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Analysis of Mechanical Properties & Structure of adding Ti & Cr Particles in AL6082 Fabricated Using Friction Stir Processing

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Abstract

The Friction stir processing (FSP) is an attractive joining processin solid state. The maximum temperatures obtained by FSP of high strength low alloy (HSLA) are considerably lowerthan those from arc welding and other conventional welding processes. So that the microstructures obtained after FSP are expected to be different from thoseafter arc welding. Firstly no solidification microstructures,i.e., fusion zone and partially melted heat-affected zone, are found after FSP. Friction Stir Processing(FSP) is emerging as a solid state technique to fabricate aluminium composites in recent years. In present work, FSP is applied to AL6082/ Ti-Cr. So we can investigate the effect of Ti-Cr on the microstructure, homogeneity and mechanical properties of AL-6082. A single pass of FSP was carried out at 1400 R.P.M. rotational speed, with travel speed of 25mm/min and an axial force of 10 KN to produce composition. The Alloying elements were added to four volume fractions as 3.75%, 5%, 6.25%, and 7.5%. The microstructure was studied using scanning electron microscopy (SEM). Various phases were identified by X-ray diffraction (XRD) the results shows grain size refined, micro hardness increases substantially, effect of alloying element %age on grain size is also reported in this paper

Keywords: Friction Stir Processing, Aluminium6082, Reinforced composite, Microstructure, Micro hardness

Introduction

The Friction Stir Processing (FSP) is the latest material surface processing technique that can be used to refine the microstructure and improve in mechanical properties of the alloyed material. The source of origin of FSP is friction stir welding (FSW) process, a solid state joining technique invented at the welding institute (TWI), United Kingdom in 1991[1,2]. Basically the FSW process joins the two same/different materials, The FSP is also based on the same principle but it is used to modify the microstructure of the specific area for which the FSP is done [3]. The FSP is a new material processing technique which can be used on material like aluminium, copper, magnesium etc. With the help of FSP technique a material can be alloyed up to some depth with another material without affecting the base metal up to some extent. As it is a solid state process it does not melt the metal that is being processed [4-5].

FSP is a process that uses a non-consumable cylindrical tool with a concentric pin at one end of the tool is used to process the material. The rotated tool is pressed into the surface of the material and in result with a combination of frictional and adiabatic heating the material gets soften, while at the same time stirring is done by rotating tool which results in homogenous mixing of the material which further refined grain structures [6-10]. As per the research, the volume of material processed has improved properties like refine in the grain size etc. and improved mechanical properties. As research is going on in various field in which FSP can be utilized widely. The airplane blades, propellers of a ship can be repaired as well manufactured with a material processed by FSP technique. This technique apart from refining the surface properties also can be used to eliminate porosity in the surface [11-13]

The figure no1 shows the schematic diagram FSP technique. In first stage a non-consumable cylindrical tool is rotated at a prefixed RPM. In second stage the tip of the rotating tool is plunged into the work piece and it generates a lot of heat by its rotation. The shape of the tool tip which is small in size fully inserted into the metal and concentric large diameter shoulder which is intended to prevent upward displacement of the melted material from the surface of the work piece. As the tool penetrates into the material surface, the rotating pin generates friction and adiabatic heating[14-16]. This combination of friction and heat softens the material and it helps further movement of the tool into the work piece. Due to rotation and further movement of tool it creates a stirring action and material flows around the pin. The depth of penetration is controlled by the length of pin and its penetration. Third stage shows the shoulder making contact with the surface of the work piece. The rotating shoulder expands the hot zone created on the surface of the work piece. Simultaneously it stops the upward movement of the uprooted and stirred material and results in a forging action on that material. When the tool is fully inserted into the work piece, it then travels across the metal at a specific rate; inches per minute as seen in the stage four [17-18].

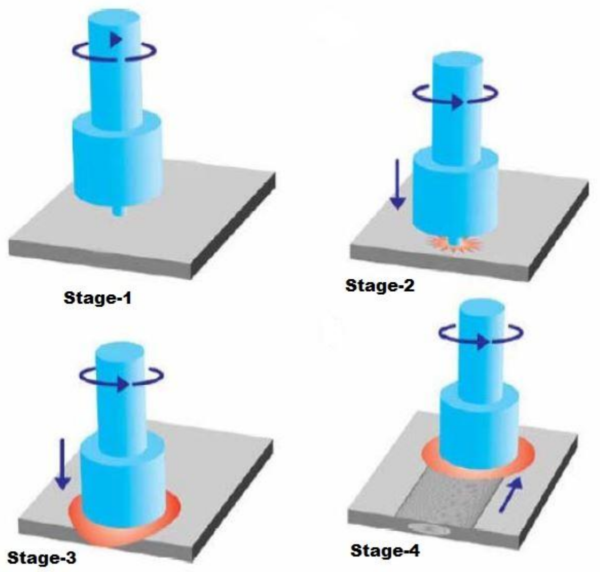

Figure 1 FSP technique

It is interesting to watch the FSP technique, as the tool progress into the metal due to heat generation within narrow region of the pin, the metal gets heated but it never melts. The peak temperature achieved in this process is around 80 to 90 percent of the melting temperature. Hence when the tool passes by, the processed work piece cools and exhibits a refined and homogenized microstructure. It means by FSP we can change the properties of the work piece within limits and the rest of the work piece got minimum influence [19-20]

Experimental Procedure

The sheet of 12mm thickness with its chemical composition corresponds to aluminum alloy AL6082 as base alloy was used. Table 1 shows the chemical composition of Al-6082.

Table 1: Chemical Composition of base alloy AL6082

Element	Mg	Si	Ti	Mn	Fe	Cu	Al
Wt %age	0.41	1.32	0.1	0.53	0.290	0.17	Bal

The sheet was cut as rectangular sample of size 150mm*50mm*12mm. The figure 2 shows the SEM of as received of plate AL6082 plate. A Groove of 6mm depth was made along the centre line of the plate using wire cut electrical discharge machine (EDM) & compacted with Ti + Cr Powder. A pin less tool was initially employed to cover the top of the groove after filling the Ti + Cr particles to prevent the particles from scattering during FSP [28]. Figure 3 show the tool made of M-35 HSS was used for the present study. The chemical of tool is given in table 2

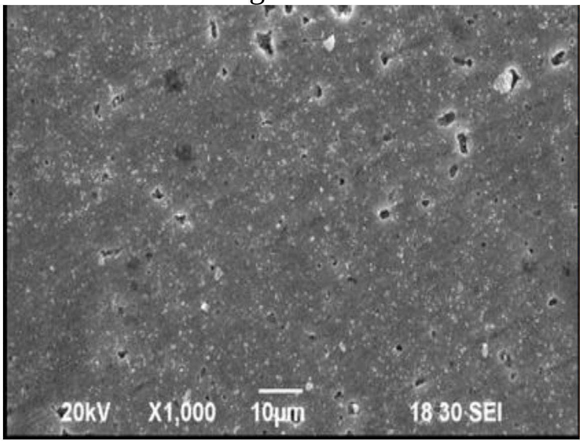

Figure 2SEM image of AL6082 as received

Figure 3 image of tool used

Table: 2 Chemical Composition of tool

Element	**C**	**Si**	**Cr**	**Va**	**W**	**Mo**	**Co**
Weight % age	0.81	0.34	3.9	2.1	6.2	5.1	4.9

The tool had a shoulder having diameter of 20mm, pin diameter 6.5mm & pin length 6.5mm was used. The FSP was carried out on a Vertical milling machine having 5 H.P motor with different speed & feed ratio as automatic operated. The process parameters employed were tool rotation speed 1400 R.P.M. , transverse speed 25 mm/min & the axial force of 10 KN FSP was processed using three plates of varying the width of grooves as 1.00mm, 1.25mm, 1.5mm, 1.75mm to have the four level of volume fraction of Ti + Cr particles as 3.75%, 5%, 6.25%, and 7.5%.

Specimens of 12 mm thickness were obtained by cutting the friction stir processed plate at itscenter perpendicular to the processing direction. All the specimens were polished as per the standard procedure. The chemical composition & SEM of the specimen was done using Scanning Electron Microscope (SEM, JEOL) in Thapar University, Patiala (India). The micro hardness was measured at CTR Ludhiana (India) using micro hardness tester at 100g applied load for 15 sec at the various locations in the specimen. The XRD of the specimen was done at Thapar University Patiala on X-ray Diffractometer (XRD, PanAlytical) to obtain the phase formed of the specimen.

Results & Discussions

Figure 4 shows the typical crown appearance of friction stir processed aluminum with Ti + Cr powder. As it can be seen from the figure that no crack, void etc. are seen on the surface of the processed specimen. The curve structure is appeared on the top surface which is similar to the conventional milling process because FSP is derived from FSW. Some trail experiments were conducted were conducted initially to set &optimize the process variable & to obtain a crack free surface because a smooth crown appearance is essential in the processed zone.

Figure 4 Crown appearance of friction stir processed specimen

Chemical composition of AL 6082 &specimen

The chemical composition of the all the three specimens named as specimen -1, specimen-2, specimen-3, specimen-4 having 3.75%, 5%, 6.25%, and 7.5%. of the alloying element of Ti + Ni in the base metal were compared with the base metal. The table 3 shows the comparison of chemical composition of fourspecimens with base metal which shows that the %age of Ti + Cr is increased in the base metal as per the %age of pouring powder.

Table 3: Comparison of base metal with specimen

Element		C	O	Mg	Si	Cr	Mn	Fe	Cu	Ni	Zn	Al
Weight %age	Base Metal	-----	-----	0.4	1.3	0.1	0.49	0.28	0.16	----	----	97.27
	Specimen -1	12.23	16.03	---	---	0.24	0.58	0.24	0.17	0.16	0.35	70
	Specimen -2	13.11	16.42		1.2	0.34	0.14	0.34	---	0.21	0.69	67.27
	Specimen -3	12.46	2.69	---	0.89	0.41	0.22	0.18	---	0.35	0.34	82.46
	Specimen -4	----	4.63	---	0.84	0.49	0.54	0.24	0.17	0.50	0.34	92.25

Micro hardness of AL6082& Specimen

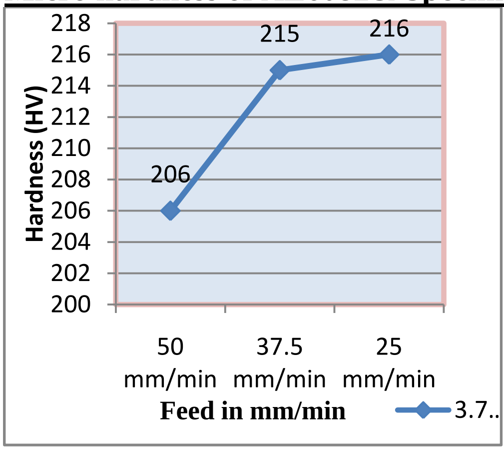

Figure 4 (a)

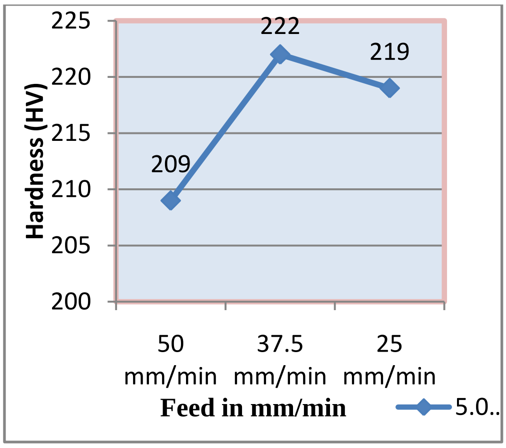

Figure 4 (b)

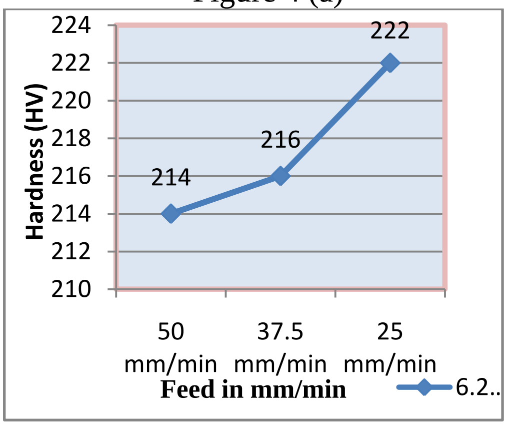

Figure 4 (c)

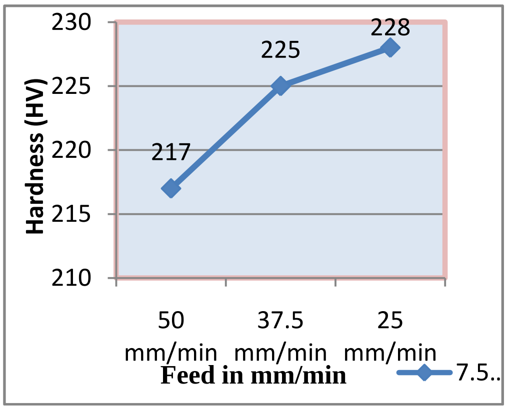

Figure 4 (d)

Figure 4 Vickers hardness at 1400 RPM

Figure 4 (a), (b), (c), (d) represents the individual Vickers hardness at 1400 RPM with different feed rate of job & by adding the different composition of the alloying element of Ni + Cr in the base metal of AL6082

Figure 5 represents the combined effect of Vickers hardness of AL6082 at 1400 RPM with different %age of alloying element to the AL6082. The increase or decrease of Vickers hardness through FSP is related with the different % age of alloying elements in AL6082. During FSP two main mechanisms could be happen. First, increasing dislocation density and dynamic recrystallization which lead to grain refinement and higher mechanical properties such as hardness. Second, softening mechanisms such as dynamic recovery which decreases the dislocation density and hardness.

The figure 5 clearly shows in that Vickers hardness value of FSPed base alloy with the alloying element of Ni + Cr with different %age of adding the alloying element is increased as compared with the as–received AL6082, due to grain refinement and also due to fragmentation and distribution of second phase intermetallic particles. It can also be noted that at tool speed of 1400 RPM the hardness distribution is almost uniform at different feed with different %age of alloying element of Ni + Cr in the AL6082. During this process an increase of 50% in the average hardness value is achieved due to higher particle concentration at higher feed rate i.e. 25 mm/min when 7.5% of Ni + Cr as alloying element is added to the AL6082.

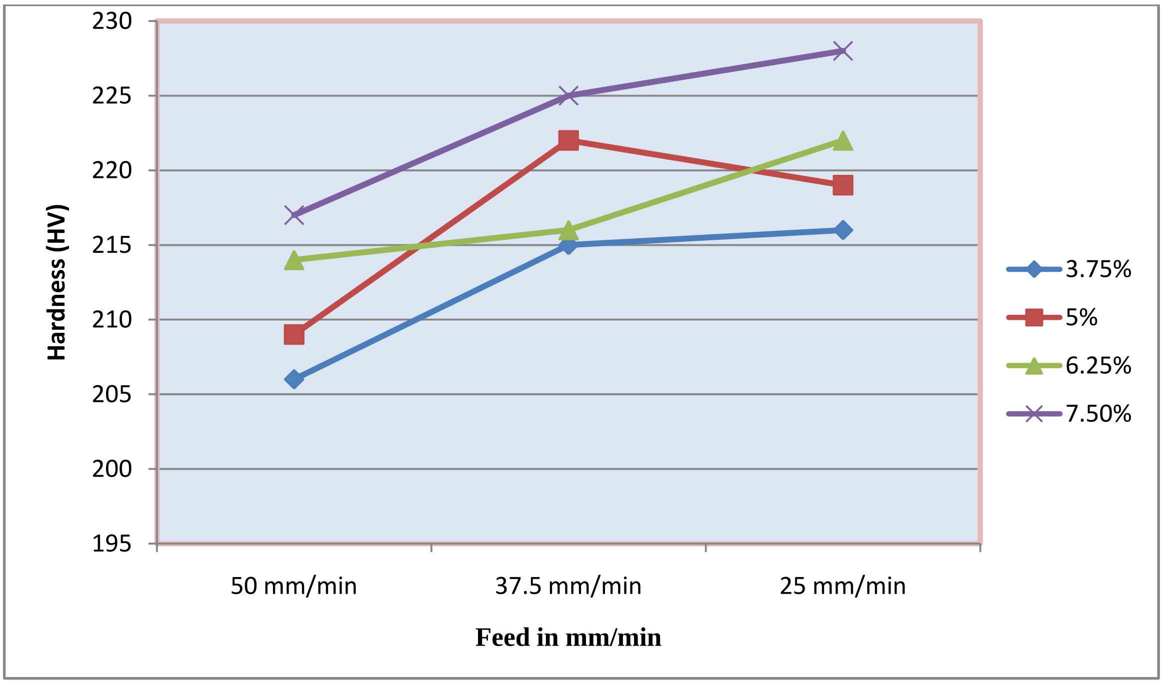

Figure 5 Combined effect of Vickers Hardness at 1400 RPM of Tool rotation speed

This increase in the Vickers hardness is achieved firstly because of the direct strengthens imparted to matrix by this strong and hard reinforcement which act as hinder dislocation movement. In this process the reinforcement are in Nano scale & well distributed by FSP. Secondly it is due to the effect of microstructural modification in the HAZ. It is also believed that homogenous distribution of Nano-sized reinforcement results in pinning of dislocation & retarding the grain growth. In the present study, evidence shows that grain refinement due to due to FSP & grain growth inhabitation due to distribution & location of Ni + Cr alloy in the AL6082, contributes more to hardness the other mechanism.

Microstructure examination / measurement

Scanning electron microscope (SEM) of JEOL JSM 6510 LV at 20 KV was done at thapar university Patiala. All the FSP stir zone samples were mechanically ground & polished with 0.1 µm aluminum paste & cleaned with the acetone & triple distilled water.

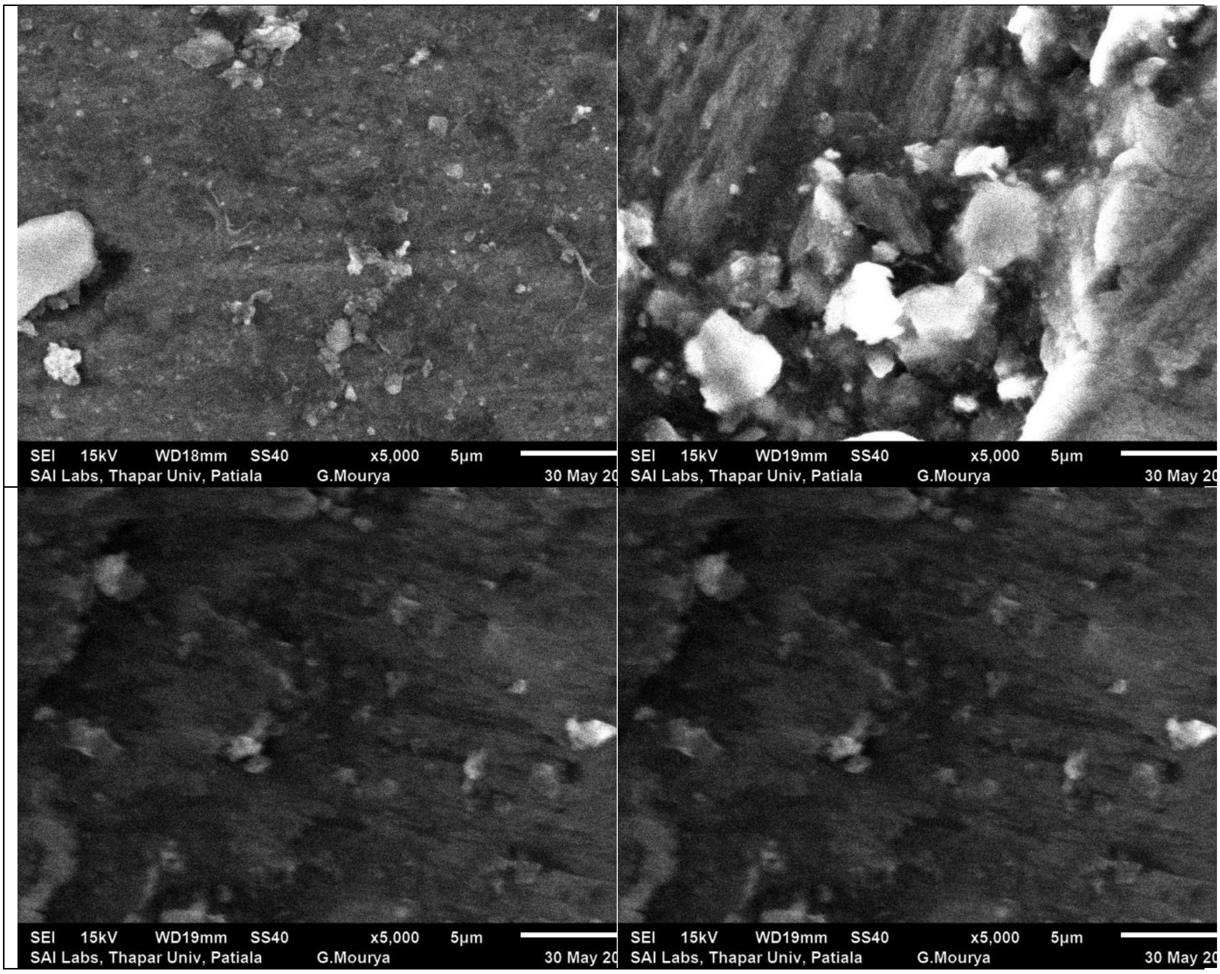

Figure 6 SEM at 1400 RPM with (a) 7.5 % of alloying element (b) 6.25 % of alloying element (c) 5.00 % of alloying element (d) 3.75 % of alloying element

Figure 6 (a), (b), (c) & (d) represents the SEM images at speed of 1400 RPM with adding the alloying element as (a) 7.5 % of alloying element (b) 6.25 % of alloying element (c) 5.00 % of alloying element (d) 3.75 % of alloying element in AL6082. According to these figures it is clear that the interface of Ni & Cr alloys was well-bonded to AL6082 without the presences of void are other kinds of defects in it. The figure 6 shows the distribution of Ni & Cr powder alloys in the AL6082. As it can be seen that the distribution of the powders are homogeneous. The size of the particle in the stirred zone is between 3.3µm to 1.9µm which is much finer than those in the initial powder used for the FSP. Therefore a single pass FSP was adequate to break the particles & improve the distribution. The SEM image also shows a good bonding between powders & the matrix. The average grain size observed in the current case is 3.3µm with 3.75% of alloying elements, 2.8µm with 5.00% of alloying elements,2.2µm with 6.25% of alloying elements,1.9µm with 7.50% of alloying elements. So the grain size is lower when the higher quantity of the alloying element in it. Furthermore the average grain size during the speed 1400 RPM is lesser than that of 1800 RPM.

Phase Identification / XRD

The X-ray Diffraction test was done on the entirespecimen prepared by FSP is done. X-ray diffraction (XRD) is a mature x-ray technology that is widely used in the minerals industry for mineral identification and quantification. XRD uses the unique crystal structure and derived x-ray fingerprint of any crystalline material, e.g. mineral, for identification. XRD, unlike other mineral or bulk techniques such as SEM-EDS (MLA) or bulk assay (respectively), is unique in being able to unambiguously identify a mineral in a bulk or pure mineral sample, irrespective of the mineral type - sulphide, anhydrous or hydrated. While it can be used to provide gross solid solution mineralchemical changes (e.g. in carbonates, feldspars) the method is insensitive to minor or trace element changes in a mineral lattice.

Every crystalline substance is made up of an intrinsic regular arrangement of atoms in the form of its crystal lattice. When the lattice is illuminated by a collimated beam of x-rays the lattice reflects the x-rays at angles (Φ) specific to the distance spacing of the individual lattice planes (d-spacing, or "d") and the wavelength of the illuminating x-radiation (λ)

The Bragg Equation relates these parameters:

$n\lambda = 2d.\sin\Phi$

The XRD of the specimen were carried at 2θ angle range from 10° - 80° with step size of 0.0130° at Thapar University, Patiala. Figure 6(a) & 6(b) shows the XRD main graphics, analyze view of specimen. Table 4(a) & 4(b) shows the pattern list of the XRD test. In both of the main graphic analyze view the four peaks values are seen the value of this peak is given in the table 4(a) & 4(b) which shows that in specimen no1 85% of Ni + Cr+ Al phase is formed whereas in the second specimen the 26% of Ni + Cr + Al phase is formed. From the table 4(a) & 4(b) it is seen that Ni is fairly mixed with aluminum in specimen- 2 whereas in specimen -1 the Ti is fairly mixed with aluminum to generate homogeneous mixture.

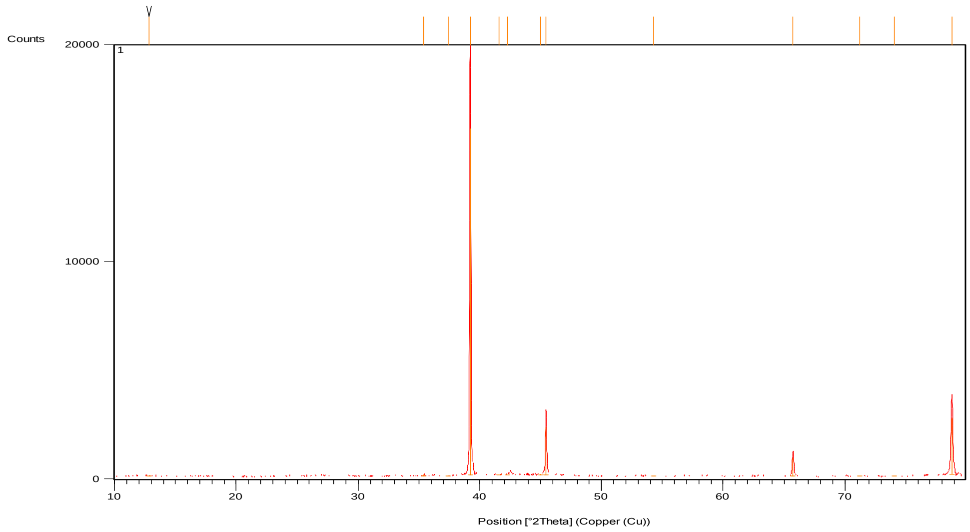

Figure 6(a) Main Graphics; Analyze View of Specimen -1

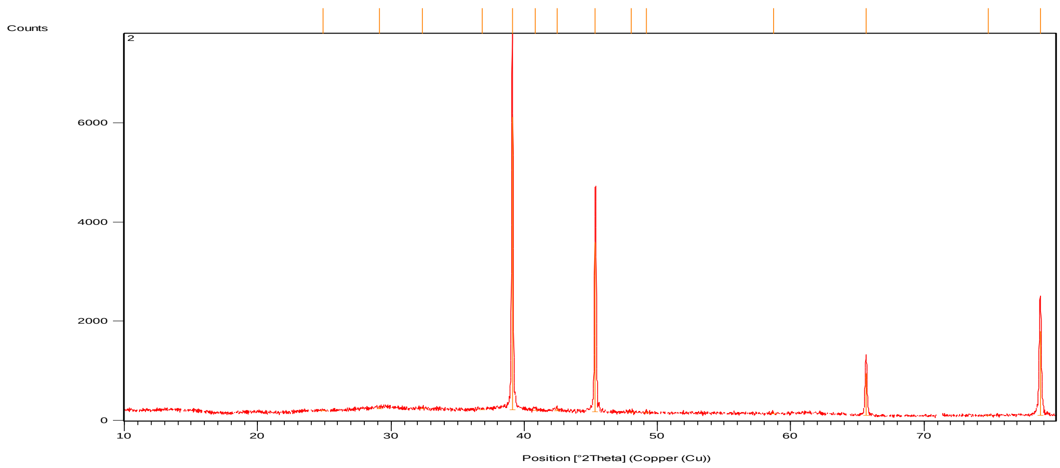

Figure 6(b) Main Graphics, Analyze View of Specimen -2

Table: 4(a) Pattern List of Specimen -1

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula	SemiQuant [%]
*	01-074-3785	47	Titanium Nickel Aluminum	-0.478	0.494	Ti (Ni0.11 Al0.89)3	85
*	03-065-3957	26	Nickel Titanium	-0.128	0.004	Ni4 Ti3	1
*	01-072-9142	55	Aluminum Titanium	0.098	0.055	Al2 Ti	10
*	01-074-5327	29	Aluminum Nickel	0.341	0.016	Al3 Ni2	5

Table: 4(b) Pattern List of Specimen -2

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula	SemiQuant [%]
*	01-072-8274	29	Aluminum Nickel Titanium	-0.472	0.019	Ti27.55 Ni28 Al63.73	26
*	01-072-2619	14	Nickel Titanium	-0.069	0.005	Ni2 Ti	7
*	03-065-7340	41	Nickel Aluminum	0.232	0.049	Al4 Ni3	50
*	01-074-4925	11	Aluminum Titanium	-0.412	0.013	Al5 Ti2	17

Conclusions

1. An increase in 41% of microhardness value is achieved at 1400 rpm with feed rate 50mm/min,when 7.5% of the Ni and Ti are added to Al 6082.
2. From the EDX test the mixing of Ti is observed from .1 to 0.48.
3. From the EDX test the mixing of Cr is observed from 0 to 0.5.
4. The grain structure is more refined from the increase in %age of pouring element.

References

1. A .Thangarasu , N. Murugan, I. Dinaharan, S.J. Vijay " Synhesis and characterization of titanium carbide particulate reinforced AA 6082 aluminium alloy composite via friction stir processing", Archives of Civil and Mechanical engineering (2015) pp. 324-334.
2. A .Thangarasu , N. Murugan, I. Dinaharan" Production and wear characterization of AA6082-TiC Surface composites by friction stir processing",12th global congress on Manufacturing and Mangement , GCMM 2014, Procedia Engineering 97 (2014) pp. 590-597
3. A.Shafiei-Zarghani "Strengthening analysis and mechanical assessment of Ti/Al_2O_3 Nano- composite produced b friction stir processing", Material Science & Engineering A 631(2015) pp. 75-85.
4. C.J. Dawes, W.M. Thomas: "Annual North American Welding Research conference 1995", pp 301-310.
5. Densimet Data Sheet , Trade Literature , Plansee GmbH , Germany
6. Fuller, C.B. (2007), Chapter 2: "Friction stir tooling: Tool materials and designs, friction stir welding and processing", ASM International.
7. J. Su, T. Nelson and C. Sterling. "Friction stir processing of large-area bulk UFG aluminum alloys". Scripta Materialia 52 (2005) pp.135-140.
8. Konkol , P. (2003), ' Characterization of friction stir weldments in 500 Brinell hardness quenched and tempered steel ', Proceedings of the Fourth International Conference on Friction stir Welding , Park City , UT , TWI, September
9. L.P. Borrego "Fatigue life improvement by friction stir processing of 5083 aluminium alloy MIG butt welds", Theoretical and Applied Fracture Mechanics 70 (2014)pp. 68–74
10. M. Lotfollahi"Effect of friction sir processing on erosion- corrosion behavior of nickel-aluminum bronze", Materials and design 62(2014) pp 282-287.
11. M. Peel, A. Steuwer, M. Preuss and P. Withers. "Microstructure, mechanical properties and residual stresses as a function of welding speed in aluminum AA5083 friction stir welds", Acta Materialia, Volume 51, Issue 16, (2003), pp. 4791-4801.
12. M. Sabbaghian" Effect of friction stir processing on the microstructure and mechanical properties of Cu–TiC composite", Ceramics International40 (2014) pp. 12969–12976.
13. M. Ueki, S. Horie, and T. Nakamura, "Factors affecting dynamic recrystallization of metals and alloys," Materials Science and Technology, (2014) vol. 3, no. 5, pp. 329-337, 1987.
14. Ma. Z.Y., Mishra, R.S., and Mahoney, M.W., "Friction Stir Welding and Processing II", TMS, Warrendale, PA, p. 221-230, 2003.
15. Mahoney , M.W. , Bingel , W.H. , Sharma , S.R. and Mishra , R.S. (2003), ' "Microstructural modification and resultant properties of friction stir processed cast NiAl bronze ", Materials Science Forum , 426 – 32 : 2843 – 8 .

16. Mahoney, Murray W., Bingel, William H., Mishra, Rajiv S., Materials Science Forum, v. 426-432, p. 2843-2848, 2003.
17. Mishra, R. S. and Mahoney, M. W., “Friction Stir Processing: A New Grain Refinement Technique to Achieve High Strain Rate Superplasticity in Commercial Alloys,” Materials Science Forum, v. 357-359, p.507-514, 2001.
18. Mishra, R.S. and Mahoney, M.W. (2007), Chapter 1: ‘Introduction, friction stir welding and processing, ASM International.
19. Mishra, R.S., Advanced Materials and Processes, v. 161(10), p. 43-46, 2003.
20. Mishra, R.S., Ma, Z.Y., “Friction Stir Welding and Processing,” Materials Science and Engineering, v. 50, p. 1-78, 2005.
21. Mishra, R.S., Ma, Z.Y., and Charit, I., Mater. Sci. Engineering A, v. A341, p. 30710, 2003.
22. Oh-Ishi, K. and McNelley, T., “The Influence of Friction Stir Processing Parameters on Microstructure of As-Cast NiAl Bronze” Metallurgical and Materials Transactions, v. 36A, p. 1575-1585, 2005.
23. P. Xue “Achieving ultrafine-grained structure in a pure nickel by friction stir processing with additional cooling”, Materials and Design 56 (2014) 848–851
24. R. Johnson and S. Kallee, “Friction Stir Welding”. Materials World, Vol. 7 no. 12 pp. 751-53 December 1999.
25. Rowe , C.E.D. and Thomas , W.M. (2006), ‘ Advances in tooling materials for friction stir welding (Cedar Metals Ltd, TWI Cambridge) ’, Materials Congress – Disruptive Technologies for Light Metals , London , April .
26. Thomas, E.D. Nicholas, J.C. Needham, M.G. Murch, P Temlesmith, C.J. GB Patent Application No. 9125978.8, December 1991.
27. Y. Huang , “Microstructure and surface mechanical property of AZ31 Mg/SiCp surface composite fabricated by Direct Friction Stir Processing”, Materials and Design 59 (2014) pp. 274–278.
28. Zhang , Y.N. , Cao , X. , Larose , S. and Wanjara , P. (2012), ‘ Review of tools for friction stir welding and processing ’, Science and Technology of Welding and Joining , 51 (3): 250 – 260.