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FRICTION WELDING ON MAGNESIUM AND ALUMINIUM ALLOY-A REVIEW

R. Praveen Kumar*
Academy of Maritime Education and Training / Assistant Professor, Department Of Mechanical Engineering, Chennai, India

R.Sumanth Raj, E.Vinoth
Academy of Maritime Education and Training / Student, Department Of Mechanical Engineering, Chennai, India

R. Rajavel
Academy of Maritime Education and Training / Professor, Department Of Mechanical Engineering, Chennai, India
*Corresponding Author

ABSTRACT

In this study, the weld ability of Aluminium Alloys 5083,6061,7075 and Magnesium AZ31 was investigated using Friction Welding. Magnesium AZ31 is the base alloy used and other Aluminium alloys were welded with Magnesium Alloy.

These Alloys are welded by changing the parameters. Parameters which were used are Spindle Speed , Friction Pressure , Friction time, Forging Pressure and Forging time.

After Friction Welding , Interface regions of the welded specimen were examined by Scanning Electron Microscope (SEM) to determine the Microstructure changes. Micro hardness and Tensile Tests are conducted to determine the Mechanical properties of the welded specimens.

The Experimental results indicate that the combination of Magnesium AZ31 alloy and Aluminium Alloys using Friction Welding Technique for achieving a weld with specific strength.

Keywords: Friction welding, Microstructure , Tensile Strength , Forging Pressure , Friction Pressure , Friciton Time

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1. INTRODUCTION

Magnesium is the lightest of all the engineering metals, having a density of 1.74 g/cm3 . It is 35% lighter than aluminium (2.7 g/cm3) and over four times lighter than steel (7.86 g/cm3). Magnesium is the eighth most common element . Due to their low weight and high specific strength properties, magnesium alloys are the lightest one among the metals currently used as building materials mainly in automotive and aerospace industry and in the fields like defense industry .While these alloys are likening to plastics interms of their density and evaporation properties, they also have the mechanical properties of a metal. It is a material sought in terms of density, strength, and rigidity advantage for fuel efficiency and performance enhancement. In addition, magnesium is much more rigid than engineering plastics and is a much more recyclable material. [4] Recyclability, as important as light weight, has become a key factor in the selection of materials for the protection of raw materials and energy resources of the world. Unalloyed magnesium has low strength and toughness values. Therefore, it is used by alloying. Al, Zn, and Mn from alloying elements increase strength, toughness, and corrosion resistance, respectively. However, more than 2% Zn causes red shortness[2].

Aluminum alloys have been widely used in the field of aerospace, electronic industries and communication equipment for its high specific strength and good formability.[3].

Table 1 Properties of Magnesium and Aluminium [4]

Property	Magnesium	Aluminium
Crystal structure	hcp	FCC
Density at 20°C (g/cm^3)	1.74	2.70
Coefficient of thermal expansion 20–100°C ($\times 10^6$/C)	25.2	23.6
Elastic modulus [Young's modulus of elasticity] (10^6 Mpa)	44.126	68.947
Tensile strength (Mpa)	240 (for AZ91D)	320 (for A380)
Melting point (°C)	650	660

The Al-Mg composite structure would allow weight reduction, further design flexibility and expand their application. Al and Mg have been successfully joined using conventional fusion welding technologies [1] They concluded that a large number of brittle intermetallic compounds (IMCs), distributed continuously in the fusion zone. Therefore, fusion welding of Al and Mg alloys is not suitable for industrial application because of formation of severe thermal cracking and excess brittle IMCs. The solid state welding technique has been used for joining similar materials and dissimilar materials due to its solid state character and advantages, such as good mechanical properties. However, some structural components, such as bars, cannot be inapplicable to joining by Linear Friction Welding (LFW) due to limitation of welding process[3].

Friction welding is a suitable for accomplishing sound joints of Al bars to Mg bars which the formation of IMCs can be control effectively with lower heat input and less welding time. Moreover, friction welding method has extensively been used in manufacturing of aerospace and automobile applications because of the advantages such as high material savings, low production times [3]. Friction welding, a solid state joining technique, is widely being used for joining Al alloys for aerospace, marine automotive and many other applications of commercial importance.[5] This is because of many of its advantages over the conventional welding techniques some of which include very low distortion, no fumes, porosity or spatter, no consumables (no filler wire), no special surface treatment and no shielding gas requirements. FSW joints have improved mechanical properties and are free from porosity or blowholes compared to conventionally welded materials. However along with these advantages there are a few disadvantages, which also need to be mentioned. At the end of the welding process an exit hole is left behind when the tool is withdrawn which is undesired in most of the applications.[6] This has been overcome by providing an offset in the path for continuous trajectory, or by continuing into a dummy plate for non-continuous paths, or simply by machining off the undesired part with the hole. Large down forces and rigid clamping Of the plates to be welded are a necessity for this process, which causes limitation in the applicability of this process to weld jobs with certain geometries.[5]. Joining of magnesium alloys by conventional techniques is very difficult due to the several problems such as, cracking, expulsion and void in the weld zone . FW is capable of joining magnesium alloy without melting it and thus can eliminate problems related to the solidification. As FW does not require any filler material in the weld zone, the metallurgical problems associated with it can be eliminated and good quality weld can be obtained[7].

AZ31 magnesium alloy is commercially available in cylindrical rod form, and offers good mechanical properties. Unfortunately, the alloy exhibits very limited ductility accompanied by brittle-like behavior at room temperature. Recent results however indicated that it is possible to form AZ31 cylindrical rods at elevated temperatures under certain conditions, and even achieve super plastic-like behavior. The results also suggest that improved ductility and formability can be achieved by refining and homogenizing the grain structure of the cylindrical rod [8]. Friction-stir welding has been shown to provide unique joining opportunities for a wide range of aluminum alloys as well as a host of dissimilar metals and alloys .The technique does not require melting or consumables and is correspondingly environmentally benign. In the present study we explore the friction welding of a common magnesium alloy (AZ31), Optical metallography and transmission electron microscopy provide a comparison of the base metal and weld zone microstructures [9]. Friction offers a potential way to obtain high-quality joint of Al to Mg alloys since the formation of IMCs is limited due to the relative low processing temperature, and the distribution of IMCs is dispersed under the combined action of high strain rate and severe plastic deformation during welding [10].

2. MODEL DESCRIPTION

By Friction welding process , the mechanical properties of magnesium AZ31, Aluminium 5083, Aluminium 6061, Aluminium 7075 alloys are investigated. These alloys are to be welded by changing the parameters. Each alloy are to be welded with five different parameters, such as spindle speed, friction pressure, friction time, forging pressure, forging time. After welding process, mechanical properties such as hardness, tensile strength and microstructure are tested at the welded joints. The properties of Magesium and Aluminium are shown in Table 1.

Friction welding (FRW) is a solid-state welding process that generates heat through mechanical friction between workpieces in relative motion to one another, with the addition of a lateral force called "upset" to plastically displace and fuse the materials. [11] Because no melting occurs, friction welding is not a fusion welding process in the traditional sense, but more of a forge welding technique. Friction welding is used with metals and thermoplastics in a wide variety of aviation and automotive applications.[12]

2.1. Parameters Description

The spindle speeds and feeds or feeds and speeds refers to two separate velocities in machine tool practice, cutting speed and feed rate. They are often considered as a pair because of their combined effect on the cutting process. Each, however, can also be considered and analyzed in its own right.[13]

Friction pressure is the pressure applied at the joining of two metals during the friction welding process. The pressure is applied at the joining end of both metals. The duration of friction pressure depends on the friction time . Friction acts on materials that or in content with one another. Plays vital role in friction welding. In this process more amount pressure applied at one practices area, so that the welding process in very effective. [14]

Friction times the normal force, the object will break away and begin to move. The kinetic frictional force is equal to the coefficient of kinetic friction times the normal force. As stated before, this always opposes the direction of motion.

Forging is a manufacturing process involving the shaping of metal using localized compressive forces. The blows are delivered with a hammer (often a power hammer) or a die. Forging is often classified according to the temperature at which it is performed: cold forging (a type of cold working), warm forging, or hot forging (a type of hot working). For the latter two, the metal is heated, usually in a forge.[15]

Forging time is the time taken for the forging pressure applied during the friction welding process .it is the time interval of forging process. Forging time is mostly same as the frication time in friction welding process.[16]

2.2. Chemical Compositions of Alloys

Commercial AZ31 extruded rods with 19mm diameter were obtained for the investigations carried out in the present study. The chemical composition of the alloy is shown in table 2. [17]

Table 2 Chemical compositions of magnesium AZ31

Alloy	Al	Zn	Mn	Fe	Si	Cu	Ni	Mg
AZ31	3.26	0.92	0.43	0.004	0.001	0.000	0.001	bal.

Chemical composition obtained by chemical analysis and tensile strength of aluminium are given inTable 3 [18].

Table 3 Chemical compositions and tensile strength of aluminium

Aluminium	% Sn	% Pb	% Zn	% Mn	% Fe	% Ni	% Si	% Mg	% Sb	% Cr	% Ti	% Cu	% Al	Tensile strength (MPa)
	0.00500	0.03360	1.14000	0.11800	0.57400	0.01220	0.55400	0.17100	0.00300	0.02420	0.01340	0.59300	96.76000	200

3. FORGING CHARACTERISTICS

The characteristics of the friction and the forge load are shown in Fig. . The factors explored, i.e. the speed of rotation, the friction and forge load and the duration of the welding process. To minimize the effect of organic contamination in the welding zone, the ends of the samples were cleaned prior to the welding operation. The welding parameters of applied load for developing friction, speed of rotation and welding duration determine the thermal phenomenon occurring during the welding process. The cleanliness of the samples may be considered as secondary importance. Increased friction load secures a slight reduction of weld-zone temperature, with the consequent production of less intermetallic compound at the interface, whilst the forging load becomes important only when considering consolidation at the interface. When examining the effect of parameters on the resulting weld properties, it is observed that increasing the speed of rotation and the level of friction load during the heating period, gives deformation conditions that activate the contacting surfaces whilst also limiting the temperature/time conditions for joint heating, and consequently minimize the formation of intermetallics [19]

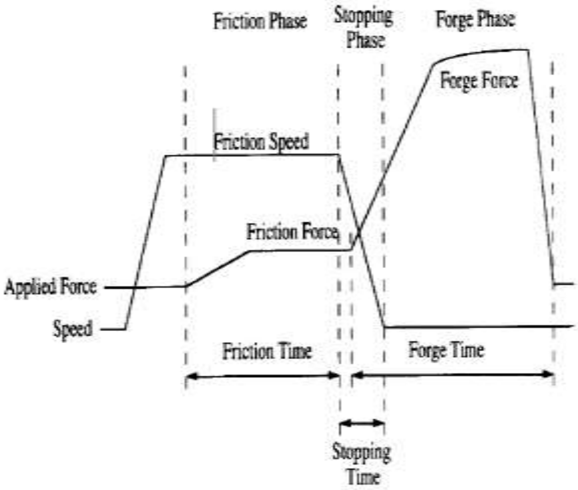
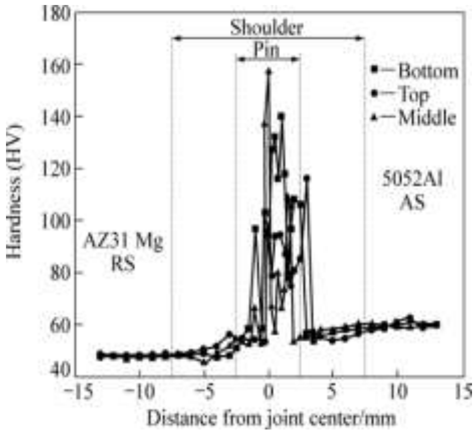


Figure 1

4. DISTRIBUTION OF MICROSTRUCTURE

The microhardness presented an uneven distribution, and the hardness of the stir zone was much higher than that of the base material. [20] The maximum value of hardness existing in the middle of the stir zone was twice higher than that of the basematerial. The hardness measured along the 1.5 mm line was generally lower than that of 3 mm and 4.5 mm due to almost no intermixing occurred between 5052 Al alloy and AZ31 Mg alloy in top region (shown in Fig.2). Onion ring structure and the intercalated microstructure were responsible for the sharp variations of hardness in the weld zone. [21]

Figure 2 Microhardness profiles of microstructure from Mg to Al with different locations



5. TENSILE STRENGTH OF FRICTION WELDING

The samples were carefully machined with coolant to minimize heating. Tensile test samples were tested at room temperature, with the weld transverse to welding direction. During test, most specimens failed at heat affected zone. Fig. 4 shows the tensile results of the AZ31 Mg alloy welded at same rotation speed and welding pressure. It can be concluded that the higher travel speed, the larger tensile strength of the joint in certain extension. When travel speed was 90 mm/min, the joint strength was close to the base material. But when the travel speed passed a fixed value (90 mm/min), the joint strength dropped as upping [22]

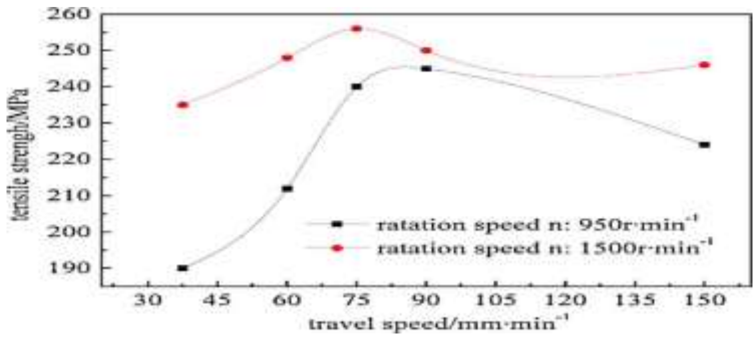


Figure 3

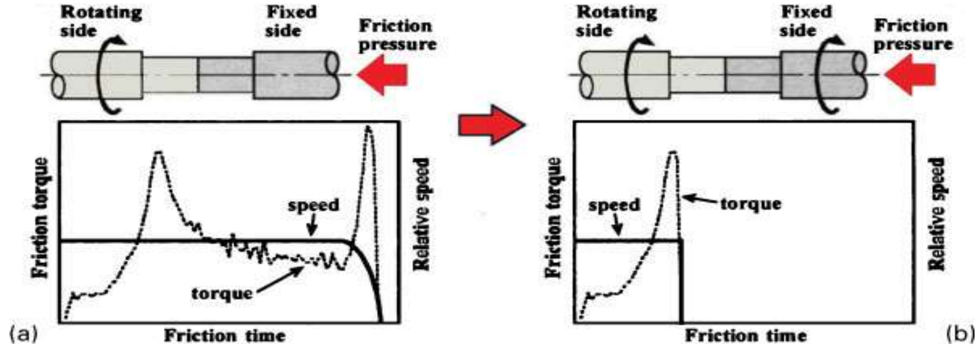
Mechanical properties of the asymmetrically rolled sheets and normally rolled AZ31 sheet (H24 condition: partially annealed) with the grain size of 10–20μm are listed in Table I. The reverse rolling is suggested to be effective to enhance the room temperature ductility in AZ31magnesium alloy. In order to clarify the origin of higher ductility of the material processed by reverse rolling compared with that by unidirectional rolling, optical microstructures of fractured specimens were observed.[23]

Table 3 Tensile mechanical properties of materials processed by normal rolling and differential speed rolling

Rolling method	YS, MPa	UTS, MPa	e_f, %	Ref.
Normal rolling	–	314	9	[10]
Differential speed rolling				
Reverse	271	311	14.6	This work
Unidirectional	258	300	7.9	This work

6. MICROSTRUCTURE AND PROPERTIES OF FW OF SIMILAR METALS

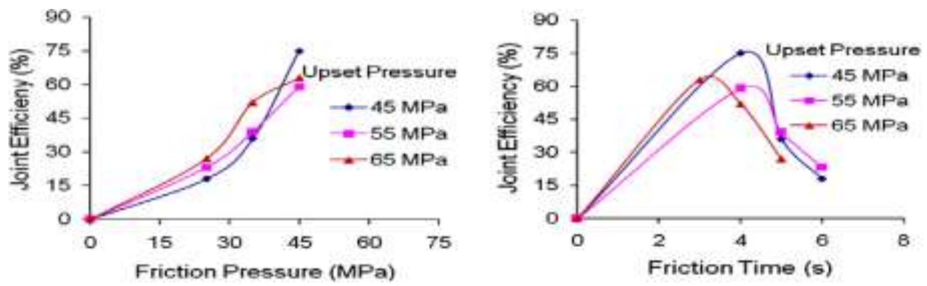
The effect of FW conditionsand aging treatment on the mechanical properties of type 7075-T6 aluminium alloy (A7075) friction welded joints. It was welded by using the LHI method in which the heat input islower than that in the conventional method. In the case ofcontinuous (direct) drive friction welding, i.e. theconventional method, the rotation of the specimen(workpiece) does not stop instantly when braking forceis applied.[24] Therefore, the relative speed between both specimens does not instantly decrease to zero as shown in Fig. 7a while the welded joint is deformed during braking. In contrast, the LHI method is as follows. The specimens are joined by using an electromagnetic clutch to prevent braking deformation as the rotational speed decreases. When the clutch is released, the relative speed between both specimens instantly decreases to zero as shown in Fig. 7b. In this case, the friction pressure can be maintained (loaded) so that the effect of braking time on deformation of the joint is negligible. [25] Hence, the strength of low carbon steel (LCS) welded joint made with the LHI method was similar to the tensile strength of the base metal. Furthermore, the welded joint madeby the LHI method had less axial shortening and less flash than joints made with the conventional method. In particular, it was clarified that the heat input with the LHI method was much less than that with theconventional method.[26]



Conventional Method LHI Method

7. EFFECT OF FRICTION PRESSURE AND FRICTION TIME ON THE JOINT EFFICIENCY

The correlation between the weld parameters and joint efficiency are shown in Fig. 5. During shorter heating times, the heating effect could become irregular and could result in unbounded regions. Longer heating times and a slow cooling rate decrease the strength in friction welding. The joint strength decreased with an increasing friction time for all the specimens tested as seen in Fig. 5. When the composite material is subjected to loading, the presence of clusters and defects reduce ductility as these areas would fail prematurely. The above factors are attributed to the failure of material at the interface, i.e., weld zone (WZ).[27]



(a) Joint efficiency vs. friction pressure (b) Joint efficiency vs. friction time

7.1. Welding parameters[27]

Table 4

Test no.	Friction pressure (MPa)	Friction time (s)	Upsetting pressure (MPa)	Upsetting time (s)
T1	25	6	45	5
T2	35	5	45	5
T3	45	4	45	5
T4	25	6	55	5
T5	35	5	55	5
T6	45	4	55	5
T7	25	5	65	5
T8	35	4	65	5
T9	45	3	65	5

7.2. Tensile tests

The strength of the 5083-5083 joint was 97% of that of the original material. In contrast, the strength of the 6061-6061joint was 63% of that of the original material. The strength of the 5083-6061 joint was almost equal to that of the 6061-6061 joint. These results show that the tensile strength of the joint is affected by the type of joint (similar or dissimilar) and the alloys (5083 or 6061). FSW of the similar materials (5083 and 6061 aluminum alloys) and dissimilar materials (6061/5083) was carried out.[28] Every combination of materials was joined successfully. Thus FSW has the potential for joining dissimilar materials such as different types of aluminum alloys. Welding properties, such as the hardness distribution and the tensile strength, were strongly influenced by the material combination.[29]

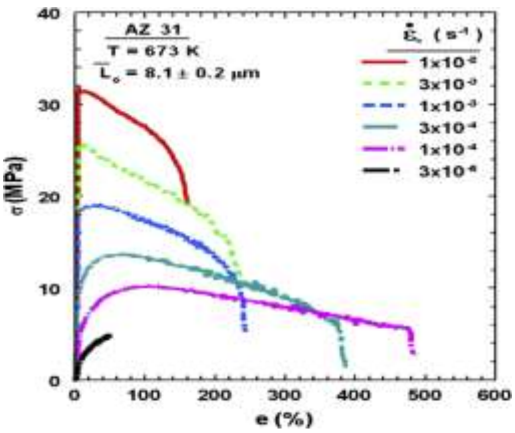
Table 5

	Strength (MPa)	Elongation (%)
Alloy		
5083	328 ± 2	24 ± 1
6061	320 ± 2	16 ± 1
Joint		
5083-5083	318 ± 2	21 ± 3
6061-6061	199 ± 6	11 ± 1
6061-5083	202 ± 3	7 ± 1

7.3. Mechanical data

Fig. 1 illustrates the variation in the nominal true stress with elongation for samples tested over initial strain rates from 3 _ 10_5 to 10_2 s_1. All samples were pulled to failure, except the test at 3 _ 10_5 s_1 which was terminated at an elongation of 50% owing to the anticipated long duration of the test. [30]. The nominal true stress was calculated based on the load and the cross-head displacement, assuming constant volume and uniform deformation.[13] The mechanical tests indicate strain hardening at high strain rates: the flow stresses reach a peak at relatively low elongations, and this is followed by flow softening. At lower strain rates, hardening is observed up to elongations of _50–100%, before gradual flow softening. A strain rate of 10_4 s_1 yielded the maximum elongation of _475%, and the elongation was reduced to _160% at a high strain rate of 10_2 s_1. Based on the ductilities, further experiments on GBS and texture focused on strain rates of 10_4 and 10_2 s_1, and these conditions correspond to superplastic and non-superplastic flow.These observations are consistent with the corresponding strain rate sensitivities and ductilities.[31]

True stress–elongation behavior of AZ31



8. RESULTS AND DISCUSSION

Aluminium alloys has the highest strength to weight ratio of any metal. So that we prefer aluminium for our project. It conducts electricity even better than copper. It is 100% recyclable without losing any of its natural characteristics for applications where magnesium needs to be avoided Aluminium is an excellent choice. [32]

Aluminium oxide quickly and the resulting surface coat of aluminium oxides resists further corrosion, by air, water and Chemicals this protective coating is clear, colourless and non-staining.[33]

The strength-to-weight ratio of the precipitation hardened magnesium alloys is comparable with that of the strong alloys of aluminium or with the Alloy Steels. [34-36]

Magnesium alloys however have a lower density, stand greater column loading per unit weight and have a specific modulus. Higher thermal conductivity of magnesium alloys of permitting rapid heat dissipation. Comparing with aluminium it is difficult to deform by cold working. It is comparatively high in cost but its efficiency cannot be matched by other materials at its range. [35-37]

Some aluminium alloys especially those in the 5xxx and 7xxx series (example 5083 and 7075) are so strong that they could be used in armour structures. Aluminium 5083 is a non-heat treatable alloy and Aluminium 7075 is a heat treatable alloy.[38]

Aluminium alloy majorly used in ship building vehicle bodies and pressure vessels etc. It is preferred majorly because of its lightweight and resistant to corrosion aluminium alloys maintains strength at high temperatures. Magnesium alloys also lightweight material and has high tensile yield strength. Both the materials all lightest of the commonly used alloys.[39-40]

9. CONCLUSION

This research paper investigates the process of collection of materials and completion of research through literature paper. The systematic studies that has been so for carried out and reported to optimise the friction welding parameters to attain the better Mechanical properties in Magnesium and Aluminium dissimilar joints. With the knowledge of various research papers, we will further proceed to the welding process magnesium AZ31 is to be joined with aluminium 5083, aluminium 6061 and Aluminium 7075 after that various test will be carried out to determine Mechanical properties like tensile strength, hardness and microstructure. Analyzation of the test results will take place after that all these processes

1. Environmental conservation is one of the principal reasons for the focus of attention on magnesium to provide vehicle weight reduction, CO2 emission and fuel economy. Weight reduction through Mg applications in the automotive industry is the effective option for decreasing fuel consumption and CO2 emissions.
2. Friction welding of Al condition, increases the strength of the weld joint as compare that of the parent material in O-condition at the cost of the ductility, for all welding trials
3. Heat input in Al–Mg dissimilar FSW could be calculated from spindle and x-axis torque.placing Al on advancing side and tool offsetting to Al, the heat input increased, and it decreased with the increase of rotation rate and traverse speed.
4. The reaction layer was made up of IMCs layer and Mg solid solution layer. The thickness of IMCs layer in Al/Mg joints increased and the Mg solid solution was transformed IMCs gradually as the friction time increased
5. The microhardness of Al/Mg friction interface was higher dra-matically than that of the Mg base material. The thickness of hardened layer on the Mg side increased as friction time increased. On the Al alloy side, the microhardness in the zone close to the friction interface was lower than that of the Al base material.

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