

THE FRICTION WELDING BY USING INDUCTION HEATING COIL PREHEAT

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Received: November 23, 2019; Revised: March 30, 2020; Accepted: March 31, 2020

Abstract

This paper aimed to develop a friction welding machine by using induction heating coil to preheat the specimen. The purpose is adjusting the melting point of the material before welding. The objectives were to determine the strength and microstructure characteristics of a joint point by using induction preheating. The two type materials used in the experiment were steel and stainless steel. The result revealed that the strength at the welding point decreased by about 35.63% and 32% for steel and stainless steel, respectively, when compared to the standard of those specimens. The results of friction welding between steel with stainless steel showed that the strength of the stainless steel and steel were about 50.66% and 26.58% less than their standard specimens, respectively. It was found that the condition of upset pressure at 60 bar with the preheating temperature of 500°C was optimum and gave the highest strength. The heat effect zone of the welding point showed that the amount of pearlite and hardness was lower at the welding center than the far distance. Also, the friction welding machine had a welding efficiency of approximately 91.52 %.

Keywords: Friction welding, induction heating, steel, stainless

Introduction

In the beginning of the 19th century, the use of connections for metal, such as the making of swords in ancient times, the connection methods were high strength and the internal structure of the material, texture, and marks were of satisfactory quality. However, there are still delays in work for the industrial sector at present. There are a variety of welding processes as it is necessary in the production of various specimens. The welding processes currently used in industrial applications are: electric welding, gas welding, friction welding,

TIG welding, mint welding, flux welding, and other various welding processes. There are benefits, advantages, disadvantages and limitations of these various processes, such as electric welding where heat is used to melt (Özdemir *et al.*, 2007). Heat spreads from the arc causing the metal to melt and smoke from arc welding. Gas welding is a welding process that uses heat from combustion of a mixture of oxygen and acetylene gas. During welding, there is pollution caused by odor or soot. Friction welding processes can weld materials that are difficult to

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melt, for example, they can weld different materials in a short time, without the need for bonding materials. The choice of each type of welding process depends on the suitability of the production in that industry. However, although friction welding can be used for different materials such as steel and aluminum, iron and copper, the strength of the weld remains ineffective. This is because the different melting points of different materials with dissimilar melting temperatures cause the grain holding in the grain to be poor because of the different sizes. Therefore, preheating a specimen with a material that has a higher melting point temperature to be at the same temperature as another specimen will adjust the condition and size of the grain in the material to a similar size and temperature (Erol Akata and Sahin, 2003; Erol Akata *et al.*, 2007; Li *et al.*, 2008) attaching tightly together, resulting in increased weld strength. In addition, the study of mechanical properties and thermal modelling of friction welding process were studied by Seli *et al.* (2010). Despite many advantages of friction welding process, it also has a chance of welding defects which may be caused by many factors that affect the quality of the welding such as speed, pressure, friction compression pressure, and friction time (Sahin and Erol Akata, 2003; Sahin, 2007). Therefore, this research has a concept of designing and developing welding processes and developing friction welding machines for welding the same as well as different metal materials (Paventhana *et al.*, 2012). The research was done by installing induction heating equipment to adjust the melting temperature of the metal to be the same which resulted in a new arrangement gain of metal particles in the material which could be grasped together. Depending on the influence of various variables that may affect friction welding with different materials, more research is needed.

Materials and Methods

Principles of Welding by Friction

The friction welding process is based on the principle of friction, causing heat to soften the specimen to a level that it can be pressed together in the flange. The welding procedure in the experiment was done by rotating the specimen on one side with the speed and torque suitable for specimen. The specimen was then given the right pressure on the other side moving it towards the other specimen that was rotating until the specimens touched each other. This caused friction which generated heat on both contact surfaces until it became soft together and therefore stopped the specimen's rotation quickly as well as provided the right pressure for the work to

move in, compressing into one piece. The turning stroke is to bring the specimen that is to be welded by friction to hold on the welding specimen on both sides and rotate the specimen on one side by providing the speed and torque suitable for the size and properties of the welding specimen, as shown in Figure 1. The process of heat generation at the contact surfaces of the welding work on both sides. The heat generated affects the weld to generate heat required in friction welding that is suitable for the specimen. The non-rotating sides push the two specimens against each other and the friction pressure is a different pressure, which determines the pressure depending on the size and properties of the friction material. Therefore, in the rotation stroke for friction, the variance must be considered. The various variables such as, friction pressure, friction time, rotation speed of weld specimen, and the speed of the specimen should be appropriate parameters and determined. The rotation process was started by rubbing the two specimens against each other by pushing the non-rotating specimen to move into friction to create heat on the contacts, as in Figure 1.

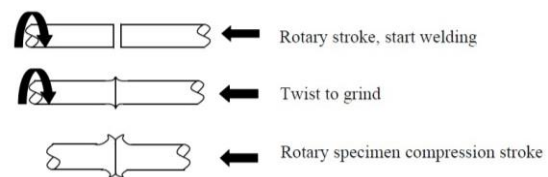


Figure 1. The friction welding process

Specimen preparation

The materials for this study consisted of steel and stainless steel. The experiment used two pieces per one test, one side of which was fixed and the other turning at about 1,200 RPM to weld by friction force under power motor of 7.5 HP. The specimen had a dimension of 100 mm in length and 15 mm in diameter according to the conditions and scope of the experiment, as shown in Figure 2.

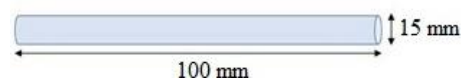


Figure 2. The specimen preparations for the experiment

Friction Welding Machine

In order for the test to be carried out correctly and successfully, designing a friction welding machine, it is necessary to have initial design in order to know the equipment needed to build the machine. The hydraulic systems was used to provide

welding pressure and the induction heating coils used to pre-heat the specimen. The simulation of the welding machine was done by designing it with a computer aid program before building, as shown in Figure 3.

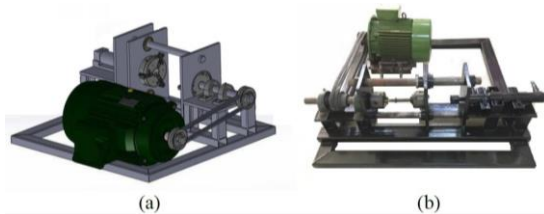


Figure 3. The friction welding machine (a) Computer aid design (b) Prototype Machine

Tensile Testing Machine

To determine the strength of the weld, it is necessary to use testing tools, including the standard tensile testing machine. The test pulls the specimen material slowly causing the material to stretch and the pulling force can be increased continuously until the specimen ruptures and the relationship between the tensile force and the displacement is recorded. The relationship between pulling force and elongation is called load-displacement curve. The test then calculates the stress and strain referred to as the graph of stress-strain which is recorded when the test begins until it ends. The device records the results of the experiment to be calculated for further analysis. Standard tensile testing machine is shown in Figure 4.



Figure 4. The testing machine: (a) Tensile testing (b) Image analysis

Experimental Setup

Figure 5 shows the preparation of the experimental setup for friction welding using induction heating for pre-heating. The experimental device was installed by the friction welding machine and the induction heating machine as shown in Figure 5(a). The installation of both specimens before welding is shown in Figure 5(b).

Results and Discussion

The Influence of Upset Pressure and Temperature

Figure 6 shows specimen setup and preheating of specimen by induction heating coil. The conditions used in the experiment were: upset pressure (compressive pressure) of 40, 50, and 60 bar at ambient temperature of 36°C and preheating at 300, 400, and 500°C under upset time of 10 sec. The experimental results can be explained as follows. Figure 7 shows the stress of friction welding from tensile test; Figure 7(a) shows the



Figure 5. Experimental setup: (a) Friction welding machine (b) Specimen setup



Figure 6. Specimen setup and preheating of specimen by induction heating coil

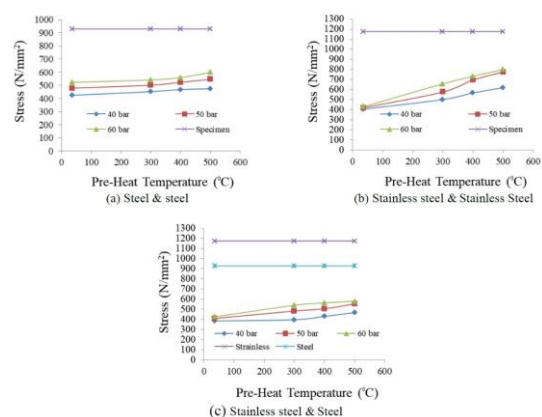


Figure 7. The result of the stress from the friction welding test

stress of specimen welding between steel and steel by using upset pressure 40, 50, and 60 bars. The experimental results showed that under upset pressure 60 bar, the specimen could receive stress better than other upset pressure which is similar to the studies result of Arayangkun and Thinvongpituk, (2008). Comparison with a friction welding specimen that was preheated at a temperature of 500°C under upset pressure 60 bar showed that the specimen shows more stress than that of other condition testing on the experimental. However, it was found that the specimen of friction welding can accept less stress than standard specimen (non-welded) by about 35.63%.

The specimen of stainless steel (AISI304) is shown in Figure 7(b). The results of tensile testing of friction welding between two stainless steel at ambient temperatures of 36°C showed that the specimen could accept stress of around 400-450 MPa and tended to increase when pre-heated at higher temperatures. The friction welding with conditions of 60 bar, 500°C preheating could accept higher stress rather than other cases. However, the welded specimen can receive less stress than un-welded specimen by about 32%.

The friction welding between steel (AISI1015) and stainless steel (AISI304) is shown in Figure 7(c). The test results showed that when both specimens were preheated before friction welding, the specimen could receive more stress corresponding to upset pressure increase. However, the tendency was reduced as compared to the specimen welded with the same type material. This is due to the different structural characteristics of the materials. When comparing strength with the un-welded specimen, it was found that the specimens by friction welding could receive less stress than the standard specimen by about 50.66% for stainless and 26.58% for steel, respectively, under the condition of 60 bars and 500°C.

Microstructure and Phase Analysis

The results showed that most of the specimens were composed of pearlite and ferrite phases and the G number by measuring at different distances. Figure 8 shows that the welded area had more ferrite and less pearlite. In theory, pearlite has a hardness of 184-390 HV and ferrite has hardness of 74-158 HV (Arayangkun *et al.*, 2008). When the amount of pearlite decreases, the welded hardness tend to decrease too. The microstructure of friction welding between steel and steel are analyzed from the photograph shown in Figure 9. It can be observed that on the microstructure image, the welding center has a smaller grain than the grain that is away from the center. The phase that occurred in the microstructure photos found pearlite which was

visible as a black color and ferrite seen as white or gray color. The microstructure image at the center of the welding has a fine grain and small amount of pearlite. When away from the center point, it is seen that there is a black grain which indicates that there is an increase in the number of pearlite while far from the center will have an increased amount of pearlite and ferrite as the main structural elements. The experimental results revealed that the welding point was high strength because the grains were smaller or finer than before. However, the welding point had reduced hardness because the pearlite decreased.

Friction Welding Machine Performance

The efficiency of a friction welding machine can be determined by Equation (1). Considering the cross-sectional area where the specimen can actually connect to the full cross-sectional area, as shown in Figure 10, Equation (1) calculated the welding efficiency of the machine in this study at about 91.52%.

$$\text{Welding machine efficiency} = \frac{\text{Cross-sectional area that can be welded}}{\text{All cross-sectional area}} \times 100 \quad (1)$$

Conclusions

From the experiments of friction welding and using induction heating preheat coil, the result showed that the strength of the specimen tended to increase

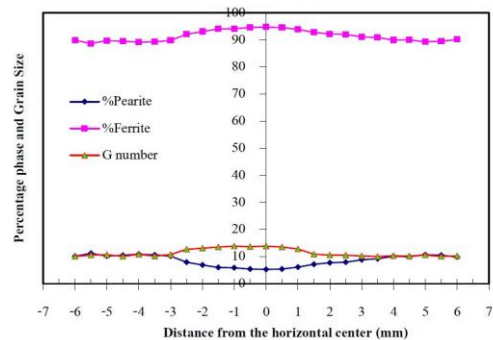


Figure 8. Phase of pearlite, ferrite and G number size at the connection line

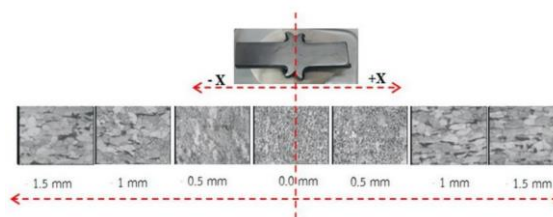


Figure 9. Microstructure photograph of specimen

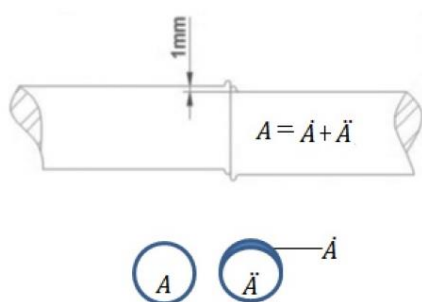


Figure 10. Illustration of welding sectional area for calculating machine efficiency

with an increase in pre-heating temperature. This occurs by the influence of preheating temperature. When the upset pressure was increased, the strength had a tendency to also increase too. Since the field area of melting point had smaller and finer grain than away from the center, the grain adhesion increased as well. In the heat effect zone of the welding point, it was found that the value of hardness was lower than away from center because the amount of pearlite which has higher strength than ferrite decreased. The efficiency of friction welding machine in this study was approximately 91.52%.

Acknowledgments

This research project was supported by Rajamangala University of Technology Isan. Contract No. SKC2561REV038

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