Influence of Tool Pin Profile and Tool Rotating Speed on Mechanical Properties of Al6082 Alloy

A. Madhusudhan Goud, V. Siva Rama Krishna

Abstract: Friction stir welding is a solid state welding which uses non consumable welding tool. It is an automatic process which generally performs on the vertical milling machine. In this type of welding, the relative motion between the tools and work piece creates heat which uses the region of work piece to be welded get softened and to joint the two work pieces. Friction stir welding process is more reliable for the materials which are generally non heat treatable. In this present investigation it will observe that how the rotational speeds of the tool and different shapes of the tool pins effects the mechanical properties of the aluminium alloy 6082. For this purpose three tools with different profiles, i.e triangular, cylindrical and square was designed and fabricated. At three different rotational speeds of 560 rpm, 900 rpm, 1800 rpm work pieces are joined using vertical milling machine. Specimens are prepared and tested for mechanical properties, tensile, impact, and hardness tests are performed and to detect the defects and voids x-ray test performed on the weld joints. And it was observed that highest tensile strength was presented when the square pin tool used at 560 rpm. The rotational speed increased mechanical properties are reducing significantly.

Keywords: Frictions stir welding, Al6082, Rotational speed, welding tools, pin profiles

I. INTRODUCTION

Friction stir welding is an solid state welding process which is invented by the welding institute in the year of 1991 [1]. Friction stir welding is simple and efficient welding method it is an energy saving and environment friendly welding method. Friction stir welding method doesn’t contain any liquid welding pool during the process complete will be done in solid state below the melting point of the materials to be joined. In friction stir welding it contains a non consumable welding tool which will have different shapes of profiles. FSW tool mainly contains the pin and shoulder. Generally the pin will be plunged in to the work pieces during the process. Before the process starts the pin of the tool rotates at the one place till it reaches the lower surface of the work pieces to be joined this is called the dwelling period [2]. Frictions stir welding tool plays vital role in the entire welding process so many literatures concluding the effect of tool geometry on the properties and formation of the defects and voids[3]. pin diameter and shoulder diameter decide the quantum of heat generated during friction stir welding. Shoulder diameter considered to be the primary heat generation source. The shoulder diameter (D) is generally kept as 3 times the plate thickness of the material to be welded.[4]

The square pin profile gives better mechanical properties of fsw joints. Strength of pieces welded by square tool is more than that of the pieces welded by round pin tool. The dissimilar friction stir welded joints have very low tensile strength if they are fabricated using the round pin tool. The square pin tool produces the pulsating effect and is having better plastic flow of material [5]. The welding parameter such as tool rotational speed, welding speed, axial force and tool pin profile play a major role in deciding the joint properties [6]. When the rotational speed of the tool increases than the properties of the joints will be reduced significantly because of the formation of voids at high speeds[7].

In this present investigation the effect of the different tool geometry will observe on the mechanical properties of Al6082. And how will be the properties affected by the tool rotational speed.

II. EXPERIMENTAL PROCEDURE

A. Materials

In this investigation aluminum alloy 6082 was used as a base material and high speed steel used to fabricate the tools. Tool material choice depends on the tool material operational characteristics like operational temperature, wear resistance and fracture roughness. H13 Tool steel could be a versatile chromium-molybdenum hot work steel that’s widely utilized in hot tooling applications. The recent strength of H13 resists thermal fatigue cracking that happens as a result of cyclic heating and cooling cycles in hot work tooling applications. as a result of its wonderful combination of high toughness and resistance to thermal fatigue cracking and additionally referred to as heat checking.H13 is employed for a lot of work tooling applications than the other steel.H-13 alloy steel that’s wide utilized in hot tooling applications. as a result of its wonderful combination of high toughness and resistance to thermal fatigue cracking and additionally referred to as heat checking H-13 is as stated in the Table no 1

| Serial no | Element       | % of content |
|-----------|---------------|--------------|
| 1         | Carbon        | 0.32-0.45    |
| 2         | Chromium      | 4.75-5.5     |
| 3         | manganese     | 0.2-0.5      |
| 4         | Molybdenum    | 1.1-1.5      |

Table no: 1 composition of H-13 tool steel
Influence of Tool Pin Profile and Tool Rotating Speed on Mechanical Properties of Al6082 Alloy

Table no: 2 Composition of Al 6082 alloy

| Serial no | Element     | % of content |
|-----------|-------------|--------------|
| 1         | Silicon     | 0.7-1.3      |
| 2         | Magnesium   | 0.40-1.00    |
| 3         | Manganese   | 0.60-1.20    |
| 4         | Iron        | 0.0-1.5      |
| 5         | Chromium    | 0.0-0.25     |
| 6         | Zinc        | 0.0-0.25     |
| 7         | Titanium    | 0.0-0.10     |
| 8         | Copper      | 0.0-0.1      |
| 9         | Aluminum    | balance      |

Aluminium alloy 6082 may be a medium strength alloy with excellent corrosion resistance. It's the best strength of the 6000 series alloys. Alloy 6082 is thought as a structural alloy. In plate kind, 6082 is that the alloy most commonly used for machining. As a comparatively new alloy, the upper strength of 6082 has seen it replace 6061 in several applications. The addition of a large amount of metallic element controls the grain structure that successively leads to a stronger alloy. It is tough to provide skinny walled, difficult extrusion shapes in alloy 6082. The extrudated surface finish isn’t as swish as alternative similar strength alloys in the 6000 series. The composition of aluminium 6082 is stated in Table no:2

B. Tool Design

Three types (triangular, cylindrical, and square) tool pin profiles are designed using CATIA V5 software and fabricated. The dimensions of the tools are collected from the literature and followed the ratios as exactly. Considered parameters in the design of the pin is

1. Diameter of the pin (d)
2. Length of the pin (L)

Length of the pin always depends on the thickness of the work piece to be welded.
Diameter of the pin always depends on the diameter of the shoulder.

D/d=3

One of the most important parameter of the shoulder is the diameter (D) because it has significant effect to the amount of frictional heat. According to the literature the diameter of the shoulder should be three times greater than the thickness (T) of the work piece to be welded.

D/T=3

Greater shoulder diameter increases the pressure force and the weld shape changes which decreases the mechanical properties of welds. So the choice of shoulder diameter requires consideration.

C. Specimen Preparation

The specimens of the size of 100mmx150mmx4mm were machined from AA6082 aluminum alloy plates. The two plates of AA6082 aluminum alloy were Friction stir welded using three different tool profiles like cylindrical, triangle, and square made of high speed steel. And the specimens were prepared according to the ASTM E8M-04 standards.

III. RESULTS AND DISCUSSIONS

A. Tensile Test

The results obtained from the tensile tests are presented in the figure 6.
The results obtained from tensile test it can be said that the tool geometry and rotational speeds are significantly influencing the mechanical properties of the aluminum alloy 6082. From the fig no 6 it can be observed that highest tensile strength was obtained at 560 RPM when square pin tool was used and the lowest results are observed at 1800RPM of speed and straight cylindrical pin was used. From the results it was known that square pin obtained the highest results when compared with triangular and cylindrical pin tools irrespective of rotational speed. And increasing with speed tensile strength reduced significantly. Highest strength was observed at lowest rotational speed. The best results were obtained at 560RPM for three types of tools. The % of elongation also influenced by the tool geometry and tool rotational speed. The results obtained from the % of elongation and rotational speed is stated in figure no 7. Highest % of elongation was obtained when square pin tool was used and at the rotational speed of 560RPM.

**Table no 3 Vickers hardness values**

| Serial no | Specimen type | observations |
|-----------|---------------|--------------|
| 1         | Triangular pin tool used at 1800 rpm | Surface defect |
| 2         | Cylindrical pin tool used at 1800 rpm | Poor/Lack of penetration |
| 3         | Square pin tool used at 1800 rpm | lack of fusion |
| 4         | Triangular pin tool used at 900 rpm | Surface defect/lack of fusion |
| 5         | Cylindrical pin tool used at 900rpm | lack of fusion |
| 6         | Square pin tool used at 900rpm | lack of fusion |
| 7         | Triangular pin tool used at 560 rpm | Surface defect |
| 8         | Cylindrical pin tool used at 560 rpm | lack of fusion |
| 9         | Square pin tool used at 560 rpm | Crack |

D. X-RAY RADIOGRAPHY TEST

Radiographic Testing (RT or X-ray or Gamma ray) could be a non-destructive testing (NDT) technique that examines the amount of a specimen. Radiography (X-ray) uses X-rays and gamma-rays to produce a x-ray image of a specimen, showing any changes in thickness, defects (internal and external), and assembly details to make sure optimum quality in operation. X-ray test was performed on the specimens after the friction stir welding of the work pieces. From the results the falling observations are drawn. Some defects are formed in the specimens as tabulated in table no 4.

C. Hardness Test

Hardness is the value which is material offers to alter in shape. Hardness test was performed on the specimens after friction stir welding was done. And hardness values are found out at the different places from the weld zone for the 9 work piece the Vickers hardness values are tabulated in the below table no 3. Highest values of hardness are obtained at the weld zone. It was observed that hardness was increased with increasing in rotational speed. This is because when rotational speed increases more heat was produced due to which at recrystallization temperature fine grains were formed which resulted in increased hardness. There was difference in hardness profiles formed at different tool rotational speeds and tool pin profiles.
Influence of Tool Pin Profile and Tool Rotating Speed on Mechanical Properties of Al6082 Alloy

From the observations it was found that more surface defects are observed when triangular pin used irrespective of the rotational speed. Lack of fusion was observed in remain two types of tools used.

IV. CONCLUSION

From this investigations following conclusion may drawn

- Tool geometry and rotational speed of tool have significant effect on the mechanical properties of the base material
- Ultimate tensile properties are observed when square pin tool was used and at 560RPM of tool rotational speed. When rotational speed increases tensile properties are decreased significantly and lowest tensile properties are observed at 1800RPM and cylindrical tool pin used. % of elongation also affected by the speed and type of pin used.
- Impact properties are also affected by the rotational speed and type of tool pin profile used. Highest impact strength observed when square pin used and at lowest rotational speed used.
- Highest hardness was observed at the weld zone. Hardness was increased with the increasing in rotational speed because at high speeds more heat generated which helped in which at recrystallization temperature fine grains were formed which resulted in increased hardness.
- More defects are formed at low rotational speeds more surface defects are formed when the triangular pin tool was used. And cracks were observed when square pin used at 560RPM.
- For the aluminum alloy 6082 square pin tool was most reliable to gain more mechanical properties after welding.

REFERENCE

1. W.M. Thomas, E.D. Nicholas, J.C. Needham, M.G. Murch, P. Templemsmith, C.J. Dawes, G.B. (1991) Patent Application No.91259788.
2. R.S. Mishra, Z.Y. Ma (2005) Friction stir welding and processing. Material Science and Engineering 50:1-78.
3. Malavrizhi, S., and V. Balasubramanian. “Influences of tool shoulder diameter to plate thickness ratio (D/T) on stir zone formation and tensile properties of friction stir welded dissimilar joints of AA6061 aluminum–AZ31B magnesium alloys.” Materials & Design 40 (2012): 453-460.
4. Mehta, Kush P., and Vishvesh J. Badheka. "Effects of tool pin design on formation of defects in dissimilar friction stir welding.” Procedia Technology 23 (2016): 513-518.
5. Singh, Jaskirat, Roshan Lal Virdi, and Khushdeep Goyal. "Experimental Investigation of Mechanical Properties of Joints Fabricated by FSW of Aluminum Alloys 5083 and 6063 with Round and Square Tool Pin Profiles." In International Conference on Advancements and Futuristic Trends in Mechanical and Materials Engineering held at Punjab Technical University, Kapurthala on October 3-6, 600, vol. 605. 2013.
6. G.Sachartha, Mohammad jawed rain DESIGN AND FABRICATION OF FRICTION STIR WELDING TOOL BY USING H13 STEEL. International Journal of Pure and Applied Mathematics Volume 116 No. 19 2017, 541-546
7. Prabha, K. Aruna, Prasad Kumar Patha, and Balla Srinivasa Prasad. “Effect of Tool Rotational Speed on Mechanical Properties Of Aluminium Alloy 5083 Weldments in Friction Stir Welding." Materials Today: Proceedings 5, no. 9 (2018): 18535-18543.

AUTHORS PROFILE

A. Madhusudhan Goud is a M.TECH student in Advanced Manufacturing Systems (AMS) from VNR VJIET, Hyderabad. His area of research work is in friction stir welding.

Dr. V. Sivaramakrishna is currently working as an assistant professor in mechanical department at VNR VJIET his area of research is friction stir welding.