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Effect of Rotational Speed on Hardness Value and Area of Vertical Bar-Plate Rotary Friction Weld Joint

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ABSTRACT

This study aims to determine the effect of rotational speed on the weld joint area and the hardness value of vertical bar-plate friction welding on dissimilar materials. Several testing methods were carried out, namely liquid penetrant, macro-observations, micro-observations and hardness test to investigation the welding results. The results of the liquid penetrant test have no effect on the welding specimens. Based on macro-observations was revealed a large enough cavity at a speed of 2.484 rpm with a cavity length of 4.76 mm, then getting smaller at a speed of 2.613 rpm with a cavity length of 2.63 mm. Then, at a speed of 4.335 rpm, no cavities were found. The micro-observation was a change in the microstructure, where in the weld metal area produces fine grains that affect the hardness value. The hardness value increases as it approaches the weld area. The highest hardness value at a speed of 4.335 rpm with a hardness value of 148.10 VHN, while the lowest hardness at a rotational speed of 2.484 rpm has a hardness value of 140.44 VHN.

KEYWORDS: *Friction Welding, Rotating Speed, Macro-observation, Hardness Micro-observation.*

1.0 INTRODUCTION

The technique of joining metal materials has been used for decades. Until the metal joining process is known as metal welding technology. Metal welding technology has been widely used in assisting daily human activities both in the world of construction and machining. Process technology is widely used in metal joining processes because of its relatively high flexibility and easy process. Welding technology also has various types depending on the type of base material to be joined and the welding technique to be used [1].

Friction welding is a welding technique by utilizing the heat generated by the friction that occurs in welding the surface of the workpiece to be joined by friction welding, in friction welding one component rotates and the other component is stationary [2]. Friction on the two surfaces of the material to be joined is carried out continuously, so that the heat generated by friction will continue to increase. With compressive and heat forces on both surfaces until the meeting of the two materials can reach the melting temperature, the welding process occurs [3]. Friction welding can be used to connect a variety of materials [4-7], provided that one of the components to be welded has some rotational symmetry, the solid surface makes it easier to do welding, the goal is to get a good quality welded joint [8].

Some of the advantages of the friction welding is that the friction pad does not use added materials, so it can save time for joining the same two materials or for different materials. While the important process parameters are rotation speed, friction time, friction pressure, forging time, forging pressure. In the process of joining the material, there is a plastic deformation process this is caused by forging pressure, so that a diffusion process occurs due to high heat to produce a high-quality connection between similar and different materials [9].

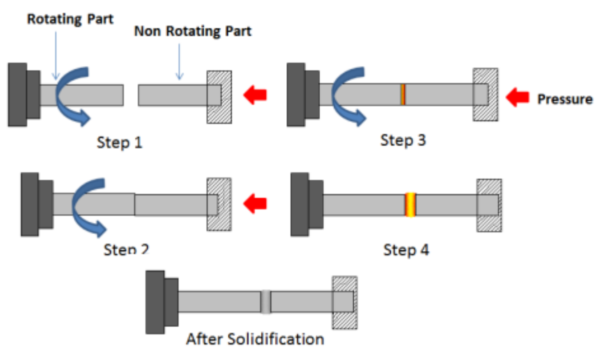

Figure 1: Friction welding process

Parameters used in friction welding are rotational speed, friction duration, and axial force (friction and forging) during the welding process [10-17].

1. Rotation Speed

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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. So, it can be concluded that the rotational speed greatly affects the speed at 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. 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, 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.

The optimizes the process parameters of friction welding joints, such as rotational speed, welding speed, defect and axial force, and capable of joining a wide variety of metals and alloys that has been challenged, recently. Therefore, this paper is proposed to determine the effect of rotational speed on the weld joint area and the hardness value of vertical bar-plate friction welding on dissimilar materials.

2.0 METHODOLOGY

2.1 Tools and Materials

The tools and materials used in this research, namely vertical bar-plate rotary friction welding machine, microstructure testing, hardness testing machine, caliper and stopwatch. The material was used the mild steel AISI 1037 on the bar and stainless steel 304 on the plate. In this study, vertical bar-plate friction welding was used on dissimilar steel materials, mild steel AISI 1037 and stainless steel 304. The experiment method was conducted to investigation of the welding parameters for rotation speed of 2.484 rpm, 2.613 rpm and 4.335 rpm.

2.2 Liquid Penetrant Test

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

1. Pre-Cleaning

Pre-cleaning was 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 aimed for the liquid to propagate into the gaps of imperfect welding.

3. Penetrant Cleaning

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

4. Giving Developer

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

2.3 Microstructure Test Preparation

The process of observing the macrostructure, prior to macro and micro-observations, the specimens were first cut into 2 parts transversely. After cutting, then grinding and polishing, the purpose was to flatten the test object using sandpaper. This aimed to clarify the structure of the material and also minimize existing scratches. There was tree specimen of welding results that can be seen in Figure 2.

The next step was for macro observing the specimen using microscope optic with 5x magnification. After macro obvserving specimen was etched using Nital 2% and then micro obvservation were made using 50x magnification (Figure 3). Macro obeservation was to see the defects that occur and measure the defect length and micro observation to see the difference of microstructure.

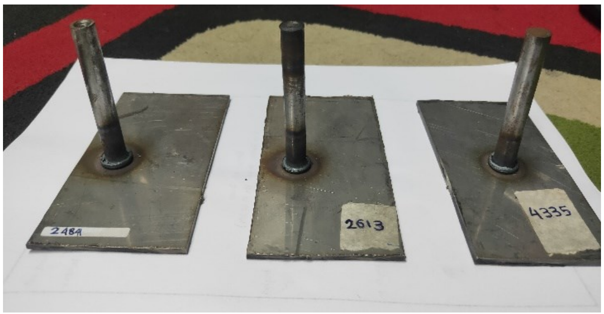

Figure 2: Welding result of speciments

Figure 3: Macro and micro observations

2.4 Hardness Test Preparation

Hardness testing was carried out to determine the hardness value of the material. Hardness testing by providing a load of 3 points for each welding area (Figure 4). The distance between the test points in each area was 3 mm with a loading of 60 kgf with a pressing time of 30 seconds. The specimens tested were 1 from each variation of rotational speed.

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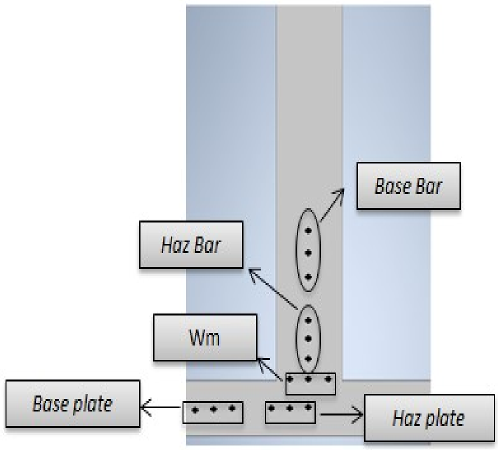

Figure 4: Test sample point

3.0 RESULT AND DISCUSSION

In this study, two different materials were used, namely mild steel AISI 1037 and stainless steel AISI 304 using the bar-plate vertical friction welding method. The welding parameters, namely, rotational speed of 2,484 rpm, 2,613 rpm and 4,335 rpm. The results of the connection with the vertical bar-plate friction welding method were tested, which included the liquid penetrant testing, macro-observations and hardness testing.

3.1 Liquid Penetrant Test Result

In the liquid penetrant test, it can be seen in Figure 5 where the observed area that was the weld joint area. Liquid penetrant testing was carried out to see any defects or cracks that occur on the surface of the welded joints. In Figure 5 (a) there was not welding defects or cracks that occur in the welded joint. In Figure 5 (b) and Figure 5 (c) also no welding defects and cracks were found in the weld joint surface area.

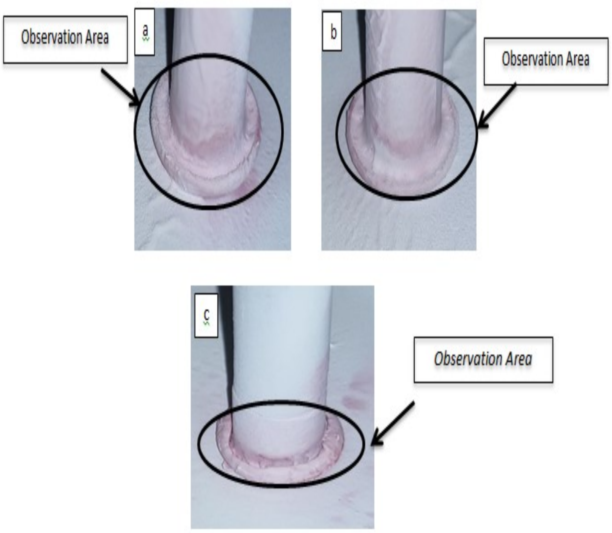

Figure 5: Macro observations, (a) Variation in rotational speed of 2,484 rpm, (b) Variation of rotational speed of 2,613 rpm, (c) Variation of rotational speed of 4,335 rpm

This was evidenced by conducting a liquid penetrant test, after being given developer liquid on the connection results, no liquid penetrant appears on the connection results. The developer fluid functions to lift the penetrant liquid, so that it detects any defects in the weld results.

3.2 Macro Observation Result

Macro observations on the surface of the weld joint with different rotating speeds. It can be seen in Figure 6, which shows a photo of macro-observations in the weld joint area. Figure 6 (a) was shown the macro-observations in the welding joint area with variations in rotational speed of 2,484 rpm. It can be seen that there was a fairly large cavity in the joint area. Figure 6 (b) shows macro-observations in the welded joint area with variations in the rotational speed of 2,613 rpm, the cavity is getting smaller. In Figure 6 (c) was shown the macro-observations on the specimen with variations in rotational speed of 4,335 rpm. There was no visible cavity.

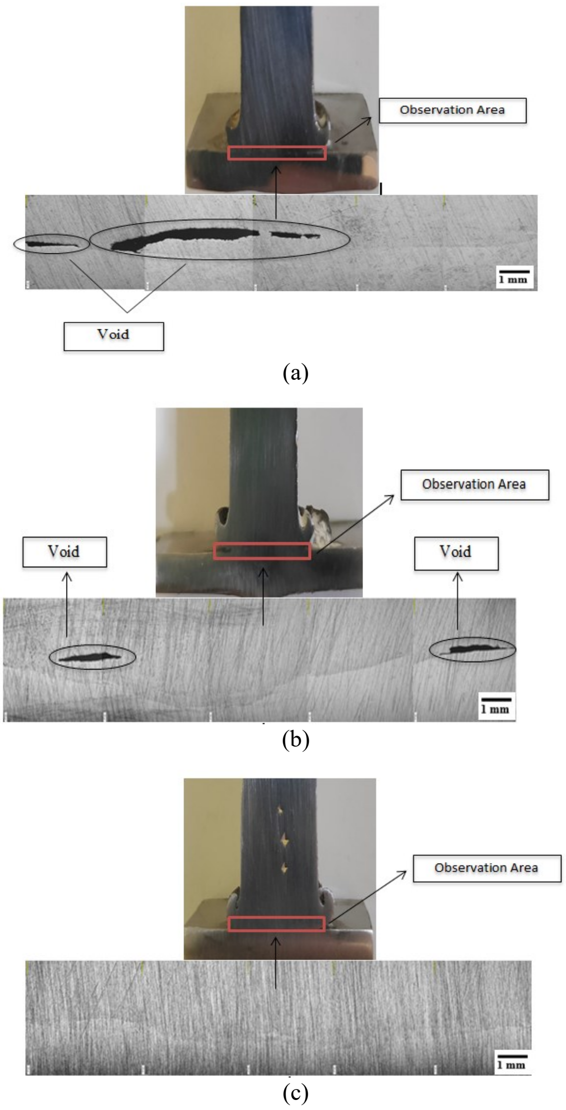

Figure 6: Macro observations (a) Variation in rotational speed of 2,484 rpm, (b) Variation of rotational speed of 2,613 rpm, (c) Variation of rotational speed of 4,335 rpm

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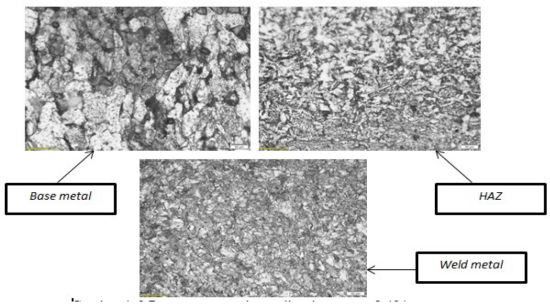
From the results of macro observations with a 5x magnification of the results of vertical bar-plate friction welding welding, there was a welding defect in the form of a cavity in the weld area. The occurrence of void at speeds of 2,484 rpm and 2,613 rpm, this defect occurred because the heat input was not high enough, so that the joints cannot blend perfectly, resulting in void in the weld joint area.

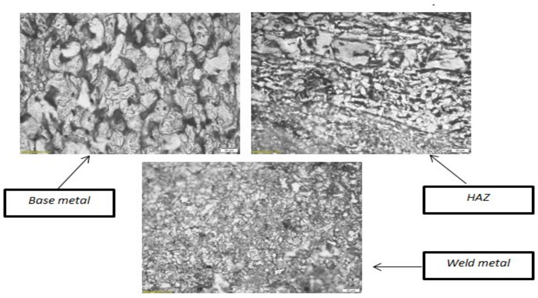
In Figure 6 (a) there was a fairly large cavity with an area of 4.76 mm in length, this cavity occurs because the rotational speed was too low. Therefore, the connection was not optimal. Then in Figure 6 (b) there was a change where the resulting area of getting smaller. The length of the cavity at a speed of 2,613 was 2.63 mm. In Figure 6 (c) no voids were found. This was because the penetration produced by the rotational speed of 4,335 rpm was able to make the two materials fuse with each other. Therefore, there was no defect in the weld area.

3.3 Microstructure Test Results

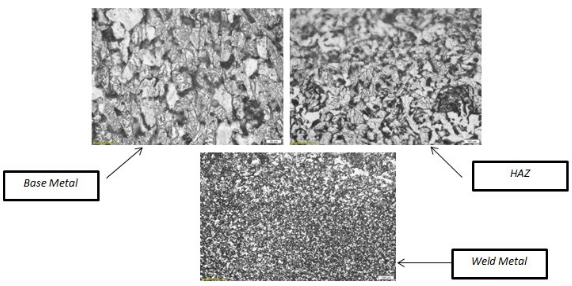
Micro-observation was carried out to see the differences in the microstructure that occurred after the connection was made by means of vertical rotary friction welding on the AISI 1037 and stainless steel 304 materials.



(a)



(b)



(c)

Figure 7: Micro observations, (a) Variation in rotational speed of 2,484 rpm, (b) Variation of rotational speed of 2,613 rpm, (c) Variation of rotational speed of 4,335 rpm

On micro-observations (Figure 7), it can be seen that there was a change in the microstructure in each area. In the area that affected the mechanical strength, namely weld metal, where the weld metal area got the high heat comparing to the areas far from the weld metal. In the weld metal area produced a fine grain structure. The fine grains affected the hardness value where the hardness of the material would increase.

3.4 Hardness Test Results

Hardness testing was carried out in each zone formed, namely the parent metal zone, the HAZ zone and the weld zone on the connection material. Each zone was tested at three points with a pressing time of 30 seconds and a load of 60 kgf. The distance between the test points of 3 mm and the loading sample is shown in Figure 8.

Judging from the graph above, it can be concluded that the hardness value at a rotational speed of 4,335 rpm has an average hardness value of 148.10 VHN. At 2,613 rpm rotational speed has an average hardness value of 142.57 VHN and at a speed of 2.484 rpm has an average hardness value of 140.44 VHN. In the weld metal area with a speed of 4,335 rpm, the highest hardness value is between 2,613 rpm and 2,484 rpm.

The difference in hardness values is due to the influence of heat input during welding where the weld metal area will certainly get higher heat compared to areas far from the weld metal area. The greater the heat input produced, the finer the grains will be, where the grains will be denser, causing a higher level of hardness. Fine-grained materials are harder and stronger than coarse-grained materials, because fine-grained materials have a larger area to block the movement of dislocations.

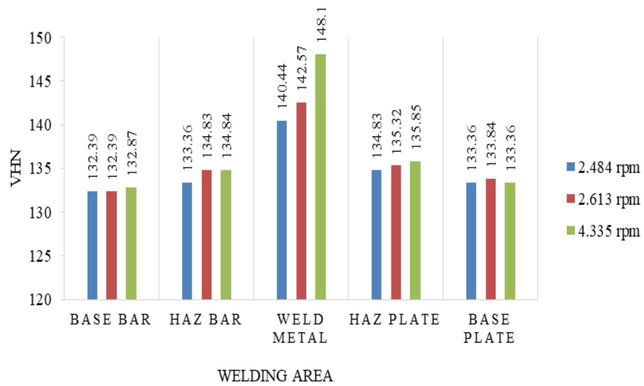


Figure 8: The value of hardness testing of the speciments

4.0 CONCLUSION

From the test results in the liquid penetrant test is not affecting the weld joint area. In macro-observations results are an influence on each given rotational speed, where the presence of a fairly large cavity occurs at a speed of 2,484 rpm with a cavity length of 4.76 mm. Then, it gets smaller at a speed of 2,613 rpm with a cavity length of 2.63 mm. Then at a speed of 4,335 rpm, no cavities are found. In micro-observation, there is a difference in microstructure, where the weld metal area experiences a higher heat than the area far from the weld metal. Therefore, the weld metal area produces a fine grain structure

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that affects the hardness value. The graph of the average value of violence in each region has a different value. In parts far from the connection area, namely the base metal area. It tends to decrease, but in the HAZ and weld metal areas, the hardness value increases. This is influenced by the heat input that occurs during the welding process. The highest hardness value is at a speed of 4,335 rpm with a hardness value of 148.10 VHN. The variation of the rotational speed of 2,613 rpm has a hardness value of 142.57 VHN. The variation of the rotational speed of 2,484 rpm has a hardness value of 140.44 VHN.

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