© Journal of the Technical University - Sofia
Plovdiv branch, Bulgaria
"Fundamental Sciences and Applications"
Vol. 30, 2024

General Characterization of 5083 Aluminum Alloys and Examination of the Joining Method Using Friction Stir Welding

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Abstract. Aluminum 5083 alloy consists of a mixture of elements such as aluminum, magnesium and manganese and is an important material used in a wide range of industrial applications. In this article, the general characterization of Aluminum 5083 alloy and its welding using friction stir welding are theoretically examined. The key properties of aluminum 5083 alloy include high strength, corrosion resistance, light weight, machinability and low temperature strength. These properties make the alloy preferred in various industrial applications. In areas such as the marine industry, aerospace, automotive and structural applications, Aluminum 5083 alloy is widely used. From ship hulls to aircraft parts, the alloy has a wide range of uses thanks to its high strength and corrosion resistance.

Aluminum 5083 alloy can be processed and shaped by various joining methods. Methods such as welding, spot welding, laser welding and friction mixture welding are used to join different parts of the alloy. The method to be applied is selected depending on factors such as the thickness and shape of the material, the requirements of the application and the equipment available. The reason why friction stir welding was chosen as the joining method of 5083 alloys in this study is that it is a modern and innovative method, as well as an effective method used especially in joining alloy and thermoplastic materials. This method provides high-strength and quality connections and causes less deformation and crack formation compared to traditional welding methods. Friction Stir Welding is increasingly used in industries such as aerospace, automotive and marine.

In conclusion, aluminum 5083 alloy is an important material in terms of its general characterization and properties. Thanks to its strength, lightness and corrosion resistance, it is a preferred option in many industrial applications.

INTRODUCTION

Aluminum has a wide range of uses as one of the basic materials of modern industry. Due to a number of advantages such as lightness, strength, machinability and corrosion resistance, aluminum and aluminum alloys are preferred materials in many fields, from automotive to aerospace, from construction to packaging industry. The physical and chemical properties of aluminum (Al) alloys vary depending on their microstructure and alloying elements. Copper (Cu), manganese (Mn), silicon (Si), magnesium (Mg), zinc (Zn) and tin (Sn) are important alloying elements added to aluminum.

According to the symbolization order most commonly used in the world for aluminum and its alloys by the American Society for Testing and Materials (ASTM), the main alloying element of 5083 aluminum alloys in the 5XXX aluminum class is magnesium (Mg).[1]

 Online ISSN 2603-459X

5XXX: The main alloying element of this series is magnesium. As the amount of magnesium increases, ductility decreases, while hardness and strength values increase.[2] This series, which does not require heat treatment, is also used in ships as it has high oxidation resistance as well as good weldability. In order to prevent stress corrosion cracking, it is used in pressure tanks and dump truck bodies that require storage at low temperatures, in alloys containing more than 3.5% magnesium, at processing temperatures above 65ºC and with certain restrictions on the amount of cold deformation.[3-4] 5XXX series alloys, which cannot be heat treated, can only change shape. They can be hardened by . Since these alloys generally have good machinability properties, they facilitate operations such as shaping, forging, rolling and welding.

5083 aluminum alloy has high strength. This feature is preferred in structural applications and other industrial areas requiring high strength. It provides a high level of corrosion resistance against aggressive environments such as sea water. This property is important in the marine industry and other corrosion-sensitive applications. Due to its good performance in processing operations; Processes such as forming, forging, rolling and welding are generally convenient and easy for this alloy. The naturally high thermal conductivity of aluminum ensures that the 5083 alloy also has high thermal conductivity. This feature supports its use in applications requiring heat transfer. Aluminum 5083 alloy has a low density, indicating a lightweight material structure. This feature provides advantages in transportation and assembly operations. Aluminum 5083 alloy has high strength at low temperatures, which provides an advantage when used in cold weather conditions. It is widely used in various industries such as shipbuilding, subsea structures, marine equipment, aerospace parts, automotive components and structural applications.[5]

TABLE 1. Chemical Composition of 5083 Aluminum Alloy (% by weight)

AA Alloy	Cu	Fe	Mg	Mn	Si	Zn	Cr	Ti
5083	0,1	0,4	4-4,9	0,4-1	0,1	0,25	0,25	0,15

Joining of aluminum alloys is carried out using various techniques. There are some variables (parameters) that determine the quality of the welding process and the resulting weld connection. In selecting these variables, the type and thickness of the material to be welded, welding geometry, welding position and the mechanical properties expected from the welded joint are taken into account. Appropriate selection of these parameters facilitates the working conditions and increases the possibility of obtaining a weld connection with the required properties.[6-7]

The most commonly used joining techniques are; They are MIG (Metal Inert Gas) Welding, TIG (Tungsten Inert Gas) Welding, Resistance Welding, Laser Welding and Friction Stir Welding (FSW).

• MIG (Metal Inert Gas) Welding: In this method, a wire electrode is combined with welding air and melted into the weld roof. The gas protects the molten aluminum from oxidation and cleans the weld area. With the MIG welding method, it is possible to weld ferrous and non-ferrous metals and alloys of all thicknesses, including very thin sheet metals.[8] This welding method has better penetration, higher efficiency and less spattering properties compared to other welding methods. For this reason, the MIG welding method is used extensively in the industry compared to other welding methods. MIG welding; It is a welding method in which filler metal is automatically added to the weld pool and the weld area is protected by an inert gas.[9-10]

• TIG (Tungsten Inert Gas) Welding: Tungsten Inert Gas welding (TIG) method is a welding method in which the generated electric arc is spent between the workpiece and the tungsten electrode, resulting in fusion power. In this welding method, the electrode used, the resulting arc and the welding environment are protected from the welding atmosphere and various chemicals by using protection gas. Inert gas is supplied to the welding environment with the help of a nozzle and eliminates the existing atmospheric air. This welding method differs from other arc welding methods. Because in this method, a filling electrode is not used as in other methods.[11-12]

• Resistance Welding: In this method, a resistance is applied between two metal parts and the parts are brought together using heat energy.

• Laser Welding: It is a method that allows precise and high-quality welding. It is widely used in the space, aviation, electronics and defense industries and requires high investment costs.[13]

• Friction Stir Welding: It is a modern and innovative welding method used to join metallic materials and combines the parts by mixing them under friction and pressure. Friction stir welding is an effective option for joining high-strength alloys such as aluminum 5083. The method to be applied is selected depending on factors such as the thickness and shape of the material, the requirements of the application and the equipment available. It was first developed in 1991 by The Welding Institute (TWI), Wayne M. Thomas and his colleagues for welding aluminum materials.[14]

Friction Stir Welding Method

The method is to use a pin with a shoulder, called a stirrer tip, which rotates at high speeds, after the parts to be welded are placed face to face on a table and fixed, it is immersed in these parts, softening the parts with the effect of heat generated by friction, and mixing the material that has a mud-like consistency. It is a friction welding method in which the parts are joined by moving the pin along the parts to be welded by plastering it on the shoulder part. The application of the method is shown schematically in Figure 1.[15-16]

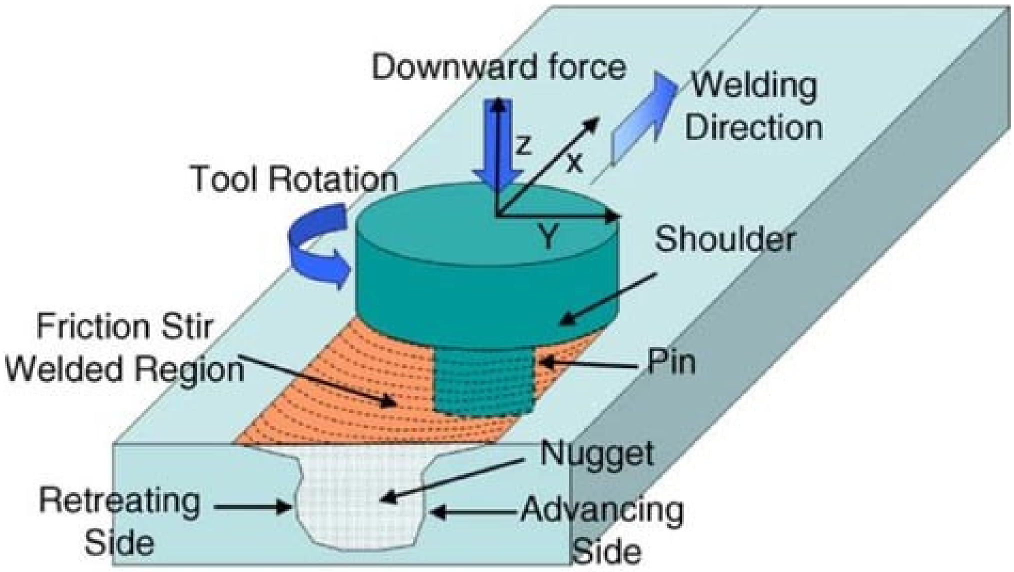

FIGURE 1. FSW detailed view[17]

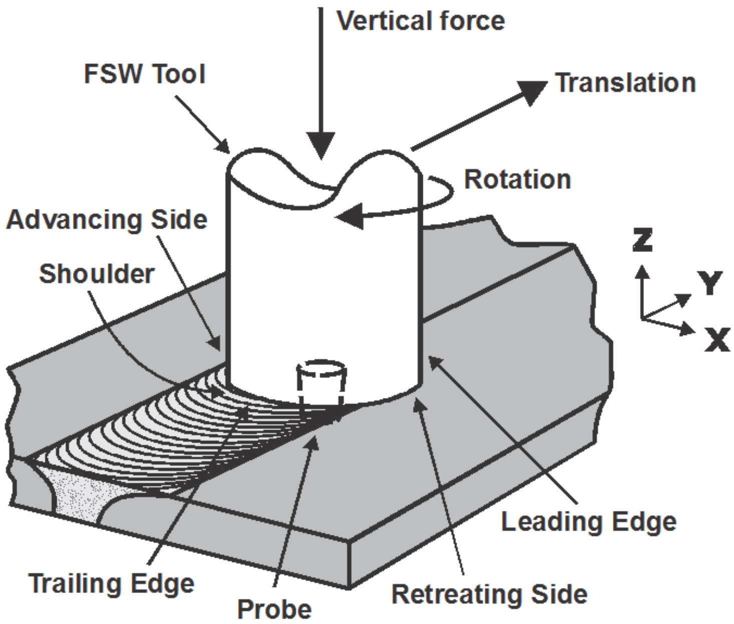

FIGURE 2. An illustration of a friction stir welding application

Advantages and Disadvantages of the Method

Friction stir welding has advantages such as low cost, environmental friendliness, slight deformation of the main material and high efficiency compared to other traditional welding methods. Its ability to weld aluminum and magnesium alloys without melting eliminates problems during solidification and is one of the popular methods for welding aluminum and magnesium alloys. Therefore, it is widely used in aviation and space, artificial intelligence technologies, ship and railway transportation sectors.[18] The intermetallic effect seen in the welding of different materials with the fusion welding method can be minimized when thermal balance is achieved during friction welding.[19]

Heating of the welding area depends on the geometry, rotation speed and feed of the tool used for welding. If, for any reason, sufficient heat generation does not occur in the welding area, the strength decreases as a result of various joining errors occurring in the welding seam.19 Deliberate or accidental deflection of the tool during welding causes the expected efficiency of the welding seam not to be obtained depending on the welded parts and their positions.[20] The optimum amount of penetration of the tool into the material is not achieved. When it is less or more, the strength of the weld seam decreases.[21]

Application Areas of the Method

Friction stir welding (FSW) has a wide range of applications, especially for aluminum and its alloys. In the automotive industry, FSW is often used to join vehicle body parts, frames, chassis components and fuel tanks. This ensures lightweight, sturdy and reliable welded joints. In the aviation industry, the use of aluminum alloys is common and FSW is used to join aircraft fuselages, wings, propellers and other parts. This is ideal for achieving high strength and lightweight welded joints. In the maritime industry, FSW is used in the joining of ship hulls, underwater structures and marine vessels. This provides high-strength welded joints that are resistant to corrosion by seawater. FSW can be used in the production of railway vehicles, assembling wagon bodies, rails and other components. This ensures reliable and durable welded joints. In the defense industry, FSW is used in the production of armored vehicles, military aircraft and other military equipment. It increases the performance of military systems by providing high strength and lightweight welded connections. FSW can be used in the energy sector, especially in the production of renewable energy sources. This can be useful in joining aluminum alloys used in the production of wind turbines, solar panels and other power generation equipment.

The application areas of FSW are constantly expanding and evolving. It can be used in any field requiring high strength, lightweight and corrosion resistant welded joints.

(a)

(b)

(c)

(d)

FIGURE 3. High speed train (a), Armored Personnel Carrier Manufactured by Friction Welding Method (b), Application of Friction Stir Welding on Ships (c), Commuter Train Side and Roof Panels Assembled by Friction Stir Welding (d)[22]

CONCLUSION

Aluminum 5083 alloy is an important alloy with a wide range of industrial applications. Its high strength, corrosion resistance, weldability and machinability make this alloy a preferred material in many industries. Aluminum 5083, which is widely used especially in the maritime, aviation, automotive and defense industries, is ideal for creating strong and durable structures with its lightweight structure.

Friction stir welding (FSW) is an effective method for joining heat-sensitive materials such as aluminum 5083. It offers lower thermal deformation and higher weld quality compared to traditional welding methods. Therefore, joining aluminum 5083 alloy with FSW is an ideal option to obtain high-quality, reliable and durable welded joints.

The results of this study show that joining aluminum 5083 alloy by friction stir welding is a method that can be widely used in industrial applications. Future research can focus on optimizing this welding method and expanding its application areas, so that the use of aluminum 5083 and similar materials can be further expanded.

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