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Studies on effect of tool design and welding parameters on the friction stir welding of dissimilar aluminium alloys AA 5052 – AA 6061

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Abstract

This research paper deals with the characterization of friction stir welded dissimilar Aluminium alloys AA 5052 and AA6061. The coupons of above metals were friction - stir welded using cylindrical pin tool using at constant speed of 710 rpm and at two different feed rates of 28 and 20 mm/min. Macrographs showed proper mixing due to effective stirring of cylindrical tool pin while keeping the lower feed rate. Further, extensive micro structural examination showed variation of grain size in each zone and their influence on mechanical properties. Tensile test and hardness measurements were done as a part of mechanical characterization. Correlating mechanical and metallurgical properties it is deduced that the sample welded at lower feed rate performed better in terms of ductility.

Keywords: Friction stir welding; Dissimilar welds; AA 5052; AA 6061; Cylindrical tool pin.

Nomenclature

Sample A	Sample welded at 710 rpm and 28mm/min
Sample B	Sample welded at 710 rpm and 20mm/min

1. Introduction

Aluminium alloys are used extensively in variety of applications ranging from much simple to critical ones such as in the making of aircraft bodies. There are instances where different series of aluminium alloys are to be welded due to its requirement in the varied service conditions. Choice of proper joining process employed becomes important in the performances of these materials in its actual service conditions, as aluminium alloys are lighter yet possessing good strength and ductility. This makes the same, an eligible material to work under variety of working environments.

Friction stir welding, a modern and an environment friendly solid - state joining process used to join relatively lighter family of materials, especially Aluminium and its alloys is dealt in this study [1, 2]. Critical applications of these alloys

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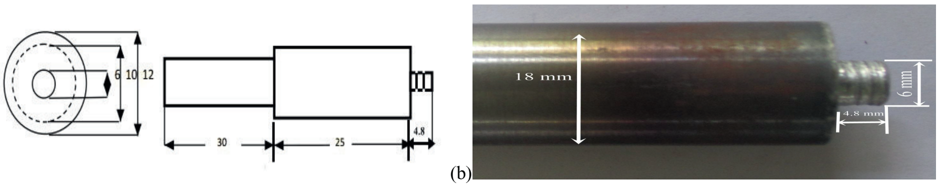
include aerospace, automobile and ship building as well [3]. The nature of the material decides the type of joining process. Friction stir welding, which is regarded as an autogenous, keyhole joining technique fills the void where other joining techniques becomes difficult to implement [4].

Solid-state welding processes are ideally suited for welding of dissimilar aluminium alloys. Because these processes do not involve melting, the issue of weld solidification cracking does not arise. Similarly, solid-state welding processes overcome a variety of other problems in fusion welding of aluminium alloys such as porosity, segregation, brittle inter metallic formation, and heat affected zone liquation cracking [5]. Aluminium Alloys of two different series AA 5052 and AA6061 are friction stir welded using specific tool design and using two different optimized welding parameters (constant speed and variable feed). This paper investigates on characterizations of the mechanical and metallurgical properties with the above dissimilar combination to evaluate the performance and characteristics of the welded joints and results inferred.

1.1. Experimental setup, tool and process parameters

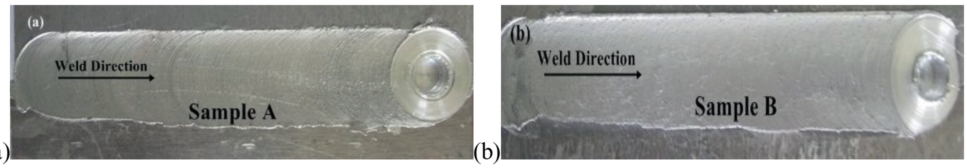
The dissimilar alloys AA 5052 and AA6061 are butt welded using standard milling machine. The coupons to be butt welded are cut to a dimension of 100mm x 50 mm and a special clamping arrangement were made in order to arrest all the degrees of freedom. Cylindrical pin tool with 2 threads were machined. AA 5052 was kept at the advancing side and AA6061in the retreating side. The two specimens were welded using two parameters: 710 rpm at 28mm/min and 710 rpm at 20mm/min which is designated as Sample A and B respectively. AISI H13 tool steel was used as a tool material. D/d ratio (shoulder/pin) was kept as 3, where shoulder diameter is 16mm and pin diameter being 6mm. Optical microscopic studies were carried out by etching the samples using Keller's reagent (150 ml water + 3ml of Nitric Acid, 6 ml of hydrochloric and hydrofluoric acid). The tensile tests were conducted using INSTRON 8801 UTM. The hardness profile were monitored using Matsuzawa MMT-X Vickers hardness tester. A 100gf was given as load and the indentations were made every 0.5mm for a length of 30mm across the weld. The tool dimension and the tool used for welding are shown in the Fig 1. (a & b).



(a) (b)

Fig. 1. Geometry of tool design (a) Cylindrical threaded tool (b) Snapshot of the tool after welding.

1.2. Surface Morphology

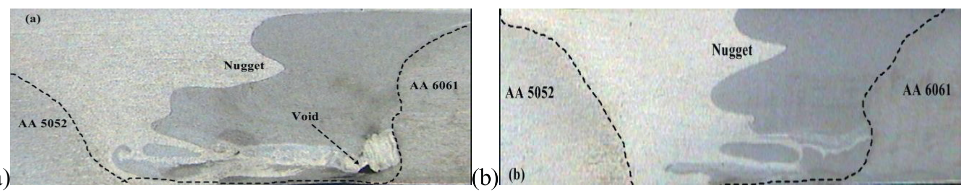


(a) (b)

Fig. 2. Snapshot of as - welded samples welded at (a) 710 rpm and 28mm/min (b) 710 rpm and 20 mm/min.

2. Results and discussions

2.1. Macro and microstructures



(a) (b)

Fig.3. (a) Macrostructure of Sample A (b) Macrostructure of Sample B

Various micro structural aspects include grain structure evolution, its texture, temperature distribution, recrystallization methods and precipitation of inter – metallic constituents. These factors influence the strength and quality of the friction stir welds which are assessed using various tests namely tensile loading, fatigue etc [5].

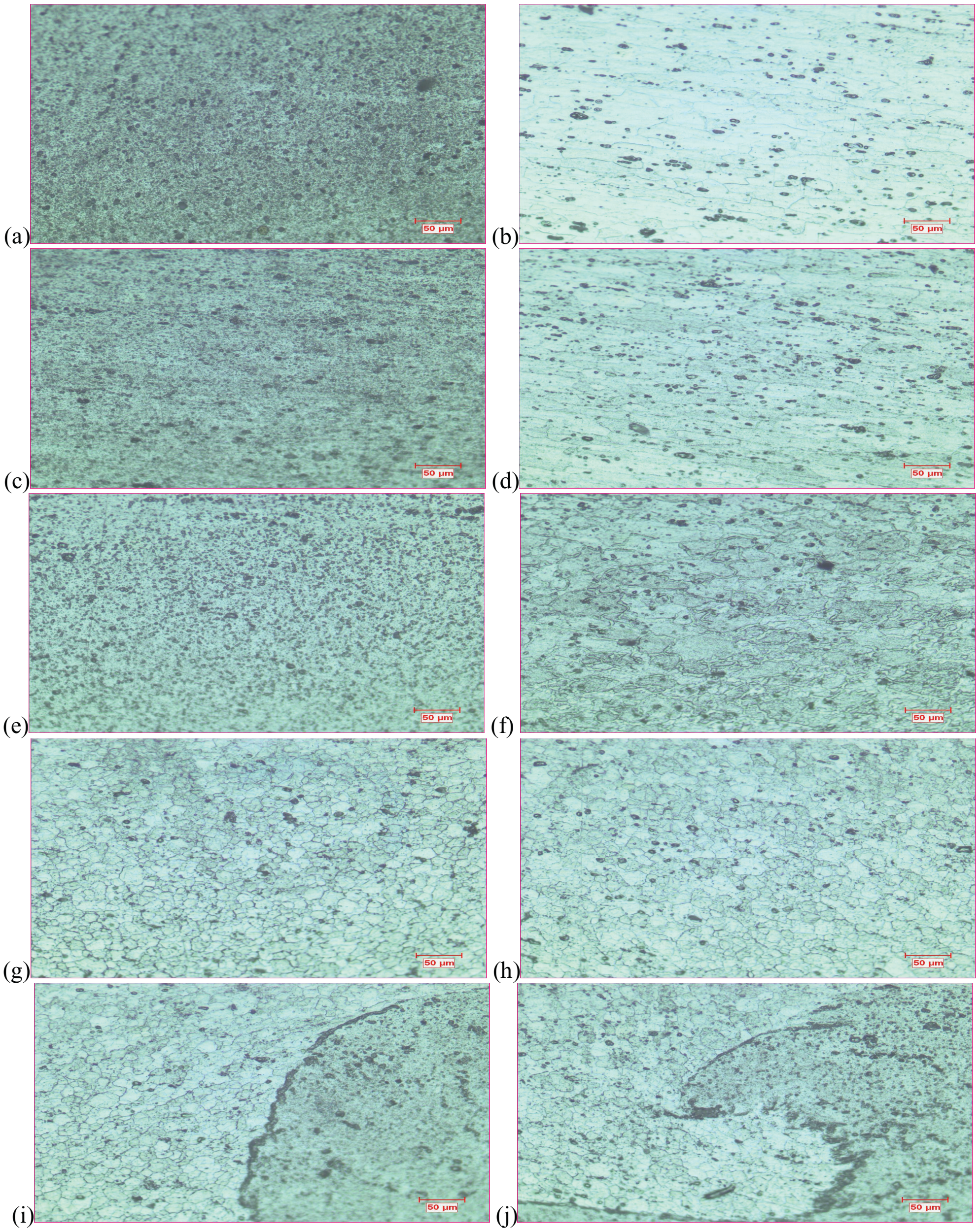


Fig. 4. Microstructures taken at the different zones of the welded Sample A and B (a)Base Metal of AA5052 (b)Base Metal of AA6061(c) HAZ of AA5052 (d)HAZ of AA6061(e)TMAZ of AA5052(f)TMAZ of AA6061(g)Weld region of Sample A (h) Weld region of Sample B(i)Interface in Sample A(j)Interface in Sample B.

The macrograph of two weldments showed proper flow of materials from advancing side to retreating side and it is evident that the considered weld process parameters proved optimum. It is also noted that there is a micro void is visible when the sample welded at 28 mm/min which may be due to lack of frictional heat involved in the weld nugget (Fig 3(a)).

The microstructures taken at various regions of the weldments of both the samples are shown in the Fig.4. The microstructures of the base metals of AA 5052 and AA 6061 are shown in the Fig.4 (a) and (b) respectively Fig.4. (g) and (h) shows the weld microstructure. It can be observed that the refined grain formation in the weld zone ad compared to both TMAZ of both alloys (Fig 4 (e&f)) this could be due to effective cooling rate. Moreover, on comparing the both TMAZ, AA 6061 side has considerable increase in grain size (Fig. 4.f) and this may lead to deterioration of tensile properties. Mahabunphachai et al [6] has analyzed that the change of grain size in the microstructure analysis due to the effects of elevated temperatures and strain rates were not significant; therefore, it was concluded that the decrease in the flow stress at high temperature levels was mainly due to the thermally activated dislocation lines.

2.2. Tensile test

The tensile specimens were EDM wire cut and prepared according to the ASTM standards for the sub size specimen [5]. As seen from the Fig. 5. (a), in both the cases the fracture has happened in the TMAZ of the AA6061 side, which affirms that the weld has exhibited better strength than that of parent metals. The UTS of both the samples has not shown any major difference but the tensile stress at break of Sample B is proportionately higher than Sample A, which means Sample B has yielded suddenly after the elastic limit, whereas Sample A fracturing at a low stress state showing immense ductility. The Load at break adds to the same. Koilraj et al [8] have optimized the welding parameters by design of experiments and concluded from their experiments, the optimum level of settings. Optimized parameters of rotational speed, transverse speed, and D/d ratio are 700 rpm, 15 mm/min and 3 respectively. Most importantly the cylindrical threaded pin tool profile was found to be the best among the other tool profiles considered and the D/d ratio plays a vital role and contributes 60% to the overall efficiency. Sato et al. [9] found that the hardness profiles in the friction stir weld zone of Al 5083 alloy could not be explained alone by the grain size in the weld. Therefore correlation of tensile results becomes vital in analyzing the nature and reason for the fracture.

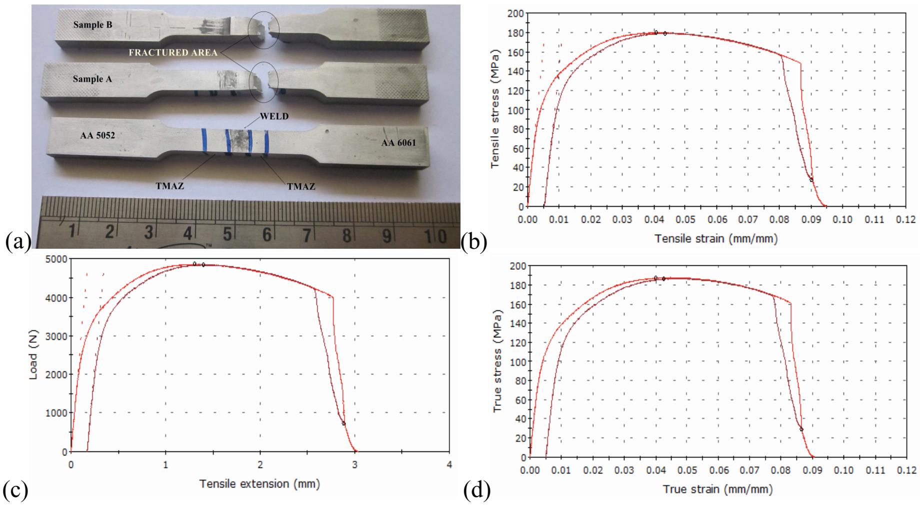


Fig.5.(a) As- tested Tensile Specimens (b) Tensile stress Vs Tensile strain (c) Load Vs Tensile extension (d) True stress Vs True Strain

Table 1. Tensile test results

Sample	Maximum Load (N)	UTS (MPa)	Tensile strain at Break (%)	Tensile stress at break (MPa)	Load at Break (kN)	Elongation (%)
Sample A	4853.06978	180	10.588	2.75	0.07	10.59917
Sample B	4837.20303	179	8.485	27.06	0.73	8.37117

2.3. Hardness Measurements

The hardness profile obtained for the samples are shown in the Fig.6. From the graph it can be ascertained that the feed rate has not much influenced the hardness of the weldments. The hardness values has shows a decreasing trend beginning from the advancing side (AA 5052) of the weldment to the retreating side(AA 6061) and has again increased gradually. It is also to be noted that the fracture has also occurred in the TMAZ of AA 6061 (minimum hardness zone). It can also be understood from the graph that hardness values of TMAZ of the retreating side are comparatively lower which could be due to lack of mixing/diffusion of AA 6061 with weld nugget. Further this could be a reason for the failure of tensile specimen in the TMAZ of AA 6061 side which is also evident from nature of the micrograph (Fig 4(f)) as discussed earlier. In addition the hardness in the weld nugget shows lower values as compared to both base metals which may be due to the grain coarsening effect.

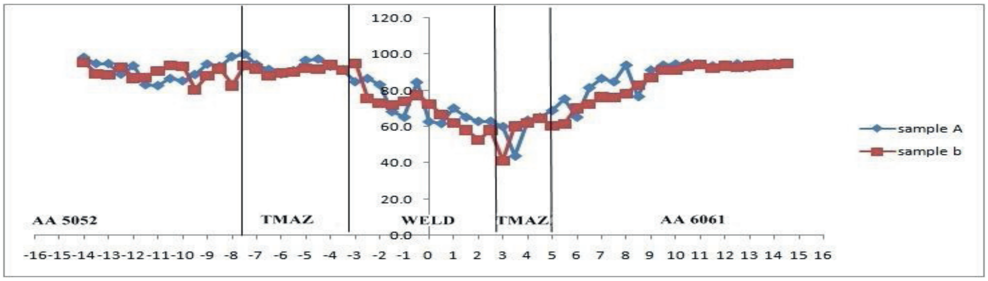


Fig.6. Hardness plot of Sample A and B

3. Conclusions

a) Friction stir welds between AA 5052 and AA 6061 Al alloys sounds promising, having demonstrated excellent weldability and performance characteristics.
b) Cylindrical threaded pin has rendered excellent bondage between both alloys (AA 5052 and AA 6061) by effective friction stir joining
c) Both the samples have exhibited nearly equal ultimate strength but Sample B has outperformed Sample A on certain fronts corresponding to better ductility.
d) Extensive micro structural study gives better understanding of the grain structures and their influence on mechanical properties.
e) The mechanical and metallurgical characterizations have shown good agreement which is clearly evident from results obtained.

References

[1]Mishraa, R.S., Mab, Z.Y., 2005. Friction stir welding and processing, Materials Science and Engineering R 50, p 1-78.
[2]Shigematsu, I., Kwon, Y. J., Suzuki, K., Imai, T., Saito, N., 2003. Joining of 5083 and 6061 aluminum alloys by friction stir welding, Journal of Material Science Letters 22(5), p. 353−356.
[3] Dawes, C.J., Thomas, W.M., 1996. Friction stir process welds aluminium alloys, Welding Journal 75(3), p.41–5.
[4]Thomas, W.M., Nicholas, E.D., 1997. Friction stir welding for the transportation Industries, Materials & Design Vol. 18, p. 269-273.
[5]Kumbhar, N.T., Sahoo, S.K., Samajdar, I., Dey, G.K., Bhanumurthy, K., 2011. Microstructure and micro textural studies of friction stir welded aluminium alloy 5052, Materials and Design 32, p. 1657–1666.
[6] Mahabunphachai, S., Koc, M., 2010. Investigations on forming of aluminum 5052 and 6061 sheet alloys at warm temperatures, Materials and Design 31, p. 2422–2434.
[7] ASTM E8/E8M – 09, 2009. Standard test methods for tension testing of metallic materials, Vol. 3.01. Annual Book of ASTM Standards;
[8]Koilraj, M., Sundareswaran, V., Vijayan, S., Koteswara Rao, S.R., 2012. Friction stir welding of dissimilar aluminium alloys AA2219 to AA5083 – Optimization of process parameters using Taguchi technique, Materials and Design 42 p.1–7.
[9] Sato, Y., Urata, M., Kokawa, H., Ikeda, K., 2003. Hall–Petch relationship in friction stir welds of equal channel angular-pressed aluminium alloys, Material Science and Engineering 354 (1–2), p. 298–305.