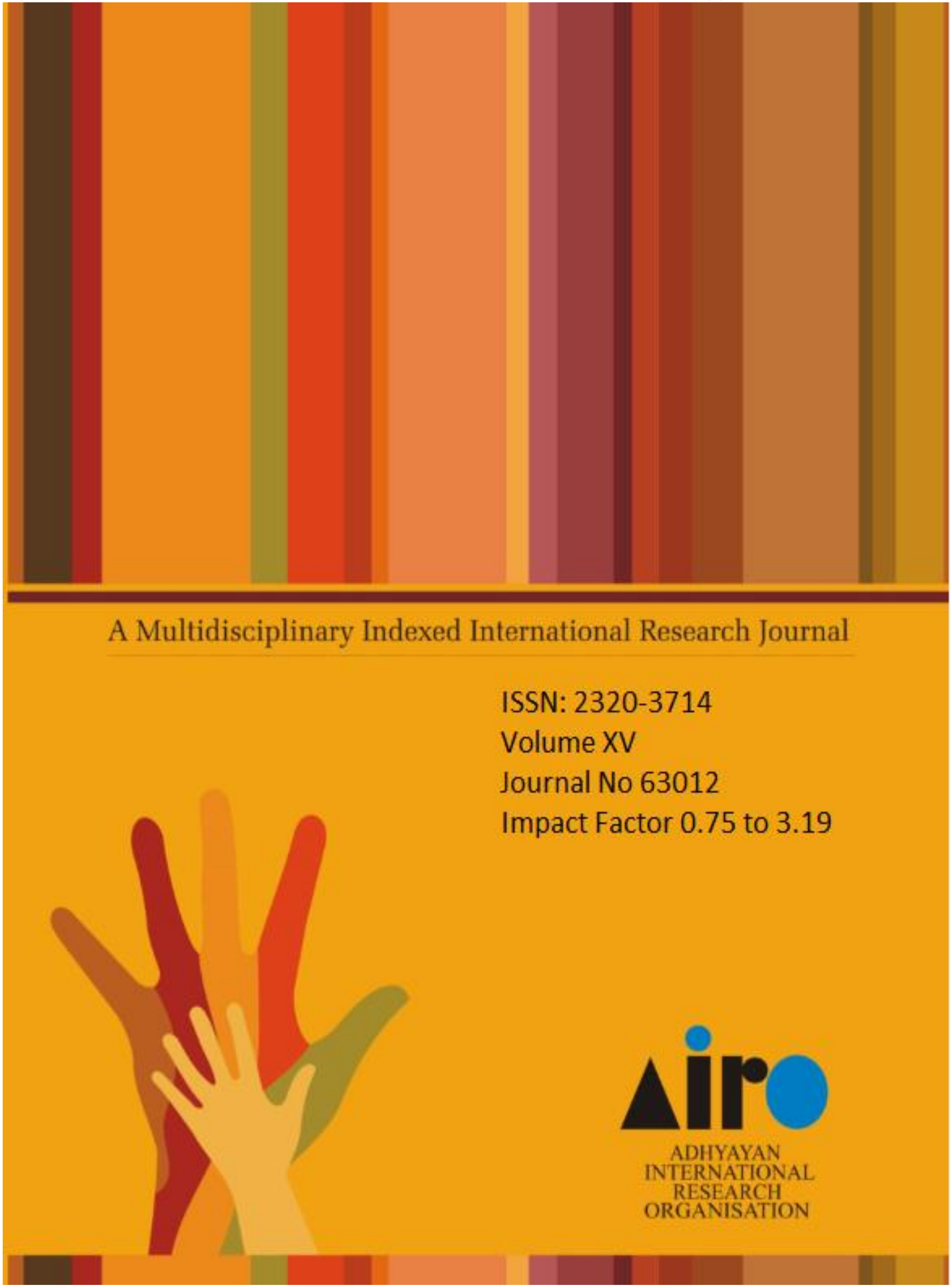

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A REVIEW ON UTILIZATION AND OPTIMIZATION OF FRICTION STIR SPOT WELDING PROCESS IN AUTOMOTIVE AND AEROSPACE INDUSTRIES

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ABSTRACT

Friction Stir Welding (FSW) is an innovative strong state joining process. This process was, in first time, create to join the comparable aluminum plates yet now the innovation can be used to weld an expansive area of materials comparable or unique. Friction Stir Welding (FSW) process was invented and experimentally demonstrated by The Welding Institute (TWI) in 2009 for joining Aluminum composites. Friction Stir Spot Welding (FSSW) is a variation of the FSW which is observed to be natural well disposed and a productive process. FSSW strategy has been gaining ground when compared to protection spot welding (RSW) and could be used in different industries including, vehicles, send building, aerospace, electrical and development. FSSW has been effectively used to join a few materials used in the previously mentioned industries. In this survey, FSSW examines are quickly condensed as far as the evolving microstructure and mechanical properties between aluminum amalgams and different materials, for example, copper, steel and magnesium and principles of FSSW instruments are considered.

Keywords— *Aluminium, Copper, Friction Stir Spot Welding, Magnesium, Steel*

I. INTRODUCTION

FRICTION Stir Spot Welding (FSSW) is a variation of Friction Stir Welding (FSW) process for spot welding applications. A non-consumable rotating apparatus is dove into the work pieces to be joined. After reaching the chose dive profundity, the rotating instrument is held in that situation for a pre-determined time now and again alluded to as abide period. Therefore, the rotating device is withdrawn from the welded joint leaving behind a friction stir spot weld. During FSSW, device entrance and the stay time frame essentially determine the heat generation, material plasticization around the pin, weld geometry and in this way the mechanical properties of the welded joint. A schematic delineation of the FSSW process is appeared in Fig.1 [1].

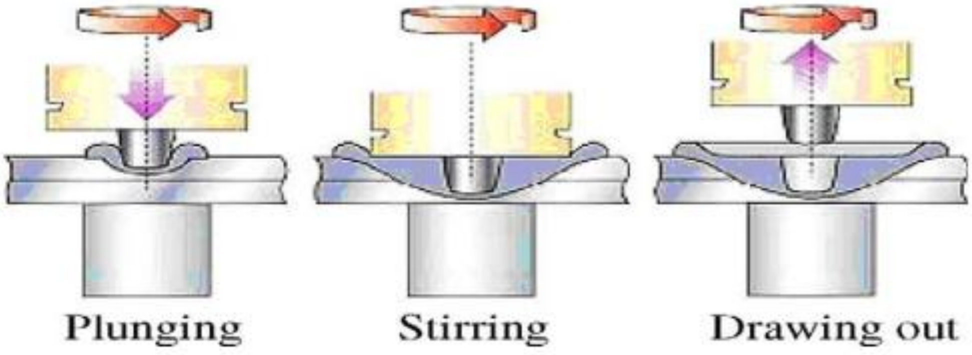

Figure 1 Schematic illustration of Friction Stir Spot Welding process

FSSW process utilizes a tool, like the FSW tool. The shoulder creates main part of the frictional or deformational heat though; the pin aids material stream between the work pieces. Other than the tool, alternate parameters involved in FSSW are, the tool pivot speed; tool dive profundity and the abide period. These parameters determine the quality and the surface finish of the welded joints. A terminology is required to precisely portray the distinctive micro structural locales display after FSSW. The cross area of the spot weld demonstrates the five characteristics including the Parent Material (PM), the Heat Affected Zone (HAZ), Thermo mechanically Affected Zone (TMAZ), The Stir Zone (SZ) and the Hook as appeared in Fig. 2.

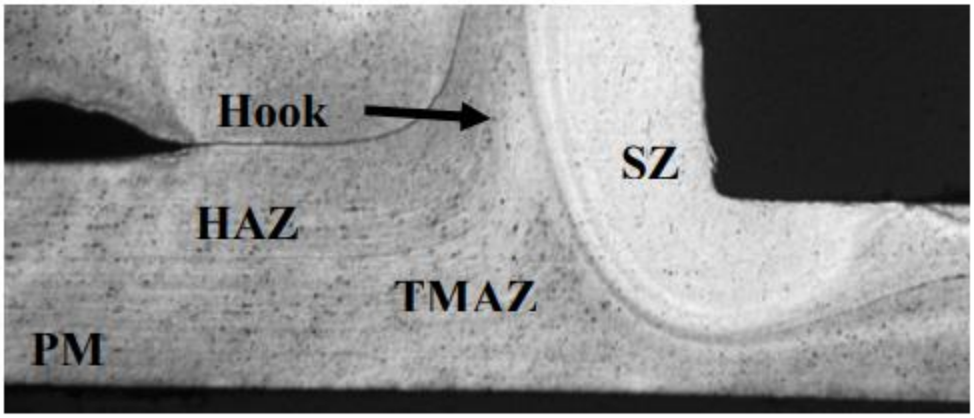

Figure 2 Cross-sectional appearance of a typical Friction Stir Spot Weld

The Parent Material (PM) is the material that is remote from the welded district that has not been distorted; in any case it might have encountered warm cycling from the weld. This isn't affected by the heat as far as the microstructure or the mechanical properties. The Heat Affected Zone (HAZ) is the locale which lies nearer to the weld-focus and has encountered a warm cycle during welding which has adjusted the microstructure and/or the mechanical property, there is no plastic distortion in this area. While, the Thermo mechanically Affected Zone (TMAZ) is found in the locale where the tool has plastically disfigured the material. In a few materials, it is conceivable to obtain noteworthy plastic strain without recrystallization in this district. There is a distinct limit between the recrystallized zone and the TMAZ. The Stir Zone (SZ) is the completely recrystallized locale that is, in the quick vicinity of the tool pin. The grains within the stir zone are generally risen to and frequently a request of magnitude littler than the grains in the parent material. While, the Hook is a characteristic component of Friction Stir Spot Welds in lap design where there is an arrangement of a geometrical imperfection originating at the interface of the two welded sheets. There are numerous distributed surveys on Friction Stir Welding and processing however so far there is no nitty gritty audit on Friction Stir Spot of comparable and different materials. This survey paper is focused on showing the current status of FSSW amongst comparable and unique materials and recommendations to fill the holes to expand FSSW industrially.

FSW can be utilized toward any path without observing the effect of gravitational consequences for the process. This strategy can create joints operating on hardware based on conventional machine tool innovations, and it has been used to weld an assortment of comparable and different compounds. The best piece of FSW is plan of welding tool. Least complex type of tool is appeared in figure 3.

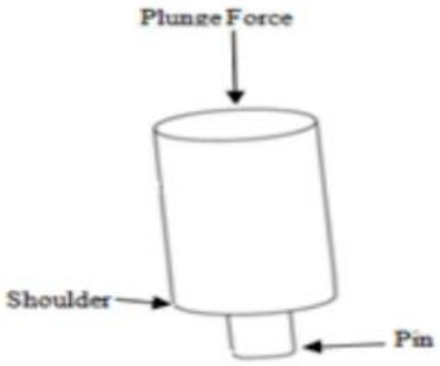

Figure 3 Friction-stir welding tool profiles

II. WORKING PRINCIPLE OF TOOLS

The working principle of friction stir welding is appeared in figure 4. The cylindrical tool is clipped on the pivot spindle of the friction stir welding machine and the work piece plates are firmly braced on an apparatus such that the work-piece appearances to be joined are kept from being constrained separated. After that the rotating tool is gradually dove between the parting lines of the two plates that should be weld together. The frictional heat delivered between revolution tool and the work piece, mollifies the work piece material without reaching its melting point. This heat encourages the development of the tool along the weld line during welding. The plasticized metal is then transmitted to the trailing edge of the tool pin. Besides it is manufactured by contact of the tool bear and the pin profile.

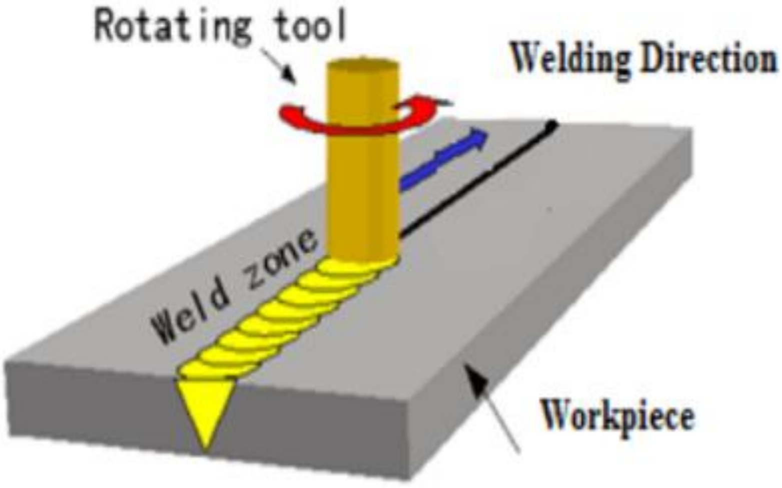

Figure 4 Schematic representation of FSW Principle

III. FSSW BETWEEN ALUMINIUM ALLOYS

Various investigations have been directed on Friction Stir Spot Welding between Aluminum amalgams throughout the years. ***Uematsu et al*** joined T4 treated 6061 using a twofold acting tool consisting of external level shoulder and inner retractable test, which could re-fill test gap. The microstructures of the weld zone were grouped into MZ (blended zone) and SZ, where fine measured up to grains were seen because of dynamic recrystallization during FSSW process. They additionally found that the rigidity of the joint was enhanced by a re-filling process in light of the fact that the compelling cross sectional area of the nugget was increased [2]. ***Merzoug et al,*** directed trials on AA6060-T5 using a tool steel of the sort X210 CR 12 and the rotational speed of the tool went from 1000 to 2000 rpm. The elastic tests made it conceivable to set up that the example delivered at 1000 rpm and 16 mm/min has a decent quality of welding, which has 5 kN to 16 mm/min and 1000 rpm compared to 1.98 kN for 25 mm/min and 2000 rpm. The smaller scale hardness moved toward the most extreme value as they moved far from the nugget zone [3].

Zhang et al, spot welded AA 5052-H112 of 1 mm thickness. They reasoned that softening happens in the welds. A minimum hardness of 19.2 HV, which equivalents to 45.7% of that of the PM, was estimated in the HAZ. Also, hardness in the TMAZ and SZ enhanced because of the recrystallization which influences the hardness distribution to show a W-molded appearance 13.The joints quality abatements with increasing tool rotational speed, while it is relatively independent of the given tool abide times [4]. ***Shen et al*** used AA 7075-T6 plates of 2 mm thickness, the rotational velocities and the abide time were differed, which were 1500, 1750 and 2000 rpm, and 3, 4 and 5 s, separately. They investigated the microstructure and the mechanical properties of the refilled FSSW of AA7075-T6. The keyhole of the weld was refilled effectively; the microstructure of the weld shows varieties in the grain sizes in the width and the thickness bearings as portrayed in Fig 5 [5].

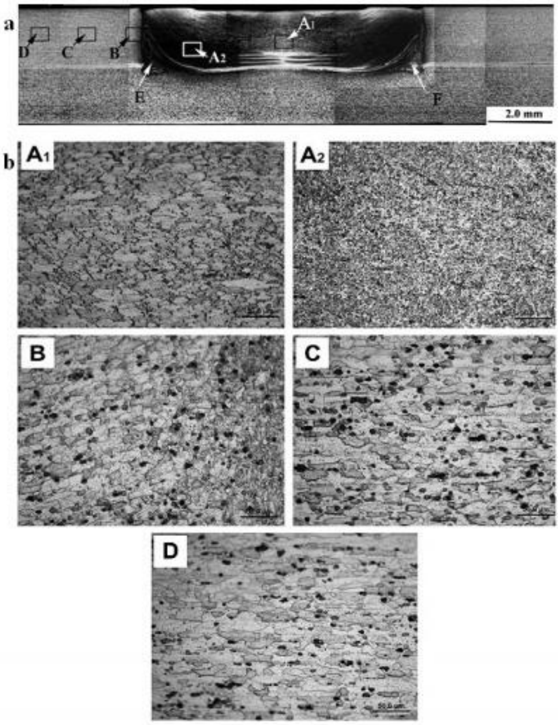

Figure 5 Microstructures on longitudinal section of RFSSW joint made at welding condition of the rotational speed of 1200 rpm and dwell time of 4 s: (a) cross section of weld zone, (b) magnified views of the regions A1-D marked in a, respectively

Tozaki et al, joined AA6061-T4 sheets with 2 mm thickness using distinctive tests lengths of 3.7, 3.1 and 2.4 mm with a shoulder width of 10 mm. The tests were made of fast steel (Japanese Industrial Standard (JIS), SKD61) and had a standard metric M3.5 left-hand string. A consistent tool dive rate of 20 mm/min and a shoulder dive profundity of 0.2 mm underneath the upper plate surface were connected. Moreover, the tool rotational paces and the tool holding times were likewise changed, which were 2000, 2500 and 3000 rpm, and 0.2, 1 and 3 s, separately. They watched that, the microstructures of the welds differed essentially depending on the test length, tool rotational speed and tool holding time and the tractable shear quality increased with increasing test length. Badarinarayan et al joined tempered AA 5083 sheets with two unique thicknesses of 1.64 and 1.24 mm. The tool bear distance across was 12 mm with a curved profile, and the pin length was 1.6 mm. The two diverse pin geometries are regular cylindrical and triangular pin. They inferred that the tool pin geometry altogether influences the snare. In the FSSW-C (cylindrical pin) weld, the snare runs steadily upward and then sidesteps the stir zone and points descending towards the weld base. While, in the FSSW-T (triangular pin) weld, the snare is coordinated upward towards the stir zone and closures with a short plateau [6]. ***Wang et al*** joined financially unadulterated AA1050-H18 sheets with a 300µm thickness. The examinations comes about recommend that under lap-shear loading conditions, the disappointment is initiated close to the SZ in the center piece of the nugget and the disappointment engenders along the circuit of the nugget to final break. The area of the initial necking/shear disappointment is close to the conceivable original indent tip and the disappointments of the Friction Stir Spot miniaturized scale welds were cracked through the TMAZ close to the weld nuggets [7].

Yuan et al, spot welded 1 mm thick AA6016-T4 sheets using two tools. They used a regular tool (CP) and a topsy turvy tool (OC) to deliver the welds. The CP tool with an inside pin has a sunken shoulder with 10 mm distance across and a 1.5 mm long advance spiral pin with root breadth of 4.5 mm and tip measurement of 3 mm. While, the OC tool was include with the same curved shoulder shape and width, and three topsy turvy 0.8 mm long hemispherical pin highlights. The two tools were machined from Densimet tungsten amalgam. Results indicated that the tool turn speed and the dive profundity significantly influenced the lap-shear detachment loads [8]. Besides, the two tools showed most extreme weld division load, around 3.3 kN at 0.2 mm bear entrance profundity; diverse tool revolution speeds, 1500 rpm for the CP tool and 2500 rpm for the OC tool.

Thoppul and Gibson, used AA6111-T4 to delivered spot welds. From the smaller scale auxiliary investigations, obviously increasing the processing time increases both the tool profundity of infiltration and the bonding area between the lap joints. Su et al investigated the Friction Stir Spot Welding of 5754 and Al 6111 sheets using a tool having a smooth pin with or without an abide period and spot welds were made using a strung tool without the application of a stay period. They didn't watch different intermixing in the spot welds made using a tool with a smooth pin with or without the application of a stay period. They additionally suggested that different intermixing during the abide period in spot welding comes about because of the incorporation of upper (Al 5754) and lower (Al 6111) sheet materials at the highest point of the string on the rotating pin [9].

IV. FSSW BETWEEN ALUMINIUM AND MAGNESIUM

FSSW process has been effectively used to Friction Stir Spot Weld aluminum to magnesium used particularly in the car and the aerospace industry. Wang et al effectively joined Al compound AA5754 to Mg combination AZ31. Their microstructure examinations demonstrated that the grain structure advancement in the stir zone was affected by grain limit dissemination, interfacial dispersion and dynamic recrystallization, which brought about fine equiaxed grains of Al12Mg17 in the weld focus. Though the hardness profile of the Mg/Mg comparable weld showed a W-formed appearance, the lower hardness values appeared in the TMAZ and HAZ of both Mg/Mg and Al/Al comparable welds. In the Al/Mg divergent weld, a characteristic interfacial layer consisting of intermetallic compounds Al12Mg17 and Al3Mg2 was identified. Both the Mg/Mg and Al/Al comparative welds had fundamentally higher lap shear quality, disappointment energy and weariness life than the Al/Mg different weld. While the Al/Al weld showed a somewhat bring down lap shear quality than the Mg/Mg weld, the Al/Al weld had higher disappointment energy and weariness life.

Chowdhury et al used FSSW process to spot weld business AZ31B-H24 Mg and AA5754 with a thickness of 2 mm. They used a tool produced using H13 tool steel which had a width of 13 mm for the looked over shoulder and 5 mm for the left-hand strung pin. A pin length of 2.8 mm, tool rotational rate of 2000 rpm, tool dive rate of 3 mm/s, tool evacuation rate of 15 mm/s, bear dive profundity of 0.2 mm and abide time of 2 s was used. There was a nearness of intermetallic compounds (Al12Mg17 and Al3Mg2). The small scale hardness profile of the Mg/Mg weld showed a Wshaped appearance, where the hardness step by step increased towards the keyhole bearing [10]. Chowdhury et al led an examination on FSSW of Commercial AZ31B-H24 Mg and AA5754-O Al compound sheets with a thickness of 2 mm were chosen for FSSW. They watched a distinctive interfacial layer consisting of Al12Mg17 and Al3Mg2 intermetallic compounds in the Friction Stir Spot Welded disparate Al/Mg and Mg/Al glue joints. Besides, they expressed that in correlation with the Al/Mg weld without cement, the degree of forming the intermetallic compounds diminished in the unique cement joints. They likewise watched a significantly higher hardness with values in the middle of HV90 and 125 in the stir zone of Al/Mg and Mg/Al cement welds because of the nearness of intermetallic compound layer 30. It was likewise watched that both Mg/Al and Al/Mg glue welds had altogether higher lap shear quality and disappointment energy than the Al/Mg disparate weld without glue.

Choi et al Friction Stir Spot joined 6K21 Al amalgam and AZ31 Mg composite with a tool made of general tool steel (SKD11) and made out of a shank, a shoulder, and a pin. The shoulder breadth, pin width, pin tallness and weld tilt angle of the tool were 13.5 mm, 9.5 mm, 0.5 mm and 0o, separately. The obtained comes about showed the arrangement of intermetallic compounds (IMCs) in the interface between the Al and Mg composite joints. These intermetallic compounds were uncovered as Al3Mg2, shaped on the Al substrate, and Al12Mg17, framed on the Mg substrate. Furthermore, the thickness of the IMCs layer increases with increasing tool pivot speed and length time, and significantly affects the qualities of the joints. Considerable thicknesses of intermetallic compounds layer genuinely break down the mechanical properties of the joints. The most extreme malleable shear break load of the Al and Mg combination joint was around 1.6 kN, nonetheless, the load value diminished with increasing of tool pivot speed and length time, owing to the splits in the Intermetallic compounds (IMCs) [11].

V. FSSW BETWEEN ALUMINIUM AND STEEL

Chen et al welded 1 mm thick 6111-T4 Al and DC04 low carbon steel sheet. The tool had a 11 mm distance across steel bear, with a parchment profile to enhance the stream of material, and a decreased 3 mm measurement WC 1 mm long test. The range of the tests orbital way was 2.5 mm which delivered a cleared area of 8 mm breadth on the steel surface. They delivered top notch friction spot welds between thin Al and steel car sheet within a weld time of 1 second which is a coveted target time by industries [12]. ***Sun et al*** used a sunken molded shoulder geometry tool with a breadth of 12 mm and a test with a width of 4 mm to FSSW a 1 mm thick business 6061 Al combination and a gentle steel. They watched no conspicuous intermetallic compound (IMC) layer along the Al/Fe interface subsequent to producing the welds. Besides, they watched that the shear tractable disappointment load can achieve a most extreme value of 3607 N. The pin length has little impact on the weld properties, which indicates that the tool life can be essentially stretched out by this new spot welding strategy [13].

Bozzi et al joined AA 6016 (1, 2 mm thick) to an excited IF-steel sheet (2.0 mm thick) using a tool machined into tungsten rhenium combination (W25Re). The intermetallic compounds layer thicknesses increases with the rotational speed and the infiltration profundity. They additionally saw that the intermetallic compounds is by all accounts important to enhance the weld quality, yet in the event that the intermetallic compound layer is too thick splits initiate and proliferate effortlessly through the fragile intermetallic compounds layer [14]. Figner et al Friction Stir Spot Welded HX340 LAD sheets of steel of 1 mm thickness and aluminum AA5754-H111 of 2 mm thickness. They saw by using legitimate choice of spindle speed and stay time, the quality of the spot weld can be enhanced essentially. In this way, a greatest load in the shear pressure trial of 8.4 kN per spot can be accomplished while by increasing the abide time, the measure of intermetallic phases (IMP) increases and severs, causing a drop in the quality. More research should be directed to streamline the process so as to utilize FSSW amongst Aluminum and Steel industrially [15].

VI. FSSW BETWEEN ALUMINIUM AND COPPER

Endeavors have been made to create Friction Stir Spot Welds amongst Aluminum and copper. This area synopses examines led and distributed. Ozdemir et al and Heideman et al have effectively Friction Stir Spot Welded a 3 mm thick AA1050 to unadulterated copper and 1.5 mm thick AA6061 – T6 to oxygen free unadulterated copper individually. It was seen while conducting an investigation on the existing writing on FSSW amongst Aluminum and Copper that very few distributed outcomes are accessible, accordingly, it is of significance that more research must be led to streamline the process to empower it to be used as an other option to riveting and Resistance Spot Welding [16].

They delivered spot welds with no plainly visible imperfections and the grains on the copper side near the Al/Cu interface were finer than those of copper base metal. The distinction in the grain sizes was credited to the impact of the rotating pin which disfigured the grains near the interface and the recrystallization of grains in the stir zone of the copper metal because of heat input. Besides, the EDS examinations led uncovered the development of hard and fragile intermetallic compounds AlCu, Al2Cu and Al4Cu9 shaped at the interface. The elastic shear test comes about demonstrated that 2.8 mm dive profundity delivered poor outcomes though 4 mm dive profundity demonstrated the most noteworthy values of shear malleable test compared to the 5 mm, it was suspected to be because of the entrance of Cu into Al in a more diffused manner. They additionally indicated that the hardness increases at the base district of the pin gap (in the Cu material) because of heat input introduced by the rotating pin. Moreover, they expressed that as the dive profundity increases, the grain estimate diminishes, which caused higher hardness at the Cu side for the 5 mm dive profundity and because of more diffuse and particular entrance of Cu into Al for 5mm dive profundity, higher hardness values were obtained on the Al side.

The tool used was a strung pin configuration using a prehardned H13 tool steel with a shoulder of 10 mm, pin measurement of 4 mm and the string pitch of 0.7 mm. Two distinctive dive profundities were used: 0 and 0.13 mm and two diverse weld times of 3 and 6 seconds. They used revolution speeds varying from 1000 to 2000 rpm. Besides, they indicated that, the dive profundity, revolution speed and tool length were the primary variables affecting the quality of the welds. There was no nearness of an inter-metallic interface in the solid welds; they were just in the type of little particles that don't associate along the bond line to wind up most inconvenient to the weld quality. Heideman et al additionally demonstrated a vertical cross area of the spot weld with a Cu ring appearing on each side of the keyhole. Cu rings pictures with their estimations using distinctive process parameters are shown in Fig 6.

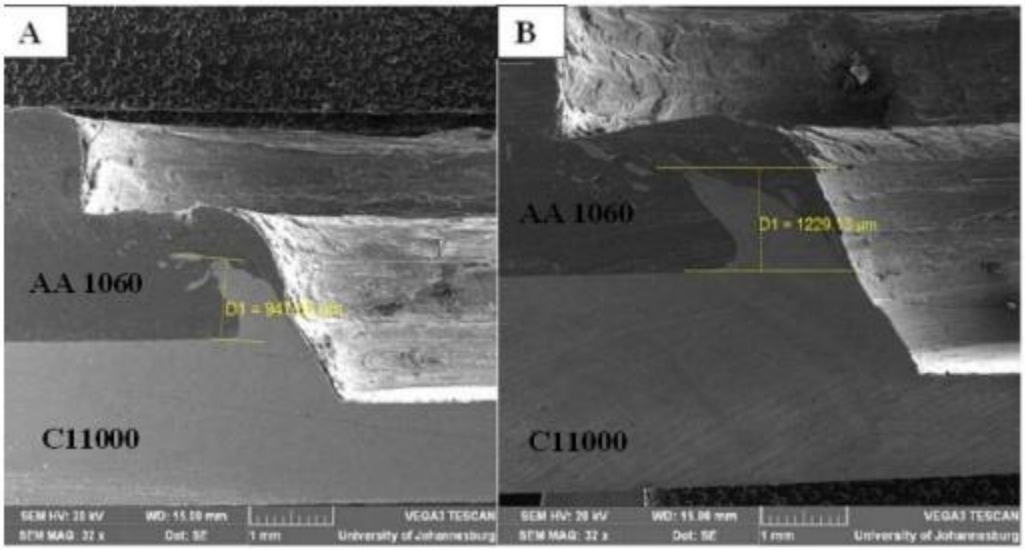

Figure 6 Copper ring size of weld produced using conical pin (3mm length) and a concave shoulder (15mm diameter) at welding conditions of 800 rpm and 0.5mm (A) and 1.0 mm (B) shoulder plunge depth.

Up until this point, no distributed work is accessible on the improvement of tool geometry and welding parameters to deliver sound Friction Stir Spot Welds (Al/Cu). Hence, it is of significance to effectively direct investigations on the enhancement of the tool geometry and process parameters to create spot welds amongst Aluminum and copper using Friction Stir Spot Welding process with a specific end goal to bridle the commercialization of the process.

VII. CONCLUSION

As per previously mentioned investigations, it is prominent that materials like aluminum and magnesium composite and hard materials, for example, steel can be welded ably with FSW procedure. Different enhancement techniques moreover Taguchi and regression demonstrate are possible to enhance the outcomes. It was discovered that distinctive input parameters on various materials have critical impact on microstructure and mechanical properties of the weld. A writing audit has been led on the FSSW process of different and comparable materials. It demonstrates that huge innovative work of the FSSW process has been accomplished worldwide and this process has built up itself as a reasonable joining alternative for the car and aerospace industries. Be that as it may, more looks into should be additionally led to completely understand and streamline the process. It was additionally seen that very little significance has been appeared on producing FSS welds amongst aluminum and copper which could be an elective answer for riveting and Resistance Spot Welding (RSW) since spot welding amongst aluminum and copper could be valuable in making electrical associations and segments. Despite the fact that, the capacity of FSSW to join lightweight, high quality aluminum composites to different materials, for example, magnesium, copper and steel is attractive, extending this process into high melting temperature materials has demonstrated challenging because of tool cost and tool wear rates. It is normal that if the process is connected productively, it can be a technical and economical process compared to the conventional welding processes.

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