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Metallographic Studies of Friction Welded High Strength Aluminium Alloy (AA7075)

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Abstract:- Friction welding (FRW), a solid state joining process, was used to weld 7075 T651 aluminium, an alloy considered essentially non-weldable by fusion processes. This weld process exposed the alloy to a short time, high-temperature spike, while introducing extensive localized deformation. Micro structural studies of the friction welded joint were analyzed in the present study. The microstructures were characterized by optical microscopy and scanning electron microscopy (SEM

Because of the unique weld procedure, a fully recrystallized fine grain weld nugget was developed, that was named as dynamically recrystallized zone (DRX). In addition, proximate to the nugget, both a thermo-mechanically affected zone (TMAZ) and heat affected zone (HAZ) were created. Metallographic results showed that TMAZ exhibits highly deformed coarsened grain structure. The welded specimen exhibited reduced strength as compared to the base metal.

Keyword:- Friction welding, AA7075 aluminium alloy, DRX, TMAZ, HAZ

I. INTRODUCTION

The welding of aluminium and its alloys has always represented a great challenge for designers and technologists. As a matter of fact, lots of difficulties are associated to the fusion welding process, mainly related to the presence of a tenacious oxide layer, high thermal conductivity, high coefficient of thermal expansion, solidification shrinkage and, above all, high solubility of hydrogen, and other gases, in molten state . Further problems can arise when attention is focused on heat-treatable alloys, since heat, provided by welding process, is responsible of the decay of mechanical properties, due to phase transformations and softening induced in alloy. As a consequence of all above-mentioned problems, also into a leader industry such as the aeronautic one, which makes wide usage of aluminium alloys and especially of the alloy studied in this present work, mechanical joints are preferred ones.. Therefore laser-beam welding and solid state welding are currently considered to the most prospective welding processes. Friction welding, a solid state welding is used in many fields and wide spread in industrial applications as a mass production process for joining similar as well as dissimilar materials because the procedure is relatively.

Friction welding is a way of joining both similar and dissimilar combinations of materials. Friction welding is a process that is well established and widely accepted throughout industry. Components joined by friction welding can be found in a wide range of products, and in many different sectors of the global market.

II. 7XXX SERIES ALUMINIUM ALLOYS.

Zinc, in amounts of 1 to 8% is the major alloying element in 7XXX series alloys, and when coupled with a smaller percentage of magnesium results in heat-treatable alloys of moderate to very high strength. Usually other elements, such as copper and chromium, are also added in small quantities. 7XXX series alloys are used in airframe structures, mobile equipment, and other highly stressed parts. Higher strength 7XXX alloys exhibit reduced resistance to stress corrosion cracking and are often utilized in a slightly overaged temper to provide better combinations of strength, corrosion resistance, and fracture toughness.

III. BASIC METALLURGY OF SOLID STATE WELDING OF ALUMINIUM ALLOYS

It has been shown that three different effective zones with differing material movement and associated temperature changes can be identified in the macrostructure of friction welded samples. The three zones can be named as

A. Weld nugget (DRX)
B. Thermo-mechanically affected zone(TMAZ)

C. Heat affected zone(HAZ)

A. Weld Nugget

A typical macrograph through an aluminium alloy friction weld (in this case the alloy is 7075) is shown in Fig. 1. The centre of the weld, commonly referred to as the 'nugget zone', consists of a very fine grained, 1-10 μrn microstructure. The majority of the grain boundaries within the nugget zone are high angle (misorientation between grains being greater than 15°), and are believed to form through dynamic recrystallization during the stirring process. The width of the nugget zone depends on the combination of tool design, welding parameters, and alloy composition.

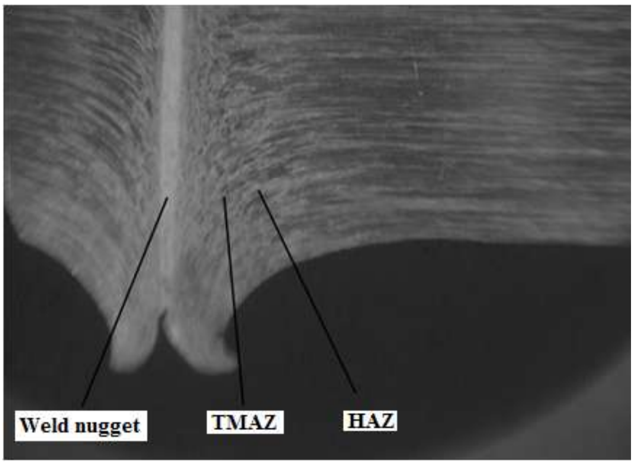

Fig. 1: Three different zones in friction weldment.

B. Thermo-mechanically Affected Zone (TMAZ)

Outside the nugget zone, aluminium alloy friction stir welds contain two other distinct microstructural zones (Figure 1). In the region immediately surrounding the nugget zone, the parent alloy grain structure becomes both heated and deformed, although to a lesser extent than for the nugget zone (this zone is referred to as the TMAZ - thermo-mechanically affected zone). This often leads to a region of partially recrystallized grains in which many of the fibrous grains, which are normally aligned in the rolling direction, are rotated. This can be very dangerous as the newly aligned high angle grain boundaries can be susceptible to stress corrosion cracking.

In other materials, the whole of the TMAZ can be recrystallized, with no apparent distinction between that region and the nugget zone. This is a feature of materials such as pure titanium, copper, and austenitic stainless steels, which have no thermally induced phase transformation, which would induce transformation in the absence of strain. The thermally induced phase transformation that occurs in ferritic steels can make interpretation of the microstructure, and precise definition of the TMAZ / HAZ boundary, difficult.

C. Heat Affected Zone (HAZ)

Surrounding the TMAZ is the heat affected zone, which for the high strength 2000 and 7000 series aluminium alloys consists of a coarse heavily overaged microstructure. As with aluminium alloy fusion welds, the HAZ in aluminium alloy friction stir welds is also susceptible to problems with corrosion.

IV. METALLOGRAPHIC STUDIES

Metallographic examinations of the material structure were made on light microscope with magnification from 50X to 400X. Metallographic examinations were used to characterize the microstructure along the weldment. For the metallographic studies, friction welded samples were sectioned in longitudinal direction as shown in figure 2. The samples have been polished in emery papers of different grades and finally disc polishing has been done for 30-45 min with dilute alumina powder of fine grade followed by polishing with diamond paste. After polishing, etching has been done with Keller's reagent. The metallographic etchant composition is 5ml ml of nitric acid (70 %), 3 ml of hydrochloric acid (37 %), 2ml of hydrofluoric acid (40 %) and 95ml of water. The etching time was 20 seconds. After etching, sample was washed and dried completely. The macro and microstructure were examined and recorded in the image analyzer with higher magnifications. After optical microscopy, metallographic studies by scanning electron microscopy were conducted to get a grain boundary microstructure.

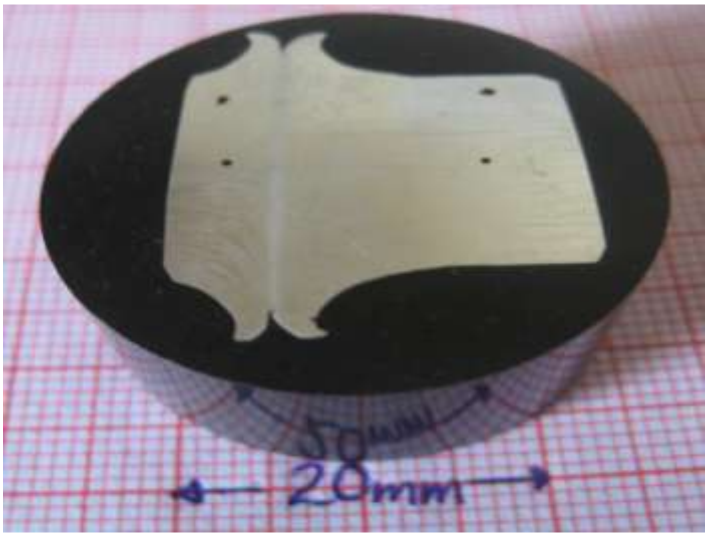

Fig. 2: Metallographic specimen

A. Friction Welding

AA7075 alloy was successfully welded by friction welding technique. Variation of parameters with time was given in figure 3. It shows the variation of load, position, speed and torque with respect to time.

The principal results of this work consist of macro, optical and SEM characterization of the Parent material, weld nugget and thermo mechanically affected zone regions of the friction welded AA7075 Aluminium alloy.

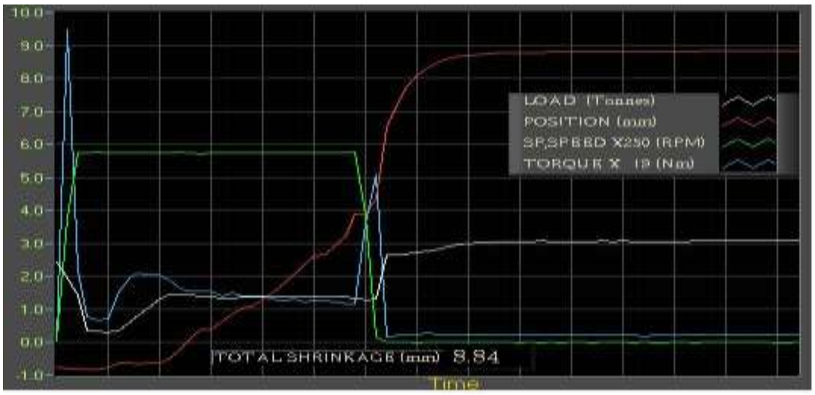

Fig. 3: Variation of parameters during FRW

B. Macrostructure

After completion of the welding, the welded specimens are cut exactly half of the diameter longitudinally. After mounting, the specimens are polished for metallurgical studies according to ASTM standards. Macro structures are taken as shown figure 4 at 10X magnification.

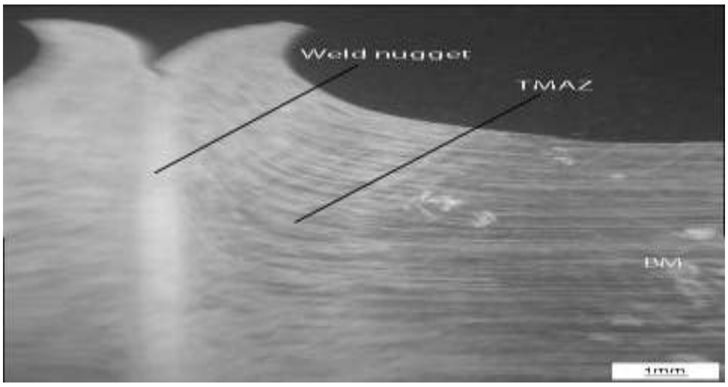

Figure. 4: Macroscopic view of friction welded joint

The figure 4 illustrates the flash geometry and grin orientation of friction welded 7075 alloy. In friction welding flash came outside will vary according to the burn off length that used for friction welding. The quantity of flash depends upon the burn off length. If burn of length is high rubbing action time is more. Due to this high heat is generated. This is the reason for high plastic deformation. Therefore flash is more when burn off length is increased.

The aluminium alloys with low strength will show circular form in flash geometry, but 7075 is a high strength Aluminium alloy, so it was not showed the flash geometry in circular shape.

C. Microstructural studies

The four effective zones consist of differing levels of material movement and associated temperature changes, and are described in Table 1.

Table 1: Typical microstructure zones associated with friction welding of AA7075.

Region	Material movement	Temperature
Weld nugget (DRX)	High(plasticized)	High
TMAZ	Low	Medium
HAZ	None	Low
Base metal	None	Very low

(1) Base Metal

The parent 7075-T6 rod exhibits an elongated matrix grain morphology as shown in Figure 5. The parent grains were in pancake shaped, mirroring the deformation imposed during rolling. These grains were several hundred micrometers long. Figure 5(a) shows the optical microstructure of base metal and Figure 5(b) represents the scanning electron microscope image of the base metal

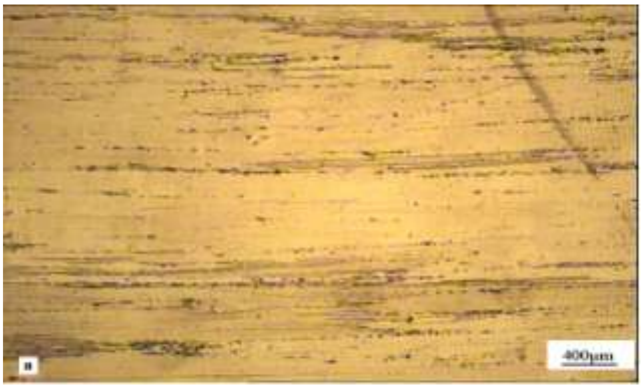

Fig. 5(a) Optical microstructure of AA7075 base metal

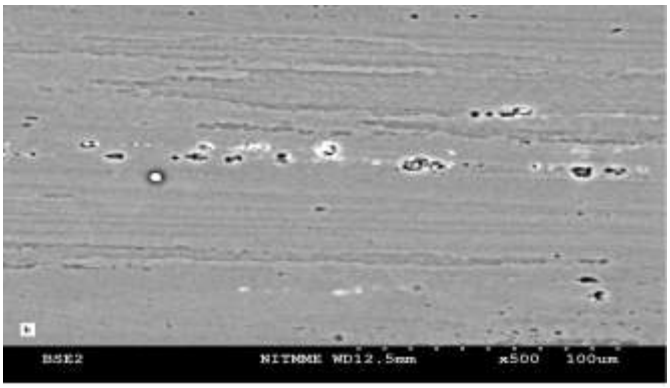

Fig. 5(b) SEM microstructure of AA7075 base metal

2) Weld nugget

Centre of the weld, commonly referred to as weld nugget. Friction welding process gave rise to noticeable microstructure changes in the weld nugget of AA 7075 alloy. The microstructure within the weld nugget in which dynamic recrystallization (DRX) occurred consisted of grains which were much smaller and equiaxed (Figure 6) when compared to the severely-elongated and pancake-shaped parent metal microstructure (Figure 5).

The weld nugget has a recrystallized, fine equiaxed grain structure on the order of 3-5 µm in diameter. No porosity was observed in the weld nugget zone. The width of nugget zone depends on the combination of welding parameters and alloying elements. The recrystallization of the weld nugget grains and the redistribution of the grain structure indicate that the temperature excursion during joining was above the solution temperature for the hardening precipitates, but below the melting temperature of the alloy. Figure 6(a) represents the optical microstructure in lower magnification. Figure 6(b) shows the higher magnification SEM image.

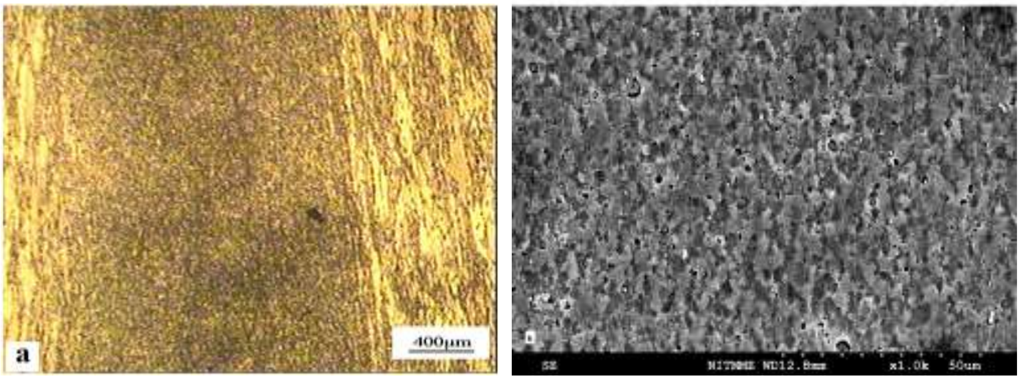

Fig. 6 Weld nugget microstructures with different magnifications

3) Thermo-mechanically affected zone (TMAZ)

The region immediately surrounding the nugget zone, the parent alloy grain structure becomes both heated and deformed, although to a lesser extent than for nugget zone (this zone is referred to as the TMAZ-thermo-mechanically affected zone). This often leads to a region of partially recrystallized grains in which many of the fibrous grains, which are normally aligned in the rolling direction, are inclined. This can be very dangerous as the newly aligned high angle grain boundaries can be susceptible to stress corrosion cracking. TMAZ is characterized by a highly deformed structure as shown in figure 7. Figure shows highly coarsened grains in TMAZ.

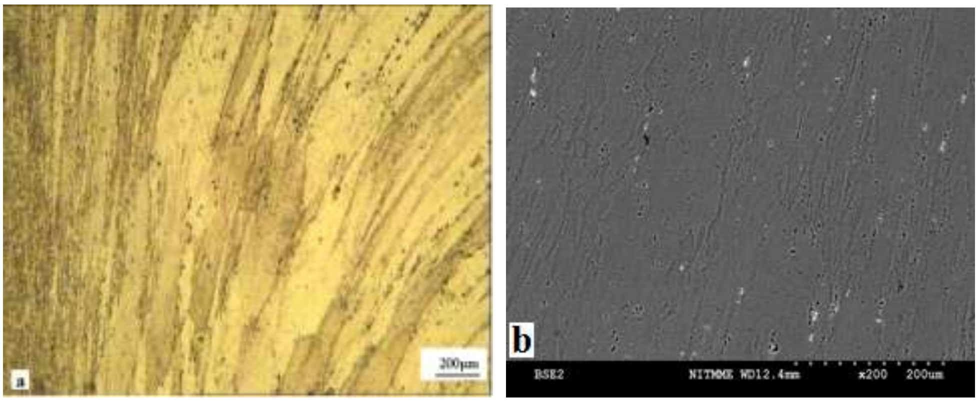

Fig. 7: Microstructure of Thermo-mechanically affected zone

Figure 7(a) shows optical microstructure and 7(b) shows the SEM image. This is the very critical portion among the all zones. Figure 8 shows the transition of weld nugget to TMAZ

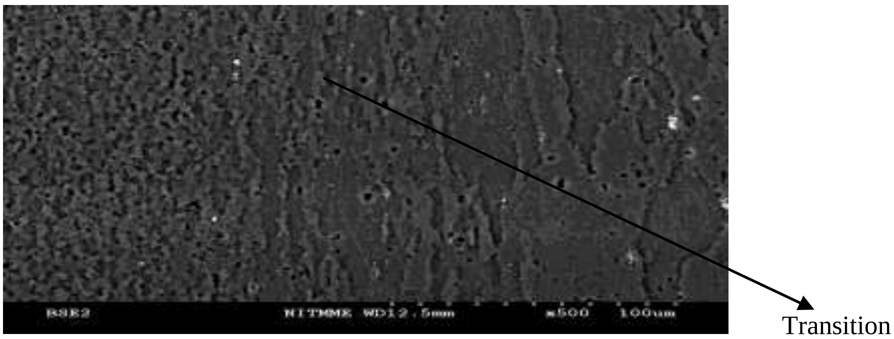

Fig. 8: Transition of weld nugget to TMAZ

4) Heat affected zone (HAZ)

Surrounding TMAZ is the heat affected zone. In the HAZ, which starts at a distance of around 6-10 mm away from the weld center, a large amount of resident parent material grains start to appear, Figure 9.

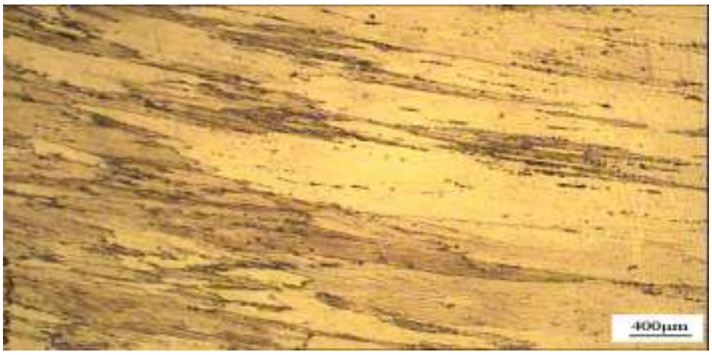

Fig. 9: Microstructure of Heat affected zone

Figure 10 show the joined microstructure of friction welded AA7075, at different positions.-half position and quarter position-.

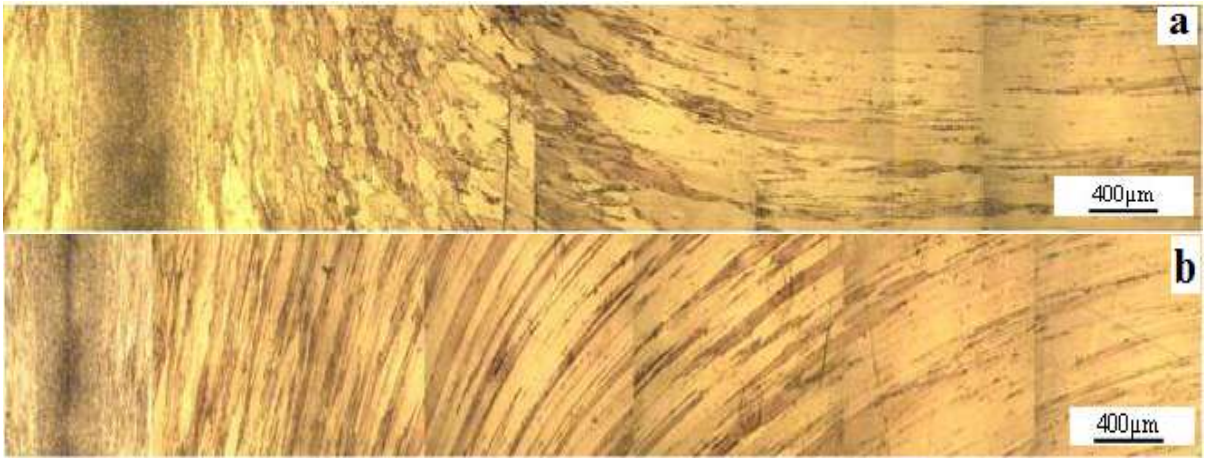

Fig. 10: Joined microstructure at (a) half position and (b) quarter positions.

V. CONCLUSIONS

Friction welding was applied successfully to AA 7075 with good bonding observed in the nugget zone.The nugget zone exhibited a recrystallized fine grain structure with grain sizes increasing moving from the weld region to the base metal.TMAZ exhibits highly deformed coarsened grain structure. This zone can count as the most critical zone among the all regions

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REFERENCES

[1]. Venugopal.T, K. Srinivasa Rao and K. Prasad Rao (2004) “Studies on friction stir welded AA 7075 Aluminum alloy”, Trans. Indian Inst.Met.Vol.57, No. 6, 659-663.

[2]. C. Yeni , S. Sayer , O. Ertugrul , M. Pakdil (2008) “Effect of post-weld aging on the mechanical and microstructural properties of friction stir welded aluminum alloy 7075” Archives of Materials Science and Engineering. Vol. 34,Issue 2, 105-109

[3]. LI Jin-feng, PENG Zhuo-wei, LI Chao-xing, JIA Zhi-qiang, CHEN Wen-jing, ZHENG Zi-qiao (2007) “Mechanical properties, corrosion behaviors and microstructures of 7075 aluminium alloy with various aging treatments” Trans. Nonferrous met. Soc. China. 755-762.

[4]. YUTAKA S. SATO, HIROYUKI KOKAWA, MASATOSHI ENOMOTO, and SHIGETOSHI JOGAN (1999) “Microstructural Evolution of 6063 Aluminum during Friction-Stir Welding” Metallurgical and materials Trans. Vol. 30 A. 2429-2437

[5]. S. Benavides, Y. Li, L.E. Murr, D. Brown, and J.C. McClure (1999) "Low temperature friction-stir welding of 2024 Aluminium" Scripta Materialia, Vol. 41, No. 8, pp. 809–815
[6]. BEATE HEINZ and BIRGIT SKROTZKI (2002) "Characterization of a Friction-Stir-Welded Aluminum Alloy 6013" Metallurgical and materials Trans. Vol. 33 B. 489-499
[7]. L.E. Murr , R.D. Flores, O.V. Flores, J.C. McClure, G. Liu · D. Brown (1998) "Friction-stir welding: microstructural characterization" Mat Res Innovat 1:211–223
[8]. P. CAVALIERE, E. CERRI (2005) "Mechanical response of 2024-7075 aluminium alloys joined by Friction Stir Welding" Journals of material science. 40. 3669 – 3676.
[9]. D.Harris and A.F. Normann (2003) properties of friction welded joints- A Review literature" Corus UK Ltd, Swinden Technology centre.
[10]. M. Kciuk (2006) "Structure, mechanical properties and corrosion resistance of AlMg5 alloy" Journals of Achievements in Materials and Manufacturing Engineering. Vol. 17. Issue 1-2. 185-188.