hardness value. This difference is due to the influence of heat input that occurs, where the weld metal area which is the area of the direct welding process will get higher heat than the area far from the weld metal. This heat input occurs due to friction and pressure on the surface of the material being joined so that heat arises as a result of the friction and pressure. The welding process unites metals so that metallurgical bonds occur under the influence of heat, so that this heat input affects the metallurgical structure of the material. The effect that occurs is that the microstructure in the weld metal area experiences grain refinement, where the grains will be closer together and prevent dislocations so that the weld metal area hardens.

Spindle rotation speed affects the hardness value where the higher the spindle rotational speed, the higher the heat input generated, which affects the microstructure and density of the weld metal so that the hardness value produced in the weld metal area will be higher, but at a lower spindle rotation speed the heat input is less, this cause to lower hardness values.

4.0 CONCLUSION

From the results of the tests carried out, namely in the liquid penetrant test, there is no influence on the surface of the weld joint, which is evidenced by the results of the liquid penetrant test. Then on macro-observations, the result is that the higher the spindle rotation speed is given. The welding defect namely the void would decrease until no voids found. It can be seen that a fairly large void is found at the spindle rotation speed of 2,484 rpm, which has a total length of 2.69 mm, then shrinks at 2,613 rpm, which has total length of 1.52 mm. The spindle rotation speed of 4,335 rpm there is no visible void. In micro-observations showed that the weld metal area had a finer grain structure than the HAZ and base metal areas this affect hardness value. From the results of hardness testing, as the spindle rotation speed increases, the result hardness value would also increase. This is influenced by the heat input that occurs. The highest hardness valued produced in the welding area is found at the spindle rotation speed of 4,335 rpm, which is 148.68 VHN.

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