BOBBIN FRICTION STIR WELDING FOR THIN PLATE COLD ROLLED STEEL SHEET

Muhammad Nur Izzuddin Bin Noor Tazlin, Mohammad Kamil Bin Sued, Mohammad Khairul Azmi Bin Mohd Kassim and Shikh Ismail Fairus Bin Shikh Zakaria

Fakulti Teknologi Kejuruteraan Mekanikal Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100, Durian Tunggal, Melaka.(UTeM)

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ABSTRACT: *Friction stir welding (FSW) is a solid-state joining process which is consist of the combination of heat and pressure in order to form a joining by the stated process. However, there is a lack of study regarding the thickness of material in Bobbin Friction Stir Welding (BFSW). Therefore, this study focuses on investigating welding performance by using the BFSW process on thin-plate material. The material used to form joining was Cold Rolled Steel Sheet (SPCC) with 1 mm thickness. To form a joining, the design of the tool is necessary, and it might give a huge contribution to the final welded product. The parameter that has been applied for this study consists of rotational speed and welding speed. CNC milling machine is used to run this process. The parameter used to form a joining is 2 different spindle speeds with the same travel speed. Temperature and current data were recorded to analyze the performance during the BFSW process. The end of this study shows that it is difficult to join thin material using the BFSW technique. The reason is the plate tends to tear and produced defects during the welding process such as distortion. Moreover, the tool is unable to form any joining due to increasing of the gap. Future work studies need to be conducted in order to overcome the problem that occurs with thin-plate materials.*

Index Terms: Bobbin Friction Stir Welding, Parameters, Temperature, Thin Plates

I. INTRODUCTION

Bobbin Friction Stir Welding (BFSW) is one of the methods in Friction Stir Welding (FSW) that applies heat and pressure to perform the welding process. The difference between Conventional Friction Stir Welding (CFSW) and BFSW is the total shoulders that are applied to the tool. BFSW are using 2 shoulders for the upper and bottom while CFSW uses one shoulder at the upper only. With the difference in shoulders at the tool used, it has been stated that BFSW is provided more advantages compared to the CFSW [1]. The application of both shoulders gives higher friction heat that helped in improved material readiness; improved weld quality [2]. However, there is a difficulty in joining thin materials; which are materials that are below 6mm [3]. The main problem during welding thin plates is the material tends to tear since higher heat friction is supplied by the tool. The tearing of the material resulting poor quality welding that represents defects such as tunnel formation and flash [3]. The application of this material is commonly used in industry. They are tended to apply CFSW compared to the BFSW technique. A previous study has discussed that BFSW are having more advantages compared to CFSW.

The application of the bobbin tool is generated more friction heat [4] which gives an effect on the material. The use of the bobbin tool must be overcome by changing the parameter used since the generated heat is different compared to the CFSW. Faster heat generated should be taken as an advantage since faster heat generated shortens the welding time. However, by increasing the amount of welding speed and rotational speed, the tool was easy to break because of the force during welding. It was believed that tools especially pins were under stress during welding because of the reflex to the angle position [5].

Therefore, the material thickness was giving a huge impact in BFSW fields. In order to overcome the material thickness issues, suitable parameters that are focusing on rotational speed and welding speed need to be found. Moreover, the best parameters can be applied by the welding industry that implements FSW as the main production to achieve a good weld quality [6].

II. METHODOLOGY

Cold Rolled Steel Sheet (SPCC) with 1mm thickness chooses as the main material in this study. SPCC is known as a material that is suited for automobiles, electrical appliances, etc. due to wider workable ranges from commercial to deep-drawing qualities. Moreover, this material was good in permeability that it fits in a welding application. However, these SPCC are having a low-temperature value which gives difficulty in BFSW since BFSW are the processes that use heat and temperature as the main process. For bobbin tools, tool steel; H13 is used due to the toughness and thermal stability. Table 1 is showing the full dimension of the bobbin tool used. 3-axis Haas CNC Milling machine has been applied as the FSW machine. Table 2 represents the parameters applied in this study. Rotational speed and welding speed are the main parameters in BFSW. Both parameters are generating heat during the process including the friction between the shoulder and work piece material. Fig. 1 shows the setup of BFSW during the process [7].

Table 1: Dimension of the bobbin tool.

Tool Design		Dimension
Tool Holder	Diameter	20mm
	Height	40mm
Upper Shoulder	Diameter	24mm
	Height	18mm
Pin	Diameter	10mm
	Height	0.9mm
Bottom Shoulder	Diameter	24mm
	Height	18mm

Table 2: Parameter setup.

Test Exp.	Rotational Speed	Welding Speed
Run 1	1000rpm	45mm/min
		75mm/min
Run 2	8000rpm	45mm/min
		75mm/min

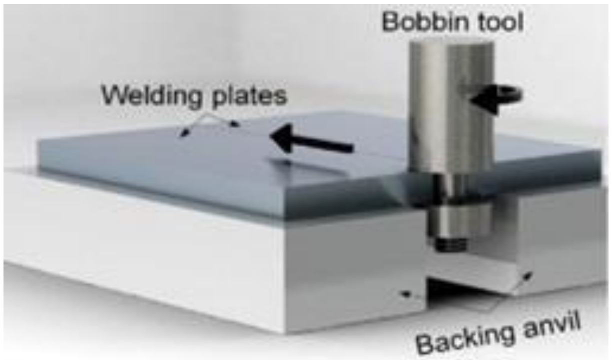

Figure 1: BFSW process.

During the welding process, two data are recorded which are temperature and current consumption. Both data are recorded along the welded path. Both of the responses were recorded to analyze the effect of each parameter during the BFSW process.

III. RESULT AND DISCUSSION

A. Weld Plate

Fig. 2 (a) and (b) represent the result of welded work piece. It shows that there is no joining occurred on both runs. Materials are showing that there is not enough heat during the process. This occurred because of the gap between the shoulders that is not in a fixed condition. The gap between the shoulders tends to increase during the process. Once there is not enough compression between the shoulder, friction between shoulder and material is easy to be decreased. Therefore, heat also was decreased. In the FSW process, heat is the main criterion to produce a good quality weld product. It was stated that poor weld quality might produce if the temperature during welding is low [8]. Moreover, the plate used is 1 mm thin that are known difficult to be weld. This material is hard to weld because there is a limited material between the shoulders during the process. Compared to the thick material, it was having more material in between the shoulder [3]. Therefore, tool design is important to be studied in order to achieve a good welding quality either thick or thin material thickness applied. This is because the temperature that is needed during BFSW depends on the friction between tool and material. Therefore, it is essential to learn the effect of tool design on the BFSW process [9]. Fig. 3 shows the bobbin tool after the experiment. The gap between shoulders surely gives an effect since the generated heat comes from the friction between the shoulder and work piece.

Figure 2: Result of BFSW; (a) Run 1, (b) Run 2.

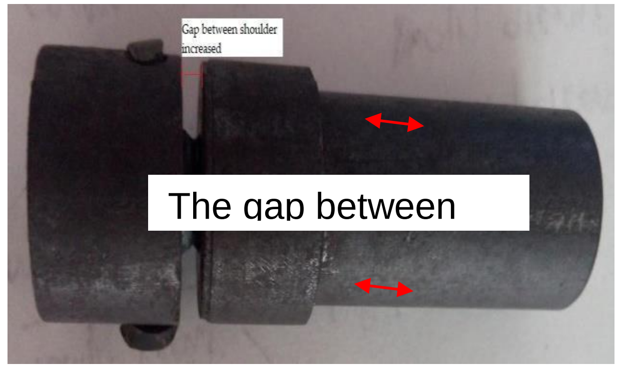

Figure 3: Bobbin tool with an increased gap between shoulders.

B. Temperature Measurement

Fig. 4 and 5 represent the temperature during BFSW for both experiments. As the tool rotates with a contact to create friction between the tool and work piece material, the temperature in the welding area are keep rising. An excessive heat softened the material while the lower temperature is creating a material removal process. The heat needed for the FSW process is quite critical since it required the exact temperature in the range of value to get a good quality of the welded product. Channels 1, 2, and 3 are recorded at the Advancing Side (AS) while Channels 4, 5, and 6 are at Retreating Side (RS). It shows that temperature keeps decreasing along the welding area at AS while at RS, the temperature keeps rising. It has been proved by [1] that AS are having decreasing pattern temperature while different from the RS. However, the maximum temperature was recorded in the range of 200-250˚C. For the SPCC material, the temperature recorded is still insufficient since the melting point for SPCC is higher. So, it required more than 250˚C to be welded using BFSW.

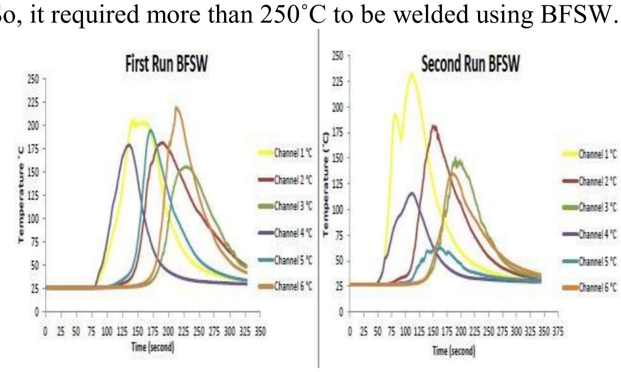

Figure 4: Temperature graph for Run 1 of BFSW.

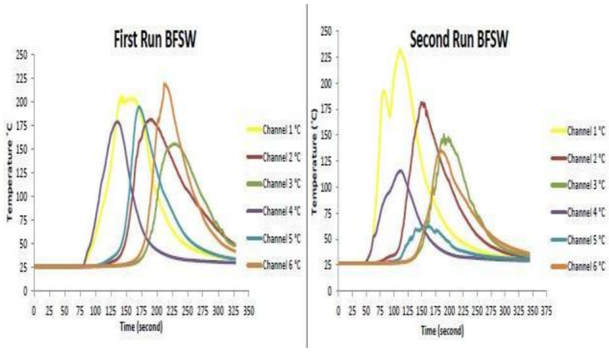

Figure 5: Temperature graph for Run 2 of BFSW.

Based on a previous study, in order to achieve good quality welding, the temperature during welding must be around 40-60% of the melting point of the material used. For this study, the temperature achieves is 18.83% from the melting point of SPCC. It is believed that temperature is not enough to get a good quality welding product. Moreover, the gap between the shoulders keeps increasing which make tools not touch with material along the process. Table 3 shows the comparison of percentage temperature for another material [10-13].

Table 3: Comparison of percentage for other material applied.

Material	Temp. during welding, ˚C	Melt. Point, ˚C	Percent., %
AA 6061-T6 [10]	350	671	52.16
AA 2024-T3 [11]	450	671	67.06
Copper [12]	530	1084	48.89
Mild Steel [13]	800	1450	55.17

C. Current Measurement

Measurement of current is important to make sure the machine used is capable to run BFSW that are required higher force during the process. During the BFSW process, the current that is served to the machine can be analyzed to know the smoothness of the process. The graph is increased once the tool is touching the material. That means, if the graph is showing decreasing in value, the BFSW process is not perfect. It might have a huge defect or even a tiny defect in the welded product.

Fig. 6 shows the data current recorded during the BFSW process. Based on the result obtained, it shows that both runs are showing the same pattern of the current measurement. Machines are required to face higher force during dwell time and the welding phase. This is because both conditions are considered new to the tool and material. Materials are still not in ready condition because of the insufficient heat. This creates an unstable graph during the welding phase. Each time the tool touches with material those results in higher friction resulting in a higher force on the machine. Moreover, the gap between the shoulders should be less than the thickness of the material plate. Therefore, a higher force with a stable current supply is needed to make sure BFSW runs smoothly. Compared to the dwell time phase, the graph is in stable condition since the tool just keeps stirring at the same point of position. It makes the material ready to be welded since enough heat at that time.

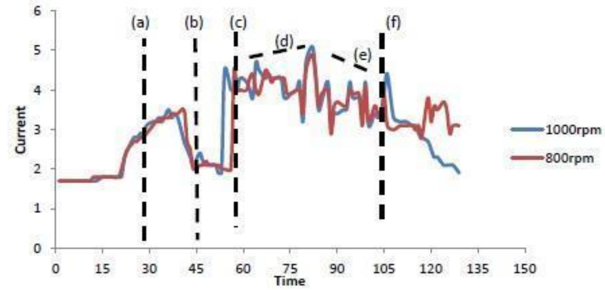

Figure 6: Graph for current recorded during BFSW process; (a) Tool entry, (b) Dwell time, (c) Weld phase, (d) Uptrend, (e) Downtrend, (f) Tool exit.

IV. CONCLUSIONS

Tool design and fabrication are highly important to make sure the welding process runs smoothly. The increasing gap between the shoulders is creating a situation the shoulder of the bobbin tool is not touching the material plate. This situation creates temperature generated during the process is low to produce a good weld quality. Moreover, in BFSW, the shoulder of the tool must be touching the material work piece to make sure that the heat is kept supplied to the material to achieve enough heat during the process. During the BFSW process, the temperature is the main criterion to create an acceptable welded product. The temperature during the welding process must achieve about 40% - 60% of the melting point for each material used. In order to achieve the targeted temperature, parameters; rotational speed, and welding speed, must be chosen wisely. Moreover, the type of machine used also give an effect on the BFSW process. The machine should be required to face higher force since BFSW is a process that has higher force during the process. Last but not least, thin material is surely difficult to weld since it is easy to tear during the process. The least amount of material in between the shoulders makes the process hard to complete. Material is tended to flow out from the shoulder since it is pushed out by the shoulder and pin. This happened because the gap between shoulders is less compared to the thickness of the material. To prevent this situation are happening, a good design of tool needs to be studied to make sure all the material is kept in the welding area or in between shoulders.

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