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Investigation of welding parameters on mechanical properties in 6061-T4 Aluminum friction stir welding

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Abstract— **Friction stir welding is a new method of solid state welding. This method is of high energy efficiency and good compatibility with the environment. Also, in aerospace and other sensitive industries, it can be used to weld high-strength aluminum-based alloys which cannot be welded easily using conventional method. In the past decade, friction stir welding has a great development in joints and connections. In the current study the process of butt welding the aluminum alloy 6082 sheets with a thickness of 5 mm was performed and simultaneous effects of tool's rotational speed and traverse speed parameters on mechanical properties such as ultimate tensile strength, tensile yield strength and hardness in friction stir welding process was investigated. The results showed that the friction stir process leads to fragmentation of Intermetallic particles, homogenizing microstructure and breaking the grains of the weld area to smaller ones. The results showed that increasing the rotational speed and decreasing the traverse speed (increasing welding step), increases input heat, rises the vertical flow, grows the grain size, and reduce the hardness.**

Index Terms— **Friction stir welding, Rotational speed, Traverse speed, Butt joints, Metallurgical properties.**

I. INTRODUCTION

Welding process is one of the permanent connection methods that can be used to join homogenous pieces and heterogeneous pieces. Welding can be considered as a permanent Metallurgical joining that can be created in solid or molten state using an intermediary (filling materials) or without intermediaries and by applying pressure. At first friction stir welding was invented for aluminum alloys and is a method of solid state joining. This welding method was introduced to world's industry by the Institute of Welding (TWI) in Cambridge, UK in 1991 [1].
Since, the different series of aluminum alloys used in the aerospace industry that have excellent properties such as high strength, and fatigue failure resistance welding these alloys such as alloy series 2000, 6000 and 7000 are very difficult. If the fusion welding is used then the joints or connections will have very week freezing and plenty holes and cavities. In aerospace industry the purpose of welding these alloys is to achieve the joints with desirable metallurgical and mechanical properties. Due to the limitations in welding, the use of this kind of alloy is limited in a wide range of aerospace structures. Aluminum alloys using friction stir welding may have a special implementation in military industry, aerospace, railway and nuclear industries.

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II. FRICTION STIR WELDING PROCESS

The basic concept of FSW welding is quite simple. The fundamental concept of friction welding is the change of mechanical energy into heat energy. The process begins in this way that the unusable tool point (pin) with a proper design, sufficient downward force, and rotational movement descends and touches the edges of two sheets or plates and because of the applied force it moves down and penetrates into the piece until tool shoulder contacts the piece and heat energy is generated due to friction (figure 1). As the pin penetrates and more force applied, due to the friction between the tool surface and the top surface of the piece, the generated heat will increase. Increasing the heat which caused by the friction, reduce metal strength and the tool's linear movement along the intersection of two metals leads to their connection, and Since the connection achieved without metal melting it is called the solid-state friction stir welding [2].

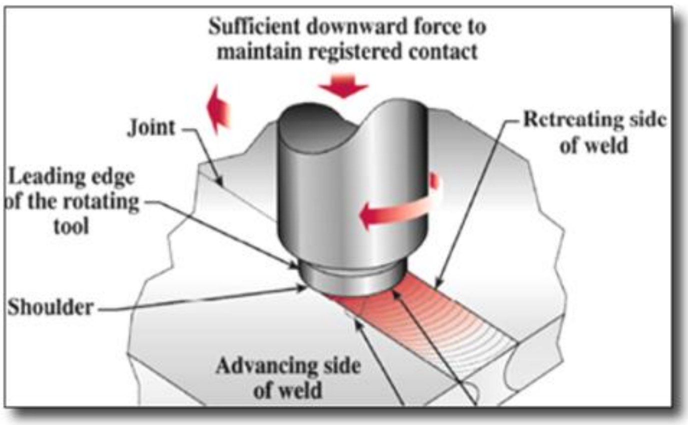

Fig 1: Schematic figure of the friction stir welding process

III. EFFECTIVE PARAMETERS IN FRICTION STIR WELDING

There are 3 important parameters for friction stir welding: spindle rotational speed is the welding engine's driving transmission force to the weld line by pin and shoulder, and in fact, it is the power required for welding. Output spin of the welding machine can play an important role in the quality and defects of welding operations. The friction varies with the engagement of pin and joining line and the change in rotation speed [3].

Traverse speed along the connecting line; In order to achieve a high quality and precision welding, it is required for the tool to move in 3 axial direction of x, y, and z. At first it is necessary for the tool to move towards the piece and placed on top of the piece, then after rotation begins in the tool, it moves towards the desired direction and welding line. Geometrical shape of tool for materials with high melting point such as steel and titanium or materials with high thermal conductivity such as copper is important. In addition to the tool's rotational speed, traverse speed and geometrical shape of tool, another very important parameter in the process is the tool's inclination angle relative to the work-piece surface. Inclination angle is suitable for the angular tools which can transfer the stirred and mixed material from pin's front to its back by the shoulder. In addition, the amount of pin penetration into the work-piece (also known as target depth) to produce a flawless and smooth welding with the tool shoulder is very important. Target depth (penetration depth) depends on the pin's height [4].

IV. Evaluation of Tool Rotational Speed for Aluminum 6061

To study the mechanical and metallurgical properties of this type of aluminum, rotational speed of 1200, 1400 and 1600 with traverse speed of 40mm/min were selected. According to table 1 and 2 analysis and mechanical properties, Welding pieces with dimensions of 4 × 50 × 200 mm made of aluminum 6061-T4 alloy were selected.

Table I: Chemical composition of 6061-T4 aluminum based on weight percentage

Component	Wt. %	Component	Wt. %
Al	95.8 - 98.6	Mg	0.8 - 1.2
Cr	0.04 - 0.35	Mn	Max 0.15
Cu	0.15 - 0.4	Ti	Max 0.15
Fe	Max 0.7	Zn	Max 0.25
Si	0.4 - 0.8	Other, total	Max 0.15

Table II: Mechanical Properties of 6061-T4 aluminum

Hardness, Vickers	Tensile Yield Strength (Mpa)	Ultimate Tensile Strength (Mpa)	Aluminum Alloy
75	145	241	6061-T4

To perform the welding operation, a tool with threaded pin with a pitch of one mm, 5mm diameter, 5mm height, and 12mm shoulder diameter was selected, and after performing the heat treatment, it was prepared for welding aluminum 6061. After applying heat treatment on each of three samples using available machine software, they were cut and prepared to do relevant analysis. The results of these Analysis to investigate were collected in Table 2 to be compared with each other.

Comparing the hardness, tensile yield strength and ultimate tensile Strength in Figures 2, 3 and 4 shown.

Table III: Comparison of mechanical properties for traverse speed of 50 mm/min

Rotation speeds (rpm)	Hardness, Vickers	Tensile Yield Strength (Mpa)	Ultimate Tensile Strength (Mpa)
1200	**58**	**111**	**202.3**
1400	**62.2**	**127.5**	**207.5**
1600	**67**	**118.2**	**214**

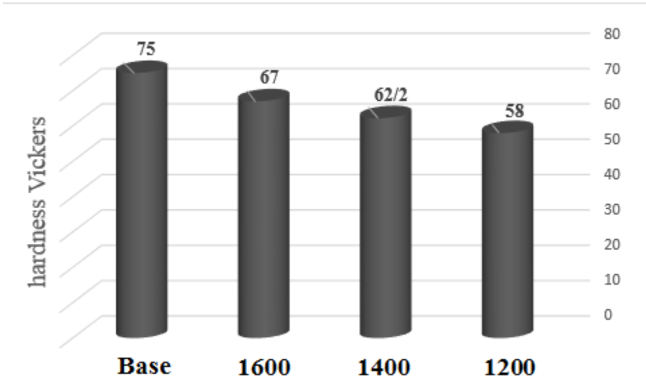

Figure 2: Comparison of hardness of base and welding pieces by several rotational speed of 6061-T4 Aluminum

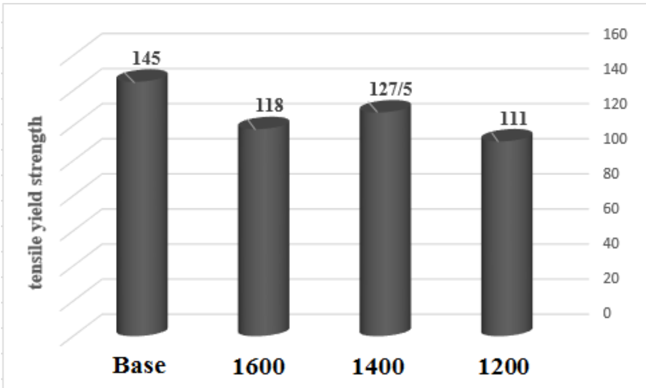

Figure 3: Comparison of tensile yield strength of base and welding pieces by several rotational speed of 6061-T4 Aluminum

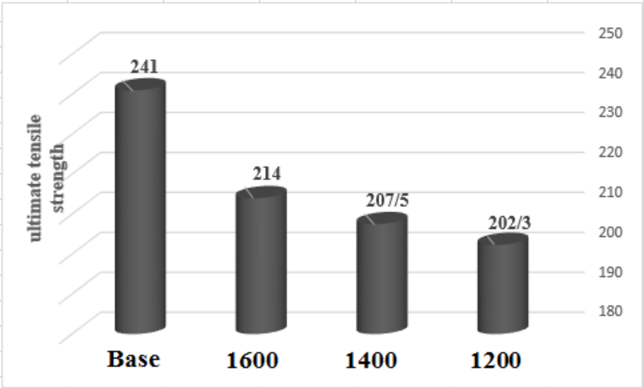

Figure 3: Comparison of ultimate tensile strength of base and welding pieces by several rotational speed of 6061-T4 Aluminum

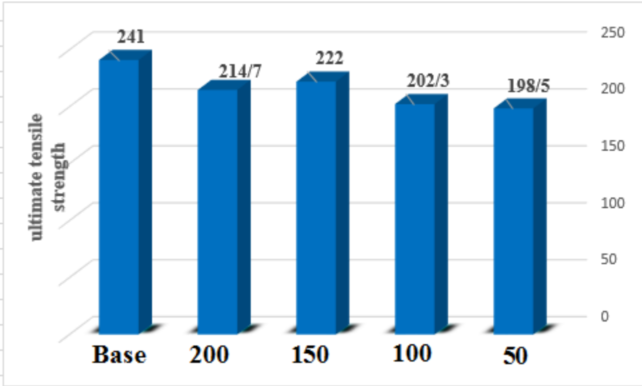

Figure 5: Comparison of hardness of base and welding pieces by several traverse speed of 6061-T4 Aluminum

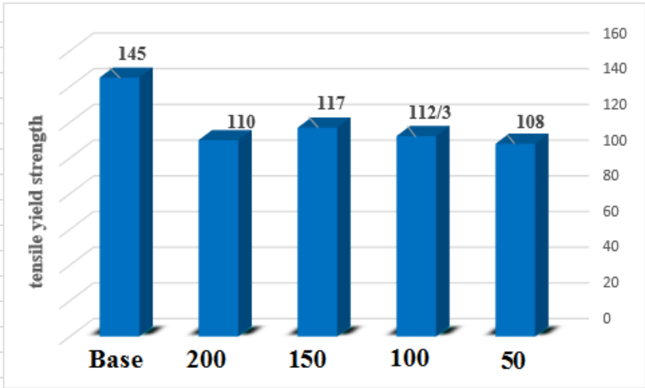

Figure 6: Comparison of tensile yield strength of base and welding pieces by several traverse speed of 6061-T4 Aluminum

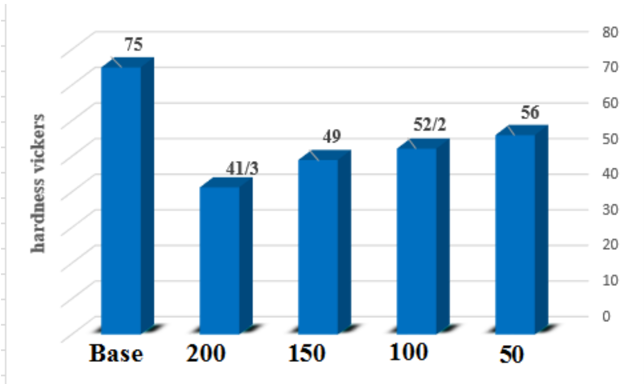

Figure 7: Comparison of ultimate tensile strength of base and welding pieces by several traverse speed of 6061-T4 Aluminum

V. THE STUDY OF THE TRAVERSE G SPEED FOR ALUMINUM IN 6061-T4

Considering the preliminary studies carried out on this type of aluminum alloy, to investigate and perform friction stir welding in this type of aluminum four traverse speed 50, 100, 150 and 200 mm/min were selected for the rotational speed of 1000rpm [4]. The welding operation has been carried out using selected pieces with dimensions of 5 × 50 × 200 mm and threaded pin tools with 1mm pitch, 5 mm diameter, 5mm height, and 12mm shoulder [5]. After welding the investigation was conducted on the microstructure and mechanical properties, and the results were collected in Table 3 in order for comparing the scientific studies, reviews and analysis of the welding process with each other.

Table III: Comparison of mechanical properties for rotational speed of 1000 rpm

Traverse speed (mm/min)	Hardness, Vickers	Tensile Yield Strength (Mpa)	Ultimate Tensile Strength (Mpa)
50	**56**	**108**	**198.5**
100	**52.2**	**112.3**	**202.3**
150	**49**	**117**	**222**
200	**41.3**	**110**	**214.7**

Comparing the hardness, tensile yield strength and ultimate tensile Strength in Figures 5, 6 and 7 shown.

VI. STYDY OF GENERATED HEAT IN ALUMINUM 6061

To investigate the heat generation and its measurement in aluminum 6061, thermocouples were installed along the piece during welding [6] and thermal information recorded by the computer.

By studying the generated temperatures the rotational speeds of 1200, 1400 and 1600 rpm with traverse speed of 50mm/min illustrated in figure 8. Also, in these welding operations preheat temperature was not used at the beginning of welding. [6]. the result show that variation in welding temperature is very low.

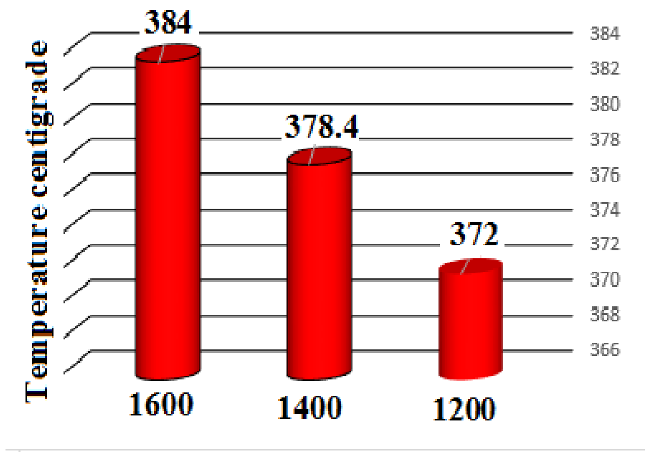

Figure 7: Comparison of 6061 aluminum welding operation temperature by installing thermocouples along the weld line.

. Figure 8 illustrates different areas of HAZ and TMAZ and Nugget. The amount of sediment in the picture is much more than the welding zone or Nugget. Due to increasing temperature in welding zone or nugget most of sediments will be dissolved in the field. It seems that the solubility of sediments in the welding zone have decreased. Sediment in the HAZ zone has grown on tool's rotational motion direction and the presence of grain boundaries are evident in welding zone.

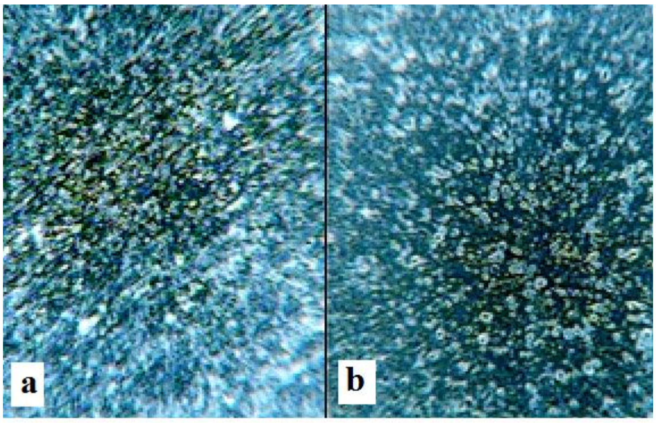

Figure 8: microstructure of nugget (a) and HAZ zone (b) rotational speed 100 rpm

VII. RESULTS

According to the results of Figure (2) to (8) it can be concluded that the During 6061 FSW process, the material undergoes intense plastic deformation at elevated temperature, resulting in generation of fine and equated recrystallized grains. The fine microstructure in friction stir welds produces good mechanical properties. Understanding of mechanical and thermal processes during FSW/FSP is needed for optimizing process parameters and controlling microstructure and properties of welds.

REFERENCES

[1] Rajiv S. Mishra, Murray W.Mahoney, ″Friction Stir Welding and Processing″ , ASM International (2007)

[2] R.S. Mishra, Z.Y. Ma, ″Friction Stir Welding and Processing″ , materials science & Engineering R 50 (2005), 1-78

[3] C.G. Rhodes, M.W. Mahoney, W.H. Bingel, R.A. Spurling, C.C. Bampton, Scripta Mater. 36 (1997)

[4] L.E. Murr, Y. Li, R.D. Flores, E.A. Trillo, Mater. Res. Innovat. 2 (1998) 150

[5] J.E. Spowart, Z.Y. Ma, R.S. Mishra, in: K.V. Jata, M.W. Mahoney, R.S. Mishra, S.L. Semiatin, T. Lienert (Eds.),Friction Stir Welding and Processing II, TMS, 2003, pp. 243–252.

[6] M.W. Mahoney, C.G. Rhodes, J.G. Flintoff, R.A. Spurling, W.H. Bingel, Metall. Mater. Trans. A 29 (1998) 1955