Study and experimental work on Friction stir welding of Similar and Dissimilar AZ31/ AZ91 Mg alloys

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Abstract:-Friction stir welding efficiently bonded two exceptional magnesium (Mg) plates, one with less aluminum (AZ31/AZ91) content as well as the opposite more aluminum (AZ91/AZ31) (FSW). The impact of procedure elements on warm crack improvement was tested. At most efficient procedure situations at one-of-a-kind parameters (AZ-ninety one/AZ-ninety one and AZ-31/AZ-31 comparable aggregate) with one-of-a-kind rpm like (1600,1400,1200) and one-of-a-kind feed charge like (25,50,75) mm/min feed under this sound weld 1400 rpm with 25 mm/min feed,), a valid metallurgical joint with great grains and dispersed (Mg17Al12) phase inside the nugget zone become achieved and parallel(AZ-31/AZ-ninety one multiple mixtures). A growing fashion in hardness measures has also revealed extended aluminum dissolution in the nugget region. The AZ31 Mg alloy aspect (advancing) had a distinct touch between the nugget sector and the Thermo mechanical affected quarter (TMAZ), but no longer the AZ91 Mg alloy side (withdrawing). it is viable to draw conclusions based on the findings. FSW can be used to sign up for assorted metals, including difficult-to-method metals like Mg alloys, and warm cracking may cause completely prevented by deciding on suitable system parameters to gain a sound joint. The impact of manner optimizing values for the joining of AZ91/AZ31 Mg alloy plates at some point of friction stir welding (FSP) became investigated on this observation. A hit joint was installed at a device circular motion of 1100 RPM also device journey space of 25 millimeter/min. The aggregate for holder along with tool rotational and travel speeds has had a large impact on the fabric waft tactics in the nugget region. The microstructural analyses revealed that the joint improvement changed in most cases as a result of the mechanical blending of the additives. The nugget sector changed discovered to be terrible, and there has been a sharp interface on the joint. Microhardness assessments throughout the weld joint addining indicated a lack of entire metallurgical bonding. The presence of magnesium and aluminum turned into revealed by way of X-ray diffraction material examination on weld area. From this result of the early observations, it may be concluded that FSP may be used to combine AZ91 Mg alloy and Az31 alloy; despite the fact that complex demanding situations in fabric blending require additional exploration.

Keywords:-Similar, Dissimilar, Az-31/Az91, FSW Process, Nugget Zone, Thermo mechanical, HAZ, TAMZ

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1. Introduction :

The ability to form permanent bonds between dissimilar metals is essential to the advancement of high-performance lightweight systems with improved gas performance in automotive programs. On the other hand, combining incompatible metals using a phase of solid state welding practices is technological demanding in fabrication shops [1]. Non-ferrous metal systems such as aluminum (Al) alloys and also magnesium (Mg) alloys was so much recognized and widely used in structural applications. Today's layout and manufacturing business has ever-increasing requirements for connecting dissimilar metals. In this regard, combining two non-ferrous metals expands the range of utilization within manufacturing trading companies. It is difficult to register different alloys in the same base material [2]. Welding of compatible alloys is particularly complex when simple materials such as Al-Mg, Al-steel and Mg-steel are chemically unique [3,4]. The melting coefficient, heat transfer charge, temperature-related plastically phase change , and amorphous crystal structure for the basic materials was most influential facts that made it as difficult as nature to incorporate liquid lands in Al and Mg alloys [1, 3]. Alternatively, friction stir welding process (FSW), a powerful technique development for joining like a dissimilar sheets not melting the as per shape , was becoming increasingly common like solid-phase joining of steels. Most of the Mg-based diverse welding research work has been done using his one of his Mg alloys in the AZ collection as the Muse material. [7] effectively bonded an AZ31-Mg alloy to a zinc-coated low-carbon metal, with the appearance of low-melting-point eutectic segments that allow greater diffusion between the magnesium alloys. reported that it was created as a result of And steel together. [8] Magnesium alloy AZ91, which he modified to Al3Mg2, was mixed with embedded eutectic of -Mg and Mg17Al12, and the lap shear force of the joint changed to AZ31 magnesium alloy on the right.alloy.

Material	% Of Elements Weight							
	MG	AL	ZN	SI	MN	CR	Ferrous	O
AZ31	96.54	2.34	0.63	0.005	0.19	0.00	0.01	0.00
AZ91	89	8.3	0.35	0.00	0.00	0.00	0.00	0.00

Table.1.Material composition

Conshohocken [9] refers to the formation of intermetallic layers of his Mg17Al12 and Al3Mg2 within the multi-welded region of Al5083 and AZ31 alloys [10] effectively welded sheets of AA5754 and AZ31 and found that have stress, ductility stages of the mate parts were reduced comparing at underlying material for total process parameters [11] Using FSW fig(1) he attached an AZ31-Mg alloy sheet to his 1060 Al alloy and observed a touch with a lamellar structure. Additionally, a center line break within the weld joint was found due to the generation of Al3Mg2 and Al12Mg17 steps within the weld region [12] found similar brittle fractures in AZ31-O welded joints. FSW Advanced Mg alloy alloy due to the critical mixing of soil materials in the stirring area. It is also observed that the tensile energy [12] of sweat tissue is reduced compared to each basic substance.. [13] suggests that intermetallic compounds (between Mg and Al) are formed at certain stages [7] during mating of AZ91 alloy to less carbon steel also AM60 Mg composition into DP600 second -segment steel.In old painting work done , FSW was successfully join AZ31 / AZ91 Mg alloy, but galvanic corrosion reduced the corrosion performance of the joints [14]. As previously mentioned, mechanical mixing of dissimilar metals is an important mechanism for forming bonds. Fabrics with and without a base layer [15,16]. However, there is insufficient information in the literature regarding mating of AZ91 Mg and Az-31 alloy[6]. As a result, FSW used AZ91 magnesium alloy and Az31 magnesium alloy for fasteners in this study. Several combinations of fixture rotation speed and tool travel speed were used to achieve a good bond. The essential factors determining fabric flow in welds of various steels were studied through microstructure examination and also microvickershardness measurements at the mating joints[9]. What ever , as per literature on mating AZ91-Mg / AZ-31 alloys is incomplete. As a final result, in modern research FSW used his AZ91 and AZ31 magnesium alloys for fastening. Various examination at tool circular motion and also fixture circular rotation were uses to obtain high quality joints. The key factors that determine material flow in characteristic metal welds have been studied by microstructural observation and microhardness measurements in welded joints.

2.Experimental work :-

Fig.1. Vertical Machining Centre

Fig.2. Make &Model : Kitamura X2 Mycentre.

Vertical or Horizontal, fig(2)Kitamura has the five-Axis machining solution [10] to give you the aggressive area needed to system all your complex, multi-sided elements in a single set-up. Kitamura's Trunnion desk design gives the users elevated accuracy and rigidity, simple set-up and simplicity of programming for the operator and permits for max stiffness and versatility with the ability to put the paintings piece toward the spindle. 4+1 or full simultaneous control, our five-axis line up has you blanketed.For the trials, sheets of the alloys AZ91 Mg (specific Magnesium, Hyderabad, India) and A31 (NUFIT PIPING answers) measuring 100x50x6mm each were fabricated the idea substances' chemical is indicated in desk The portions of labor were placed on the work surface of Fig. 2,3,4,5 and 6. snap shots showing (a) the paintings components make-up on the work surface of the FSW tool and (b) the popular milling machine that were employed on this work.a trendy-motive CNC milling gadget (Kitamura)and an FSW device produced through FSW turned into utilised to complete the operation.composed of 15mm shoulder diameter H13 tool steel, apin with a five-1mm taper and a 4mm distance [5]. Fig. 1displays a image of the gear and FSW system that have been utilised.in this investigation. It became welded done using a distinctive device (1200, 1400, 1600, and 1800 rpm) rotational prices and distance (25, 50, and 75mm/min) speeds The technique specs had been chosen based totally on the literature and thinking of the gadget's available speed and feed changes out the tests [17]. The weld joint become obtained and analyzed for each mixture of processing parameters.At 1200 rpm, a a hit joint with out a flaws become produced.25 mm in keeping with minute feed.30x10x6 mm every combination 6 specimens were sliced throughout the Microstructural investigations and weld route have been achieved[14]. The samples had been initially polished the use of various specimes find out like comparable and numerous Az31 and Az91 Alloys (1200rpm with 25 mm/min ,50mm,min,75mm/min traverse speed we applied) like simmlar to 1400mm rpm and 1600rpm with similar mating and assorted mating allyos completely I made 18 combinations[3] .Use sandpaper grades was at 2000 grit, usual at clay form sharpening. This samples are well polished. Using wheel polisher and diamond paste. After each step, use ethanol to loosen the sample very well and dispose of any leftovers from the forecasting the grinding step. Chemical etching reagent also used to take picric acid reagents and optical microscopy pictures with polished samples. Germany). When measuring hardness (Omnitech, India), his three samples of 50 x 30 x 4 mm were cut across the weld. Measurements were taken at a period of 0.5 mm, so the ground structure, heat affect zone (HAZ), and thermodynamic nuzzet zone then auto affected zone

(Tmaz) are measured [2]. The weight of 185 gm along with in the dwell time of 15 sec was used for the measurements. Xray diffraction studied (XRD, Baruker Advances D8, Usa) are performed on base metals, welded joints, etc. A scan from 25° to 88° [15]with a step length of 0.1° for CuK emission was achieved.

2.1.Selection of work pieces :-

a) <u>AZ-91 :-</u> A block like 350x45x55mm -1 nos .This we cut by using metal cutter into a different sizes like 110x55x10mm-28 nos.Again we use milling machine to make the piece like 50x100x6.00(+0.1).

b)Az-31:-Directly I buy a material like 50x100x6.00(+0.1)
c)tool selection :-I buy a raw material H13 tool steel like dia25x150-4 NOS
AISI H13 metal is a 5% Cr metal alloy with high molybdenum and vanadium content for ultra high performance equipment. Molybdenum imparts excellent durability and excessive hardening. Vanadium enhances dispersion of difficult vanadium carbides and increases toughness. H13 Device Metal is a hardened metal[16]. It has moderate tempering resistance, moderate thermal fatigue resistance, and excellent hot cracking resistance, while retaining excessive hardness and performance at improved temperatures. It is deep cure, has fully expanded toughness, and can be air cooled to cure large areas. It is also resistant to thermal fatigue, erosion and delamination making it suitable for a variety of high temperature applications. Ideal as a mold cover for aluminum die casting and magnesium die casting. Fig(3).However, H13 metal is susceptible to hydrogen embrittlement and can be nitrided to increase tarnish resistance.

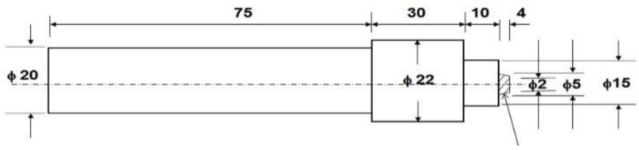


Fig.3.H-13 Tool Steel Material

2.2.Experimental Process:-

2.2.1. Similar butt joint with metal process parameters (AZ-31)/ 25 TTS(Tool traverse Speed)

Fig.4.a.the weld made at 1200RPM at 25 Tool traverse Speed with similar welding Az31alloy ,Fig.4.b. the weld was made at 1400RPM at 25 Tool traverse Speed with similar welding Az31alloy ,Fig.4.c. the weld made at 1600RPM at 25 Tool traverse Speed with similar welding Az31alloy

In AZ31 similar butt welding at 25 tool traverse speed, the weld was made at different RPM , here as per my experimental work we used here CNC -Vertical Milling Machine, a tool was tapered threaded at 4.3mm length will go between the two metals showing in fig.4.(a),fig4.(b),fig.4.(c) AISI H13 m,etal is a 5% Cr metal alloy with high molybdenum and vanadium content for ultra high performance equipment [1]. Molybdenum imparts excellent durability and excessive hardening. Vanadium enhances dispersion of difficult vanadium carbides and increases toughness. H13 Device Metal is a hardened metal. It has moderate tempering resistance, moderate thermal fatigue resistance, and excellent hot cracking resistance, while retaining excessive hardness and performance at improved temperatures[31]. It is deep cure, has fully expanded toughness, and can be air cooled to cure large areas. It is also resistant to thermal fatigue, erosion and delamination making it suitable for a variety of high temperature applications. Ideal as a mold cover for aluminum die casting and magnesium die casting. However, H13 metal is susceptible to hydrogen embrittlement and can be nitrided to increase tarnish resistance.and the width will be at top point i,e tool shoulder the with of butt weld is 5mm and the depth point bottom it touches with 2mm tip and the shoulder to endpoint the length was 4.3 mm , but here we use the material thickness was 6.1 to 6.3mm because we need to achieve the proper weldig. Friction stir welding is currently used to successfully consolidate sheets of AZ31 Mg alloy. Achieving a robust weld between two similar metals has been found to be highly dependent on the speed of rotation [32]and travel of the tool.The tool circular orientation of 1200 Rpm,1400rpm ,1600 rpm along with tool traverse speed of 25 mm/minute were determined to be suitable settings for an FSW fixture along with shoulder dia of 15 millimeter, a tape pin of 5 to 2 millimeter, also the length of 4.35mm. We found that the bonding between AZ31-Mg and AZ31 alloys is often the result of mechanical intermixing and weak metallurgical bonding. The stirred quarter region and the AZ31 similar matrix had a sharp interface according to microstructural observations and microhardness studies. Furthermore, it was found that the second phase of AZ31-Mg [17] alloy faded and the particles of the stirrer became smaller. No significant new values were found in the XRD analysis after FSW. Initial results suggest similar studies to determine the effects of the presence of various metals in welded joints from the mechanical and corrosive behaviourr for joints. Using AZ31 Mg FSW and additional studies on mechanical performance, corrosion range, and AZ-31 base fabric, it is clear that the alloy was AZ31 alloy paltes was joined. Moreover, it was noted that the second segment of AZ31-Mg alloy also small size grains decreased from the stir region. In this case not a significant found values was found in the XRD analysis after FSW[18]. Additional research to determine the impact of using non-identical metals It is proposed to evaluate how the participation at dissimilar materials at the mating parts affects the mechanical then corrosion properties for the joint.

3.Experiment setup with Results and Discussions

3.1.1. Similar butt joint with metal process parameters (AZ-31)/ 50 TTS(Tool traverse Speed).

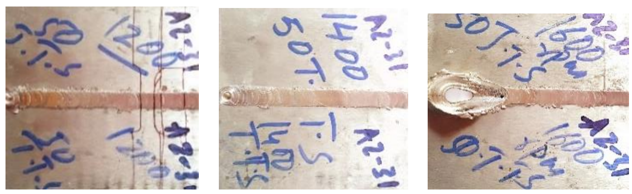


Fig.5.a.the weld made at 1200RPM at 50 Tool traverse Speed with similar welding Az31alloy,Fig.5.b. the weld was made at 1400RPM at 50 Tool traverse speed with similar welding Az31ally,Fig.5.c. the weld was made at 1600RPM at 50 Tool traverse Speed with similar welding Az31alloy

In AZ31 similar butt welding at 50 tool traverse speed, the weld was made at different RPM , here as per my experimental work we used here CNC -Vertical Milling Machine, a tool was tapered threaded at 4.3mm length will go between the two metals and the width will be at top point I,e tool shoulder the with of butt weld is 5mm and the depth point bottom it touches with 2mm tip and the shoulder to endpoint the length was 4.3 mm [19], but here we use the material thickness was 6.1 to 6.3mm because we need to achieve the proper weldig. Friction stir welding is currently used to successfully fig.5.(a),fig5.(b),fig.5.(c) consolidate sheets of AZ31 Mg alloy. Achieving a robust weld between two similar metals has been found to be highly dependent on the speed of circular motion also move the tool. A tool circular motion of 1200 Rpm,1400rpm ,1600 rpm then the tool traverse of 25 milli meter/minute were determined to be suitable settings for an FSW fixture touches the shoulder diameter of 15 millimeter, a taper pin of 5 to 2 mm, and also the measured length of 4.3mm. We found that the bonding between AZ31-Mg and AZ31 alloys is often the result of mechanical intermixing and weak metallurgical bonding. The stirred quarter region and the AZ31 similar matrix had a sharp interface according to microstructural observations and microhardness studies. Furthermore, it was found that the second phase of AZ91-Mg alloy faded and the particles of the stirrer became smaller. No significant new values were found in the XRD analysis after FSW. Initial results suggest similar studies to determine the effects of the presence of various metals in welded joints at mechanical , corrosive behaviour from the joints. Using AZ31 Mg FSW [20] and additional studies on mechanical performance, corrosion range, and AZ-31 base fabric, it is clear that the composition and AZ31 composition plates will be join. Moreover, it was noted that the second segment of AZ31-Mg alloy with low size grains decreased at stir point. Not a significant values are found in the XRD analysis after FSW. Additional research to determine the impact of using non-identical metals It is proposed to evaluate how the supervision of Non similar metals in the welded mate affects the mechanical ,corrosion properties from the joint.

S.NO	RPM/Tool travel speed	25(T.T.S)	50(T.T.S)
1	1200	ok	ok
2	1400	ok	ok
3	1600	ok	ok

Table.2.Machining process done as per the set by step

3.2.Similar butt joint with metal process parameters (AZ-91).

3.2.1. Similar butt joint with metal process parameters (AZ-91)/ 25 TTS(Tool traverse Speed).

Fig.6.a.the weld made at 1200RPM at 25 Tool traverse Speed with similar welding Az91alloy,Fig.6.b. the weld was made at 1400RPM at 25 Tool traverse speed with similar welding Az91ally,Fig.6.c. the weld was made at 1600RPM at 25 Tool traverse Speed with similar welding Az91alloy

In Az91 similar butt welding at 25 tool traverse speed, the weld was made at different RPM , here as per my experimental work we used here CNC -Vertical Milling Machine, a tool was tapered threaded at 4.3mm length will go between the two metals and the width will be at top point i,e tool shoulder the with fig.6.(a),fig6.(b),fig.6.(c) of butt weld is 5mm and the depth point bottom it touches with 2mm tip and the shoulder to endpoint the length was 4.3 mm , but here we use the material thickness was 6.1 to 6.3mm because we need to achieve the proper weldig. Friction stir welding is currently used to successfully consolidate sheets of AZ31 Mg alloy. Achieving a robust weld between two similar metals has been found to be highly dependent on the speed of circular motion and traverese of the tool. A tool circular motion speed of 1200 rpm,1400rpm ,1600 rpm and a tool traverse speed of 50 millimeter /min were determined to be suitable settings for an FSW fixture and also a shoulder diameter of 16 millimeter, a tapered from 5 to 2 mm of pin size , also a length up to 4.3mm. We found that the bonding between AZ31-Mg and AZ31 alloys is often the result of mechanical intermixing and weak metallurgical bonding. The stirred quarter region and the AZ31 similar matrix had a sharp interface according to microstructural observations and microhardness studies. Furthermore, it was found that the second phase of AZ31-Mg alloy faded and the particles of the stirrer became smaller. No significant new values were found in the XRD analysis after FSW. Initial results suggest similar studies to determine the effects of the presence of various metals in welded joints from mechanical, corrosive behaviour from joints. Using AZ31 Mg FSW and additional studies on mechanical performance, corrosion range, and AZ-31 base fabric, it is clear that the compaosition AZ31 comaposition sheets can be mating . Moreover, it was noted that the second segment of AZ31-Mg alloy with low size grains decreased in the stir point . Not a significant enrich values is found in the XRD analysis after FSW[21]. Additional research to determine the impact of using non-identical metals It is proposed to evaluate how the supervision of non similar metals in the mating affects the mechanical, corrosion properties at the joint.

3.2.2. Similar butt joint with metal process parameters (AZ-91)/ 50 TTS(Tool traverse Speed).

Fig.7.a.the weld made at 1200RPM at 50 Tool traverse Speed with similar welding Az91alloy,Fig.7.b. the weld was made at 1400RPM at 50 Tool traverse speed within stir welding Az91ally,Fig.7.c. the weld was made at 1600RPM at 50 Tool traverse Speed with similar welding Az91alloy

In Az91 similar butt welding at 50 tool traverse speed, the weld was made at different RPM, here as per my experimental work we used here CNC -Vertical Milling Machine, a tool was tapered threaded [22]at 4.3mm length will go between the two metals fig.7.a,fig.7.b,fig.7.c and the width will be at top point i,e tool shoulder the with of butt weld is 5mm and the depth point bottom it touches with 2mm tip and the shoulder [34] to endpoint the length was 4.3 mm , but here we use the material thickness was 6.1 to 6.3mm because we need to achieve the proper weldig. Friction stir welding is currently used to successfully consolidate sheets of AZ91 Mg alloy[23]. Achieving a robust weld between two similar metals has been found to be highly dependent on the speed of rotation and travel of the tool. A tool circular motion speed upt to 1200 rpm,1400rpm ,1600 rpm and a tool traverse speed at 50 mm/min were determined to be suitable settings for an FSW fixture with 4.3mm. We found that the bonding between AZ91-Mg and AZ31 alloys is often the result of mechanical intermixing and weak metallurgical bonding. The stirred quarter region and the AZ91 similar matrix had a sharp interface according to microstructural observations and microhardness studies. Furthermore, it was found that the second phase of AZ91-Mg alloy faded and the particles of the stirrer became smaller. No significant new values were found in the XRD [34]analysis after FSW. Initial results suggest similar studies to determine the effects of the presence of various metals in welded joints on the mechanical and corrosive behavior of the joints. Using AZ91 Mg FSW and additional studies on mechanical performance[35], corrosion range, and AZ-91 base fabric, it is clear that the alloy and AZ91 alloy sheets can be joined. Moreover, it was noted that the second segment [24] of AZ91-Mg alloy with smaller grains decreased in the stir region. No significant new values were found in the XRD analysis after FSW. Additional research to determine the impact of using non-identical metals [33]It is proposed to evaluate how the presence of dissimilar metals in the welded joint affected at mechanical ,corrosion properties for similar and non similar mating.

S.NO	RPM/Tool travel speed	25(T.T.S)	50(T.T.S)
1	1200	ok	ok
2	1400	ok	ok
3	1600	ok	ok

Table.3.Machining process done as per the set by step.

3.3.Dissimilar butt joint with metal process parameters (AZ-91/AZ-31)

3.3.1. Similar butt joint with metal process parameters (AZ-91/31)/ 25 TTS(Tool traverse Speed).

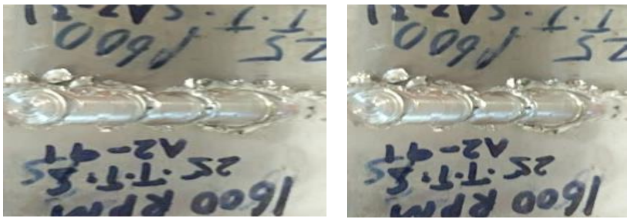


Fig.8.a.the weld made at 1200RPM at 25 Tool traverse Speed with Dissimilar welding Az91/Az31alloy,Fig.8.b. the weld was made at 1400RPM at 25 Tool traverse speed with Dissimilar welding Az91/Az31alloy.

In AZ31/AZ91 Dis similar butt welding at 25 tool traverse speed, the weld was made at different RPM , fig.8.(a),fig8.(b) here as per my experimental work we used here CNC -Vertical Milling Machine, a tool was tapered threaded at 4.3mm length will go between the two metals and the width will be at top point i,e tool shoulder the with of butt weld is 5mm and the depth point bottom it touches with 2mm tip and the shoulder to endpoint the length was 4.3 mm , but here we use the material thickness was 6.1 to 6.3mm because we need to achieve the proper weldig. Friction stir welding is currently used to successfully consolidate. Friction stir welding is currently used to successfully consolidate sheets of AZ91 Mg alloy and AZ31 alloy. Achieving a robust weld between two dissimilar metals has been found to be highly dependent on the different speed . We found that the bonding between AZ91-Mg and AZ31 alloys is often the result of mechanical intermixing and weak metallurgical bonding. The stirred quarter region and the Az91 matrix had a sharp interface according to microstructural observations and microhardness studies. Furthermore, it was found that the second phase of AZ91-Mg alloy faded and the particles[15,25,35] of the stirrer became smaller. No significant new values were found in the XRD analysis after FSW. Initial results suggest similar studies to determine the effects of the presence of various metals in welded joints on the mechanical and corrosive behaviour of the joints. Using AZ91 Mg FSW and additional studies on mechanical performance, corrosion range, and AZ-31 base fabric, it is clear that the alloy and AZ 31 alloy sheets can be joined. Moreover, it was noted that the second segment of AZ91-Mg alloy with smaller grains decreased in the stir region. No significant new values were found in the XRD analysis after FSW. Additional research to determine the impact of using non-identical metals It is proposed to evaluate how the presence of dissimilar metals in the welded joint affects the mechanical and corrosion properties [25] of the joint. Here we using SEM Analysis we found some mechanical failure and other analytical things under the retareting and advancing zones[27,28,29,30], The basic microstructure of magnesium alloy AZ91 consists of primary α-phase with aluminum-rich β-phase (Mg 17 Al 12) fig(11.a),fig(11.b),fig(11.c),fig(11.e),fig.(11.f)precipitated along grain boundaries. The grain size of the base metal was approximately 200 μm [26]. Figure shows the microstructure of an FSP treated sample of the same RD without coolant.

Fig.9.Microstucture taken at cross section of Welding process at low magnification dissimilar welding processAz-91/Az-31

Fig.9.Optical microscopy images of the cross sectional view of the AZ31/AZ91 mating after FSW are appeared .Under this distribution of β phase (Mg17Al12) is restricted at the receding way (AZ91-Mg way)[27]. The nuzzetet zones we usually discovered to be mixing with both AZ31 /AZ91 Mg alloys, here the distribution of AZ31 alloy ,and also appeared to be greater than that of AZ91 alloy. This is evident from the more ductile nature of AZ31 compared to AZ91 alloy. In this area indicated by the white arrow in the figure. 10.appears perfect metallurgical continuous between AZ31 / AZ91-Mg alloys.In this left for the interface, the β-(Mg17Al12) phase[1,332,37,39,] appeared as small discrete white colour atoms . Comparing with the original microstructural for Mg-based alloy AZ91 (Fig. 11.a), it is assumed that the network-like the Mg17Al12 phase at grain boundaries was decomposed into low size grains under FSW. Fig.(11.a) also shows the distribution of the "α+β" area under the "α" (Mg/Al formed crystal solution) under the "β" regions (Mg/Al compound, Mg17Al12). In this region indicates for the black arrow at [27] .

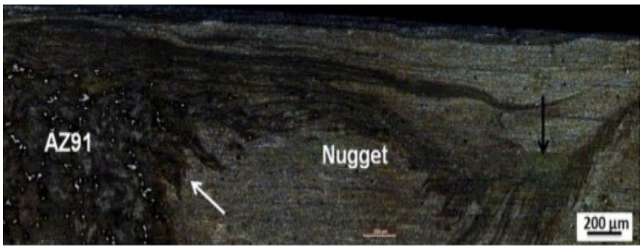


Fig.10. Microstucture taken at cross section of Welding process at high magnification dissimilar welding processAz-91/Az-31

Fig.10. contains more fine-grained AZ91-Mg alloy compared to AZ31-Mg alloy. This means that these regions are enriched in aluminum compared to other bright regions in the nugget zone (less AZ91 present). Therefore, it can be confirmed that the AZ31 region and the mixed region of AZ31/AZ91 [36] are mixed in the nugget region. This observation also suggests an increased aluminum solubility under the nuzzet zone, which appropriately affects a bulk mechanical properties of the compound.

3.4.Optical micro scope at dismilar AZ91/Az31 cross sectional view

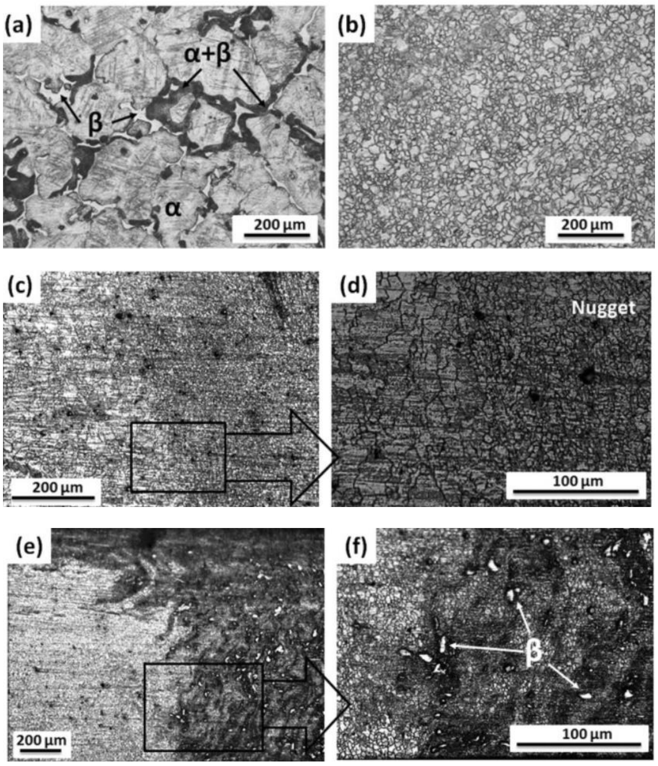


Fig.11.Optical micro scope colleted the pictures from different regions 11.a.Az91-Mg alloy base Micro structure ,12.b.Az-31 base metal micro structure ,11.c. Nuzzet zone also for base metal interface , at AZ31-Mg comaposition,11.d. under this enlarged picture,11.e. Nuzzet zone for base metal interface on AZ91 alloy side,11.f. enlarged image for Az91.

3.5.1. Similar butt joint with metal process parameters (AZ-91/31)/ 50 TTS(Tool traverse Speed).

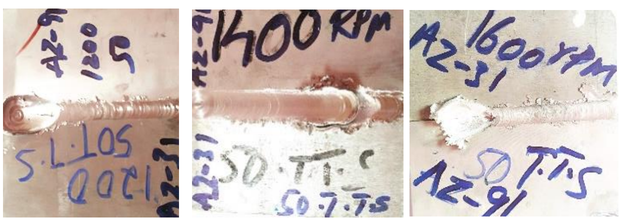


Fig.(12.a)the weld made at 1200RPM at 50 Tool traverse Speed with Dissimilar welding Az91/Az31alloy,Fig.12.b. the weld was made at 1400RPM at 50 Tool traverse speed with Dissimilar welding Az91/Az31alloy,Fig.12.c. the weld was made at 1600RPM at 50 Tool traverse Speed with Dissimilar welding Az91/Az31alloy.

In AZ31/AZ91 Dis similar butt welding at 50 tool traverse speed, the weld was made at different RPM, here as per my experimental work we used here[3,7,9] CNC -Vertical Milling Machine, a tool was tapered threaded at 4.3mm length will go between the two metals and the width will be at top point i,e tool shoulder the with of butt weld is 5mm and the depth point bottom [37] it touches with 2mm tip and the shoulder to endpoint the length was 4.3 mm, [35]but here we use the material thickness was 6.1 to 6.3mm because we need to achieve the proper welding[28]. Friction stir welding is currently used to successfully consolidate. Fig 12.(a), 12.(b),12.(c),Friction stir welding is currently used to successfully consolidate sheets of AZ91 Mg alloy and AZ31 alloy. Achieving a robust weld between two dissimilar metals has been found to be highly dependent on the speed.. We found that the bonding between AZ91-Mg and AZ31 alloys is often the result of mechanical intermixing and weak metallurgical bonding. The stirred quarter region and the Az91 [37] matrix had a sharp interface according to microstructural observations and microhardness studies. Furthermore, it was found that the second phase of AZ91-Mg alloy faded and the particles of the stirrer became smaller. No significant new values were found in the XRD analysis after FSW[29].. Moreover, it was noted that the second segment of AZ91-Mg alloy with smaller grains decreased in the stir region. No significant new values were found in the XRD analysis [36,37]after FSW. Additional research to determine the impact of using non-identical metals .

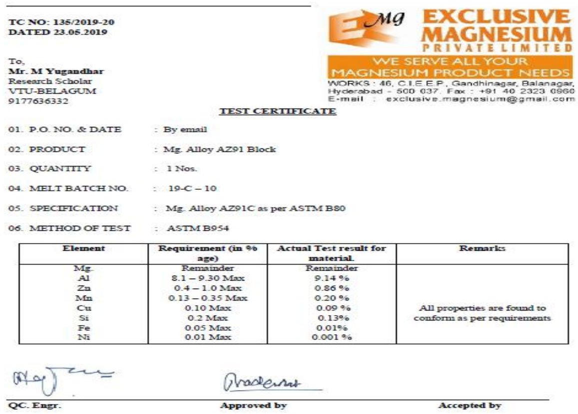
S.NO	RPM/Tool travel speed	25(T.T.S)	50(T.T.S)
1	1200	ok	ok
2	1400	ok	ok
3	1600	ok	ok

Table.4.Machining process done as per the set by step.

3.6.Tool process parameters

a.Machine :-Lathe (At 650 rpm-800rpm)
b.Special prepared lathe tool(single point cutting tool)
c.Tool pitch 1.5mm and depth 1mm(for threads –probe)
d.Heat Treatment(HRC-55-65)
e.Balckning

3.6.1.Data collection:-(Material chemical composition):Az-91: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To,
Mr. M Yugandhar
Research Scholar
VTU-BELAGUM
9177636332

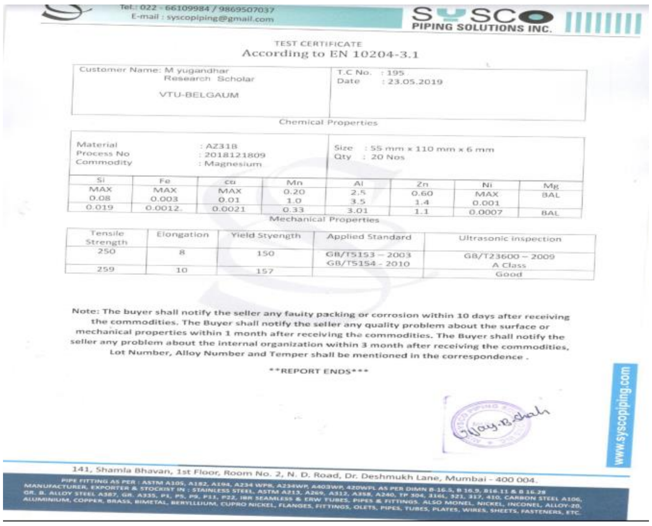
TEST CERTIFICATE

01. P.O. NO. & DATE : By email
02. PRODUCT : Mg. Alloy AZ91 Block
03. QUANTITY : 1 Nos.
04. MELT BATCH NO. : 19-C – 10
05. SPECIFICATION : Mg. Alloy AZ91C as per ASTM B80
06. METHOD OF TEST : ASTM B954

Element	Requirement (in % age)	Actual Test result for material.	Remarks
Mg.	Remainder	Remainder	All properties are found to conform as per requirements
Al	8.1 – 9.30 Max	9.14 %	
Zn	0.4 – 1.0 Max	0.86 %	
Mn	0.13 – 0.35 Max	0.20 %	
Cu	0.10 Max	0.09 %	
Si	0.2 Max	0.13%	
Fe	0.05 Max	0.01%	
Ni	0.01 Max	0.001 %	

QC. Engr. Approved by Accepted by

Az-31:-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TEST CERTIFICATE
According to EN 10204-3.1

Customer Name: M yugandhar
Research Scholar
VTU-BELGAUM

T.C No. : 195
Date : 23.05.2019

Chemical Properties

Material : AZ31B
Process No : 2018121809
Commodity : Magnesium

Size : 55 mm x 110 mm x 6 mm
Qty : 20 Nos

Si	Fe	cu	Mn	Al	Zn	Ni	Mg
MAX 0.08	MAX 0.003	MAX 0.01	0.20 1.0	2.5 3.5	0.60 1.4	MAX 0.001	BAL
0.019	0.0012	0.0021	0.33	3.01	1.1	0.0007	BAL

Mechanical Properties

Tensile Strength	Elongation	Yield Styength	Applied Standard	Ultrasonic inspection
250	8	150	GB/T5153 – 2003 GB/T5154 - 2010	GB/T23600 – 2009 A Class
259	10	157		Good

Note: The buyer shall notify the seller any faulty packing or corrosion within 10 days after receiving the commodities. The Buyer shall notify the seller any quality problem about the surface or mechanical properties within 1 month after receiving the commodities. The Buyer shall notify the seller any problem about the internal organization within 3 month after receiving the commodities, Lot Number, Alloy Number and Temper shall be mentioned in the correspondence .

REPORT ENDS*

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141, Shamla Bhavan, 1st Floor, Room No. 2, N. D. Road, Dr. Deshmukh Lane, Mumbai - 400 004.

S.no	Similar/dissimilar(Az31-Az91)	Speed (rpm)	Feed mm/ min	End Results
1	Az(31/31)	1200	25	Good joint without cracks or nodefects
2	Az(31/31)	1200	50	Good Sound joint without any cracks or no defects
3	Az(31/31)	1400	25	Sound weld with no defects without cracks
4	Az(31/31)	1400	50	Sound weld with no defects without cracks
5	Az(31/31)	1600	25	Sound weld with no defects without cracks but at end point it forms counour holes removing material from the work piece and then it sticks to the tool tip and shoulder less in 25mm tts
6	Az(31/31)	1600	50	Sound weld with no defects without cracks but at end point it forms counour holes removing material from the work piece and then it sticks to the tool tip and shoulder high in 50mm tts
7	Az(91/91)	1200	25	Sound joint without cracks or defects
8	Az(91/91)	1200	50	Sound weld with no defects without cracks but at end point it forms counour holes removing material from the work piece and then it sticks to the tool tip and shoulder high in 50mm ttsat the center of the process
9	Az(91/91)	1400	25	The Sound joint was made without any cracks or no defects
10	Az(91/91)	1400	50	The Sound joint was made without any cracks or no defects
11	Az(91/91)	1600	25	Sound joint without cracks or defects
12	Az(91/91)	1600	50	The Sound joint was made without any cracks or no defects
13	Az(31/91)	1200	25	The Sound joint was made without any cracks or no defects
14	Az(31/91)	1200	50	From starting to end of the process it forms very bad welding , it forms hot cracks and improper welding
15	Az(31/91)	1400	25	Not found
16	Az(31/91)	1400	50	Defects found not a sound weld but it forms hot cracks and also forms countors on the work piece
17	Az(31/91)	1600	25	Defects found not a sound weld but it forms hot cracks and also

				forms countors on the work piece
18	Az(31/91)	1600	50	Defects found not a sound weld but it forms hot cracks and also forms countors on the workpiece

Table.5.Maching process and its defects

3.7.XRD for AZ31/AZ91Alloys:

The experimental science known as X-ray crystallography uses incident X-rays [19] to bend them in several different directions to determine the atomic and molecular structure of crystals. A picture of the electron density in the crystal can be constructed in three dimensions by measuring the angles and intensities of these diffraction beams (Fig. 13). From this electron density, the average positions of atoms in the crystal, their chemical bonding, their crystallographic disorder, and other details can be derived [33]. X-ray crystallography has played an important role in the advancement of several scientific disciplines because many substances can be crystallized including salts, metals, minerals, semiconductors and other inorganic, organic and biomolecules. did. When first applied, this technique identified atomic-level differences in various materials, especially minerals and alloys, the size of atoms, the length and nature of chemical bonds, and the types of chemical bonds. Numerous biological compounds [38], including vitamins, drugs, proteins, and nucleic acids such as DNA. crystal structure. By measuring the angles and intensities of these diffracted beams, a three-dimensional image of the electron density in the crystal can be constructed. From this electron density, we can derive the average position of atoms in the crystal, their chemical bonding, their crystallographic disorder and other details. X-ray crystallography plays an important role in the advancement of several scientific disciplines, as it can crystallize many materials, including salts [26], metals, minerals, semiconductors, other inorganic molecules, organic molecules, and biomolecules. has been fulfilled. Did it. When first applied, this technique identified atomic-level differences, atomic size, length and type of chemical bonds, and types of chemical bonds in various materials, especially minerals and alloys [39].Numerous biological compounds including vitamins, drugs, proteins, nucleic acids such as DNA.

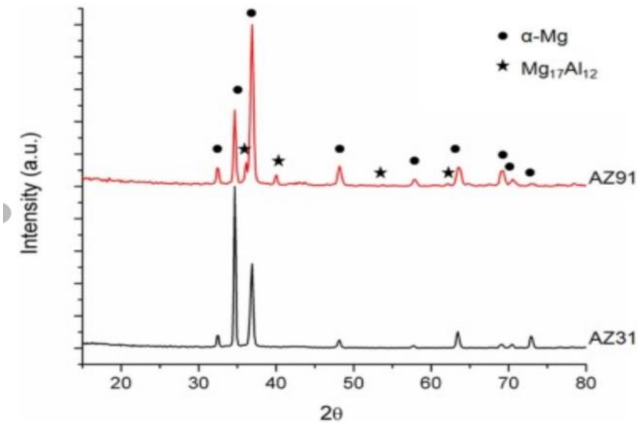


Fig.13.XRD- for Az31 and Az91 Alloys

3.8.Micro Vickers hardness Test.

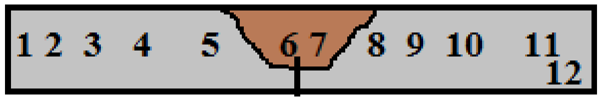


Fig.14.Micro Vickers hardness Test

Sl.No	Locations	H.V @ 0.5 Kgf Load
1	Parent metal	48.8
2	Parent Metal with near HAZ-1	59.8
3	Parent Metal with near HAZ-2	58.9
4	Parent Metal with near HAZ-3	69.4
5	HAZ	104.9
6	Weld Zone	107.2
7	Weld Zone	110.3
8	HAZ	64.2
9	Parent Metal with near HAZ-1	63.0
10	Parent Metal with near HAZ-2	63.6
11	Parent Metal with near HAZ-3	65.2
12	Parent metal	68.7

Table.6.Micro Vickers hardness values for Disimialr magnesium alloys Az91/Az31

The figure shows images (14)of a weld taken with different processing settings. It provides an overview of post-weld observations. From this result, it is clear how important the rotation speed and running speed of the device are to create an impressive intersection. It was found that when the tool was rotated at 1600 rpm per minute, additional heat was generated, washing away excess tissue and depositing some ground tissue on the shoulder of the FSW device. Tissue slippage is reported to be exacerbated at feed rates above 25 mm/min, resulting in deep grooves at the junction, as seen at Fig.10. A same behaviour was observed in the weld when the device rotation speed was reduced to 1400 rpm with a feed of 50 mm/min. A similar behavior is observed in welds, where the seam is invisible at the rate of was 6 millimeter/min. Curiously, a feed rate of 25 millimeter/min produces a moderately high quality effect, as shown in the figure. (11). During welding, the weld became visible, demonstrating tremendous metallurgical power.Although a genuine joint, failure identified as a hot crack, shown in Figure (10), occurred while the weld joint was periodically cooled to ambient temperature. The joint appeared to develop similarly while the process continued at 1200 rpm and 25 mm/min.What ever , as earlier as the mate warmed up to room atmosperhic condition, the narrow hot cracks was found, samae at the weld moving at 1400 rpm/50 mm/min. Fusion welding techniques result from hot cracking during and immediately after solidification [2]. The shrinkage that occurs at some point in the solidification of the liquid metal in the weld explodes the residual stresses in the weld, and if these stresses are large[37], fracture occurs. When these stresses become large or uneven, joints and fractures occur [1]. The heat generated at the connection point must be dissipated with the FSW through the workpiece, the FSW device and the surrounding air during heavy rain welding [18]. Much of the heat dissipation in this process was through the tool and workpiece. As a result, different regions of treated and untreated tissue have different temperatures. The thermal conductivity of floor coverings is a valid reason for the formation of hidden stresses. Differences in thermal conductivity at the weld point make it difficult to find residual marks in the presence of contrasting base metals, as in modern tests, and promote hot crack formation after cooling[16]. Formation of hot fractures during cooling of the joint. This caused the joint[24], which appeared perfect during manipulation but was inappropriate up to noraml atmospeheric condition [39], to magnify the warm fracture (e), as shown in Fig. 2(d) ,2.(e). As shown in Fig. 2(f), at a given feed speed at 25 mm/min at 1100 Rpm, the final heat and flow following fabric eliminated the formation of thermal cracks and produced disease-free joints. The weld joint go segment achieved at 1100 rpm with 25mm/min. within the enlarged photo (Fig. 3(e)), primary materials and a subsequent section[17] with elongated grains are seen. on the stir quarter, it became seen that the fabric from Al6063 had routinely mixed with AZ91 and formed a junction.pics captured by using optical microscopes of basic Az31andmatching base and stir area interfaces, in addition to base AZ91[23].The microstructure of the bottom and stir region are compared in Fig. five.subsequent to the AZ91 Mg alloy. in advance than FSW (Fig. five(a)), the-grains incorporate much less than 1% (as seen with the aid of the black arrows).metal aluminium. As visible by means of the white, an excessive amount of aluminium leads to the formation of community-formed Mg17Al12.arrows. it's interesting to look how little secondary section is present within the stir sector (Fig. with smaller grain in 5(b))length (11.4 m) in contrast to the simple fabric, AZ91 Mg alloy (a hundred and sixty.2 mm) in grain size. Likewise, the grain size turned into decided.AZ31 stir region has a grain size of 17 m, that's much less than the cloth's initial grain size [40](ninety four.4 m).The XRD patterns of the two fundamental materials[38] are shown in parent 6.the weld joint, and so forth. XRD plots of the primary substances,with the aid of evaluating with the, all peaks were found and listed.trendy statistics (for Al-JCPDS and Mg-JCPDS No 35-0821, respectively). The X-Ray Diffracted of the mating revealed peaks that were indicative of both base substances. NoIn the weld sector, extra peaks had been discovered, however following FSW, peak intensities were seen to have risen. particularly,strength of (002). large grain in 5(b))compared to the AZ91 Mg alloy base fabric, size (11.four m)grain diameter (a hundred and sixty.2 mm). similar to that, the grain length was decided.as 17 m in the Al6063 stir sector, that's smaller than the material's preliminary grain size of ninety four.four m.each of the premise substances' XRD patterns are displayed in parent 6.likewise the weld junction. the usage of the simple cloth XRD graphs,by comparing with the, each peak became recognized and catalogued.general information (for Al-JCPDS and Mg-JCPDS No 35-0821)No 04-0787). Peaks that correspond to each base substances may be seen in the weld joint's XRD consequences.Inside the weld region, there have been a few new peaks that had been discovered, however following FSW[31], the height intensities were seen to have risen. in particular,the degree of (002), materials for bases that drastically decorate the mechanical corrosion styles, etc. In standard, XRD analysis helps thematerial from each base materials is gift within the weld.area and shows that the most effective orientation occurs there because of FSW.The joint's microhardness distribution is displayed.in Fig. 7. due to the existence of zones, the hardness fluctuations in AZ91 Mg alloy are usually noticed as greater (i)stable combinations of magnesium and aluminium, as well as magnesium and Al (Mg17Al12). The variety of hardness, consequently, ranged from lower on the grains and higher on the presence of the secondary segment as discovered in our prior research [20], near the grain border.it's interesting to notice that within the modern study, the stir area shows much less variation within the substances for bases that considerably decorate the mechanical corrosion styles, and so forth. In general, XRD evaluation helps the material from each base the raw was present at [22]and shows that was most beneficial orientation occurs there owing to FSW.The joint's microhardness distribution is displayed.in Fig. 7. due to the life of zones, the hardness fluctuations in AZ91 Mg alloy are generally noticed as greater (i)solid combinations of magnesium and aluminium, in addition to magnesium and Al (Mg17Al12) (Mg17Al12). The variety of hardness therefore ranged from decrease on the grains and higher on the presence of the secondary segment as discovered in our earlier research [20], close to the grain border.it's exciting to note that in the cutting-edge examine, the stir quarter shows less variation in the the first findings, it's far clear that AZ91 Mg FSW can be used to combine alloy and Az31 alloy sheets, phrased Text

Additional studies on overall mechanical performance and corrosion. The microhardness value obtained by measuring the entire weld is displayed. These results show that the hardness gradually increases from AZ31 to AZ91 [36]. Large variations in hardness values were found within the nugget zone due to the combined effects of the fine grain structure and the presence of the hard Mg17Al12 phase along with some regions of AZ31. Solid solution strengthening also helps increase the hardness of as more aluminum dissolves through the reduced Mg17Al12 phase of and the nugget zone becomes a supersaturated solid solution. Therefore, in this study, we successfully demonstrated the feasibility of FSW for joining dissimilar metals, especially difficult-to-join metals such as Mg alloys (AZ31/AZ91), and found that the speed and feed of The effect on hot crack removal was also revealed. Succeeded in details. explained. Figure 5 shows his typical photographs of AZ31/AZ91 welded tensile specimens. Table 2 shows the mechanical properties of the base metals (AZ31 and AZ91-Mg alloys) and welds. Observation shows that the joint strength is higher than that of AZ91 base metal and lower than that of AZ31. This difference was seen at $p<1$. 1 as being statistically significant. 0.05 level. The decrease in joint strength can be attributed to the presence of both brittle [35] and soft phases in the joint. These preliminary results therefore indicate that various Mg alloys are self-bondable by solid-state FSP and the mechanical properties of welded joints are promising. Further studies are planned to evaluate joint performance under different mechanical loads

(5) and environmental conditions.

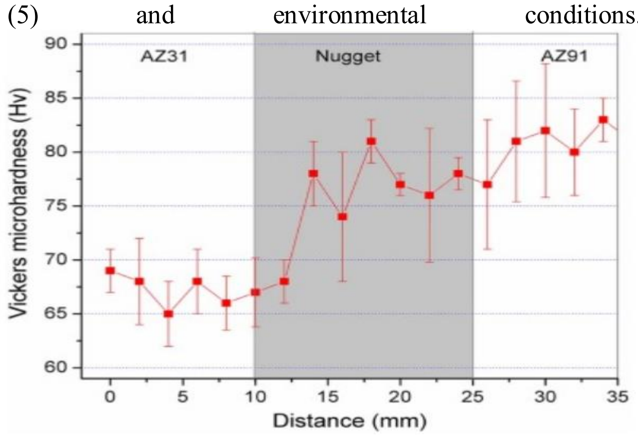


Fig.15.Micro Vickers hardness dissimilar Magnesium alloys graph.

3.9.Tensile test elongation Results:-

S.No	Material	Ultimate Tensile strength(MPa)	Young s Modulus (Mpa)	Percentage Elongation
1	Az-31/Az31 alloy	232 ±6	202±4	15.3±1.2
2	Az-91/Az91 alloy	199±3	185±7	4.3±0.3
3	Az-31/Az91 alloy	192±2	180±3	4.5±2.2

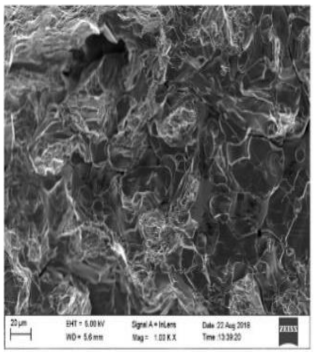
Table.7.Stress -starin relation for tensile test

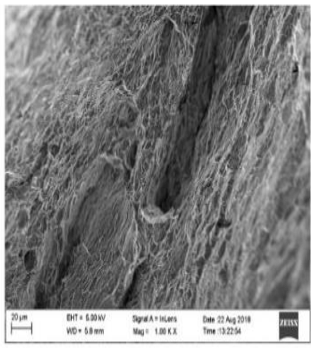
Tensile test of AZ31/ AZ91 alloys and AZ31/AZ91 welded joints (all mean differences were found to be statistical appropriate the significance level of $p<0.05$).

3.10.Salt spary test on AZ91and Az31 Alloy:-

Samples are polished on all surfaces to remove surface defects such as pits and cracks. The sample is polished to reduce the size and number of scaratch lines like at the sample. The initial weight of the sample is observed. Fill a 1 liter beaker with distilled water and mix 35 g of He NaCl powder to make a 3.5% NaCl solution. He transfers the prepared solution into two Erlenmeyer flasks. Specimens of each casting type are tied to a wooden rod with a thread so that when the specimen hangs from the neck of the flask it remains completely submerged in the solution without touching the bottom. Cover the flask with aluminum foil and let stand for 24 hours[34]. The sample is then removed, washed with distilled water, dried and weighed. Soak these samples in a chromium trioxide solution for 10 minutes to remove the corrosion products. The sample is washed again with distilled water and weighed after drying. In die casting applications, high purity AZ91 alloy has been shown to produce parts with saltwater corrosion properties that are 10 to 100 times better than standard purity alloy. In the work presented, two major issues for further development of the alloy were resolved [22]. Differences in iron impurity content and activity are quantitatively related to the amount of manganese present in the metal, casting alloys with well-controlled manganese content and permanent form or sand impurities. has been shown to produce parts with saltwater corrosion behavior. Equivalent to die-cast parts. Only the nickel resistance of the alloy was significantly affected by the associated slow solidification rate.Salt spary test on AZ31 Alloy:- Corrosion resistance and adhesion of AZ31 magnesium alloy rolled sheet coated with hydroxyapatite (HAp) were evaluated by salt spray test (SST: JIS Z 2371) [22] and cross-cut test (CCT: JIS K 5600). The duration of HAp coating solution treatment was 4 or 6 hours. Consisting of a continuous inner layer and a porous outer layer, the HAp coating covers the surface uniformly regardless of treatment time. After 7 days of SST, the HAp-coated surface showed no significant delamination, but some visible pits. His HAp coating in non-corrosive areas retained its original morphology after He SST in SEM observations. The rating number (RN) of HAp-coated samples was >9. This was much higher than the RN4 observed in the chemically polished sample almost completely covered with filiform corrosion[33]. The RN of HAp-coated samples increased slightly with longer treatment times. The adhesion of HAp coatings was not affected by SST according to CCT. After removing the corrosion products and HAp coating from the uncorroded areas, small holes several hundred microns in diameter appeared[33]. However, no blanket corrosion occurred under the HAp coating. HAp coatings exhibit high corrosion resistance and good adhesion to AZ31 substrates[1,5].

3.11.SEM Analysis :-





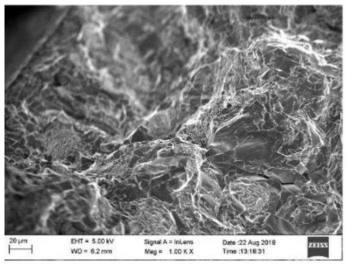


Fig.16.a.SEM picture for high magnification to find the how the material behaviour and it contains the microstructure of AZ91 alloy contains for intermetallic structure of Al-Sm (Al2Sm /Al11Sm3) and Al-Mn-Sm, α-Mg and β-Mg17Al12 phase.
Fig.16.b.SEM picture for high magnification to find the how the material behaviour and it contains the (Al2Sm and Al11Sm3) and Al-Mn-Sm, α-Mg, and β-Mg17Al12 phase.and shows the fracture surface and how the garins activities (Medium magnification)
Fig.16.b.SEM show High Magnification the grains having what kind of alloys is forming under Al-Mn-Sm, α-Mg, and β-Mg17Al12 phase.

In this SEM image of the crack surface of the tensile test piece is shown. Fracture forming at heat Affected Zone of the FSW bonding process. Macrophotographs show a small brittle surface morphology on the fracture surface fig16.(a,b). [12,14,16]The macro chart also shows large sink marks. This may indicate a casting defect. Two macro images covered the entire fracture surface. The magnification of Sem is 1500x. The fracture surface field is shown at 1500x magnification fig.16(b). A trough-like surface that may have been caused by casting errors has been corrected at high magnification[31]. This image is the same sample, but with a different fracture surface. You can see the fine morphology of the fracture surface at a high magnification of 1500 times fig16.(b). This SEM image shows a magnified image of 1500 times. The cracked surface forms thin cracks running perpendicular to the stress paths. In the heat-affected zone, fractures appear as intergranular cracks running along the direction of grain movement. Fig.16.(c)Central 1500X SEM picture of material at fracture area . This fracture ara is brittle, the fracture surface is fine-grained, and there is no pitting corrosion. It shows a fracture surface area containing a large trough that may indicate a fault at the material surface. The huge valley that appeared on the fracture surface [6,8,9] was resolved at 1500x magnification. Figure 12 shows another fracture patch with deep grooves in the sample fracture material.

4.Conclusion:-

Friction stir welding is currently used to successfully consolidate sheets of AZ91 Mg alloy and AZ31 Mg alloy. Achieving a robust weld between two dissimilar metals has been found to be highly dependent on the speed of rotation and travel of the tool. A tool rotation speed of 1100 rpm and a tool travel speed of 25 mm/min were determined to be suitable settings for an FSW fixture with a shoulder diameter of 15 mm, a conical pin of 3-1 mm, and a length of 3 mm. We found that the bonding between AZ91-Mg and AZ31-Mg alloys is often the result of mechanical intermixing and weak metallurgical bonding. The stirred quarter region and the Al6063 matrix had a sharp interface according to microstructural observations and microhardness studies. Furthermore, it was found that the second phase of AZ91-Mg alloy faded and the particles of the stirrer became smaller. No significant new values were found in the XRD analysis after FSW. Initial results suggest similar studies to determine the effects of the presence of various metals in welded joints on the mechanical and corrosive behavior of the joints. Using AZ91 Mg FSW and additional studies on mechanical performance, corrosion range, and AZ-31 base fabric, it is clear that the alloy and Al6063 alloy sheets can be joined. Moreover, it was noted that the second segment of AZ91-Mg alloy with smaller grains decreased in the stir region. No significant new values were found in the XRD analysis after FSW. Additional research to determine the impact of using non-identical metals It is proposed to evaluate how the presence of dissimilar metals in the welded joint affects the mechanical and corrosion properties of the joint.

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