FRICTION STIR WELDING of MAGNESIUM ALLOYS - A REVIEW

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ABSTRACT:

The selection of proper material for each application is a critical part in every manufacturing industry. In the field of aerospace and automobile the major requirement is light weight yet strong material which can possess every aspect of design parameters. Magnesium alloy one of the major raw material used in these industries due to its light weight, good thermal conductivity etc. Also Friction stir welding is the joining process that is being used in these industries as it is a solid state joining process. This paper gives a detailed review about Friction Stir welding of Mg alloys. The review period is considered from 2009 to 2015.A detailed review about Friction stir welding of Mg alloys has not been done before in this manner. This review work may be a ready reference for subsequent researchers.

KEYWORDS:

Friction stir welding, Magnesium alloy

1.INTRODUCTION

The modern technologies are gaining more and more importance in almost every field and Manufacturing industry not an exception. .Welding has been a constant part of every manufacturing industry in which Automobile industry is the major partner. More and more research has been going on related to welding techniques [1]. Friction stir welding is one of the latest welding techniques that have found a major part in automotive sector. Friction stir welding is a solid state joining technique invented and developed by The Welding Institute (TWI), UK. Firstly Friction stir welding was used for welding Aluminium alloys. Later had found application in welding Magnesium, Copper alloys etc. Some materials such as Aluminium 7xxx series, 2xxx series which were considered un weld able are now possible with Friction stir welding.

In FSW a cylindrical shouldered tool with a profiled pin is rotated and plunged into the joint area between two plates. For proper welding the plates must be clamped during the process.[1] Friction Stir welding is a solid state joining process and the heat generated during the rotation of the tool will cause the materials to get joined without reaching melting point. The plasticized material is transferred to the trailing edge of the tool pin, is forged with the tool shoulder and pin.

2. MAGNESIUM ALLOY

Magnesium alloys are promising alternatives for Aluminium , steel etc. due to its outstanding properties. The stiffness to weight ratio, low density, high damping capacity etc is some of them. These properties had enabled them to become a major part of automotive industry. A reduction of 20- 70% of total weight of the components can be achieved. Mg alloys are having a hexagonal lattice structure and therefore during plastic deformation there are some complications when compared to Cu etc.[2] Mechanical properties of Mg alloys are improved by adding rare earth elements. Mg alloys are characterized with low melting point, large thermal expansion and therefore welding of Mg alloys using conventional methods will lead to cracks, pores etc. Commercial Mg alloys contain Al (3-13wt%) Mn (0.1-0.4wt %), Zn (0.5-3wt %) and some are hardeneble by heat treatment. Mg alloys are often designated by 2 numbers. Letters denote the main alloying elements and numbers represents nominal composition of alloying elements. Addition of zinc and calcium alloys will increase the chance of occurring solidification cracking. Addition of zinc upto 2% is normal but further increase will cause poor weld ability.

3. FRICTION STIR WELDING

Friction Stir Welding (FSW) is an innovative solid state welding technique which was first invented by The Welding Institute (TWI), UK in 1991.This technique was developed aiming Aluminium alloys but later it had found profound application in welding of Mg alloys, Cu alloys etc.[3] These alloys once considered unweldable are now possible by FSW.This method utilizes a non-consumable rotating tool to produce frictional heat and thus producing plastic deformation at the location of welding. FSW process consists of a rotating tool with a shoulder and probe arrangement. The heat is developed due to friction between the work piece surface and the tool[3]. The heat thus produced is used to soften the work piece before reaching its melting point.

The heat generated during the process is about 80-90% of the melting temperature. With FSW traditional components current and voltage are not present as the heat input is purely mechanical replaced by force, friction etc. The quality of an FSW joint is always better than other fusion welding processes. In this process the FSW material consists of four distinct microstructural zones namely Nugget zone (NZ),Thermo mechanically affected zone(TMAZ),Heat affected zone (HAZ) and Base material (BM).The process parameters chosen during FSW process has great influence on these zones.[4]

3.1 Welding Parameters

The welding parameters are key players during every welding technique and FSW is no exception. Proper selection of welding parameters influences the final weld quality and resulting microstructure. In FSW the parameters chosen are tool rotational speed, welding speed, tilting angle, pin profiles, axial down force (Z-axis) etc. The down force will ensure the generation of frictional heat to soften the material. An increase in the tool rotational speed and decrease in tool travel speed will cause a hotter weld. For a good quality weld the welding temperature must be sufficient and it should not be too less or too high. Some other influencing parameters are the work material dimension, chemical Composition etc. The tool rotational time is another important factor though look less important it plays a major part in the weld microstructure. The more the welding tool is rotated and moved the more will the microstructural change will take place. The grain arrangement will change abruptly with increasing rotations. Proper fixtures are needed for work material arrangement otherwise during tool rotation there are chances for misalignment. Majority of studies are concentrated on tool rotational speed, welding speed , tool pin profile and axial force.

3.2Welding tool

Welding tool design is critical in FSW processes Optimizing tool geometry will produce more heat there by breaking the oxide layer, higher welding speeds etc. Tool material should possess high hardness at elevated temperatures and should maintain that hardness till the end of the process. Weld quality and tool wear are two important considerations in the selection of tool material, the properties of which may affect the weld quality by influencing heat generation and dissipation. The weld microstructure may also be affected as a result of interaction with eroded tool material.H13 tool steel is usually used for FSW .The shape of the pin design depends on the material thickness, ability to break the oxide layer formation, heat generation etc. A non-profiled tool is capable of producing enough heat. The various types of pin profiles used are cylindrical, cylindrical threaded pin, conical etc. The shape of pin profile greatly influences the final weld microstructure, grain refinement etc. FSW has several advantages over conventional welding techniques. Bending and tensile tests can be done rigidly and from the economical point of view FSW has many cost reducing benefits such as low energy consumption, no welding consumables etc.

This review mainly focuses on FSW of Mg alloys. Such a review in this area has not been done in this manner yet. Effort has been done to identify the FSW process parameters on Mg alloys and its resultant details. The period of review was from 2009-2015.The influence of various process parameters on final weld quality, microstructure analysis, Optimization techniques used etc are focused on the paper. Thorough literature review has been done to point out every single detail in FSW of Mg alloys. This paper will be helpful for forthcoming researchers.

Table 1 Summary of Friction Stir welding of Magnesium alloys Review

Year/Author (s)	Objective (s)	Work piece material	Tool material & Design	Process parameters & levels	Remarks
2015 /Prakash kumar Sahu and Sukhomay pal	Parameter optimization using Taguchi's Grey relational Analysis	AM20 Mg alloy plates 100mmx 100mm x 4mm (In wt %)Al-2.03 ,Mn-0.43 Zn - 0.18 , Si-0.04 bal Mg	H13 tool steel SD : 16-24 mm PD : 6 mm PL : 3.5 mm	WS : 63 – 132 mm/min TRS:600 – 1100 rev/min SD:16-24 mm PLD : 0.12-0.21 mm	Shoulder diameter and plunge depth were the most influencing parameters.
2015/V Jaiganesh and P.Sevvel	Influence of process parameters on microstructural and mechanical properties	AZ80A wrought Mg alloy 150mmx50mmx5mm (in wt%)Al:7.8,Mn:0.3, Cu:0.05,Si:0.1 , Fe :0.005, Ni : 0.005 bal Mg	M35 HSS tool SD :12 mm PD : 7- 4 mm PL : 4.75 mm	TRS : 500-1000 rev/min Feed : 0.5 – 3 mm/min Axial force : 5KN	Good quality welds were obtained. Large coarse grains are converted to fine grains in stirred zone thus leading to superior mechanical properties.
2015 / Bhukya Srinivasa Naik et al.	To find out the residual stresses and tensile properties	AZ31B-H24 Mg alloy 1200mmx 500mm x2mm (in wt%)2.5-3.5Al , 0.7-1.3 Zn , 0.2 -1.0 Mn , bal Mg	H13 tool steel SD : 19.05 mm PD : 6.35mm TL: 4.45 mm TS: 1.27mm P : 0.8 thread/mm Tilt angle : 0.5° PLD : 0.25 mm	WS : 10 or 20 mm/min TRS : 1000 or 1500 rev/min	Higher WS and lower TRS lead to higher failure load Shear tensile fracture initiates around the region of SZ/TMAZ.
2015/ S.Mironov et al.	Microstructure evolution during FSW	AZ31 Mg alloy 4mm thick sheets (in wt%)Mg-3.0Al-1.0 Zn	Tool steel SD : 15mm (concave) PL: 3.7mm (M5 threaded) Tilt angle : 3° PLD : 3.5mm	WT : 0.57 – 0.85 T_m TRS : 300-3000rpm WS : 200 mm/min	Lowering of grain boundary misorientation (grain convergence) Lowering of temperature leads to increase in tool load.

Year/Author (s)	Objective (s)	Work piece material	Tool material & Design	Process parameters & levels	Remarks
2014/ Sevvel .P and Jaiganesh V	Mechanical properties charectarisation and microstructural analysis through optimized process parameters	AZ31B Mg alloy 150mm x50mm x5mm (In wt%) Al- 2.87,Zn-0.72, Mn-0.30,Cu-0.05,Si-0.08,Fe-0.005,Ni-0.005 Bal Mg	Taper cylindrical pin profiled HSS tool(M35 grade) D/d ratio : 3 PD: 4mm PL : 4.75mm	TRS : 500-1000rpm WS : 0.5-3.0mm/min AF : 3KN	Defect free joints are obtained & microstructure has been improved also tensile strength and yield strength.
2014/ B.S.Naik et .al	Characterization of micro structure &mechanical properties	AZ31B-H24 Mg alloy 1200mm x 500mm x 2mm (in wt%) Al 2.5-3.5,Zn 0.7-1.3,Mn 0.2-1.0,bal Mg	H13 tool steel-50 HRC SD : 19.05mm PD : 6.35mm TL : 4.45mm Pitch : 0.8thread/mm	WS : 10 & 20 mm/s TRS : 1000 & 1500 rpm WP : 0.4-1.2 mm/rev	Grain coarsening wes seen in SZ,TMAZ,HAZ.Texture changes had taken place in the stir zone.WS and TRS has strong effect on failure loads of lap welds.
2014 / Yong zhao et .al	Microstructure analysis and Mechanical properties testing	NZ20K & AZ31 Mg alloy 300mmx100mmx 2mm (in wt %) NZ20K – Nd 1.5-2.5,Zn 0.2-0.4,Zr 0.3-0.5,bal Mg . AZ31 – Zn 0.5-1.5,Al 2.5-3.5,bal Mg	H13 tool steel SD : 14mm(concave) PD : 4mm PL : 2mm Tilt angle : 2.5°	TRS : 1300 rpm WS : 60mm/min	Uniform distribution of grains. A decrease in Tensile strength and UTS is observed with respect to temperature. Increase.
2014 / A.Ugender et.al	Influence of Rotational speed on microstructure and mechanical properties.	AZ31B Mg alloy 240mmx120mmx5mm (In wt%) Al -3,Mn-2.0,Zn-1.0,Cu-0.05,Si-0.1,Fe-0.005,bal Mg	HSS tool (TT) SD : 18mm PD : 6mm PL : 4.8mm Tilt angle :2.5°	TRS : 900,1120,1400,1800 rpm WS : 40mm/min	TRS has a significant influence on grain refinement .Optimum results were obtained at an rpm of 1400.

Year/Author (s)	Objective (s)	Work piece material	Tool material & Design	Process parameters & levels	Remarks
2014/Inderjeet Singh et al.	Effect on welding parameters on weld joints During lap welding	AZ31B-O Mg alloy 150mmx75mmx5mm (in wt%) Si <0.1, Fe < 0.005,Cu 0.05,Mn 0.2-0.5 Zn 0.5-1.5,Al 2.5-3.5 Ni 0.05,Co<0.05 bal Mg	High carbon high chromium steel (Left Hand threaded) SD : 18-20mm PD : 7mm PL : 4.8mm D/d ratio : 2.56 & 3	WS : 40 , 60 mm /min TRS : 1200 , 1950 rpm WP : 0.0020 mm/rev – 0.0500 rev/min SD : 18 mm & 20mm	High weld pitch yields high tensile strength.at 0.050 mm/rev Proper grain refinement ,impact toughness got improved in joints
2013 / S.Rajakumar et al.	To study the effect of process parameters on weld quality	AZ61A Mg alloy 300mmx150mmx6mm (in wt%) Al 5.96, Zn 1.28,Mn 0.17 , bal Mg	High Carbon Steel (in wt%) C 0.75 Si 0.25,Mn 0.32,bal Fe Tool pin profiles SC,SQ,TH,FL,TR SD : 18mm PD : 6mm D/d ratio : 3 PL : 5.8mm Thread angle : 60 °	Tool pin profiles SC,SQ,TH,FL,TR TRS : 800 – 1600 rpm (Varying on types of tool pin) WS : 30 – 150 mm/min (Varying on types of tool pin) AF : 3-7KN (Varying on types of tool pin)	Maximum tensile strength was obtained by using threaded cylindrical pin with TRS of 1194rpm,WS of 92.19mm/min, AF of 5.05KN.
2012/ S.H.Chowdhury et al.	Microstructure analysis and properties testing on joints	AZ31B-H24 Mg alloy 2mm in thickness (in wt %) Al 2.5-3.5 ,Zn 0.7-1.3 , Mn 0.2- 1.0 ,bal Mg	Tool steel with left hand threaded pin PL : 1.65mm PD : 3.175mm	WS : 5 – 20mm/s TRS : 1000-2000 rpm	Texture weakened due to increased TRS and decreasing WS.WS and TRS has great influence on the Yield strength than the UTS.

Year/Author (s)	Objective (s)	Work piece material	Tool material & Design	Process parameters & levels	Remarks
2011/A.Razal Rose et al.	To calculate the influence of welding speed on Tensile properties.	AZ61A Mg alloy 300mmx300mmx6mm (in wt%)Al 5.96,Mn 0.17,Zn 1.28,bal Mg	High Carbon steel PD : 6mm SD : 18mm PL : 5.9mm	TRS : 1200 rpm WS : 30 – 150 mm/min AF : 5KN	WS has maximum influence on microstructure and tensile properties. Maximum tensile strength was obtained at TRS of 1200 rpm and WS of 90mm/min.
2010 / K.L.Harikrishna et al.	Effect of process parameters on weld quality	ZM21 Mg alloy 25mm in thickness (in wt %) Mg -2Zn-1Mg	H13 tool steel Threaded pin (LH) PD : 5mm PL : 4.5mm SD : 15mm	TRS : 450,600rpm WS : 20 -45 mm/min PLD : 0.1-0.2mm Tilt angle : 2°	Grain size increased at the Heat affected zone and Nugget zone with respect to thickness.
2009 / G.Padmanaban et al.	Investigation of process parameters on final weld quality and mechanical properties	AZ31B Mg alloy 220mmx75mmx6mm	High carbon steel (Threaded pin) PL : 5.7mm SD : 18mm PD : 6mm D/d ratio : 3 (in wt %) C 0.75,Si 0.25 , Mn 0.32	TRS : 1000 – 2000 rpm WS : 0.37 – 2.25 mm/s AF : 2,3,4 KN	Higher tensile properties wee obtained with a TR of 1600 rpm, WS 0.67 mm/s and AF 3KN.

PD : Pin Diameter
SD : Shoulder Diameter
PL : Pin Length
PLD : Plunge Depth
TRS : Tool Rotational Speed
WS : Welding Speed
AF : Axial Force
TL : Thread Length
TS : Thread Spacing
WT : Weld Temperature
WP : Weld Pitch
SC : Straight Cylindrical
SQ : Square
TH : Threaded Cylindrical
FL : Fluted
TR : Triangular
LH : Left Handed
NZ : Nugget Zone
HAZ : Heat Affected Zone
TMAZ : thermo Mechanically Affected Zone

The review of Friction stir welding of Mg alloys is in between 2009 and 2015.early researches were concentrated on the effect of selected process parameters on final weld quality and on mechanical properties.G.Padmanabhan and V.Balasubramanian [14] in 2009 done experimental investigations on fourteen joints using different levels of Tool rotational speed, welding speed etc. A tool rotational speed of 1600 rpm, welding speed of 0.67mm/sec and an axial force of 3KN yielded superior joints. The tensile properties of the welded joints were also been found out and optimum values were obtained. Formation of finer grains, optimum level of heat generation and higher hardness were the main reasons for increased tensile strength.K.L.Harikrishna et.al.[13] in 2010 concentrated on Friction stir welding of ZM 21 Mg alloy which is having a nominal composition of Mg-2-Zn-1Mn(in wt. %).Proper selection of process parameters obtained a defect free good grain structured welds. Bend performance of the welds was satisfactory. The work reveals that friction stir welding is possible for joining ZM21 Mg alloys for thickness up to 25mm.

A.Razal Rose et .al.[12] work in 2011 is focusing on the influences of welding speed on tensile properties of Friction stir welded AZ61A Mg alloy.(in wt. %, Al -5.9,Mn-0.17,Zn-1.28,bal Mg)Welding speed has been found to have great influence on Grain size of stir zone, hardness etc. Among the selected values a tool rotational speed of 1200 rpm, axial force of 5KN exhibited maximum tensile strength.S.H.Chowdhury et.al.[11] in 2012 analyzed the influence of process parameters during friction stir welding of AZ31B-H24 Mg alloy(wt.% Al 2.5-3.5,Zn 0.7-1.3,Mn 0.2-1.0 bal Mg) Tool having a pin length of 1.65mm and pin diameter of 3.175mm is used. Lowest hardness was obtained at the center of Stir zone .The welding speed and rotational rate had stronger influence on yield strength .A welding speed of 20mm/s , rotational rat of 1000 rpm produced higher yield strength welds.S.Rajakumar et.al [10] in 2013 showed a relationship between process parameters and tensile strength. Response surface methodology was used for the formation of empirical relationship.AZ61A Mg alloy was used for experimentation (in wt. % Al 5.96,Zn 1.28,Mn 0.17,bal Mg).Tool rotational speed, traverse speed, stirrer geometry were considered. Optimization was done with the help of Response surface methodology. A tool rotational speed of 1194rpm, welding speed of 92.19mm/min, axial force of 5.05KN yielded maximum tensile strength.Inderjeet Singh et.al [9] in 2014 studied the effects of welding parameters on similar friction stir welded joints of AZ31B-O Mg alloy (in wt. % Si<0.1,Fe /,0.005,Cu 0.05,Mn 0.2- 0.5,Zn 0.5-1.5,Al 2.5-3.5,Ni 0.05,Co/,0.05,bal Mg).The mechanical properties and microstructure were investigated. At a high welding pitch of 0.050mm/rev with a shoulder diameter of 20mm yielded a 91% increase in tensile strength that the base metal. All joints show an improvement in impact toughness, a maximum harness value of 67.25Hv was observed at the same weld pitch and shoulder diameter.S.Ugender et.al. [8] in 2014 experimented on AZ31B Mg alloy to find out the influences of welding parameters on mechanical properties and microstructure(in wt.%, Al 3.0,Mn 2.0,Zn 1.0,Cu 0.05,Ni 0.005,Si 0.1,Fe 0.005 bal Mg).The friction stir welding had been carried out at 900rpm,1120rpm,1400rpm and 1800rpm with tool materials High speed steel and stainless steel. The micro hardness values obtained had shown an increase at low rotational speeds. A lowering of tensile strength was obtained at rotational speeds of 1400rpmand 1800 rpm.

Yong Zhao et.al. [7] in 2014 compared the micro hardness values and tensile properties of NZ20K (Mg-2Nd-0.3Zn-0.4Zr) and AZ31 Mg alloy at room temperature and 200°C.NZ20K had a chemical composition of (in wt.%) Nd 1.5-2.5, Zn 0.2-0.4, Zr 0.3-0.5,bal Mg and AZ31 having a chemical composition (in wt.%) Zn 0.5-1.5, Al 2.5-3.5, bal Mg. Tool rotational speed and welding speed were the selected process parameters with a pin diameter of 6mm,pin length of 4.8mm,shoulder diameter of 18mm of high speed steel material with a tilt angle of 2.5°.A defect free joint was obtained under 13oorpm and 60mm/min.The ultimate tensile strength showed a decrease in value at 200°C than at room temperature. The hardness of the joint at Nugget zone had improved from that at the base metal.B.S.Naik et.al.[6] in 2014 had done a detailed investigation on texture development during Friction stir lap welding of AZ31B–H24 Mg alloy(in wt.% Al 2.5-3.5,Zn 0.7-1.3,Mn 0.2-1.0 bal Mg) at varying tool rotational speeds and welding speeds. H13 tool steel was used with a pin diameter 6.35mm, shoulder diameter of 19.05mm, pitch of 0.8thread/mm.Tool rotational speed of 1000rpm and 1500rpm, welding speed of 10-20mm/s were the selected process parameters. Severe grain coarsening was noted in The Stir zone, Thermo mechanically affected zone and heat affected zone during welding. Microstructural analysis shown that the stirred zone contained Al_8Mn_5 and β-$Mg_{17}Al_{12}$ particles similar to that in base metal. A hardness trough was obtained in the friction lap welded AZ31B-H24 Mg alloy. The stir zone exhibits lowest hardness values of 72-82 pct. of base metal. The tool rotational rate and welding speed had a greater influence on the failure loads of friction stir lap welds.Sevvel.P, Jaiganesh V [5] in 2014 experimented on the characterization of mechanical properties and microstructural analysis of AZ31B Mg alloy during friction stir welding and optimization. During that year majority of works are concentrated on AZ31B Mg alloys.(in wt.% Al 2.37,Zn 0.72,Mn 0.30,Cu 0.05,Si 0.08,Fe 0.005,N 0.005 bal Mg).A detailed investigation was carried out to find out the influence of optimized process parameters on resultant joints.HSS tool with a tapered cylindrical profile was used. Maximum tensile strength was obtained at a tool rotational speed of 1000rpm, welding speed of 0.5mm/min .The detailed microstructure analysis revealed that the grain fragmentation was good and obtained uniform orientation.S.Mironov T.Onuma et.al.[4] in 2015 also concentrated o AZ31 Mg alloy but on varying welding temperatures.AZ31 Mg alloy is having a hexagonal close packed structure was examined. Tool steel with a shoulder diameter of 15mm,pin length of 3.7mm,tilt angle of 3°,plunge depth of 3.5mm was used. A temperature range of 0.57-0.85Tm was used. Due to the HCP structure the maximum misorientation across grain boundaries could not exceed 30°.The lowering of temperature from 0.85Tm to 0.64Tm during Friction stir welding had led to an increase in tool load.

Bhukya srinivasa naik et.al.[3] in 2015 experimented on the tensile properties and residual stresses on friction stir welded AZ31B-H24 Mg alloy(in wt% Al 2.5-3.5,Zn 0.7-1.3,Mn 0.2-1.0 bal Mg. Tool rotational speed and welding speed were the selected process parameters with ranges from 1000-1500rpm and 10 & 20mm/s.H13 tool with shoulder diameter 19.05mm,pin diameter of 6.35mm,thread length of 4.45mm,thread spacing of 1.27mm,pitch of 0.8 thread /mm, tilt angle 0.5° was used for experimentation. The results proved that the tool rotational rate and welding speed had strong effect on tensile shear failure load. When the test temperature was increased the energy absorbed during tensile sear loading had also increased. The detailed fractographic analysis indicates that crack initiation was observed from the stress concentration zone.Jaiganesh.V, P.Sevvel [2] in 2015 experimented on the effects of process parameters on the microstructure and mechanical properties of Mg alloy. The alloy grade chosen for purpose was AZ80A Mg alloy(in wt% Al 7.8,Zn 0.7,Mn 0.3,Cu 0.05,Si 0.1,Fe 0.005,Ni 0.005 bal Mg)A tapered cylindrical pin profiled High speed steel tool was used for friction stir welding with tool rotational speed, feed rate and constant axial force as the process parameters. A defect free sound weld was obtained at a tool rotational speed of 100 rpm and feed rate of 1.5mm/minute microstructural analysis resulted in proper distribution of fine grains in the stir zone. Also high yield strength and superior mechanical properties were obtained. Prakash kumar sahu,Sukhomay pal[1] in 2015 used multi response optimization of process parameters during friction stir welding of AM20 Mg alloy with the help of taguchi grey relational analysis.(in wt.% Al 2.03,Mn 0.43,Zn 0.18,Si 0.04 bal Mg).The process parameters chosen were tool rotational speed, welding speed, shoulder diameter and plunging depth.H13 tool steel was used having shoulder diameter of 16-24mm,pin diameter of 6mm ,pin length of 3.5mm.Taguchi's L_{18} factorial design has been used in this work eight weld quality parameters ultimate tensile strength, yield strength, percentage elongation, compressive stress, bending angle, average hardness at nugget zone,thermomcehcnical zone and heat affected zone were calculated. A plunge depth of 0.12mm, rotational speed of 1100 rev/min,welding speed of 98mm/min ,shoulder diameter of 24mm yielded optimum results. From response surface methodology it was found that shoulder diameter and welding speed were having most influence.Eventhough the review period is short this paper will be a ready reference for upcoming researchers

4. CONCLUSION

In this work Friction stir welding of various types of Mg alloy grades has been considered. The influence of each process parameters on final weld quality, microstructural analysis, mechanical properties etc. have also been considered. Among various grades of Mg alloy AZ31 grade has been used in major. The process parameters selected were mainly Tool rotational speed, Welding speed, tool tilt angle etc. Thorough literature review related to Friction stir welding of Mg alloys has been done from 2009 to 2015.The works of various researchers has been highlighted throughout the paper. Remarks of various works are also highlighted.

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