Review of Experimental Investigation & Mechanical Characterization of Aluminium Alloys by using Friction Stir Welding

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Abstract— The increasing application of innovative materials, such as high strength aluminum alloys, is challenging the manufacturing processes of the Aerospace and Aeronautics Industries. Despite this challenge the processes need to comply with high requirements regarding the reproducibility and the quality of the products. For this reason the adaption of conventional welding technologies to the new materials is considered to be difficult. Therefore, innovative welding technologies such as Friction Stir Welding (FSW) have been developed Friction Stir Welding is a well solid state joining technology. Many processing conditions and materials properties affect the microstructural evolution and mechanical behavior of the made joints. The main parameters involved in the welding process have been studied and the results presented in the present study. The analysis was conducted through employing a multi-objective optimization tool capable of correlating all the material properties and processing parameters to the final mechanical performances of the welds. The Aluminium alloy plates of are welded in rectangular butt joint geometry by friction stir welding (FSW) process, using CNC vertical milling machine. Process parameters such as welding speed and tool rotational speed play an important role to obtain a better weld joint for similar metals/materials. The friction stir welding tool is one of the critical components to the success of this process. It consists of a cylindrical shoulder and a pin with different geometry. In the experimental work, tool has been made with cylindrical pin having four different geometries for friction stir welding of the similar circular metal plates. Effects of process parameters on butt welded rectangular joint were investigated for weld strength.

Key words: Aluminium Alloys, Friction Stir Welding

I. Introduction

In this research work, it is discover that welded joint between Aluminium metals alloys can be formed using friction stir welding by selecting proper tool pin profile and welding parameters. The literature review is carried out on the various fields of research on friction stir welding which is aiming to improve the performance of weld strength. In this, following literature;

Heena K Sharma, (2016) [1]: This paper reviews effects of process parameters on butt welded circular joint were investigated for weld strength. In this research work, it is found that welded joint between dissimilar metals alloys Al 6061 and Mg AZ31 can be formed using friction stir welding by selecting proper tool pin profile and welding parameters. In this case, the plates were not welded successfully due to the following reasons: Path of welding, pin geometry used during FSW, Higher value of welding parameter, being the prime reason. Process parameters such as welding speed and tool rotational speed play an important role to obtain a better weld joint for similar materials. The friction stir welding tool is one of the critical components to the success of this process. In the experimental work, the said tool has been designed with cylindrical pin having four different geometries for friction stir welding of the dissimilar circular metal plates. Friction stir welding has been carried out at welding speed varying from 10 to 40 mm/min and tool rotational speed from 800 to 2000 rpm. Effects of process parameters on butt welded rectangular joint were investigated for weld strength. As the path of welding is circular, more difficulties have been faced compared to linear path welding. The experiments that lower values of tool rotational speed and welding speed are better for FSW of dissimilar alloys under consideration when using HCHCr tool material.

Jong-Hoon Yoon (2016) [2]: FSW butt jointed AA2195 specimens were tested. The microstructures were characterized with electron microscopy and during welding, surface temperatures were measured. It is shown that the temperature in advancing side is higher than retreating side which supports the results of micro-hardness profile at nugget zone. The weld zone can exhibit higher micro-hardness than parent material due to grain recrystallization and the hardness profile inside of the nugget depends on the cooling rate. Low hardness around the nugget zone is related to the dissolution and coarsening of precipitates at HAZ in the advancing side and/or retreating side. It shows the minimum micro-hardness value appears at the location just adjacent to tool tip near heat affected zone interface. The effect of surface oxide on the tensile strength of joint is investigated by comparing to specimen without surface oxide. It is shown that the effect of removing oxide is effective on relatively low rotating speed condition of 300 and 400 rpm, while as little influence to specimens welded higher rotating speed in this study. Friction stir welding process map of this alloy represents the strength at each process parameters, which are rotating and traveling speeds.

V.C. Sinha (2016) [3]: In the present study, the microstructure and mechanical properties of similar and dissimilar friction stir welded joints of AlA and Cu were evaluated at tool rotational speeds from 150 to900 rpm in steps of 150 rpm at 60 mm/min travel speed. In the optical microstructure, the shear zone, heat affected zone and thermo mechanically affected zone were clearly observed for all the FSW joints. The grain size of shear zone, thermo mechanically affected zone and heat affected zone for all the joints increased with the increase in tool rotational speeds. The Al4Cu9, Al Cu, Al2Cu and Al2Cu3intermetallic phases have been observed at the interface and stir zone region of dissimilar Al/Cu FSWed joints. In AlA-AlA and Cu-Cu FSWed joints have shown good surface continuity above 150 rpm tool rotational speed. The dragging effect of the

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tool was observed on the joint surface in Cu-Cu FSWed region at 450 rpm and 600 rpm tool rotational speed. For AlA-Cu FSWed joints surface discontinuity was observed up to 300 rpm tool rotational speed. Low heat input due to low tool rotational speed was supposed to cause these types of defects in the weld region. In the macrostructure of AlA-Cu FSWed joint at 150 rpm mixing of copper was observed only near the shoulder portion, however above this tool rotational speed good mixing of aluminum and copper were observed in the stir zone region.

B. Ratna Sunil (2015) [4]: FSW has been successfully adopted to join AZ31 and AZ91 Mg alloys and clearly demonstrated the role of process parameters to avoid the formation of hot cracks during welding. Two dissimilar magnesium (Mg) alloy sheets, one with low aluminum (AZ31) and another with high aluminum (AZ91) content were successfully joined by friction stir welding (FSW). The effect of process parameters on the formation of hot cracks was investigated. A sound metallurgical joint was obtained at optimized process parameters (1400 rpm with 25 mm/min feed) which contained fine grains and distributed (Mg17Al12) phase within the nugget zone. An increasing trend in the hardness measurements has also confirmed more amount of dissolution of Aluminum within the nugget zone a sharp interface between nugget zone and thermo mechanical affected zone (TMAZ) was clearly noticed at the AZ31 Mg alloy side (advancing) but not on the AZ91 Mg alloy side (retreating). From the results it can be concluded that FSW can be effectively used to join dissimilar metals, particularly difficult to process metals such as Mg alloys, and hot cracking can be completely eliminated by choosing appropriate process parameters to achieve sound joint. The effect of process parameters on the formation of hot cracks was investigated. Increased hardness in the nugget zone can be attributed to the grain refinement and the presence of Mg17Al12 particles along with solid solution strengthening. Hence from the present study, it can be concluded that FSW can be used as a potential technique to join dissimilar Mg alloys, particularly AZ series alloys, for various structural applications.

Kwang-Jin LEE (2014) [5]: Microstructure evolution in the FSW welds of AA6061 and AZ31 obtained under off-set condition was investigated by EBSD technique. Microstructural characteristics of three different regions, namely BM, SZ, and interface of AA6061 and AZ31; have been clearly identified with EBSD analysis. In the analyzed microstructure, no obvious welding defects were found. The SZ of both AA6061 and AZ31 exhibited a microstructure composed of fine and recrystallized grains. The grains on the SZ of AA6061 were much smaller than those of AZ31. The texture in the SZ of AZ31 was significantly changed with the (0001) Basal plane inclined to the TD. Microstructure of the interface was characterized by lamellar-like shear bands rich in either Mg or Al. Alternate layers of large Mg and Al bands along with their dispersed fragments were observed in the microstructure, indicating intense inhomogeneous material flow in the SZ. This paper considers microstructure evolution in the FSW welds of AA6061 and AZ31 obtained under off-set condition was investigated by EBSD technique. In the analyzed microstructure, no obvious welding defects were found. Microstructure of the interface was characterized by lamellar-like shear bands rich in either Mg or Al.

Michael F. Zaeha (2014) [6]: Considering AA2219 in temper condition O, a functional relation between the process parameters (n, v and Fz) and the average hardness value of the nugget zone was established in this paper. It is known, that a high formability of the joint requires a low hardness increase of the welding seam. The results of this paper show that this can be achieved by a reduced rotational speed n, an increased welding speed v and a reduced axial Force Fz. Furthermore, a correlation between the changes of the process temperature and the hardness of the microstructure was found. The results indicate that a thermal solution of the overage precipitates and a resulting solid solution hardening are responsible for the increasing hardness in the weld zone. Therefore, “cool” welding conditions lead to an enhanced formability of the joint. In addition to the described parameter settings a cooling of the work piece or the welding tool is appropriate.

Venkatesh Kennan M (2014) [7]: The FSW process parameters were optimized with respect to mechanical and metallurgical properties of the weldments. In addition, tool pin profile has also influenced the weld quality. Maximum weld strength of 194 Mpa and 209Mpa were obtained for cylindrical threaded and squared pin, respectively. SEM image was analyzed at a magnification of 2.5KX. EDAS was taken at the center of the weld zone. Presence of Al (83.85%) and Cu (8.73%) were prominent in that region. Formation of the oxide layer within the weld zone could most probably enhance the corrosion properties. For both the tool pin geometry fracture occurred at the HAZ of 6061 side. On the other hand, fracture occurred at the stirred zone, for other tool pin geometry. The welded specimen shows lower strength compared to both the base material. Joint efficiency obtained is 80% for cylindrical threaded pin and 87% for squared pin. From this research work, it is inferred that the rotational speed of 710 rpm, traverse speed of 28mm/min and D/d ratio of 3, for cylindrical pin, is considered to be the most efficient. Furthermore, better mechanical properties were observed with 6 mm squared pin, rotational speed of 1000 rpm and traverse speed of 40mm/min. in addition, the cylindrical threaded and squared pin tool profile are found to be the best among other tool profiles that were considered.

Raj Kumar VAKa (2014) [8]: 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. Friction stir welds between AA 5052 and AA 6061 Al alloys sounds promising, having demonstrated excellent weldability and

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

Pasquale Cavaliere (2013) [9]: In the present study the effect of processing parameters on tensile, fatigue and crack behavior of several aluminum alloys is described. The experimental data were employed to build a database capable of developing a model useful for predicting mechanical performances of FSW joints. Friction Stir Welding is a well-known solid state joining technology. Many processing conditions and materials properties affect the microstructural evolution and mechanical behavior of the produced joints. The main parameters involved in the welding process have been studied and the results presented in the present paper. The fatigue life and crack behavior of several aluminum alloys FSW joints have been presented. The analysis was conducted through employing a multi-objective optimization tool capable of correlating all the material properties and processing parameters to the final mechanical performances of the welds. It was underlined the different weight of processing parameters on final performances of the welds. The quality of the model was evaluated through the potential error calculation of each output monitored during the analysis.

G. Elatharasan,V.S, V. S, V.S, V.S. (2013) [10]: The UTS, YS and TE in FSW process were modeled and analyzed through response surface methodology (RSM). A central composite design (CCD) in RSM consisting of three variables. Rotational speed, traverse speed and axial force have been employed to carry out the experimental study. Analysis of variance (ANOVA) was applied to study. Empirical relationship were developed to estimate the Ultimate tensile strength, Yield strength and tension Elongation of friction stir welded AA 6061-T6 aluminum alloy. The ANOVA analysis showed that the developed model can be effectively used to predict the UTS, YS and TE of the joints at 95% confidence level. UTS and YS of the FS welded joints increased with the increase of tool rotational speed, welding speed and tool axial force up to a maximum value, and then decreased TE of joints increased with increase of rotational speed and axial force, but decreased by increasing of welding speed, continuously. Empirical relationship were developed to estimate the Ultimate tensile strength, Yield strength and tension Elongation of friction stir welded AA 6061-T6 aluminum alloy. The ANOVA analysis showed that the developed model can be effectively used to predict the UTS, YS and TE of the joints at 95% confidence level. UTS and YS of the FS welded joints increased with the increase of tool rotational speed, welding speed and tool axial force up to a maximum value, and then decreased. TE of joints increased with increase of rotational speed and axial force, but decreased by increasing of welding speed, continuously. A maximum tensile strength of 197.50 Mpa, Yield strength of 175.25MPa and % of Elongation of 6.96 was exhibited by the FSW joints fabricated with the optimized parameters of 1199 r/min rotational speed, 30 mm/min welding speed and 9.0 KN axial forces.

Ch VENKATA RAO (2015) [11]: To overcome the problems of fusion welding, friction stir welding (FSW) is recognized as an alternative solid state joining method aimed to improve the mechanical and corrosion properties. Tool profile is one of the important variables which affect the performance of the friction stir weld. Differential scanning calorimetric results show the evidence of precipitate dissolution during FSW. It was found that the microstructure changes, such as grain size and its orientation precipitate dissolution during FSW influence the hardness and corrosion behaviour. Pitting corrosion resistance of friction stir welds of AA2219 was found to be better for triangle profile tool compared to conical profile which is attributed to material flow and strengthening precipitate morphology in various zones. Higher amount of heat generation during FSW made using triangle profile tool may be the reason for greater dissolution of strengthening precipitates in nugget zone and coarsening in thermo mechanically affected zone (TMAZ) and heat affected zone (HAZ). EBSD analysis indicates a continuous dynamic recrystallization process leading to the formation of equiaxed grain structure in the weld mugget of triangle profile. Selection of tool profile is important in achieving the better combination of mechanical properties and corrosion resistance of AA2219 aluminum-copper alloy friction stir welds

II. CONCLUSION

FSW has been successfully adopted to join Al alloy clearly demonstrated the role of process parameters. In the analyzed microstructure, no obvious welding defects were found. FSW may be used as a potential technique to join dissimilar Al alloy and particularly AZ series alloys, for various structural applications. The mechanical and metallurgical characterizations have shown good agreement which is clearly evident from results obtained.

III. REFERENCES

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