Three axis milling machine applications for welding samples test neutron instrument using friction stir welding method

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Abstract. Milling machine is one of the conventional machine that capable of working on a flat surface, side cutting upright, leaning even the making of grooves and gear. This work on machine tools or finish a workpiece using milling knife (cutter) as chisel cut rotating on the axis of the machine. Welding is one of the important process in the manufacture of sample for industrial use. Friction stir welding one of welding techniques without welding medium. The welding process from this technique is obtained from the combination of heat and pressure due to friction between the spindle and the welding materials. Study on friction stir welding is carried out using a milling machine 3 axis with spindle as a tool for welding processes. The test materials Al and Mg alloy. The sample is positioned steady in sample holder, while the spindle spins welding instrument. Welding is carried out using the Y direction of the engine with a direct corner frais welding processes of 1o. Z-axis direction is used to immerse the spindle holder between two stir welding material to be in the welding, as for the direction of the X-axis is keep stable in its position. Spindle shaft dimension D = 25 mm, L = 100 mm spindle shaft, spindle las D = 5 L = 5, 4 mm. The speed of rotation of the engine use a two-speed variation, i.e 1450rpm and 180rpm. In this research, the result show that using 180rpm of the speed rotation engine with the feeding speed is 1,3 mm/min, and the temperature 55° C, is the optimum condition for welding of Al alloy by Mg, The welding surface look smooth without any cracks contour, as well as the level of its homogeneity of material both look almost reached a percentage of 50:50.

1. Introduction
Welding is one of the most important processes in the industrial world and is an integral part of industrial growth. Welding is a local connection process between two or more metal parts by utilizing heat energy. Welding is a technique of bonding of metals applied as in the construction of steel buildings and machinery construction. The breadth of use of welding technology is because in the process of making a construction or machine building will become lighter and simpler, so the cost of production becomes cheaper and more efficient. The rapid development of science and technology demands the developers of human resources. Many people are trying to develop in search of better efficiency in the field of welding techniques. Welding is an integral part of the growth of industry improvement as it holds a major role in engineering and repair of metal production. The scope of use of welding techniques in the field of construction is very wide, covering the shipping, bridges, steel rod frame or Aluminium, conduit pipes and other [1]. In the world of research some results from welding techniques are very important, where the results of the weld can be used as a sample in the field of research on metals.
Center for Science and Technology of Advanced Materials (PSTBM) is one of several research centers in BATAN, which contains research on weld metal. One of the neutron scattering equipment in PSTBM conducts research on the weld-lasen result of metal Al with Mg alloy using Frictin Stir Welding (FSW) technique. So it takes a welding equipment that can do these welding techniques.

The FSW was discovered by The Welding Institute (TWI) in 1991 as a state-dense splicing technique. In principle, the process is very simple, which is an unbaiting tool with a pin and shoulder that is specially designed to be inserted and rotated on the sides of the specimen and running along the specimen to form a connection. The Tool has two functions that are energy generation function and a melted material mixer to form the connection. The process parameters that are important in the FSW process are the rotary speed tool ($\Omega$, RPM), the traversal velocity (mm/min), the depth of the tool (mm) and the slope of the tool relative to the vertical lines (degrees) [2].

This research was conducted to apply the technique of gluing FSW to a percentage of conventional 3-axis milling machine made in Korea. Where actually the main function of the milling machine is to perform the bribe of a workpiece. This is done in order to sample welding needs with FSW technique on the research program that is fulfilled.

2. Research Methods

In this research milling machine serves as the main tool in performing the welding process. Milling machine is a conventional machine that most can do the type of machining when compared with other conventional machines. Some workmanship that can be done is the creation of grooves, the manufacture of gears, the nutrition of the surface is flat on the upright and horizontal sides, cuts and others. This machine is driven by a motor that uses electricity as a power, engine rotation, depth of cut, the feeding speed of the engine Milling can be adjusted to the needs of the operator. The milling machine that performs the motion of the feeding is a workpiece, while the cut motion is done by Chisel. Which means that on a milling machine only perform movements rotating in motion, and the workpiece moves to perform the motion of feeding [3].

The machine used in this research is a Korean-made FIRST 3-axis (x, y, z) milling machine, with a stroke on the x-axis as far as 600mm, y of 300mm and Z of 500mm.

![Milling Machine Facilities in PSTBM - BATAN](image)

Welding is done using the Y-axis direction of the milling machine with the tilt angle of the pin shoulder of 1°. The Z-axis direction is used to immerse the spindle pin shoulder of the stirrer welding between the two materials that will be weld. PIN is immersed according to the length of 5, 4mm, so that the remaining material is not exposed to pin is 0, 6mm. As for the direction of the X axis remains silent and stable. Trunk Dimensions Spindle D = 25mm, L rod spindle = 100mm, spindle weld D = 5 with L = 5, 4mm. Speed of engine rotation using two speed variations, which are 1450rpm and 180rpm, average welding time (feeding rate) of 1, 3mm/min with the weld length of 40mm. The weld
samples used in this study were Al AA 6061 and alloy Magnesium (Mg) AZ31. With the sample dimensions for both $P = 100\text{mm}$, $L = 60\text{mm}$, and $T = 6\text{mm}$.

3. Results and Discussion

Welding with FSW method is not the same as the Fusion Welding process such as electrode welding, TIG, or the like. FSW welding process is a solid phase welding method, so this process produces a strong connection and also has good mechanical properties. The length of the pin is slightly lower than the depth or thickness of the material to be welded in order not to contact the base. Shoulder must be in contact with material that will be welded to suppress and keep material in soft condition.

![The Friction Stir Welding process (FSW)](image)

**Figure 2.** The Friction Stir Welding process (FSW)

The FSW process is a process that uses rotating tools that are similar to the process of milling process. Therefore, a lot of research in this field is done using the platform milling machines both conventional and CNC. But because of the nature of the FSW process involving a very large style, then a large-capacity tool machine becomes an option [5].

In this research the milling machine used is a conventional milling machine where for the 3rd movement of its axis is still being moped by the operator, and using the speed setting program with the motor. Although on both axes ($x$ and $z$) have been mounted drive motors but its usefulness is only to read the position of the workpiece only. When welding is done position of the workpiece is on the working table in the direction of the working table axis ($x$). The position of the second welding plate must be positioned precisely at the center of the machine spindle, so that the welding material distribution can be divided evenly on either side. Before the pin shoulder is immersed, it must first be screwed the angle of the sheen by $1^\circ$. This is conditioned to allow the pin shoulder to stir the weld material and push it towards the running weld. The pin shoulder is immersed by moving the $z$-axis slowly to the height of the pin in the study by $5,4\text{mm}$. 
With the proper use of material tools, then in a process the melting point of the tool must be higher and harder than the material to be welded. It becomes very important that the material tool must have enough strength, otherwise the tool can be twisted, cracked, even broken. At Friction Stir Welding (FSW) a cylindrical-shaped tool (cylindrical-shoulder) equipped with a shoulder and a pin or probe that can integrate or as a separator from the possibility of entering a different material. Shoulder and probe design is essential for welding quality, where the probe from the tool generates heat and moves the material being welded, shoulder also plays an important part of providing additional friction treatment as well as Prevents plasticised material from the weld area besides maintaining the temperature stability of the weld material. The two also move at a fixed pace and move across both joints of the material to be merged. Tool design is a very influential factor in the quality of the weld, as the precise design of the tool can improve the weld quality and weld speed as much as possible.

The spindle speed pin shoulder In this case uses two speeds of 180rpm and 1540rpm. By measuring the feed rate speed of 1, 3mm/min and the weld length of 40mm was obtained that the speed of spindle affects the temperature of the welding, the faster the rotation is faster and higher also the heat temperature is inflicted. Because the tool material used is KNL steel so the relevant speed so that the temperature of the welding is stable is at a speed of 180rpm. The heat that occurs makes the material around the pin become softened and the result of the rotation motion and translasi of the tool. The Material in front of the pin moves backwards and this occurs continuously during welding, resulting in changes in the micro structure and generating 4 weld zones as in Figure 4 and 5.

![Figure 3. Position of pin shoulder during welding [4].](image)

![Figure 4. Heat Zone on FSW [6].](image)
Figure 5. Welding Result using FSW

From the experiment obtained the test result table as in table 1.

| RPM and tool type | 1-10mm | 11-20mm | 21-30mm | 31-40mm |
|-------------------|--------|---------|---------|---------|
| 180rpm (ss)       | 51° – 53° | 54°     | 55°     | 55° – 56° |
| 180rpm (KNL)      | 54° – 55° | 55°     | 54° – 56° | 55° – 56° |
| 1540rpm (ss)      | 60° – 64° | 64° – 69° | 69° – 72° | 72° – 75° |
| 1540rpm (KNL)     | 70° – 75° | 75° – 80° | 80° – 85° | 85° – 90° |

From this research was obtained that by using a speed of 180rpm with welding time (feeding speed) averages 1, 3mm/min, average stable temperature 55° is the maximum yield for welding Al with Mg alloy, where the welding surface is visible Without any contours of the sample contour, as well as the homogeneity level of both materials looks almost reached the percentage of 50:50, such as Figure 4. The temperature stability data of the tool used can be seen in the chart 1.

Graph 1. Temperature X Distance Weld
As for the results of samples which have been made after a test experiment using the texture diffractometer, showed significant results. Where is the peak diffraction of the material welding can be seen and identified, as shown in Figure 6.

![Figure 6. Example data FSW sample with DN2](image)

4. Conclusion

From the research conducted above, it can be concluded that:

1. Obtained that by using a KNL type tool with a speed of 180rpm with welding time (feeding speed/rate) averages 1, 3mm/min, average stable temperature 55° is the maximum result for welding Al with Mg alloy. It can be seen from not Defect the results.

2. FSW application on conventional milling machine allows to be done. Because the results are so acceptable and it can also reduce the cost of purchasing a valuable FSW machine much higher than this type of conventional milling machine.

3. Tool selection must be precise and adjusted to the type of material to be welded, because it is very influential on the quality of the weld.

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