A Review on Mechanical Properties of Aluminium Alloy Processed by Friction Stir Processing

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Abstract

From last few years friction stir processing (FSP) is a growing Technology for the processing or welding of aluminium alloy. This process changes the microstructure of the present metals and creates a very fine grain structure. These fine grain structures provide good mechanical behaviour in different working conditions. This process also mixes the metal without change of face and gives a homogeneous structure in material composition. This Technology plays a very important role in the manufacturing of aircraft, naval ship etc. In this paper review is given on the friction stir processing by going through the various past data that was analyzed by the different authors on different condition. There was different variety of aluminium alloys like Al 6063, Al 7075, Al 2212 etc, was used by the authors. Hence it is concluded that friction stir processing improves the mechanical behaviour of aluminium alloy.

Keywords: FSP-Friction Stir Processing, Al- Aluminium

INTRODUCTION

In 1991, a technology was invented by The Welding Institute (TWI) which is called Friction Stir Welding. Friction Stir Processing is suitable for joining Aluminium Alloys which are used for the production of the aircraft component. In this method, a pin tool is connected to the cylindrical arm which rotates at constant speed. This pin is used to join two plates by clamping them and gives a spinning to the tool in between the joint. This technology is also used for the improvement of the mechanical properties of the metals, which is known as Friction Stir Processing. This is similar to working as FSW, the only difference is that FSP is used to improve the mechanical properties of the plate where FSW is used to join two plates and improve weld strength.

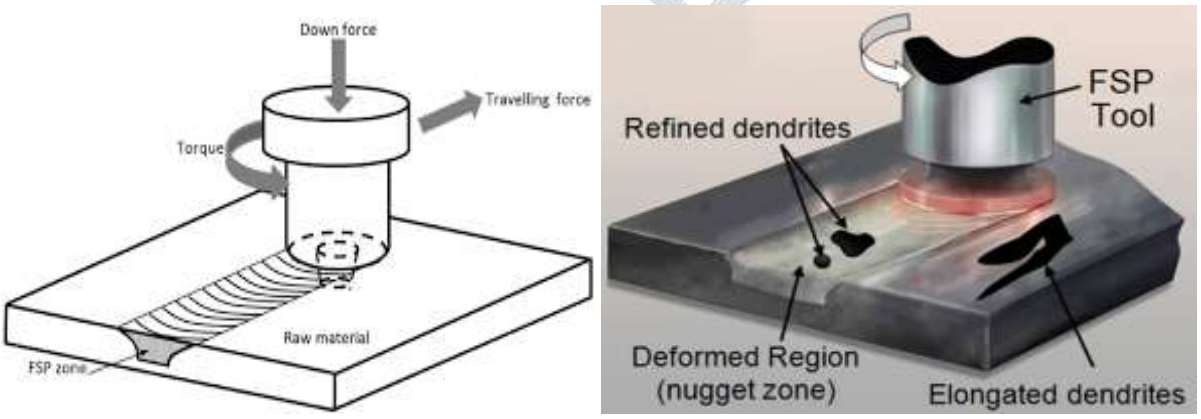

Fig.1 Schematic FSP working.

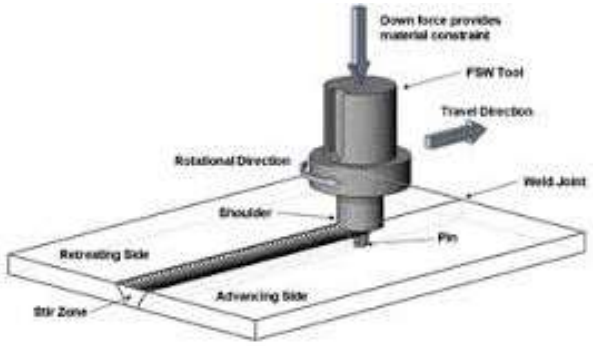

Fig.2 Schematic FSW working.

In FSP a pin type tool is inserted into the plate of aluminium alloy and a constant speed is provided to the tool, which is called processing speed. When this tool starts rotating there is friction between the tool and the structure or metal present. This friction provided heat into the processing zone. Due to this processing different zone are produced which have different structure and properties. The heat produced by the process goes to the grains present in the metals. By gaining this heat the grain size of the metals start to changes and a very fine grain size are produced. This grain size of the metals defines the properties of the materials. This process starts from one end of the plate and moves forward with constant speed to the next end of the plate. When the process complete one cycle end work continued until the whole sheet is processed. The improvement of grain size shows improvement in fatigue strength, thermal properties, mechanical strength etc.

BASIC PRINCIPLE OF FSP

A schematic diagram of FSP is shown in Figure1. Friction Stir Processing is a modification of friction stir welding where the extreme deformation of the material is produced by passing a rotating welding tool over the material and in turn we get a refined material having positive variations in its mechanical properties and microstructure. Friction stir processing causes dramatic reduction in grain size and a high level of second phase refinement. The main difference between friction stir welding and friction stir processing is the existence of joint. Friction Stir Processing is useful in enhancing the mechanical properties and microstructure of the material at any range of temperature.

FSP is the re-processing of the welding area. It is used to enhance the properties of the alloy which are difficult to be welded by using conventional methods. Alloy properties like hardness, impact strength, tensile strength and microstructure are enhanced by using friction stir processing. There are three regions of friction stir processing:-

1. Heat Affected Zone (HAZ)
2. Thermal Mechanical Affected Zone (TMAZ)
3. Welding Nugget

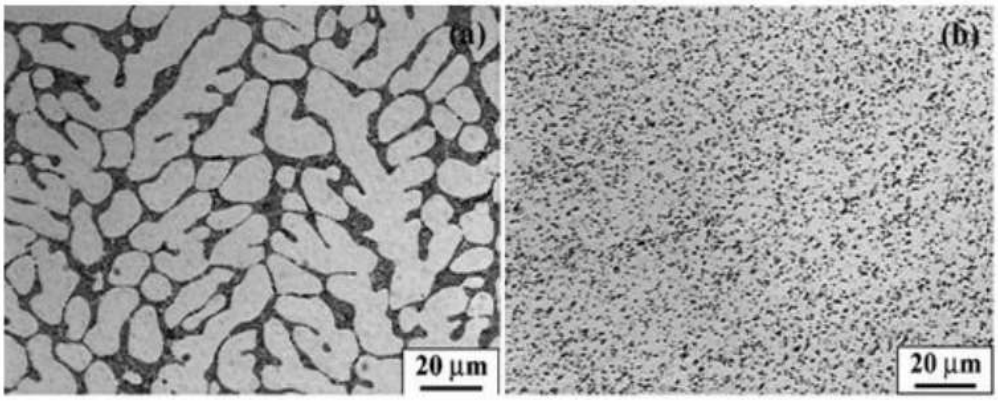

Figure: Microstructure of cast Al alloy: (a) before FSP and (b) after FSP.

In the thermal mechanically affected zone, the grains are distorted due to mechanical deformation by the processing tool. And there is less thermal energy for full recrystalization of material.

Fig: Working on Friction Stir Processing

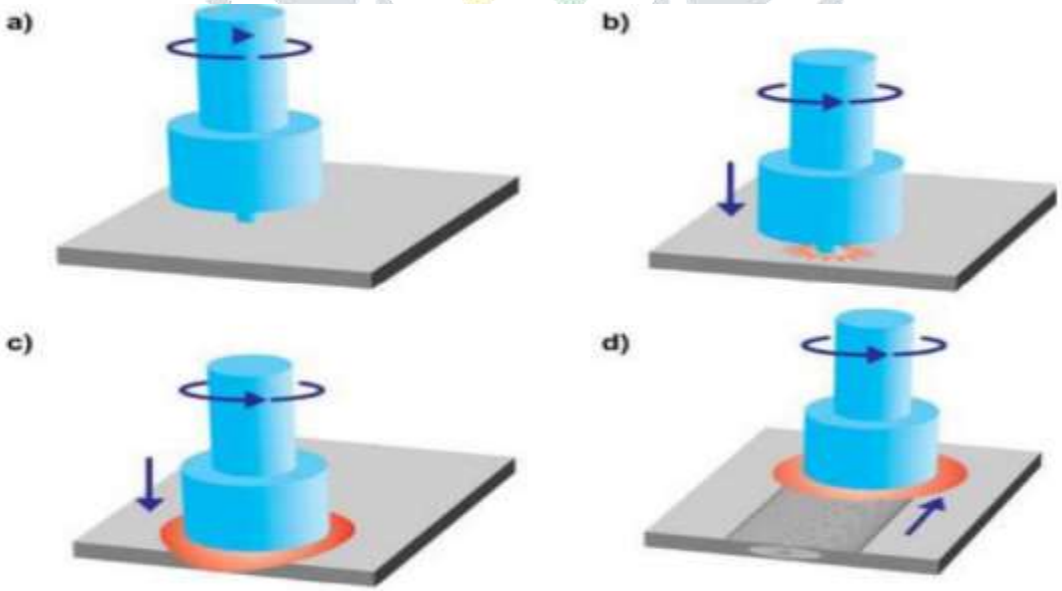

Figure: Schematic illustration of FSP: a) rotating tool prior to contact with the plate; b) tool pin makes contact with the plate, creating heat; c) shoulder makes contact, restricting further penetration while expanding the hot zone; d) plate moves relative to the rotating tool, creating a fully recrystallized, fine grain microstructure (courtesy of Mahoney and Lynch 2006[72]).

As a result, there is a reduction in mechanical properties like tensile strength, hardness etc. Also precipitate dissolution occurs due to influx of thermal energy. And the formation of new precipitates may not be of same size, so material's hardness is less in this region.

However in the Heat affected zone, there is not enough energy to cause recrystalization of the material. However the heat produced by this process is enough for coarsening of the precipitates, which is essential for maintaining the strength of alloy. It also causes a loss in mechanical properties. As shown in figure the coarsening of the precipitates cause a lower resistance to plastic deformation. In the heat affected zone, neither the heat generated by the welding process nor the mechanical deformation affects the microstructure at a large scale. There is not any change in coarsening of precipitates or grain deformation. The value of hardness is high in this region.

The processing area experiences the most plastic deformation and heating from the welding fixtures. Due to this, the temperature of the processing area reaches a temperature near to the melting point of the alloy. Due to this high temperature and deformation, the re-crystallization of the alloy occurs at a very high rate, forming a fine grain structure with minimum degradation in mechanical properties.

FSP OF ALLOYS

Al-Si alloys are commonly used as a casting material. This class of Al alloys has a low molten viscosity, and allows components with complex geometries to be produced with minimal defects and low shrinkage. However, in order to improve the performance of the alloy to meet the other demanding requirements, additional alloying elements are commonly added. Depending on the composition and the Silicon (Si) content, the microstructure that develops will vary, and this will in turn lead to alterations to the properties of the alloy.

LITERATURE REVIEW

In 2006, G.Ambrogio, L. Fratini, F. Micari analysis o the taylored sheet of Aluminium by applying friction stir processing. In this study they proposed that friction stir processing improve the welded strength by creating new grain structure as compare to a normal welding method.

In 2006, Livan Fratini, Mario Piacentini were apply friction stir processing on 3D industrial part for the analysis of strength. In this analysis it was proposed that FSW is best method for joining of 3D part as compare to normal joining method. Friction stir processing improves the mechanical properties of the weld in welding line.

In 2009, Meysam Mandani Shahri, Rolf Sandstrom made a study of fatigue strength of Aluminum welded by friction stir processing using critical distance. In this this study Aluminium 6065A was used as base metal. A lap joint of sharp notch was created by the friction stir processing. All the information of process was collected and analysed and found that a little fatigue crack was present at notches. But fatigue parameters were very low as that it propagates very slow and complete fracture was not takes place. The whole analysis determines that fatigue in notch would not responsible for failure in the welds.

In 2009, P. Bala Srinivasan, K.S Arora, W. Dietzel, S. Pandey, M.m Schaper made study on microstructure, corrosion, behaviour and mechanical properties of Aluminium AA2219 processed by friction stir processing. In this study an Aluminium plate of AA2219-T87 was process by friction stir

processing. This plate was passed under the different testing like UTM etc. The collections of data from different testing provide the information about grain size, strength, thermal properties. A testing was also made to find the corrosion properties by planning the specimen plate under different condition. The whole analysis gave a clear view that friction stir processing is the best method for welding and processing of Aluminium AA2219 –T87 that improve grain size and many mechanical properties.

In 2009, M.Zadeh, A.F. Golestaneh, Aidy Ali B.B Sahari were analysis on friction stir welded joint of Alloy 2024 Al to find the fatigue strength of the alloy. During study a comparison was made between welded joint by elementary method and friction stir processing and proposed that the friction stir welding of 2024 Al provide a good fatigue life.

In 2011, M. Grujcic, G. Arakere, B. Pandurangan, A. Hariharan, C.F. Yen, B.A. Cheesemah and C. Fonutzonlais gave a review on friction stir weld of AA5083-H321. In this review all past data on friction stir processing of AA5083-H321 and different kind of Aluminium was analysed that a fine grain size of the Aluminium provide a good life and properties of the metal. These properties of the Aluminium was used in different area life aircraft, Navel ships etc. It was found that the friction stir processing is best for Aluminium processing for good properties.

In 2013, Dr. K.N Pandey, Saurabh Kumar Gupta analysed fatigue strength of mild steel by friction stir welding. In this analysis fatigue strength was observed at constant amplitude load and different R-ratio. Due to the friction stir processing grain size of the metal was very small that provide good fatigue strength and different properties. It was also found that the hardness in base metal was small with respect to weld zone.

In 2014, Gauta Venkateswarlu, M. Joseph Davidson, Pulla Sammaiah observed the effect of friction stir processing on AZ31B Mg Alloy. Taguchi parametic design concept and L9 orthogonal array was used to study the behaviour of AZ31B Mg Alloy at different parameter (tool tilt angle, rotational speed) in friction stir processing. Many observations were carried at different processing speed and tool tilt angle. To find the optimum mechanical properties ANOVA was used. The whole observation shows that the rotational speed, transverse speed as well as the tilt angle plays a major role in the improvement of the grain size or mechanical properties of the material in frictional stir processing.

In 2015, Antonio Carlos de Oliveira Miranda, Andrian Gerliah, Scott Walbridge gave review on fatigue parameter and probabilistic fracture on Aluminium weld process by friction stir processing. In this review Antonio Carlos collect a huge past data on friction stir process. In this study it was found that friction stir processing is the best for Aluminium and many other metals to join with good mechanical properties.

In 2016, Hussain Zuhaulawati, Mohd Noor Halmy Indra Putra Almanar, Anasyida Abu Seman and Brij Kumar Dhindaw were studied Al 1100 with Rick Husk Ash Silica at different processing speed. A continuous line of Al 1100 plates were made and amorphous silica powder was placed in pattern during the processing. During process different friction stir processing speed (600rpm, 865rpm, and 1140rpm) was given with a constant speed feed of 45mm/min at angle of 2°. The observation from different speed show that the processing speed of 1140rpm produced a fine grain structure matrix and complete recrystallization in the stir zone. This processing speed also show a good dispensation of silica powder of particle size 10µm in aluminium matrix whole observed shows that the friction stir processing improve the properties of the Al 1100.

In 2016, Ali A. Aslman, Ayad M. Takhakh, Kadhim K. Resan studied the mechanical properties and numerical evaluation of Al 6061-T6 after friction stir processing (FSP). In this paper a methodology was

used to improve the mechanical properties without changing the phase of metal and obtain a fine grain structure. Al 6061-T6 is used as a testing material to study the behaviour of metals before or after the process. Al6061-T6 was processed at a variable speed of (1100, 1300, 1500 rpm) with a constant feed (60mm/min). The result obtained at different speed was observed and find best result at a speed of 1300 rpm. The efficiency rate was 89.05%. Numerical data was also observed for the thermal development such as thermal conductivity, specific heat etc. The result of the research was good in comparison with experimental result.

In 2017, D. Fersini, A. Pironodi was analysing the fatigue strength of Aluminium weld plate that was proceeds by friction stir processing. In this study Aluminium 2024-Tm was used as base metal. A lap joint of Aluminium 2024-Tm was created by the friction stir processing. After creating a joint a finite element method was used to find out the strength and fatigue life of the base metal. The whole analysis determined that the friction stir processing improve the grain size of the metal which result have good mechanical properties.

Conclusions and Future Scopes:

All information collected from different sources give following conclusion and future aspects:

1. Different varieties of Aluminium and nature of work pieces shows that the microstructure of the metal play an important role in the properties and FSW was found the best method to improve mechanical properties.
2. To consider the impact of process parameters on strength can be elevated.
3. Material flow can be incorporated into the modal to evaluate the residual stress design precisely.
4. Different type of metal other than Aluminium may be processed by this method by modifying the tool used for the process and many other parameters.

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