Friction stir welding of comparable AZ91 Mg alloys was studied and tested

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Abstract: -Due to the extremely reactive nature of magnesium (Mg) alloys, fusion welding is complicated. In the presence of oxygen, magnesium quickly oxidized. As a result, solid-state fusion welding procedures are the ideal approaches for welding Mg alloys. AZ91 Mg alloy sheets were bonded by friction stir welding (FSW) in this study, and the joint quality was tested using microstructural investigations and micro hardness measures. According to the findings, the joint was defect-free, and the size of the huge intermetallic that emerged in the base alloy was reduced. These findings point to Al dissolution in an Mg matrix. Micro hardness tests demonstrate the enhanced hardness in the weld zone caused by the FSW.

Keywords: joining, magnesium alloys, friction stir welding, AZ91.

Received: June 4, 2022. Revised: September 8, 2022. Accepted: October 7, 2022. Published: November 3, 2022.

1. Introduction

The primary property of the material was strength to weight ratio the weight of the material particular density (1.735 g/cm3) and then compare the base material i,e aluminium specific density (2.34 g/cm3), [1,3,5,7]and this material having the good damping property. Another characteristic of magnesium is its limited ductility and poor welding properties. The AZ-91[2,4,6,10] material is available on the market in the form of casting billets, which may be converted into slices and then back into the desired shape, such as rectangular, square, or round, and it has a very poor machining property as well as a very excellent damping property. AZ-91[8,13,15] material is mostly used now a days for structures, the automobile industry, aerospace industry, medical industry, marine industry and robotic industry, especially for end effectors for the Robot and we are triggering this material especially where we decrease the weight . Among all the Aluminium-based magnesium combination AZ series material especially in this material contains Aluminium and zinc composition it have separate proportions are in terms different Proportions and this FSW process was explained by Mishra.Mating of Magnesium alloy is very difficult by applying normal welding process because this material easily reacts with oxygen and easily the thermal property for this material is too high . Then we use the other fusion-based machining technique, which is friction stir welding. This process developed a solid-state phase fusion welding technique and mated two comparable and non-similar junctions, and this challenges and constructing a metallurgical joint between AZ-91 and AZ-91 [11,21,33,34] alloy by FSW process was completed. In this process I carried out the tensile test and microstructure, Micro Vicker's hardness and finally we made the SEM test also Ease of Use. Invented by Wayne Thomas of TWI Ltd in 1991, friction stir welding (FSW) overcomes many of the problems associated with traditional joining techniques. FSW is a solid-state process that produces high-quality welds in difficult-to-weld materials such as aluminum and is becoming the process of choice for manufacturing light transportation structures such as boats, trains, and aircraft. Manufacturers are under increasing pressure to produce stronger, lighter products that use less energy, pollute less, cost less, and faster than ever before. FSW is a repeatable, low-energy, solid-state mechanical process capable of producing very high-strength welds in a wide variety of materials, offering a potentially low-cost, environmentally friendly solution to these challenges. Offers. The

FSW was manufactured by his TWI Ltd. invented and developed. Therefore, in addition to well-founded basic scientific knowledge, we have extensive experience in industrial application of processes. FSW is a solid-state joining process that produces high quality, high strength, low strain joints that can be butt or lap joined in a variety of material thicknesses and lengths. A

rotating FSW tool is inserted between the two clamped plates. Frictional heat forms a plasticized zone around the tool. The rotate tool moves along the connection line. A hardened solid phase bond is formed. Because

FSW is a solid state process, it eliminates many of the deficiencies associated with fusion welding techniques such as shrinkage, freeze cracking and porosity. His TWI membership of

includes many of the world's suppliers of FSW equipment. TWI is a leader in solid state friction welding and manufacturing technology. We have been active and innovative in welding research and development since the 1960s, responding to industry needs and providing consulting services to all industries.

Industry support includes consulting on component design, process selection and quality issues, troubleshooting, feasibility and pre-production testing, and application and prototyping development. We also accept orders for small-lot welding and overlay welding.

TWI has been responsible for many important innovations and developments in solid state bonding. Invented at TWI, friction stir welding has been rapidly adopted by the industry. Linear friction welding has evolved into a mature joining process for turbine blades. Friction stir welding (FSW) is a solid-state welding process in which a rotary tool is guided along the join line between her two workpieces. Used to connect two opposite faces. During welding, friction generates heat and mechanically separates the metal from the weld. FSW differs from normal friction welding in that frictional heat is generated by a separate wear-resistant tool rather than the parts between them. The

friction stir welding process uses a rotating tool consisting of a cylindrical shoulder and a small probe or pin protruding from the bottom, as shown in the photo. During welding, the shoulder rubs against the top surfaces of the two parts, generating frictional heat, and the pin or probe simultaneously generates additional heat by mechanically mixing the metals.

2. Experimental Work:

- Billet The composition of magnesium alloy material is as follows: aluminium requires (8.1 to 9.30) but it contains 9.14 percent, zinc requires (0.4 to 1.0Max) but it contains 0.86 percent, manganese requires (0.13 to0.35 max) but it contains 0.2 percent, copper requires (0.10Max) but it contains 0.09 percent, silicon requires (0.2Max) but it contains 0.13 percent, ferrous requires 0.05 percent but it contains (0.01 percent), and nickel requires 0.01 percent. This AZ-91 particularly maintains a distinct composition [11,12]. Alloy. he friction-mix welding process is performed by rotating and translating a pin and shoulder set that sets a specific profile on the surfaces of the materials to be joined. The pressure and rotational motion that the tool exerts on the surface creates friction and heat on the surface. This softens the material being welded and provides the mixture with a pin with a special profile in the welding area. A feed motion given to the tool will perform a weld along a given line. Application examples of friction stir welding are shown below.

Friction stir welding as a cold pressure welding process has been successfully used to join dissimilar metals and alloys requiring high performance, especially where strains and residual stresses are undesirable. The friction stir welding process can be applied to sheets and plates of various thicknesses. Friction stir welding (FSW) is a solid-state joining process in which a rotary tool is guided along the join line between her two workpieces. Used to connect two opposite faces. During welding, friction generates heat and mechanically separates the metal from the weld. FSW differs from normal friction welding in that frictional heat is generated by a separate wear-resistant tool rather than the intervening parts. friction stir welding process uses a rotating tool consisting of a cylindrical shoulder and a small probe or pin protruding from the bottom, as shown in the photo. During welding, the shoulder rubs against the top surfaces of the two parts, generating frictional heat. The pins or probes simultaneously generate additional heat by mechanically mixing the metals along the mating surfaces. At the same time, the probe is designed to perform mixing perfectly. The photo shows a typical tool profile used in friction stir welding. Heat is generated from a combination of friction and mixing. During the process the metal does not melt, but softens. Softening of the metal occurs and it becomes highly plasticized. As the tool advances along the joint, the front of the rotating probe forces the metal around it. And the power developed forges metal into sweat cheats. The shoulder therefore helps limit the flow of plasticized metal around the probe.This material was purchased from the Exclusive magnesium alloy in Hyderabad, and the tool was H13 Tool Steel, and the form was Taper threaded pin with a length of 4mm, a width of 5mm, and a shoulder diameter of 15mm. The vertical CNC Milling machine was used to carry out the FSW procedure [13,24]. He FSW is completed with a rotating cylindrical device which has profiled pin (additionally acknowledged a probe) having diameter smaller than the diameter of shoulder. During welding the device is fed right into a butt joint among clamped workpieces, till the probe pierces into the workpiece and shoulder touches the floor of the workpieces.[12] The probe is barely shorter than the weld intensity required, with the device shoulder using atop the paintings floor.[13] After a quick stay time, the device is moved ahead alongside the joint line on the pre-set welding speed.[14] . Friction stir welding follows the easy precept of warmth technology thru friction as its call implies. Name of FSW offers a clean description of its operating precept. It consists of 3 phrases so as friction + stir + welding. Firstly frictional warmth produced among device and workpiece floor melt the paintings piece cloth. Secondly this smooth cloth is stirred with the aid of using rotating device from ahead to backward direction. At final weld is shaped among the plates with the aid of using cooling of stirred cloth. Two separate plates which we need to enroll in clamp collectively on baking plates with a 0 root gap. FSW device that's a mixture of shoulder and pin is inserted among those plates. FSW device rotates among those plates and traverse alongside weld direction. Friction produced at some point of rubbing of device with plate`s surfaces converts into warmth. This frictional warmth paperwork weld among plates [5]. FIGURE 2.1: Schematic of Friction Stir Welding [6]2.2 Heat SourcesThere are reassets that are answerable for manufacturing of warmth in entire process.i. Frictional warmth produced among the device shoulder and paintings-piece cloth surfaces.ii. Heat produced with the aid of using the mechanical blending process (forging and extrusion ofplasticized deformed cloth) [7]. Frictional warmth produced in first degree has functionality to elevate the temperature under the melting temperature of paintings-piece which we need to be joined. Soften cloth receives plastically deformed with the aid of using stirring motion of device and produced warmth with the aid of using mechanical blending. This 2nd degree produced warmth similarly allows the paintings-piece cloth for softening.Heat manufacturing, plastic deformation, and dynamic recrystallization are befell at some point of FSW process. These are accountable to shape distinct zones of micro-shape and cloth properties. Tool shoulder in touch with higher maximum floor of paintings-piece cloth creates an inordinate quantity of warmth as evaluation to backside floor. This distinction in thermal warmth enter and boundary situation are answerable for developing a thru thickness variant in recrystallization and grain boom which results in awesome decrease and higher nuggets. Welds at the least of two cm thick has proven the clean difference among the higher and decrease nuggets. Outside of weld nugget quarter there may be any other cloth quarter.This quarter is referred to as thermo robotically affected quarter (TMAZ). TMAZ is thermally affected and robotically deformed thru stirring device pin at some point of FSW. This quarter is proven as quarter C in following Fig. 2. There is likewise a forth cloth quarter. Being too distance, this quarter isn't suffering from the stirring of FSW device however nonetheless subjected to warmth as warmth become carried out away from the FSW joint at some point of processing. This quarter is called warmth affected quarter (HAZ) [8]. HAZ is proven as D in Fig. 2. FIGURE 2: FSW Zones [8]. Frictional warmth is generated among the wear-resistant device and the paintings pieces. This warmth, together with that generated through the mechanical blending manner and the adiabatic warmth in the cloth, reason the stirred substances to melt with out melting. As the device is moved ahead, a unique profile at the probe forces plasticised cloth from the main face to the rear, in which the excessive forces help in a cast consolidation of the weld. This manner of the device traversing alongside the weld line in a plasticised tubular shaft of steel consequences in extreme solid-country deformation concerning dynamic recrystallization of the bottom cloth.[15]

Fig1.(a)work piece clamping

fig1.(b).material sticking on tool

fig1.(c)material sticking on tool

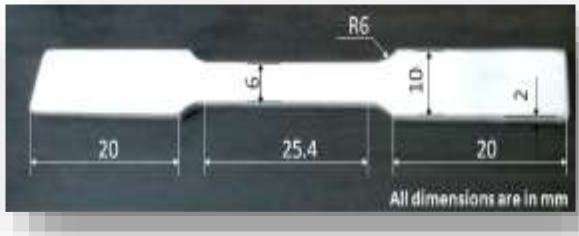
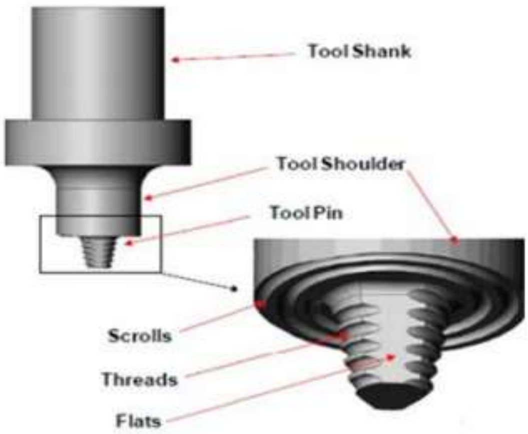


fig1.(d)Machine clamping work pieces

The FSW procedure was carried out on a vertical CNC milling machine. 1200 RPM, 50 mm/min. The work piece is carried on the bed of the Vertical CNC Milling machine, and then we insert the tool by utilising collect and Chuck, [24,27,29]and then we gently apply the force and saddle moment between the work piece and the work Tool. Then, using the axial force and rotational speed, begin the process of mating the two components. The tool will penetrate the work piece up to the Tool shoulder, and the shoulder will touch up to the work piece surface at a depth of 4mm, and then the tool process tool will travel with a 5mm breadth at the top and bottom and a 1mm length [1,5,15,19]. The tool was rotated in the traverse direction and then the process was started at 1200rpm and 50mm tool traverse speed, and the joint was obtained in different condition from the work piece start point and the end point after doing the same practise first I obtained the beads after mating the two pieces into single Butt joint [12]. After successfully connecting the specimens. Then, using a wire cut EDM (electric discharge machine), create a specimen measuring 28mmX10mmX6mm [31,33,35,37,38] from the work piece in a specific place. After the specimen was made, the several types of graded emery sheets were used to polish it, followed by the application of alumina paste and cleaning with ethanol. To begin chemical etching, several chemical etching chemicals (5gm picric acid, 5ml acetic acid, 5ml distilled water, and 100ml ethanol) were used, then the specimen was washed with ethanol and dried



FIG(2).1.Fsw tool

using a drier machine. A polarised optical microscope was used for micro structural observations[12,14,16,18]. Micro Vickers hardness was performed utilising a micro Vickers hardness machine[23] and a total of ten indentions. The Universal Testing Machine can reach the welding joint at a strength rate of (1.25X10 000 s1). Specimen preparation in accordance with ASTM Standard[9]

3. Results and Discussions :-

The above images depict the procedure, i.e. (F.S.W) of Az-91 Mg alloys and the joint created by utilizing a tool rotation speed of 1200rpm and a tool traverse speed of 50 mm. As a result, the quantity of (Mg17Al12) [16,17]phase AZ91 Mg alloy in this same base material has the same brittleness and plastic deformation as AZ91 Mg alloy[28]. And previously, I discussed how the base material reacts during the (F.S.W) process, how the materials phase changes, and how thermal conductivity causes both the tool and the material to phase transform, causing the material to stick on the surface of the [10,11,2]Tool to stick, causing the material and the process to be interrupted or the process to stop**.**

Figure 3.(a) Material peeled surface

stop**.**

*Figure 3.(b**) AZ alloy produced with a pin type probe***

Figure 3.(c) Improper Bead portion

This graphic demonstrates how the material behaves when it comes into touch with the tool and workpiece. This image depicts the difficulties of the machining process. This allows us to learn how the material deforms, fractures, and fails, and how the material adheres to the tool. It indicates that if the plastic deformation is greater in this location, a failure may occur; the circles indicate how the failures may be impacted by the mating of the parts. This results in the joint failing under the F.S.W Process. Thermal strains emerge when the dissipation of heat generated when welding AZ91 / AZ91 [25,28,33] is not uniform owing to differences in thermal conductivity [10]. This heat conductivity of the same alloy also demonstrates the attained flawless joint. It is true that this suggests a higher level of hot crack development during the welding of comparable metals. Thermal strains emerge when the dissipation of heat generated during welding of AZ91 and AZ91 is non-uniform owing to thermal conductivity differences[21]. If these thermal stresses are not balanced, it results in hot fractures, as seen by a microscope in the current joint process at 1200 rpm and 50 mm/min feed. The total amount of heat generation in AZ91alloy is different compared to AZ91 alloy in this part at the same tool rotational speed and traverse speed, and thus obtaining a set of parameters where we avoid development of hot cracks is an important job in joining of AZ91/AZ91[31,33,35,37,39] alloys to get very strong metallurgical continuity.

4. Micro Examination:-

Micro inspection is carried out for a variety of reasons, but it is most frequently done to evaluate the material's structure in order to determine its quality: makes sure the proper heat treatment is used detects [21,23,27,34,36,39]undesirable inclusions and phases Verify that castings are devoid of voids, fractures, and segregations determines the locations of excessive grain growth. For microscopic inspection[34,28], a thoroughly prepared specimen [22]and magnification are required. A strict step-by-step procedure must be followed in order to properly prepare the specimen and the material's surface.

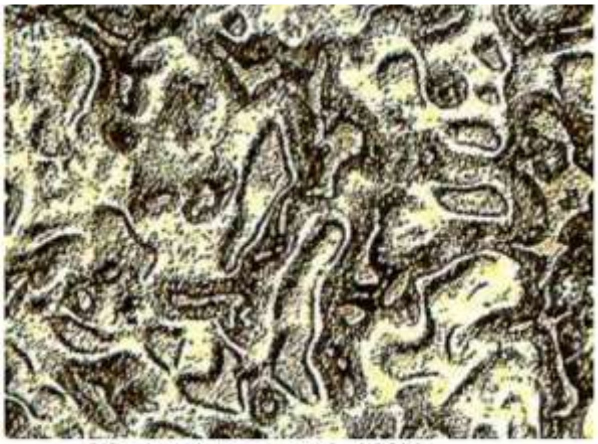


Fig.4.a.Parent metal -100X

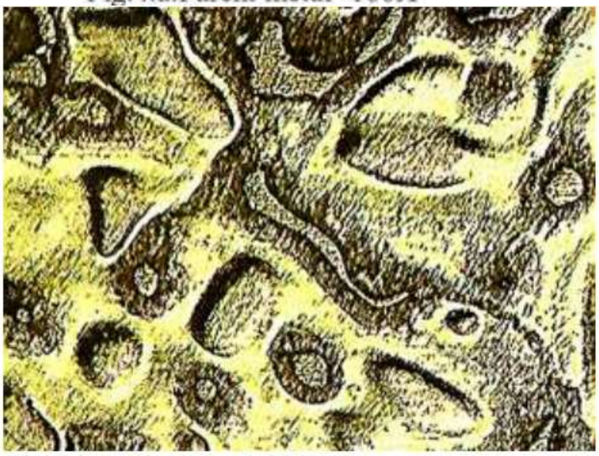


Fig.4.b.Parent metal-200X

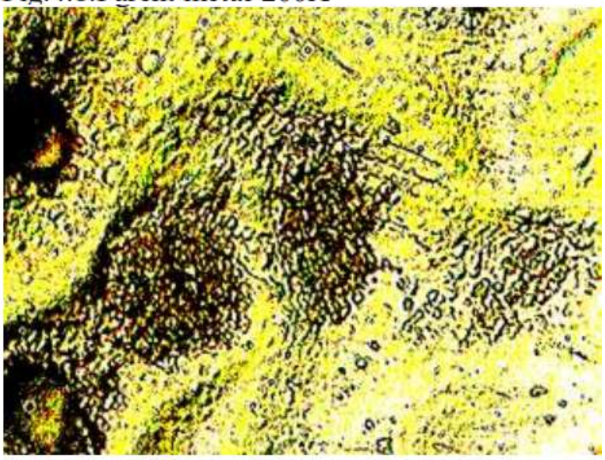


Fig.4.c. Parent metal-500X

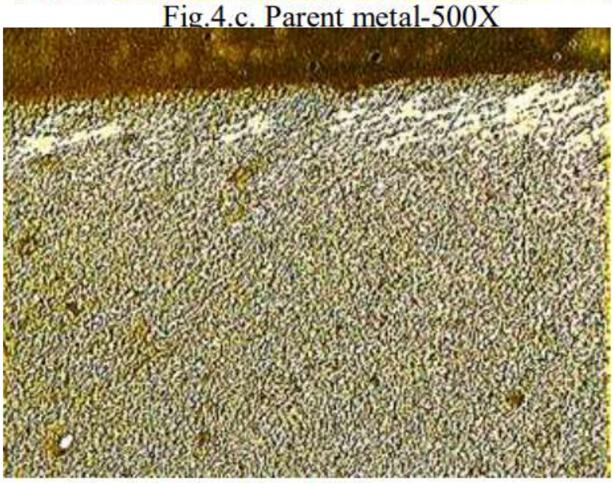


Fig.4.d. Shoulder-100X

Fig.4.e. Shoulder-200X

Fig.4.f. Interface-100X

Fig.4.g. Interface-200X

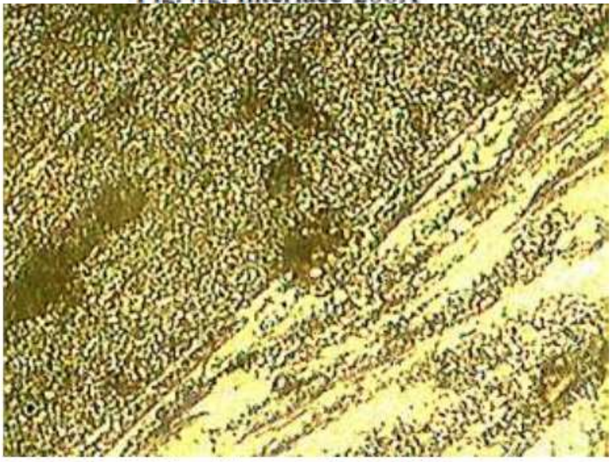


Fig.4.h. Interface-500X

Fig.4.i. Weld-100X

Fig.4.j. weld-200X

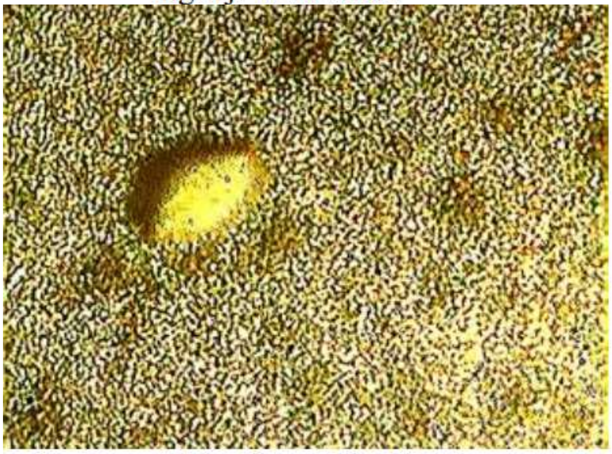


Fig.4.k. weld-500X

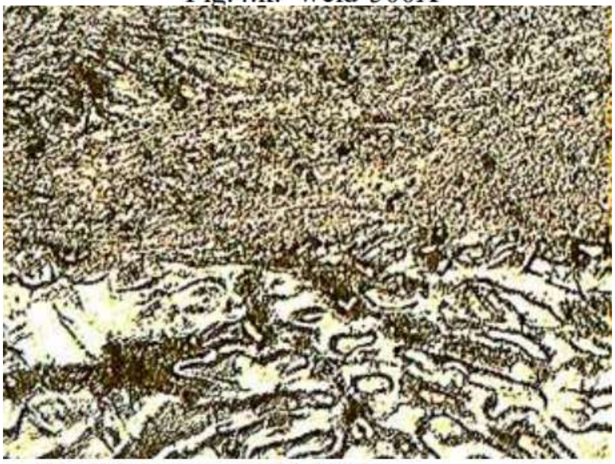


Fig.4.l. bottom weld-100X

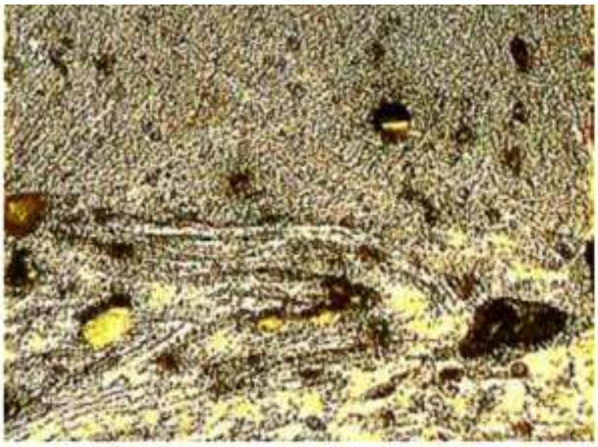


Fig.4.m. Bottom weld-200X

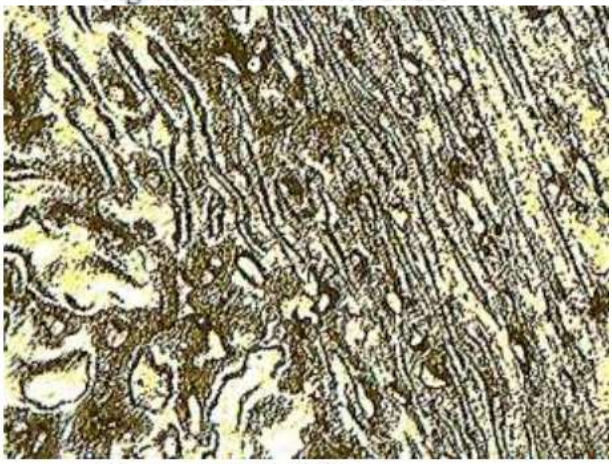


Fig.4.n. HAZ-100X

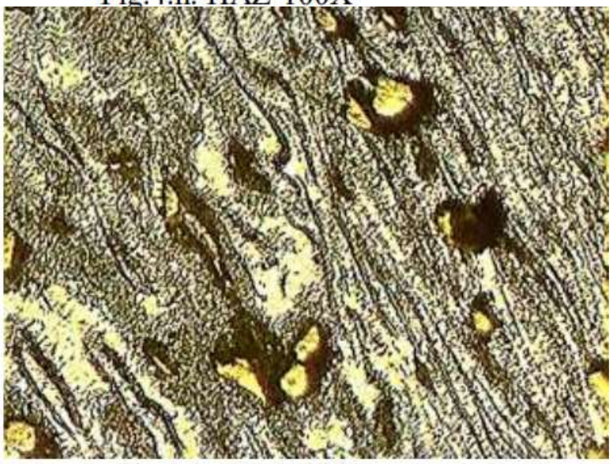


Fig.4.O. HAZ-200X

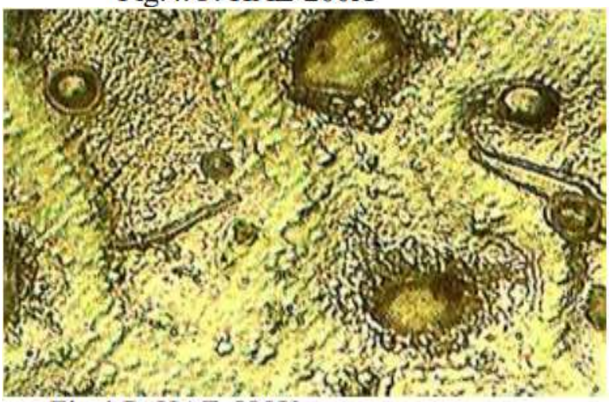


Fig.4.P. HAZ-500X

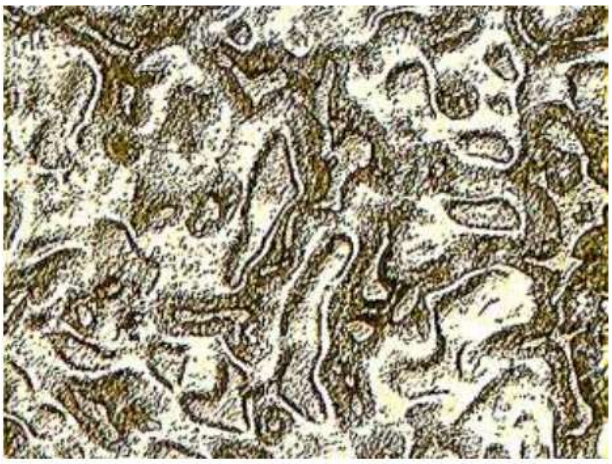


Fig.4.Q. Parent-100X

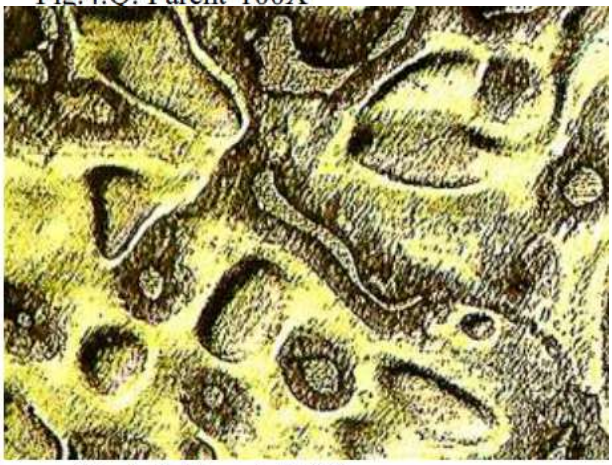


Fig.4.R. Parent-200X

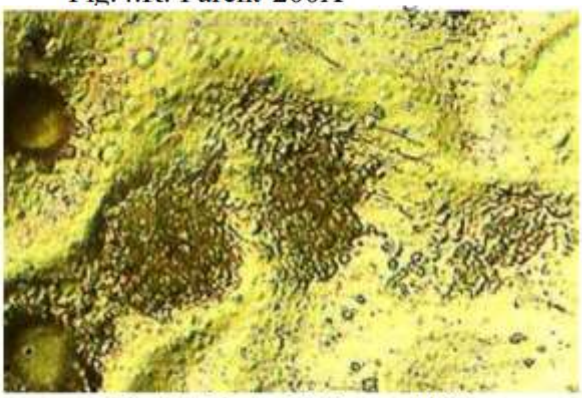


Fig.4.S.Photo-19 Parent-500X

Magnification: 100X, 200X, & 500X. Etchant: Picric+ Acetic acid+ H2O2 soln[5,6]. Figure 4(a,b,c) depicts the microstructure of the parent metal, Magnesium alloy, on the right side of the FSW process. Primary alpha magnesium granules coexist with precipitated beta grains in the microstructure[6,7]. The beta grains are in the eutectic phase of $Mg_{17}Al_{12}$[8,9,10]. The magnifications in Fig.4(a,b,c) vary. The field is the same, specifically the parent metal on the FSW process's left side. The parent metal appeared to be a magnesium alloy cast. Figures 4.d and 4.e [1,9,15,17,257,34]show the microstructure of the FSW process's shoulder zone, where the FSW tool's shoulder has treated the sheet's surface. The microstructure reveals small fractured particles with both alpha and beta grains shattered by frictional heat and stress. Figures 4.f and Fig 4.g & Fig.4.h. [32,37]These photomicrographs were taken at the FSW process's interface zone, which contains both the source metal Mg alloy and the treated nugget zone. The fusion line is the middle line. The heat-affected zone of the parent metal on the right side of the fusion line has experienced plastic deformation and has increased plasticity[8,9]. The plasticity was produced by the greater frictional heat. Primary and secondary phase grains have both distorted. The nugget zone with minute broken grains is seen on the left side of the micrograph. Both alpha and beta grains are stretched along the tool's direction fig4(i,j&k): These photos were taken at the nugget zone's heart (refer to sketch). The microstructure of the alloy displays small broken particles/grains. Figures 4.l and 4.m depict the FSW process’s bottom zone and the interface between the bottom parent metal and the nugget zone.The nugget zone is at the top of the picture, and the parent metal with plastically distorted grains is at the bottom[6,7,8].Figure -(n,o&p): Shows the parent metal heat-affected zone on the left side. The micrograph depicts the influence of heat and stress on grain movement and elongated grains at the nugget zone. Fig.4.(Q&R): This image depicts the microstructure of the parent metal, Magnesium alloy, on the left side of the FSW process[11,12]. Primary alpha magnesium granules coexist with precipitated beta grains in the microstructure. The beta grains are in the eutectic phase of Mg17Al12. Figures a,b, and c are at various magnifications[5,38].The parent metal on the left side of the FSW process has the same name as the field.

5. Tensile Examination:-

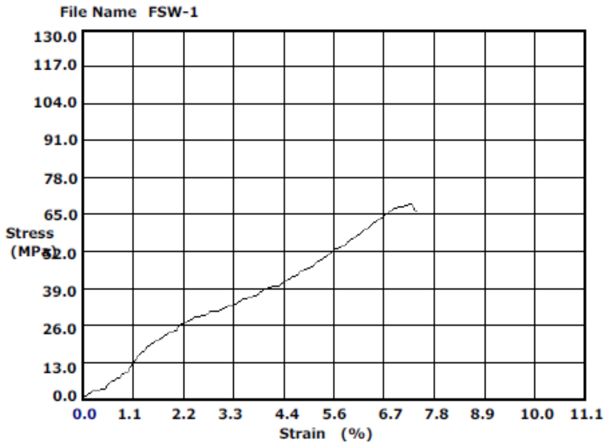


Figure (5) Stress starin Relation for Az91-Az91 Material

In this image, we discuss the failure of the specimen in the centre of the tool, i.e. where we obtained the weld, and we find the length of elogation[21,25,27] and stress/starin relation ship under the weld. Tensile strength: 69.12 Mpa, Yield strength: 60.12 Mpa, Elongation: 1.14 percent are the different numbers obtained from this graph. Following this test, we discuss the Micro vicker hardness utilising the prior micro examination samples.

6. Tensile Fractography:-

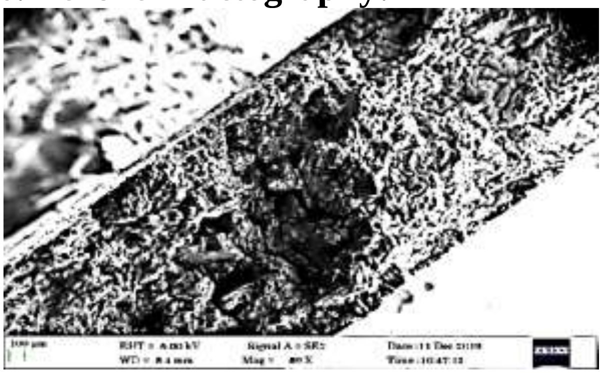


Fig.6.1. Depicts a SEM micrograph

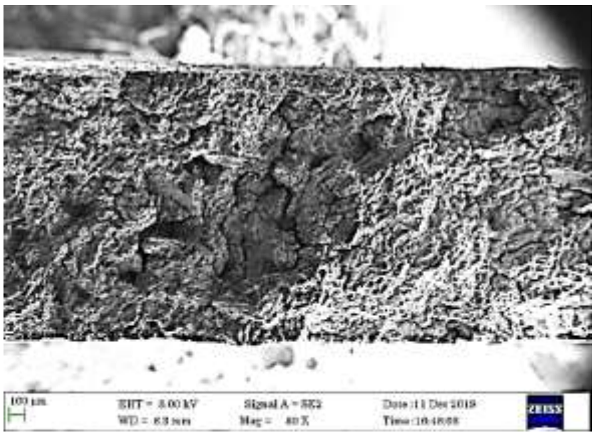


Fig.6.2. Depicts a SEM micrograph

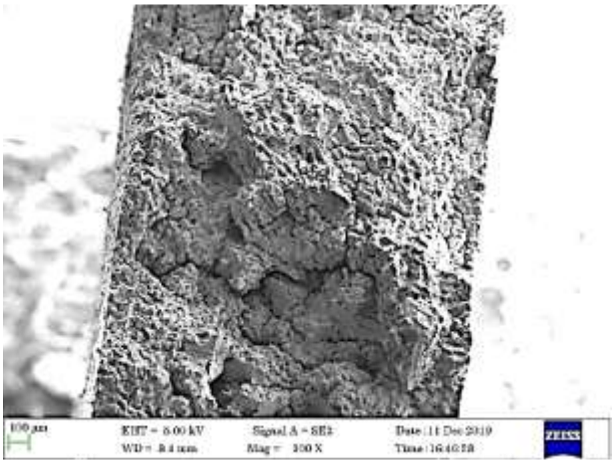
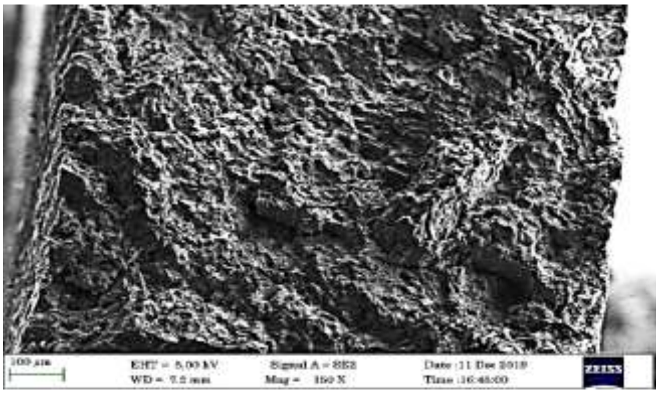


Fig.6.3. Depicts a SEM micrograph



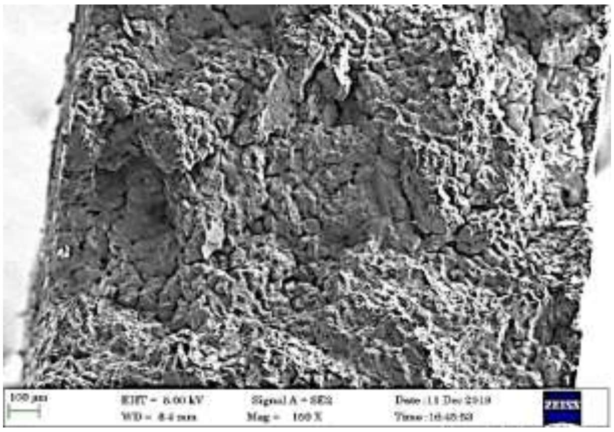


Fig.6.4. Increased magnification
Fig.6.5 Increased magnification

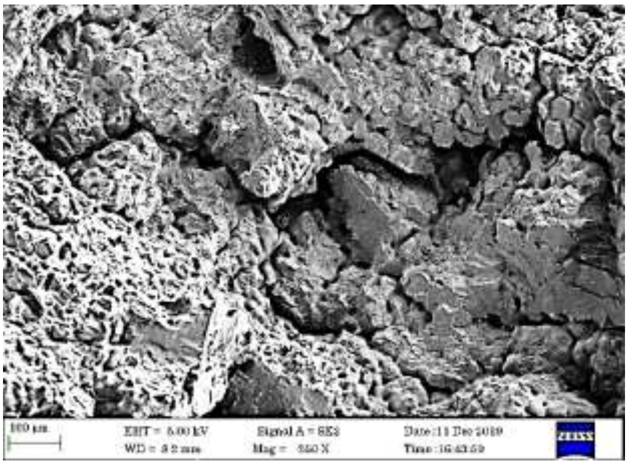


Fig.6.6 Increased magnification First,

Fig 6.6 Increased magnification
The researcher defines the model in the model specification by figuring out each.2Determine the model. All of the model's parameters have a single solution for the specified model.Estimate the model in step three. The stated model includes parameters, and it is necessary to estimate their values using sample data.

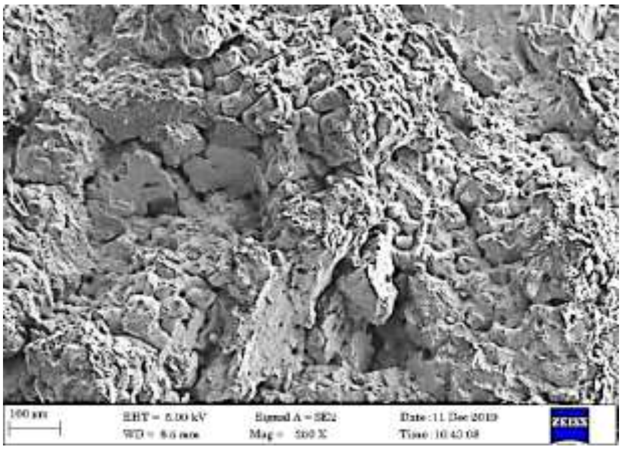


Fig .6.7 Intergranular crack running

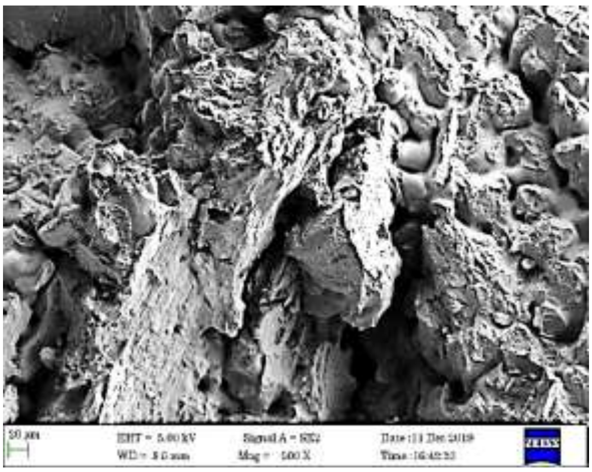


Fig.6.8 Depicts the fractured surface

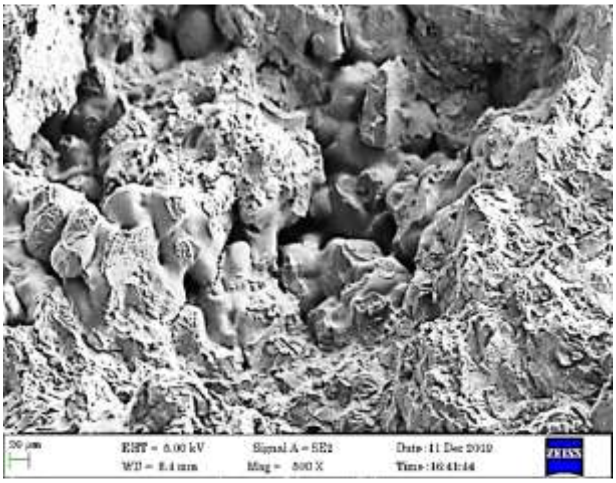


Fig.6.9 shattered surface material.

Fig6(1,2,3) depicts a SEM micrograph of the tensile test specimen's cracked surface. The fracture had formed in the heat-affected zone of the FSw joining procedure. The photo-macrograph depicts the shattered surface's tiny brittle surface morphology. The macro graph also shows a huge dip, which might indicate a casting flaw[34,36]. The two macrographs covered the whole fracture surface. The Sem has an 80X magnification. Fig6.3 shows one field of the broken surface at 100X[12,13]. The trough-like surface, which might be due to a casting flaw, has been rectified by the increased magnification. Fig.6.4,Fig.6.5&Fig6.6.This image depicts the same sample but a different fracture surface[37,38]. The fine-grained morphology of the shattered surface is seen at a higher magnification of 150 X[7,8]. Fig 6.6: The enlarged picture of Fig 6.3 at 250X is seen in this SEM micrograph[34,35]. The cracked surface has formed a thin crack that is perpendicular to the path of tension. At the heat-affected zone, the fracture appears as an intergranular crack running along the direction of grain movement. (See microstructure in images Fig.6.6 and Fig.6.7)[9,10]. Figure 6.7 is a 250X SEM micrograph of the shattered surface[31,32]. The broken surface morphology is brittle with a fine-grained fracture surface and no dimples. Fig 6.8 depicts the fractured surface field with a huge trough [25,29], which might indicate a fault on the material's surface. The enormous trough that occurred at the fracture surface has been resolved by the increased magnification of 500X. Fig 6.9 depicts another fractured surface field[40] with a deep trough that existed at the sample's shattered surface material.

7. Conclusion:-

Finally, we conclude that we successfully mate the two comparable Mg alloys AZ91/AZ91. This method is used in naval and aerospace equipment as well as structure frames. When compared to earlier aluminium alloys, this FSW technique helps to reduce total body weight. This is one of the cheapest processes for combining two metals during the fusion welding stage. In this procedure, we discovered how the material stress, strain, elongation, failures, and SEM analysis, which helps us understand how the material behaves at the micron level. At a higher level, we employ this substance to assist the human body, and we expect to see positive effects in the future.

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