IMPACT OF TOOL ON AL-2014 VS ELECTROLYTE COPPER JOINTS IN FRICTION STIR WELDING

Nagamalleswararao.A[1], H. Ameresh[2]
[1,2]Department of Mechanical Engineering AGI-Hyd and Research Scholar ANU- Guntur.

Abstract
Friction stir fastening could be a solid-state connection method that uses a non-consumable tool to hitch 2 facing work items while not melting the work piece material. The materials which may be joined mistreatment this fastening are copper and its alloys, lead, metal and metal. The materials used are metal 2014 it's simply machined insure temperatures, and among the strongest offered metal alloys, further as having high hardness. Solution Copper enhances the qualities of copper as Associate in nursing electrical conductor. Electrical instrumentation usually contains electrolytic copper.

Keywords*:* Fastening, copper and its alloys, hardness, temperatures, electrolyte.

INTRODUCTION

The conventional fusion fastening of aluminium and its alloys has continuously been an excellent challenge for designers and technologists. The difficulties related to this sort of joints area unit principally relating to the presence of a tenacious compound layer, high thermal conduction, high constant of thermal growth, set shrinkage, and high solubility of H and different gases in liquified state. Friction stir fastening connexion technique has been shown to be viable for connexion aluminium alloys, Cu, Ti, Mg, steel and plastics. The most necessary category of materials has been metallic element. a variety of just about all categories of metallic element alloys are with success friction stir welded. These embody the 1xxx, 2xx, 3xxx, 4xxx, 5xxx, 6xxx and 7xxx alloys, also because the newer Al-Li alloys. Applications of aluminium a pair of series embody aeroplane body, automobile chassis, body, engine blocks. Dissimilar materials like Cu-Al have special properties lovesmart thermal and electrical conductivities Therefore; it will be applied for applications love bus-bars, connectors, foil conductors of transformers, windings of capacitors and condensers, refrigeration and heat-exchangers tubes, etc.

The defects formation is major think about friction stir fastening which incorporates onion rings, flash, tunnel defects, cracks and voids. FSW tool plays a serious role to getquality be a part of. it's necessary to ascertain the impact of tool style on formation of defects in dissimilar FSW system. Aluminium 2014alloy is associate metallic element primarily based alloy typically employed in the region trade.

It is simply machined in bound temperatures, and among the strongest offered metallic element alloys also as having high hardness. but it's troublesome to weld because it is subjected to cracking. 2014 is that the second most well-liked of the 2000- series metallic element alloys, once 2024 metallic element alloy as shown in fig.2.It is usually extruded and solid.The corrosion resistance of this alloy is especially poor. Aluminium (2014T6) is well machined in bound temperatures, and among the strongest offered metallic element alloys, also as having high hardness.

Tool geometry

Tool pure mathematics is that the most cogent side of method development.

The tool pure mathematics plays a vital role in material flow and successively governs the traverse rate at that FSW will be conducted

An FSW tool consists of a shoulder and a pin. As mentioned earlier, the tool has 2 primary functions: (a) localized heating, and (b) material flow. within the initial stage of tool plunge, the heating results primarily from the friction between pin and work piece.

The tool is plunged until the shoulder touches the work piece. The friction between the shoulder and work piece leads to the largest part of heating. From the heating side, the relative size of pin and shoulder is vital, and therefore the alternative style options aren't vital. The shoulder conjointly provides confinement for the heated volume of fabric. The second perform of the tool is to 'stir' and 'move' the fabric. The uniformity of microstructure and properties still as method hundreds is ruled by the tool style. With increasing expertise and a few improvement in understanding of fabric flow, the tool pure mathematics has evolved considerably. Complicated options are a dditional to change material flow, admixture and scale back method hundreds. Tool pure mathematics affects the warmth generation rate, traverse force, force and therefore the thermo mechanical setting older by the tool. The flow of plasticized material within the work piece is littered with the tool pure mathematics still because the linear and motionmotion of the tool .Important factors square measure shoulder diameter, shoulder surface angle, pin pure mathematics together with its form and size.

Tool material used in friction stirs welding Joints

FSW, the tool profile primarily influences the blending and recombining of the plasticized material. method parameters and power geometries have an effect on the FSW forces that square measure vital for warmth generation. a very important a part of the tool could be a pin (probe). Tool pin protrudes from the bottom of the tool shoulder and its length is marginally smaller than the plate thickness .Literature clearly indicates that researchers have used completely different types of tool pin profile for his or her study. Friction stir attachment was dole out on similar AA2014 Vs AA2014 by 2 completely different tool styles. gift investigation provides associate degree insight on formation of defects underneath the result of various tool pin styles. The tool pin profiles comparable to polygon and polygon were utilized in the current experimental investigation by keeping alternative parameters constant. These tool pin profiles were designed supported its static and dynamic constant areas from best appropriate profile. Besides, the defects were analyzed through visual observation, macrostructure, microstructure investigation and scanning microscope. AA 2014-T6 materials of 5mm thickness were accustomed build however joint via friction stir attachment technology. there have been 2 completely different tool styles utilized in this experimental study, that was created up from tool H13 grade. Experimental half was divided into 3 set of experiments whereby polygon and power pin profiles were utilized in 1st set of experiments. Pin diameter was half dozen millimetre and within the second set of experiment polygon tool was utilized by keeping same dimensions.Whereas the tool geometries thatplay a very important role in friction stir attachment embrace cylinder, taper, pin, threaded, internal taper etc. Wide sorts of heat flux to be made conjointly rely on tool pure mathematics. the sort of tool pure mathematics to be used depends on the sort of metals to be joined and alternative properties throughout attachment. The microstructure of the weld made are often influenced by the interaction with the scoured tool material. The strength of the work material determines the stresses iatrogenic to the tool. Tool material properties influence the warmth generation within the tool and therefore the temperatures earned. Such properties like thermal conduction square measure then vital in tool material choice to realize specific properties within the final joint. Thermal stresses experienced during a tool square measure addicted to the constant of thermal growth. Tool material choice might also be supported hardness, plasticity and reactivity of the work materials.

Machine used for this Friction Stir fastening Project

Vertical shaper was employed in the friction stir fastening of Al 2014 t6 . in situ of edge cutter the polygonal shape and polygonal shape tools were inserted for friction stir fastening. edge machines square measure terribly versatile. they're sometimes acc ustomed machine flat surfaces, however also can turn out irregular surfaces. they'll even be accustomed drill, bore, cut gears, and turn out slots. the sort of shaper most ordinarily found in student outlets could be a vertical spindle machine with a swivelling head. though there square measure many alternative sorts of edge machines, this document can focus solely on the vertical shaper. The tool will be bored to death and down with a quill feed lever on the pinnacle. The bed during which the materials for fastening square measure placed is enraptured in a very horizontal plane. Once associate degree axis is found at a desired position it's fastened into position with the gibb locks. Most edge machines square measure equipped with power feed for one or a lot of axes. Power feed is drum sander than manual feed. Power feed additionally reduces operator fatigue on long cuts. On some machines, the ability feed is managementled by a forward reverse lever and a speed control knob. the pinnacle of a vertical shaper will be canted from facet to facet and from front to back. this permits for providing varied tilt angles.

EXPERIMENTAL PROCEDURE

Welding Of atomic number 13 2014 T6 By polygon Tool

1. 2 base metals of atomic number 13 2014-T6plate of 5mm thick and size two hundred millimeter x a hundred millimeter were welded by stirring them in conjunction witha polygon tool a by exploitation vertical shaper. The atomic number 13 plates square measure butt articulated .

2. H-13 alloy steel is chosen as tool material as a result of its high strength at elevated temperature, thermal fatigue resistance and low wear resistance. The diameter of the shoulder and pin used were 24mm, 8mm severally and length of the pin is two.8mm.

3. clarification of Friction Stir fastening used during this Study A rotating pin is plunged into the atomic number 13. The feed given to the tool was 31mm/min and therefore the tool is revolved at 1120 rate. The rotating pin is pushed toward the faying surface of the atomic number 13 plate and, consequently, the chemical compound film is automatically off from the faying surface by the rubbing motion of the rotating pin .Aluminum, that is in a very fluid-like plastic state because of the warmth generated by the friction of the rotating tool shoulder, adheres to the activated faying surface of the atomic number 13, so connection between 2 atomic number 13 plates is achieved .Welding by FSW is usually completed through stirring by a rotating pin inserted round the center of the weld interface of lap base plates.

4. when fastening, samples for determinant strength, impact strength, hardness and microstructure square measure machined from the welded sample.

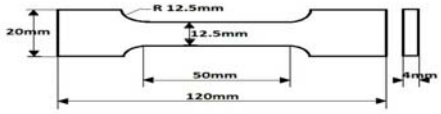


Fig 1: Tensile test specimen

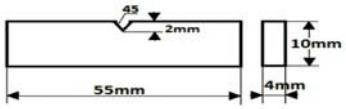


Fig.2: Impact test specimen

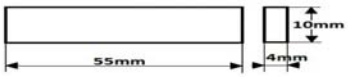


Fig.3: Hardness test specimen

WELDING OF ALUMINUIM 2014 T6 AND ELECTROYLTE COPPER BY HEXAGONAL TOOL

1. 2 base metals consisting of Associate in Nursing solution copper Associate in Nursingd metal 2014 t6 every of size 200x100mm were welded by stirring them along withan polygon tool 7a by mistreatment vertical miller.

The metal and solution copper plates were butt joined.

2. H-13 alloy steel is chosen as tool material thanks to its high strength at elevated temperature, thermal fatigue resistance and low wear resistance. The diameter of the shoulder and pin used were 24mm, 8mm severally and length of the pin is a pair of.8mm.The feed given to the tool was 31mm/min and also the tool is turned at 1120 rate.

3. when attachment of metal plate and copper plate samples for enduringness, impact strength, hardness and microstructure were machined from the welded plates.

WELDING OF ALUMINUIM 2014 T6 AND ELECTROYLTE COPPER BY OCTOGONAL TOOL

1. 2 base metals of metal 2014-T6 plate of 5mm thick and size two hundred metric linear unit x a hundred metric linear unit were welded by stirring them along withanoctagonal tool assembly by mistreatment vertical miller. The metal plates area unit butt articulate.

2. H-13 alloy steel is chosen as tool material thanks to its high strength at elevated temperature, thermal fatigue resistance and low wear resistance. The diameter of the shoulder and pin used were 24mm, 8mm severally and length of the pin is a pair of.8mm.The feed given to the tool was 31mm/min and also the tool is turned at 900 rate

3. when attachment, samples for deciding enduringness, impact strength, hardness and microstructure area unit machined from the welded sample.

RESULTS AND DISCUSSIONS

Hexagonal Tool

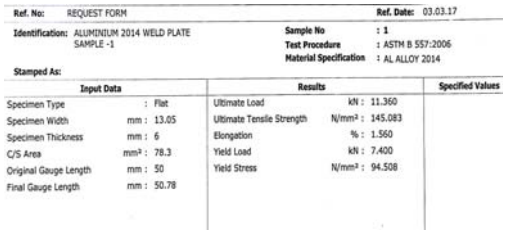
1. Al 2014 T6

Successfully joints were obtained by FSW processes for the all the method parameters employed in the investigation. Typical example of FS welds is shown

Fig.6**:**FSW joint of AA2014 T6

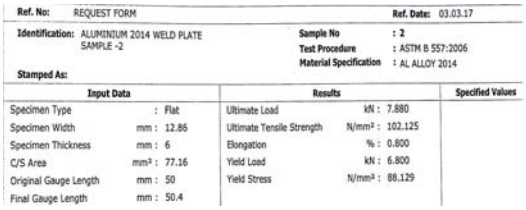
The surfaces of the weld square measure seen at the method condition of 1200rpm, 31mm/min of feed and ten angle. Usually, the FSW method leaves a pin hole at the weld finish, as seen in Figure and also the style of the weld is completed in such the way that the give up the opening is cut and not used for more processes. The mechanical properties of AA 2014 t6 alloy FSW joints of such final strength, proportion of elongation and hardness square measure evaluated. At every condition 3specimens square measure tested and average of the results of 3 specimens is given.

The strength of the welded Al 2014 t6 joint performed in UTN-40 was found to be one hundred twenty.00N/mm2 (taking average of three values of tensile strength) by exploitation polygonal shape tool profile. the share elongation of the specimens was found to be one.18(taking average of three values of elongation).



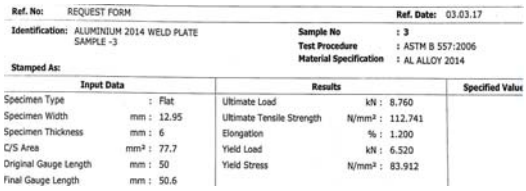
Ref. No: REQUEST FORM — Ref. Date: 03.03.17
Identification: ALUMINIUM 2014 WELD PLATE SAMPLE -1
Sample No : 1
Test Procedure : ASTM B 557:2006
Material Specification : AL ALLOY 2014
Stamped As:

Input Data			Results		Specified Values
Specimen Type	: Flat		Ultimate Load	kN : 11.360	
Specimen Width	mm : 13.05		Ultimate Tensile Strength	N/mm² : 145.083	
Specimen Thickness	mm : 6		Elongation	% : 1.560	
C/S Area	mm² : 78.3		Yield Load	kN : 7.400	
Original Gauge Length	mm : 50		Yield Stress	N/mm² : 94.508	
Final Gauge Length	mm : 50.78				



Ref. No: REQUEST FORM — Ref. Date: 03.03.17
Identification: ALUMINIUM 2014 WELD PLATE SAMPLE -2
Sample No : 2
Test Procedure : ASTM B 557:2006
Material Specification : AL ALLOY 2014
Stamped As:

Input Data			Results		Specified Values
Specimen Type	: Flat		Ultimate Load	kN : 7.880	
Specimen Width	mm : 12.86		Ultimate Tensile Strength	N/mm² : 102.125	
Specimen Thickness	mm : 6		Elongation	% : 0.800	
C/S Area	mm² : 77.16		Yield Load	kN : 6.800	
Original Gauge Length	mm : 50		Yield Stress	N/mm² : 88.129	
Final Gauge Length	mm : 50.4				



Ref. No: REQUEST FORM — Ref. Date: 03.03.17
Identification: ALUMINIUM 2014 WELD PLATE SAMPLE -3
Sample No : 3
Test Procedure : ASTM B 557:2006
Material Specification : AL ALLOY 2014
Stamped As:

Input Data			Results		Specified Valu
Specimen Type	: Flat		Ultimate Load	kN : 8.760	
Specimen Width	mm : 12.95		Ultimate Tensile Strength	N/mm² : 112.741	
Specimen Thickness	mm : 6		Elongation	% : 1.200	
C/S Area	mm² : 77.7		Yield Load	kN : 6.520	
Original Gauge Length	mm : 50		Yield Stress	N/mm² : 83.912	
Final Gauge Length	mm : 50.6				

The hardness of the weld of Al 2014 t6 exploitation polygonal shape tool by applying a load of 250 kgf by a RAB-250 brinell hardness take a look at machine was found to be ninety two.7BHN(taking average of three values).

Ref.No: REQUEST FORM Ref. Date: 03.03.17

Machine Details		Test Details	
Name	: BRINELL HARDNESS	Test Procedure	: IS 1500:2005
Model No/Srl.No	: 15/08/014 RAB-250	Type of Hardness	: BHN
Calibration on Date	: 01.10.2016	Indentor	: 5 mm
Calibration Due Date	: 30.09.2017	Load Applied	: 250 Kgs

Sl.No	Location	Observed Values in BHN			
		Impression 1	Impression 2	Impression 3	Average
1	WELD ZONE SAMPLE NO : 1	95.0	93.9	95.0	94.63
2	WELD ZONE SAMPLE NO : 2	96.1	95.0	97.2	96.10
3	WELD ZONE SAMPLE NO : 3	84.9	85.8	86.8	85.83

The energy the weld of Al 2014 t6 will absorb before fracture performed in KI-300 was found to be half dozen.6 joules exploitation polygonal shape pin profile..

Ref No: REQUEST FORM Order No: -- Ref. Date: 03.03.17

Machine Details			
Equipment Used	: KRYSTAL ELMEC	Test Procedure	: IS 1757-1988
Srl.No	: 2006/912 KI-300	Type of Impact	: CHARPY - V
Calibration on Date	: 10.09.2016	Notch Depth	: 2mm
Calibration Due Date	: 09.09.2017	Notch Angle:	: 45°
		Specimen Size	: 10 x 5 x 55 mm
		Impact Test Temp	: At Room Temperature

Sl.No	Location of the Sample	Observed Values (Joules)			
		Impact 1	Impact 2	Impact 3	Average
1	WELD ZONE SAMPLE NO : 1	6	0	0	6.00
2	WELD ZONE SAMPLE NO : 2	8	0	0	8.00
3	WELD ZONE SAMPLE NO : 3	6	0	0	6.00

The microstructure of the weld of Al 2014 T6 was inspected in a neighborhood zero.5005mm2 underneath AST M E 112. The microstructure was found to be Equi axed grains and written like structure and grain size was found to be 5.5.

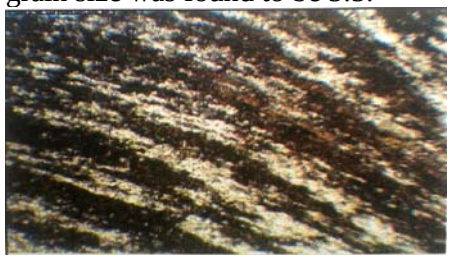


Fig.4**:** Microstructural view of AA 2014T6 FSW joint

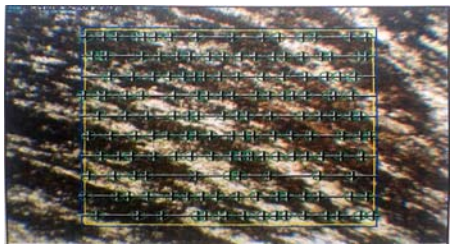


Fig.5**:** Microstructural view of AA 2014T6 FSW joint

GrainSize analysis :Results Summary

Fields measured	1
Analysed Area	.5005 sq mm
Standard used	ASTM E 112

	Grain size#
ASTM Grain size#	5.5
Intercepts	139
Mean Int length(um)	50.9
Std dev.	-
95% CI	-

HEXAGONAL TOOL ALUMINUIM 2014 T6 AND ELECTROYTE COPPER

Successfully joints were obtained by FSW processes for the all the method parameters employed in the investigation. Typical example of FS welds is shown

Fig.6**:**FSW joint of AA 2014T6 & ETP Copper

When the fastening was performed by polygonal shape tool at 1120 rev, the Al and copper butt was found to contain tunnel defect. .

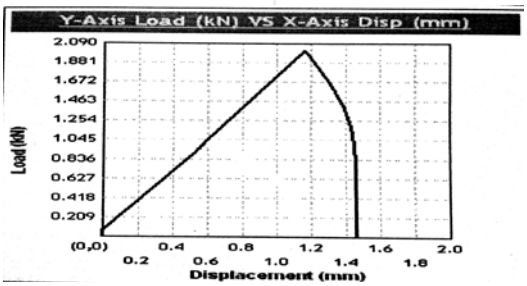
This was eliminated by reducing the speed of polygonal shape tool from 1120rpm to 900rpm.This yielded higher weld look with none defects.

The surfaces of the weld square measure seen at the method condition of 900rpm, 31mm/min of feed and ten angle. Usually, the FSW method leaves a pin hole at the weld finish, as seen in Figure and also the style of the weld is completed in such the way that the give up the opening is cut and not used for more processes. The mechanical properties of AA 2014 t6 alloy and solution copper FSW joints of such final strength, proportion of elongation and hardness square measure evaluated.

Fig.7**:**Tensile test specimen of AA 2014T6 & ETP Copper

The strength of the Al 2014 T6 and solution copper welded joint performed in UTN-40 was found to be fifty two.04/mm2 by exploitation polygonal shape tool profile. the share elongation of the specimen was found to be 1.480.

Input Data			Results		
Specimen Type		: Flat	Ultimate Load	kN :	2.040
Specimen Width	mm :	12.25	Ultimate Tensile Strength	N/mm² :	52.041
Specimen Thickness	mm :	3.2	Elongation	% :	1.480
C/S Area	mm² :	39.2	Yield Load	kN :	1.560
Original Gauge Length	mm :	50	Yield Stress	N/mm² :	39.796
Final Gauge Length	mm :	50.74			



The hardness of metallic element 2014 t6 and solution copper weld joint victimisation polygon tool by applying a load of 250 kgf by a RAB-250 brinell hardness check machine was found to be ninety seven.97BHN.

Fig. 8**:**Hardness test specimen of AA 2014T6 & ETP Copper

The energy absorbed by metallic element 2014 t6 and solution copper welded joint before fracture performed in KI-300 was found to be four.0 joules victimisation polygonpin profile

Fig.9**:**Impact test specimen of AA 2014T6 & ETP Copper

The microstructure of the weld of metallic element 2014 t6 and solution copper was inspected in a vicinity zero.5005mm2 underneath ASTM E 112. The microstructure was found to be equi axed grains and scripted like structure and grain size was found to be half-dozen

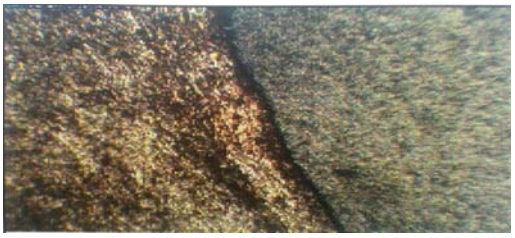


Fig.10**:**Microstructural view of AA 2014T6 & ETP copper FSW joint

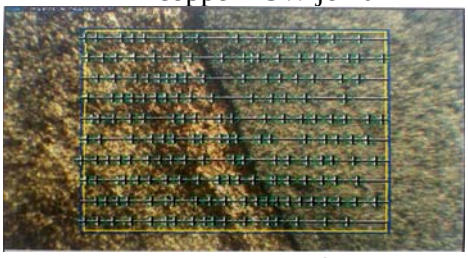


Fig.11**:**microstructural view of AA 2014T6 & ETP copper FSW joint

GrainSize analysis :Results Summary

Fields measured	1
Analysed Area	.5005 sq mm
Standard used	ASTM E 112

	Grain size#
ASTM Grain size#	6.
Intercepts	177
Mean Int length(um)	40
Std dev.	.
95% CI	.

OCTAGONAL TOOL ALUMINUIM 2014 T6 AND ELECTROYTE COPPER

Successfully joints were obtained by FSW processes for the all the method parameters utilized in the investigation. Typical example of FS welds is shown

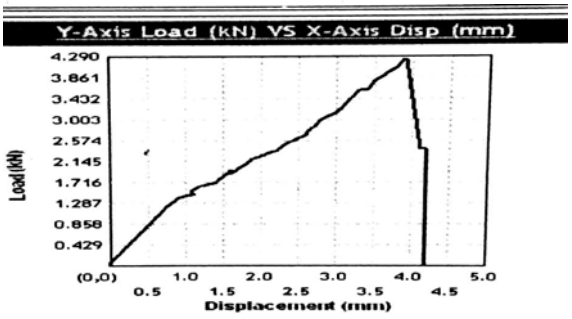
Fig.12**:**FSW joint of AA 2014T6 & ETP Copper

The surfaces of the weld area unit seen at the method condition of 900rpm, 31mm/min of feed and ten angle. Usually, the FSW method leaves a pin hole at the weld finish, as seen in Figure and also the style of the weld is completed in such the simplest way that the give up the opening is cut and not used for additional processes. The mechanical properties of AA 2014 t6 alloy and solution copper FSW joints of such final strength, share of elongation and hardness area unit evaluated.

The strength of the metallic element 2014 t6 and solution copper welded joint performed in UTN-40 was found to be thirty seven.39N/mm2 by victimisation polygon tool profile. the proportion elongation of the specimen was found to be a pair of.940.

Fig.13**:**Tensile test specimen of AA 2014T6 & ETP Copper

Input Data			Results		
Specimen Type	:	Flat	Ultimate Load	kN :	4
Specimen Width	mm :	18.9	Ultimate Tensile Strength	N/mm² :	3
Specimen Thickness	mm :	6	Elongation	% :	2
C/S Area	mm² :	113.4	Yield Load	kN :	3
Original Gauge Length	mm :	50	Yield Stress	N/mm² :	26.455
Final Gauge Length	mm :	51.47			



The hardness of metallic element 2014 t6 and solution copper weld joint victimisation polygon tool by applying a load of 250 kgf by a RAB-250 brinell hardness checkmachine was found to be seventy five.00BHN..

Machine Details		Test Details	
Name	: BRINELL HARDNESS	Test Procedure	: IS 1500:2005
Model No/Srl.No	: 15/08/014 RAB-250	Type of Hardness	: BHN
Calibration on Date	: 01.10.2016	Indentor	: 5 mm
Calibration Due Date	: 30.09.2017	Load Applied	: 250 Kgs

Material Identification: AL 2014 - ETP COPPER WELD PLATE, OCTAGONAL TOOL, RPM-900

Material Specification: AA 2014 & COPPER

Sl.No	Location	Observed Values in BHN			
		Impression 1	Impression 2	Impression 3	Average
1	WELD ZONE	76.3	75.5	73.2	75.00

Specified Values: --

The energy absorbed by metallic element 2014 t6 and solution copper welded joint before fracture performed in KI-300 was found to be four.0 joules victimisation polygonpin profile.

Machine Details			
Equipment Used	: KRYSTAL ELMEC	Test Procedure	: IS 1757-1988
Srl.No	: 2006/912 KI-300	Type of Impact	: CHARPY - V
Calibration on Date	: 10.09.2016	Notch Depth	: 2mm
Calibration Due Date	: 09.09.2017	Notch Angle:	: 45°
		Specimen Size	: 10 x 5 x 55 mm
		Impact Test Temp	: At Room Temperature

The microstructure of the weld of metallic element 2014 t6 and solution copper was inspected in a vicinity zero.5005mm2 underneath ASTM E 112. The microstructure was found to be equi axed grains and scripted like structure and grain size was found to be half-dozen.

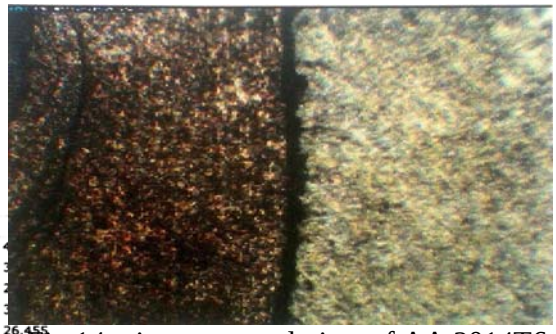


Fig.14 microstructural view of AA 2014T6 & ETP copper

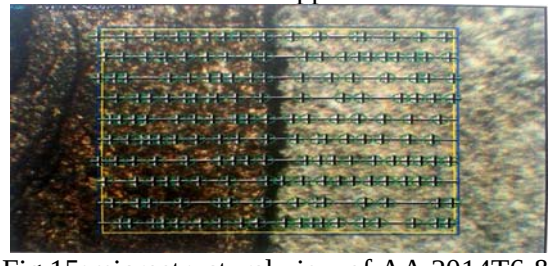


Fig.15**:**microstructural view of AA 2014T6 & ETP copper

GrainSize analysis :Results Summary

Fields measured	1
Analysed Area	.5005 sq mm
Standard used	ASTM E 112

	Grain size#
ASTM Grain size#	6.
Intercepts	175
Mean Int length(um)	40.4
Std dev.	.
95% CI	.

CONCLUSION

The following conclusions were drawn from the experimental study of friction stir welded joints victimisation each polygon and polygon t ool.

1. once the tool is modified from polygon to polygon, the strength, hardness of weld and impact absorbed by welded joint will increase in metallic element 2014 t6. However, the grain size in each the cases remained identical and is capable five.5.
2. hen the tool is modified from polygon to polygon,
the strength and hardness of weld of the metallic element 2014 t6 and solution copper welded joint is shrivelled. However, the grain size in each the cases remained identical and is capable half-dozen and conjointly impact absorbed by welded joint remains identical and is capablefour joules.
3. The strength was increased from 120N/mm2 to 225.69N/mm2, hardness from ninety two.7BHN to 95.80BHN and impact absorbed from half-dozen.6 joules to twelvejoules in metallic element 2014 t6 welded joint.
4. The strength was shrivelled from fifty two.04/mm2to thirty seven.39N/mm2 and hardness from ninety seven.97BHN to ninety five.80BHN
5. So, it may be complete that has no. of sides of tool in an exceedingly friction stir attachment increases(keeping alternative par ameters like speed of tool, feed of tool and shoulder diameter constant), the mechanical properties of metallic element joint is increased and also the aluminium-electrolyte copper joint is shrivelled.

REFERENCES

[1] W.M. Thomas, E.D. Nicholas, J.C. Needham, M.G. Murch, P. Templesmith, C.J. Dawes, G.B. Patent Application No. 9125978.8 (December 1991).

[2] C. Dawes, W. Thomas, TWI Bulletin 6, November/December 1995, p. 124.

[3] B. London, M. Mahoney, B. Bingel, M. Calabrese, D.Waldron, in: Proceedings of the Third International Symposium on Friction Stir Welding, Kobe, Japan, 27–28 September, 2001.

[4] C.G. Rhodes, M.W. Mahoney, W.H. Bingel, R.A. Spurling, C.C. Bampton, Scripta Mater. 36 (1997) 69.

[5] G. Liu, L.E. Murr, C.S. Niou, J.C. McClure, F.R. Vega, Scripta Mater. 37 (1997) 355.

[6] K.V. Jata, S.L. Semiatin, Scripta Mater. 43 (2000) 743.

[7] S. Benavides, Y. Li, L.E. Murr, D. Brown, J.C. McClure, Scripta Mater. 41 (1999) 809.

[8] L.E. Murr, Y. Li, R.D. Flores, E.A. Trillo, Mater. Res. Innovat. 2 (1998) 150.

[9] Y. Li, E.A. Trillo, L.E. Murr, J. Mater. Sci. Lett. 19 (2000) 1047.

[10] Y. Li, L.E. Murr, J.C. McClure, Mater. Sci. Eng. A 271 (1999) 213.

[11] H.B. Cary, Modern Welding Technology, Prentice-Hall, New Jersey, 2002.

[12] C.J. Dawes, W.M. Thomas, Weld. J. 75 (1996) 41.

[13] R.S. Mishra, M.W. Mahoney, S.X. McFadden, N.A. Mara, A.K. Mukherjee, Scripta Mater. 42 (2000) 163.

[14] R.S. Mishra, M.W. Mahoney, Mater. Sci. Forum 357–359 (2001) 507.

[15] Z.Y. Ma, R.S. Mishra, M.W. Mahoney, Acta Mater. 50 (2002) 4419.

[16] Nagamalleswararao.A, H. Ameresh, C.Srinivas, IJRASET,Volume 6 Issue II, February 2018.

[17] P.B. Berbon, W.H. Bingel, R.S. Mishra, C.C. Bampton, M.W. Mahoney, Scripta Mater. 44 (2001) 61.

[18] J.E. Spowart, Z.Y. Ma, R.S. Mishra, in: K.V. Jata, M.W. Mahoney, R.S. Mishra, S.L. Semiatin, T. Lienert (Eds.), Friction Stir Welding and Processing II, TMS, 2003, pp. 243–252.

[19] Z.Y. Ma, S.R. Sharma, R.S. Mishra, M.W. Manohey, Mater. Sci. Forum 426–432 (2003) 2891.

[20] M.R. Johnsen, Weld. J. 78 (2) (1999) 35.