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FRICTION STIR WELDING: AN EMERGING TECHNOLOGY IN AUTOMOBILE INDUSTRIES

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Abstract
A long times ago welding was carried out to join two similar metals. After that some advancement is done in the field of welding to join two dissimilar metals. Although friction stir welding (FSW) has been successfully used to join materials that are difficult-to-weld or unweldeable by fusion welding methods, it is still in its early development stage and, therefore, a scientific knowledge based predictive model is of significant help for thorough understanding of FSW process. Light metals considerably add value by improving fuel economy and performance of vehicle. The cost of new material is always compared with presently employed product. The most important variable for selection of material is cost of material. In the automotive industry, the requirements of both environmental regulation and customer demands for greater performance and safer vehicle are currently accommodated by developing a lightweight, and therefore essentially energy efficient vehicle.

Key Words: Friction Stir Welding, Solid State Weld, Effect Of Fusion, Dissimilar Metals.

I INTRODUCTION

In the automotive industry, the requirements of both environmental regulation and customer demands for greater performance and safer vehicle are currently accommodated by developing a lightweight, and therefore essentially energy-efficient vehicle. Electric resistance spot welding has been used for many years in the automotive industry for joining body sheet components, and it is particularly well suited for uncoated low carbon steel. Difficulties arise when applying such spot welding to low resistance metals, such as aluminum. It is known that resistance spot welding between dissimilar metals, such as between a steel and aluminum, often creates an intermetallic compound (IMC) as a result of alloying between the dissimilar metals. In addition, the formation of the IMC results in deteriorated mechanical properties because the IMC is known to be brittle. In particular, for a combination of steel and an aluminum alloy, an IMC is likely to be formed and the electrical and thermal properties impose large restrictions on current conditions, making it very difficult to obtain sound welding. In recent years, many demands have been generated for a joining between dissimilar metals [1].

II LITERATURE REVIEW

In this paper G. Buffa et al.[2] proposed continuum based FEM model for friction stir welding process, and he calibrated this model by comparing with experimental results of force and temperature distribution and then he used this to investigate the distribution of strain and temperature in heat affect zone and the weld nugget. The non-symmetric nature of FSW process is correctly predicted by model, and the relationships between the tool forces and the variation in the process parameters. It is found that the about the weld line effective strain distribution is non-symmetric while the temperature profile is almost symmetric in the weld zone.

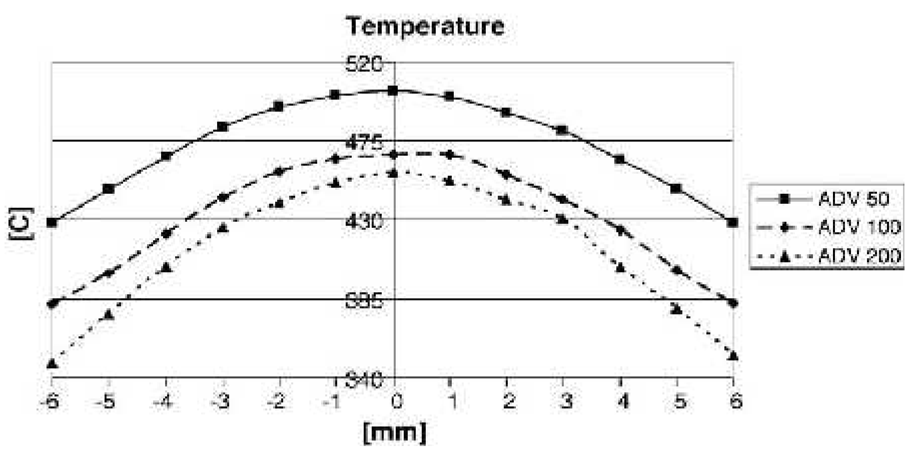

Fig1:- Temperature distributions along *x–z* section in FSW joint as a function of advancing speed.

In their paper author conclude and proposed a three dimensional numerical model for FSW process, that is thermo-mechanically coupled, uses rigid-viscoplastic material description and a continuum assumption for the weld seam. With the proposed model the prediction of the effectsof process parameter on process thermo-mechanics, such as the temperature, strain, strain rate as well as material flow and forces can be done. Then the comparison of predicted results and experimental data and good agreement is obtained. Depending upon the preliminary simulation results, it is found that an increase of the maximum temperature and maximum strain in the nugget and an expansion of the heat affected zone with the decrease in advancing speed. Because the heat generation during FSW is dominated by rotating speed of the tool which is much higher than the

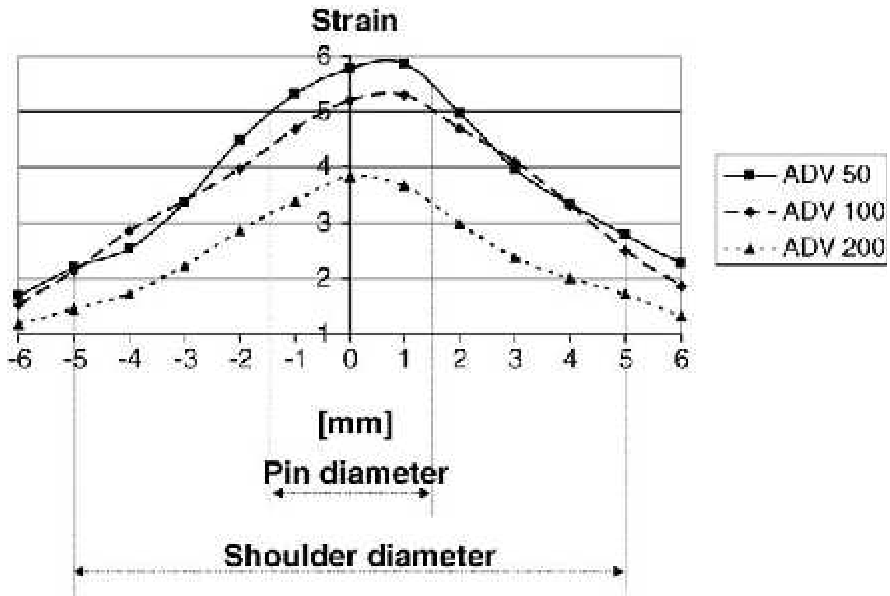

Fig2:- Effective strain distributions along x–z section joint as a function of advancing speed.

advancing speed so temperature distribution about the weld line is nearly symmetric. As the material flow during FSW is mainly controlled by both advancing and rotating speeds so the material flow (deformation) in the weld zone is nonsymmetrically distributed about the weld line.

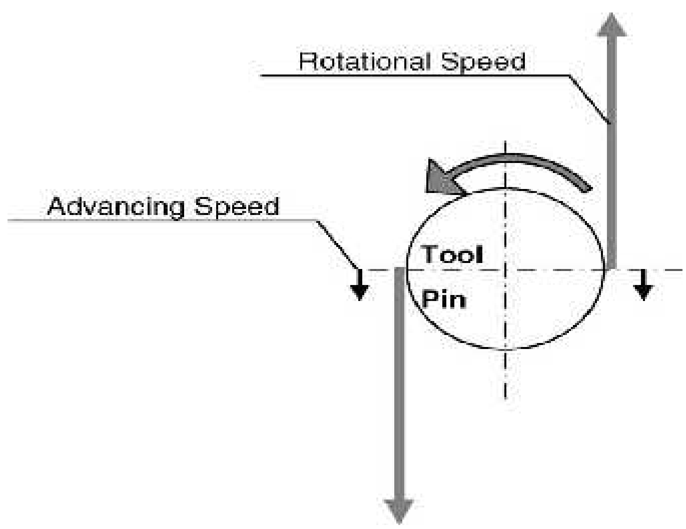

Fig3:- Sketch of the advancing speed and peripheral velocity composition at pin surface.

G.Buffa et al.[3] in this paper discuss about design of the friction stir welding tool using continuum based FEM model. They observed that in friction stir welding (FSW), the welding tool geometry plays a fundamental role in obtaining desirable microstructures in the weld and the heat-affected zones, and consequently improving strength and fatigue resistance of the joint. They in this paper, a FSW process with varying pin geometries (cylindrical and conical) and advancing speeds is numerically modeled, and a thermo-mechanically coupled, rigid-viscoplastic, fully 3D FEM analysis able to predict the process variables as well as the material flow pattern and the grain size in the welded joints is performed. The obtained results allow finding optimal tool geometry and advancing speed for improving nugget integrity of aluminum alloys.

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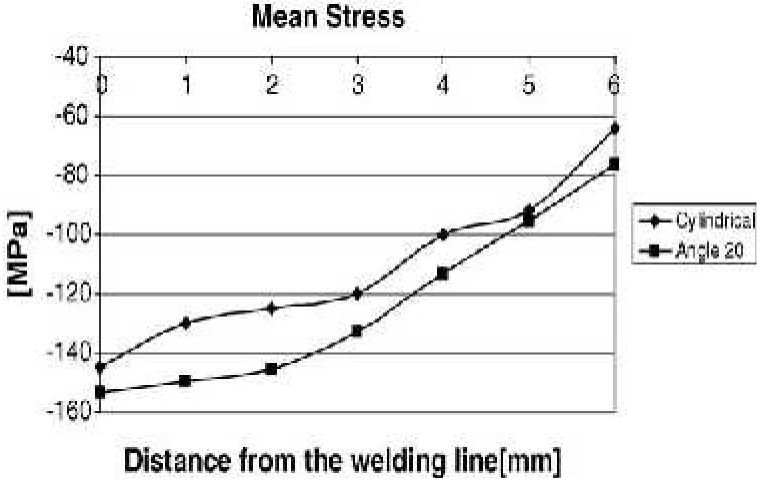

Fig4:- Mean stress along a *x–z* section, advancing side.

They conclude that with increase in the pin angle enlarges both the thermal mechanical zone and heat affected zone results in a bigger size weld nugget. With pin angle, overall temperature in weld zone increase. On increasing the pin angle the plastic deformation in the nuggest zone increases. However as the pin angle is above a certain value the maximum deformation reaches its asymptote and also upto a critical value of the pin angle strain rate also increases. After this value, strain rate reaches its asymptote. They also conclude that a helical movement in the weld zone produces on using a conical pin in FSW process. Due to this movement material flow down in the leading edge and flow up in the trailing edge material circulation and leads to more uniform thorough thickness distribution of parameters. On increasing advancing speed a significant refinement in the grain size is observed. On increasing the pin angle a more uniform grain size distribution and temperature, as well as a wider nugget area are obtained. And they suggests that a tool pin angle of 40◦ and an advancing speed equal to 100 mm/min is an optimal combination for obtaining the best joint strength taking consideration of nugget area, grain size and tool wear as well as welding forces. They also suggest, although the analysis is for the AA7075 aluminum alloy but the present model is also capable to work properly with different workpiece materials, thus become an effective tool for optimal design of tool geometry and process parameters for the FSW process.

Y. Abe et al.[4] in their study discuss about the joinability of aluminium alloy and mild steel sheets using a self piercing rivet and they evaluated it by a finite element simulation and in experiment. They proposed the self piercing riveting because it has potential as a replacement for spot resistance welding generally used for steel sheets, because aluminium and steel has different melting points so it is not easy to apply resistance welding to joining of aluminium and steel sheets.

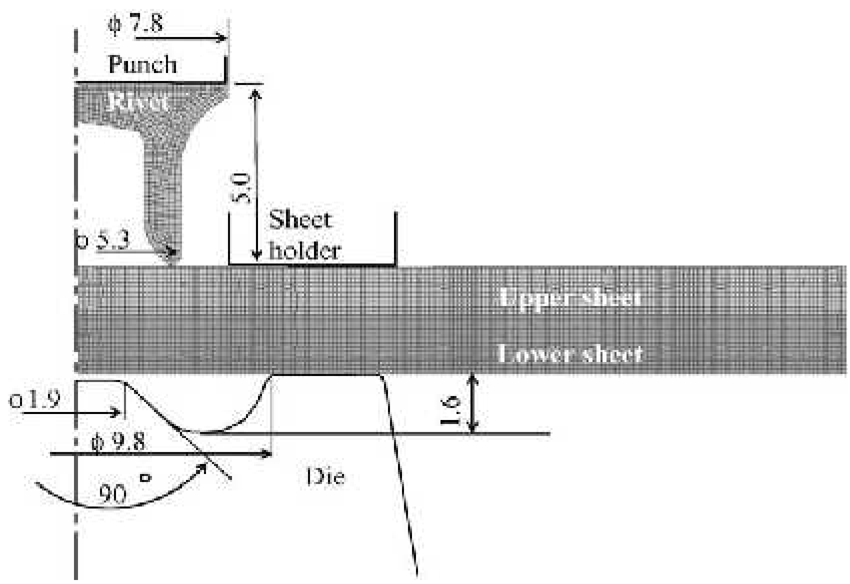

Fig5:- Finite element model for self piercing riveting.

the joining of aluminium and steel sheets is a key technique to increase in the application of aluminium parts. The self piercing riveting is applied to joining of not only aluminium sheets but also aluminium and steel sheets. The optimization of joining conditions is desirable because the joinability deteriorates due to large difference of flowstress between the aluminium and steel sheets. The finite element simulation is effective in determining the optimal conditions.

Takehiko Watanabe et al.[5] tried to butt-weld an aluminum alloy plate to a mild steel plate using friction stir welding, and studied the effects of a pin rotation speed, the position for the pin axis to be inserted on the tensile strength and the microstructure of the joint. They also examined the behavior of the oxide film on the faying surface of the steel during welding. The aluminum alloy base metal shows the maximum tensile strength i.e. 86% of the joint. At the upper part of the steel/aluminum interface a small amount of intermetallic compounds was formed, while in the middle and bottom parts of the interface no intermetalic compounds were observed. At the fracture paths in the joint the the intermetallic compounds formed. The authors applied the friction stir welding to join aluminum alloy containing magnesium to steel. Author concluded that with lower rotation speed leads to the insufficient increase in temperature at the weld and so that a pin was worn out in a short time. With higher rotation speed, there is excessively increased in temperature that leads to burning of magnesium in the Al alloy, resulting in an unsound joint. The author also observed that at the pin offset of 0.2mm toward steel the maximum tensile strength of a joint was obtained in this study. When the offset is large, steel pieces were scattered in aluminum alloy matrix resulting in some voids, and thus leads to decrease in the joint tensile strength. Intermetallic compounds were not formed at the interface between the steel and aluminum alloy. The little intermetallic compound was observed at the upper region of the weld. This leads to a decrease in the joint strength.

Yasunari Tozaki et al.[6] observed that depending on probe length the microstructures of welds varied significantly, tool rotational speed and tool holding time. The thickness of the upper sheet under the shoulder indentation and the actual nugget size are the two particular aspects. At the shortest tool holding time and the slowest tool rotational speed the former decreased with increasing probe length, but in other welding conditions it was nearly the same, while the latter increased with increasing probe length, tool rotational speed and tool holding time. With On increasing probe length the tensile shear strength increased, while the cross-tension strength was not affected significantly by probe length. The tensile shear strength increased and while the cross-tension strength decreased with increasing tool rotational speed and tool holding time.

S. Bozzia et al.[7] produce a joint of 2mm thickness IF-steel to a 1.2mm thick Al 6016 has been performed by friction stir spot welding. At the interface Al 6016/IF-steel the intermetallic compounds have been identified and quantified as a function of tool penetration and the rotational speed. TEM observations indicated the presence of tangles of elliptical intermetallic compounds. The influence of IMC on tensile shear strength has been established. An IMC layer seems necessary to improve the weld strength, but if the layer is too thick, cracks initiate and propagate easily through the hard IMC tangles. Author investigated the interface Al 6016/IF-steel in FSSW spots. It aimed at characterizing the intermetallic compounds (IMC) formed during spot welding. IMC layer thickness increases with the penetration depth and the rotational speed. IMC structure and hardness depends upon conditions of welding. An IMC layer seems to be necessary to improve the weld strength, but if the IMC layer is too thick cracks initiate and propagate easily through the brittle IMC tangles. For a rotational speed of 3000rpm and a tool penetration depth of 2.9mm an optimal IMC layer thickness of 8_mhas been measured.

In this paper C.M. Chen and R. Kovacevic [8] with combined effect of solid state welding and effect of fusion performed the joining of AISI 1018 and aAL6061. The process is derived from friction stir welding (FSW) but with slight change that in this an adjustable offset of the probe location with respect to the butt line is maintained. Metallographic studies has been conducted by electron probe microscopy, optical microscopy, and the utilization of the X-ray diffraction technique. The author observed that in the weld zone the intermetallic phases Al13Fe4 and Al5Fe2 exist. During the welding significantly worn of tool during welding and after traveling 100 mm at a rotational speed of 917 rpm tool get broken. The structure of the weld is significantly affected by the wear of the tool, and breakage of the tool was detected by the incorporated acoustic emission (AE) sensors. The author observed that the joining of an AISI 1018 steel to Al 6061 alloy with a sound heterogeneous weld microstructure is feasible using this process and the detection of tool breakage can be carried out by the AE sensing technique.

In their study author conclude that to joining of AISI steel and Al 6061can be carried out by combined effect of solid state welding and effects of fusion. During welding they observed intermettallic compounds in the nuggest zone . they also observed due to wear of tool lessen homogenization of structure and formation of hole at the welding zone. The author observed that the joining of an AISI 1018 steel to Al 6061 alloy with a sound heterogeneous weld microstructure is feasible using this process and the detection of tool breakage can be carried out by the AE sensing technique

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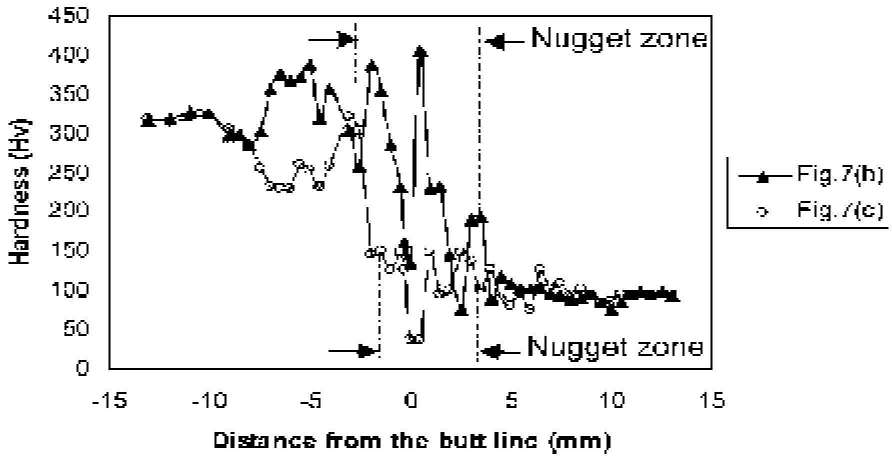

Fig 6:- Microhardness profiles in the mid-thickness of FSW cross-sections

.III BENEFITS OF FSW

Friction stir welding (FSW) has been successfully used to join materials that are difficult-to-weld or unweldeable by fusion welding methods. Friction sir welding (FSW) has many benefits over the conventional methods. In FSW there is good dimensional stability, repeatability, No loss of alloying elements, Fine microstructure and absence of cracks. In FSW no shielding gas and surface cleaning is required. With FSW dissimilar metals like aluminium and steel can be joined effectively. It become a hot cake for automobile industries because they stress upon reduction of weight by using alternate metals. FSW is a solid phase process and there is low distortion of work piece. It eliminate grinding wastes and saves consumable materials. Improved materials use as it can join materials of different thickness. Due to fabrication of joints by FSW fuel consumption in light weight aircraft automotive and ship applications [9].

IV CONCLUSION

Friction Stir welding (FSW) is a major point of interest for industries. Hard materials such as steel and other important engineering alloys can now be welded efficiently using this process. Dissimilar metals can be easily joined with sound results using FSW. With FSW materials even with different thickness can easily be joined and hence there is saving of material and otherwise reduction in wastage of materials. By using FSW reduction in the defects are observed and improving uniformity of weld properties and, at the same time, expanding the applicability of FSW to new engineering alloys. FSW can weld aluminum and copper of > 75mm thickness with single pass. With FSW the automobile industries getting great benefits as by using dissimilar metals in industries properties of numerous metals can be benefitted. Although friction stir welding (FSW) has been successfully used to join materials that are difficult-to-weld or unweldeable by fusion welding methods, it is still in its early development stage and, therefore, a scientific knowledge based predictive model is of significant help for thorough understanding of FSW process

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