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DETERMINATION OF HARDNESS AND MICROSTRUCTURE DURING CROSS PLASTIC FLOW EVALUATION ON TWIST EXTRUSION PROCESSES

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ABSTRACT

The Twist Extrusion process is used to produce grain refinement in bulk forms, many severe plastic deformation techniques were used to refine the structure like Equal Channel Angular Pressing (ECAP), High Pressure Torsion (HPT), multiple forging, and twist extrusion. The aim of this paper is to study the twist extrusion forming process of severe plastic deformation of AA 7075 Aluminium alloy. In this study, the hardness and microstructure of the sample were analyzed at room temperature after high temperature annealed condition. The effect of the twist channel angle behavior is analyzed by three stages of cut section.The grain refinement behavior of the twist extrusion Aluminium alloy is severely deformed by one pass of Twist Extrusion (TE) process, which has been investigated by using the microstructure and hardness. The result indicates that the hardness of the extruded sample is increased by 136 HV and changes of the grain refinement are observed by the microstructures. The findings revealed that at the end of the twist channel the sample shows the most efficient grain refinement.

Keywords: *AA7075 Aluminium alloy, Twist extrusion, Micro hardness, Severe Plastic Deformation*

INTRODUCTION

Recently, severe plastic deformation processes are used to produce nano and ultrafine grained materials in bulk materials. Many researches aimed to increase the mechanical properties and special attention is needed to develop the innovative idea of the severe plastic deformation technique. Grain refinement is well identified to result in strength development of alloys, with the experimental relation between a mean grain size d and yield strength σ_y illustrated by the hall-petch relationship [1]. In this study, a billet is hard-pressed through a twist extrusion die, where the transverse cross section remains constant and the twisted billet rotates at a twist angle of β 60° about its longitudinal direction [1]. In TE, DmirtyOrlov et al. have obtained extensive improvement in the past research. This is the best technique on the new severe plastic deformation processes [2]. The twist extrusion method has been investigated in different ways which is clearly explained large plastic strain accumulated during the process the billet was inserted into the twist angle about 60°. The billet was processed by TE, to readjust grain refinement of microstructure and mechanical properties [3]. Aluminium alloys are used in most of the industrial applications because of the enhanced properties like high strength, better corrosion resistance, dimensional stability, very good ductility, high machinability, good formability etc. AA7075 Aluminium alloy has very good mechanical properties, such as high mechanical strength, light weight, good vibration-damping characteristic and stiffness which are needed to support aerospace, aircraft and structural components. There are various types of products which can be produced using twist extrusion such as aerospace, automotive industry, and surgical components. This study aims to research the effect of TE on ultrafine grain refinement, severe plastic deformation processes in predicting Material property performance [4]. Stolyarov et al. have Studied, the microstructure and anisotropy of the mechanical properties of titanium in a two stage cold deformation. In the stage-1, the samples were prepared for TE, in the stage-2, after TE, the sample was cold rolled in flat rolls [5]. The twist extrusion method was examined and the ultra-fine grain structure with an average size of 0.3 µm was found in copper by TE [6]. In the following relationships, the enhanced $\varepsilon_{imax}$and the least ε_{imin}values (within the workpiece cross section) of the degree of deformation ε_i after one pass upon TE were derived [5, 10]:

$$\varepsilon_{imax}= \tan\beta_{max}; \quad (1)$$
$$\varepsilon_{imin}= 0.4+0.1 \tan \beta_{max} \quad (2)$$

Many technologies based on severe plastic deformation methods have come out recently, such as twist channel angular pressing[7,8], planner twist extrusion[9], Two consecutive clockwise dies (Route I) an alternative

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clockwise- counter clockwise dies (Route II)[10] direct extrusion after three twist extrusion passes [11], Equal channel angular pressing and TE (ROUTE I: Clockwise Die + Clockwise Die, ROUTE II; Clockwise Die + Counter Clockwise Die [12], Equal Channel Multiple – Angular Extrusion (ECMAE) and Equal Channel Angular Extrusion (ECAP) [13,16], and twist extrusion [14,15,16].

METHOD & MATERIAL

The experiment was conducted on a four column hydraulic press machine with a maximum capacity of 100 tons as shown in fig.1. For this research, AA7075 Aluminium alloy is chosen for the work material with dimensions of 100 mm × 28 mm ×18 mm and the properties of the AA7075 alloy are shown in Table 1. Initially, the work material was prepared with 2 mm of edge and surface layer was machined to the desired shape of the billet. The As-received billet was annealed at 773K for 90 min, and cooled in the furnace to produce a fully annealed material. Then, it is pressed through a twisted channel at a slope angle (β) of 60˚ and a rotation angle (α) of 90˚ inthe clockwise direction. The billet was twist extruded at the room temperature with a ram displacement of 15 mm/s. The applied force was maintained at a constant value of 100 tons. The experiment was performed at room temperature with one pass twist extrusion forming of techniques. The TE billet was examined through the cross plastic flow evaluation by microstructure and micro hardness. The microstructure for the cross plastic flow evaluation was obtained by using an Olympus gx51 Optical Microscope (OP), with computerized imaging and evolution software with a magnification of 100x and 200x. And also, the micro hardness values were measured by Wolpert group equipment with a load of 1000g (HV_{1kg}) and 10s dwell time. The measurements of the plastic flow distribution by micro hardness and microstructure examinations were taken at distances from the center of the transverse cross-section to fringes at selected points.

Table 1. Chemical compositions of AA 7075 Aluminium alloy (at wt. %)

Al	Zn	Mg	Cr	Cu	Si	Ti	Mn	Fe
90.07	5.6	2.5	1.6	0.23	0.4	0.2	0.3	0.4

Fig.1. Four column hydraulic press for twist extrusion process

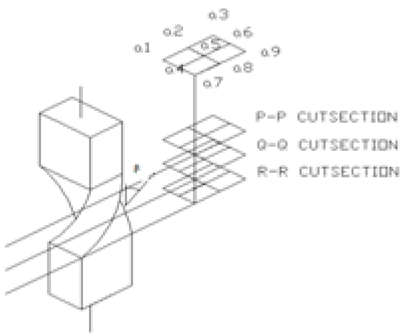

Fig. 2. The cross sectional view of the TE Billet

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The cross transverse sectional view of the billet is shown in fig. 2. By conducting the one pass twist extrusion process on the annealed sample of AA 7075 alloy, the cross flow evaluation of the sample was analyzed from the beginning of the twist zone to the exit zone of the twist channel. The evaluation studies were carried out during the TE process; at this stage the plastic flow was not done completely. The evaluation studies were carried out at three different cut sections such as P-P, Q-Q, and T-T during the twist extrusion.

RESULT & DISCUSSION

Micro Hardness of the P-P, Q-Q and R-R Cross sections through the path trace of the twist channel:
The results and discussion may be combined into a common section or obtainable separately. In order to evaluate the micro hardness value, it is necessary to follow the flow of the specimen during TE, which is evident at the beginning and the end of the twist channel, and the total hardness value of its grain refinement, is shown in figs 3 & 5. The die inserts and guides are removed from the die assembly and the partially extruded billet was examined to observe the plastic flow of the sample at various stages of the deformation with the cut section. Fig. 2 shows the following stages of the cut section of the extruded sample.

(a) P-P cut section of the sample at 10mm from the twist channel entry.
(b) Q-Q cut section of the sample at 20 mm from the twist channel entry.
(c) R-R cut section of the sample at 30 mm from the twist channel entry.

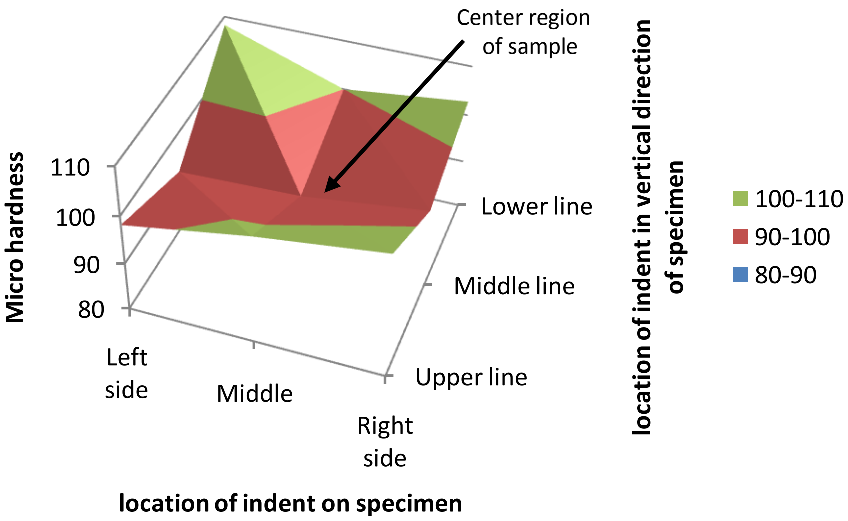

Fig.3 Vickers micro hardness for cut section P-P

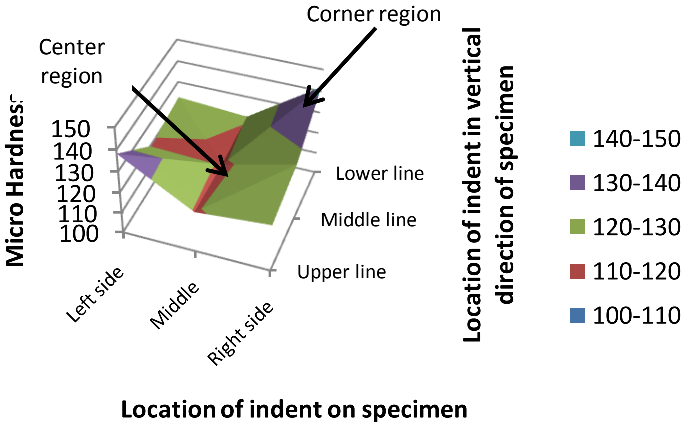

Fig. 4 Vickers micro hardness for Q-Q cut section

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All the microstructure and hardness tests were performed at the corner and center of the cross-section, where the sample experiences the most strain occurring in the corner of the sample. The Vickers Hardness tests were performed on the cross sections, as well as only twist channel flow behavior of the sample during TE of severe plastic deformation. Fig. 3 shows nine different locations of the sample as the upper line carried out three readings such as the left side, middle and right side of the TE sample, and again the same thing for the middle and lower lines. The evaluation was performed by at least nine separate measurements on each cut section of the sample.

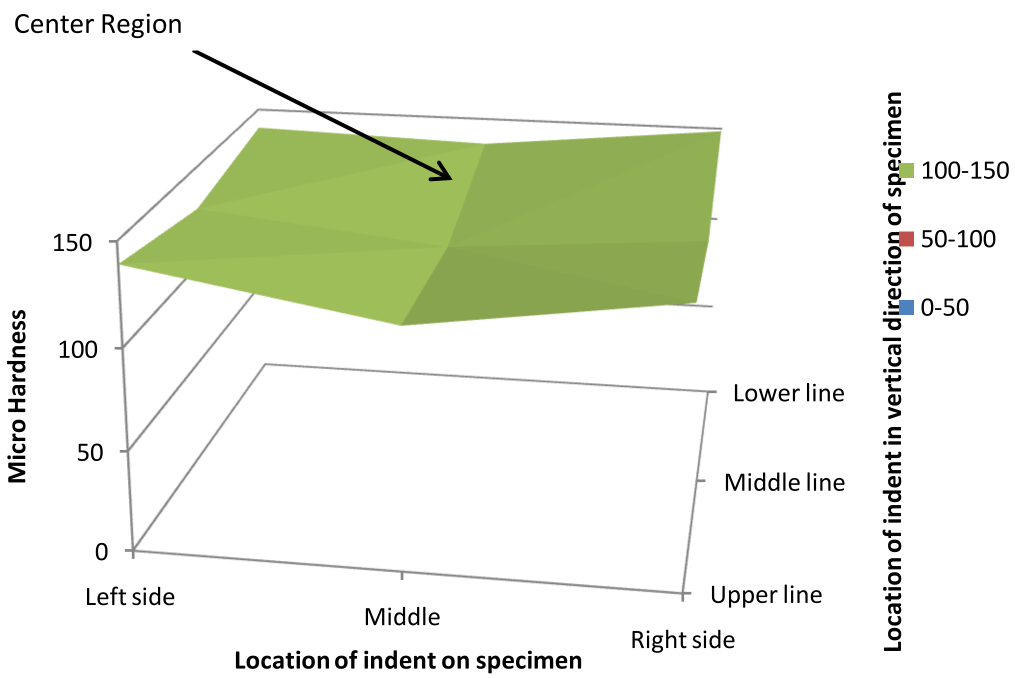

Fig. 5 Vickers micro hardness for R-R cut section

The micro Vickers hardness of the TE Sample of AA 7075

The variation of plastic flow was analyzed by the micro Vickers hardness property after processing the TE sample of AA 7075. Fig. 2 shows the hardness and microstructure test locations on the cross sections as a_1, a_2….a_9. The result shows center and edge regions in specified locations of the sample. In the beginning stage of the TE VIZ, P-P cut section, the center region hardness is 91+/- Hv. The edge region hardness increases on an average range from 101 +/- Hv. Q-Q cut section stage, these center region and corner region value are 199 and 129 +/- Hv. Fig. 5 shows the hardness values at the end of twist channel, cut section of the sample. The opposite corner values upgrading better than center region values. The R-R cut section stage hardness value was obtained and the average center region and corner region values are 124 and 137. Fig. 5 shows non homogeneous hardness distribution at the transverse cross section area of R-R cut section of the twist extruded samples. Fig. 6 shows the as annealed specimen was examined by the Vickers hardness test. The hardness result shows the left corner, middle and right corner values of the sample. The average value of hardness is 86 +/-3.Fig. 7 shows the variation of the micro hardness of AA7075 Aluminium alloy during TE, and the comparison of the result in the twist channel flow behavior before TE and the as annealed state. Note that the behavior of the curve obtained, differs in respect of left corner, middle and right corner of the specimen. It is seen that the hardness value is increased in the right corner of the specimen due to its rotational direction of the twist channel effect, and the effect of grain refinement that occurred in the sample. The micro hardness varies more from the center towards the corner region of the sample. The microstructure of the constituent phases has changed very little along the direction of the twist extrusion.To investigate the extent of the zones of plastic flow in the specimen, the

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specimens were sectioned and analyzed at intervals of 10 mm starting from the twisting zone. It is evident from Fig. 8 that the hardness increases significantly at the end indicating that one pass TE has been completed. There is a consequent increase in the hardness of the AA 7075 one TE pass sample.This hardness variation occurred due to refinement of the grains which is evident from fig 8.The initial hardness of as annealed specimen is 88 Hv.By performing one pass TE the hardness of about 136 Hv was developed. However, by employing TE processes with twist channel entry to exit, the hardness value increases from 88 Hv to 136 Hv.

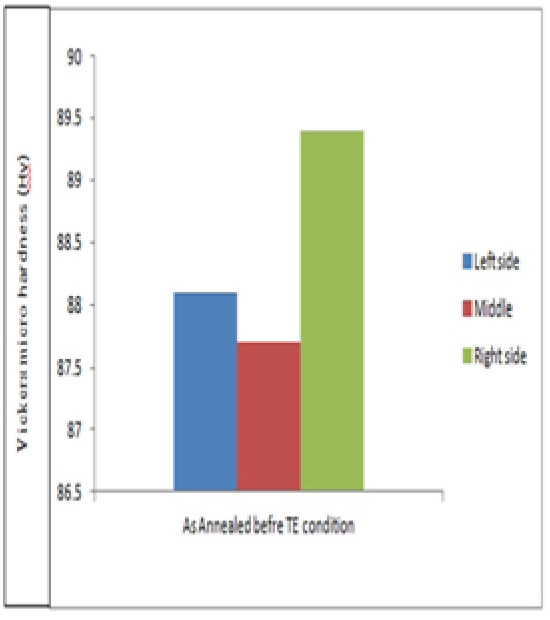

Fig. 6 as annealed before TE sample of AA 7075.

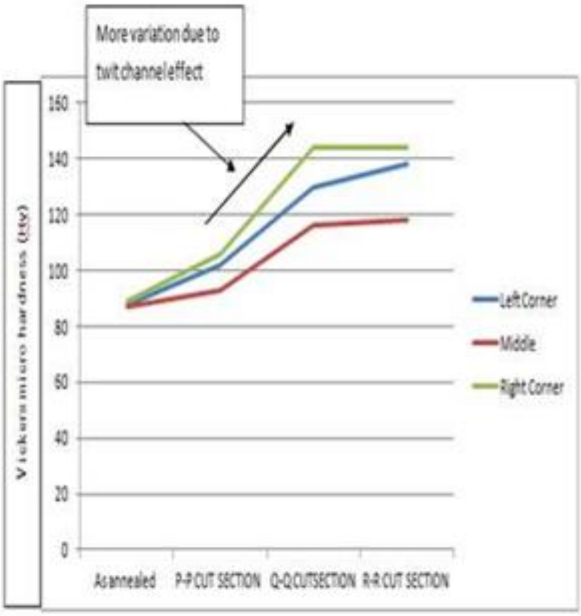

Fig. 7 Twist channel plastic flow behavior analyzed by micro hardness

Microstructure Evaluation for P-P, Q-Q and R-R Cross section through the path trace of the twist channel
The microstructure of the processed sample of AA 7075 was investigated by optical microscopy, the specimens for micro structural examination are prepared after polishing and etching and killer's solution is used as an

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etchant.The measurements a_1, b_1 and c_1 indicate with 100x magnifications and a_2, b_2 and c_2 indicate with 200x magnification of the optical microscope structure. a_1a_2, b_1b_2 and c_1c_2 are taken from the left top corner, center and left bottom corner of the sample. Fig 9 shows the microstructure of the as annealed samples. It shows the grain coarsening due to annealing [3]. By performing the one pass twist extrusion process of the as annealed sample 7075, the cross flow evaluation of the sample from the beginning of its entering the twist zone to the outlet twist zone is analyzed**.** The microstructure observations were performed in the cut section from the twist channel zone of the TE cross sections like P-P, Q-Q and R-R. Cut section P-P result; this zone is the entry zone of the twist extrusion process. The P-P was prepared from 7 mm entry zone of the twist extrusion process resulting in directional changes of the grains Fig. 10 shows the microstructure is taken from the P-P cut section of the sample. The microstructure observations were performed on the sample from the left corner, center region and right corner.The orientation of the parent metal grains was observed and retained at this point. Probably the effect of cold or warm twist extrusion has not affected much the center core of the sample, which is evident from fig. 10 and the microstructure of the constituent phases not changed much along the direction of the twist extrusion.The microstructure is taken from the second Q-Q cut section of the sample. This cut section was prepared from 20 mm entry zone of the twist extrusion process resulting in directional changes of the grains. The microstructure is taken from the core section of the sample, which is observed in fig.11 and the microstructure of the constituent phases has not changed, except the bending of the grains along the direction of the extrusion.Fig. 12 illustrates the optical microscope image of the cross section of R-R cut section and the cut section zone is placed in the TE die at the end of the twist angle and 30 mm from the twist channel entry. The evolution of the microstructure from the initial twist channel entry to ending state is documented in fig. 10 to fig. 12. As expected the grain refinement obtained at the end of the twist channel is significantly different from the initial state P-P cut section grain refinement.

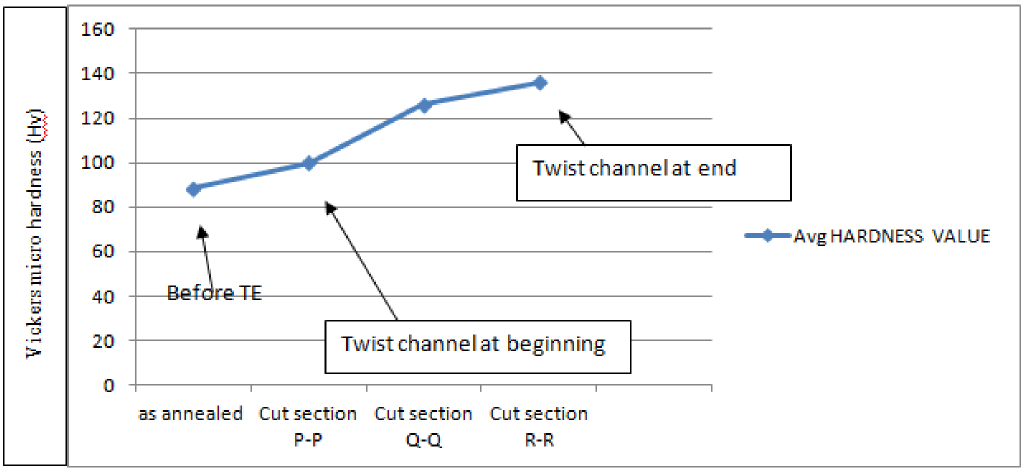

Fig 8 Avg. Vickers micro hardness values before TE and during TE

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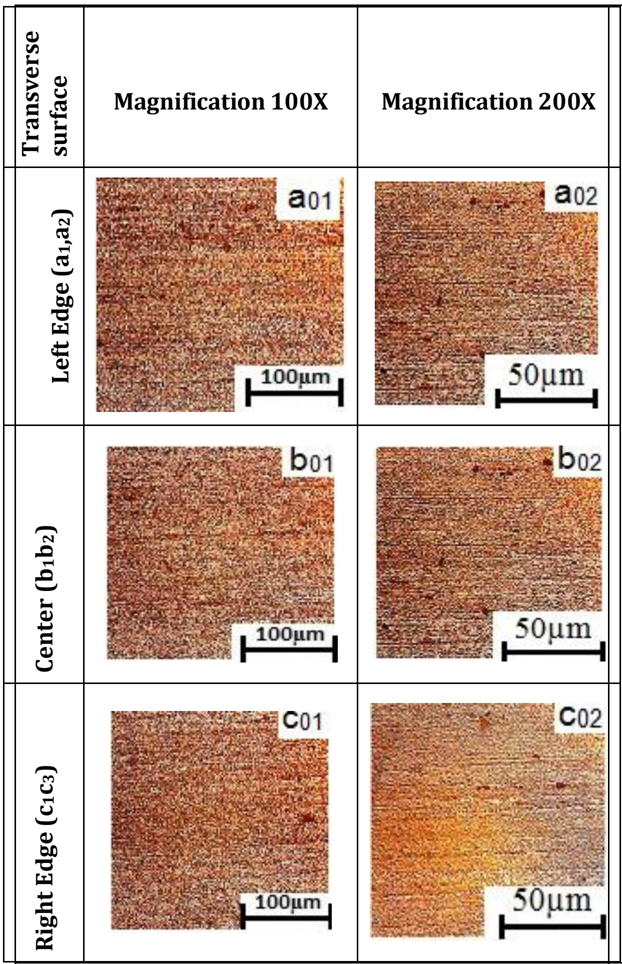

Fig. 9 OM of AA 7075 microstructure (a_1,a_2) left edge, (b_1b_2) center regionand (c_1c_3) right edge of as annealed condition (before TE)

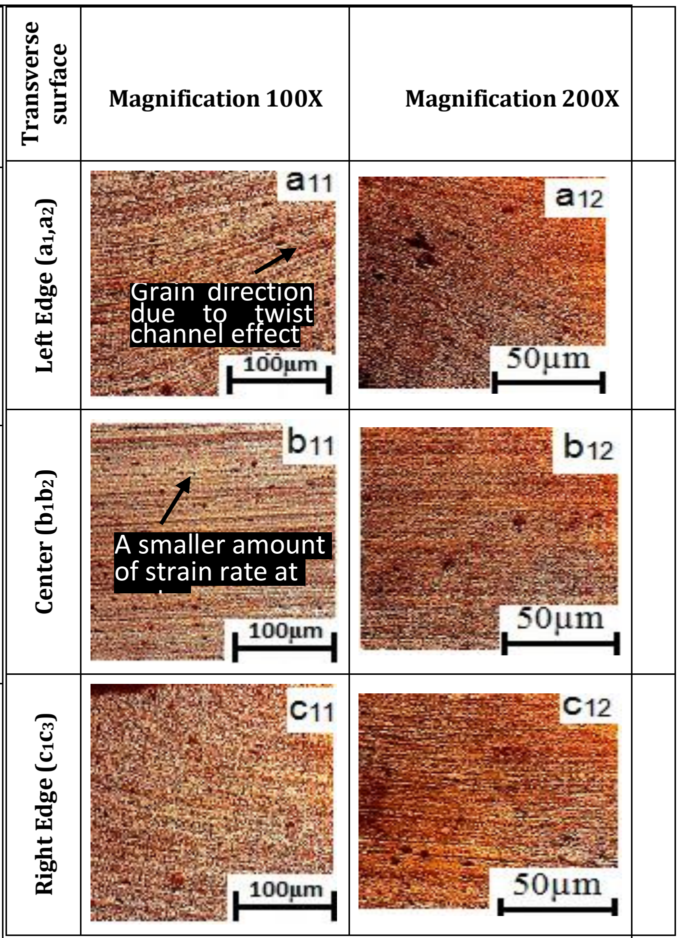

Fig. 10 OM of AA 7075 microstructure (a_1,a_2) left edge, (b_1,b_2) center regionand (c_1,c_3) right edge of cut section P-P during TE

Fig. 12 shows that the microstructure became finer grained in the lateral region of the cross section, compared to the central region of the Q-Q cut section. More micro structural changes occurred in the third cut section due to the rotation of the material between the entry zone of the channel to the end zone of the channel, by the severe torsion effect caused to the material. The degree of structural anisotropy is determined from the different cut sections before TE and after severe plastic deformation by TE. A change in the mechanical properties of Aluminium also occurs along with the refinement of the microstructure and TE methods leading to a selective enhancement of strength properties and a noticeable a significant anisotropy of strength and plasticity that doesn’t exist in the delivery state. Therefore, it may be suggested that repeated TE passes can be applied to increase the SPD unique properties.

Development of micro hardness and microstructure during twist extrusion

The regimes of heat treatment were applied to the sample of AA7075 Aluminium alloy. The regimes consisted of annealing at a temperature of 500°c for 90 minutes. The grain size was increased due to the annealed effect, which is severely affected by the twist angle and torsion effect of the die. The development of micro hardness values were measured at every stage of cut section and it shows the improvement stage by stage in the plotted surface graph figs. 3 and 4. As the significant amount of grain refinement varies across every stage of the cut section’s plane, and it increases from the center towards the corners, the corners have more mechanical properties than the center due to the bend and shear that occurred in the twist channel. [10]. Figure 10 shows the variation of microstructure at different stages of the cut sections with microstructure displayed at the center region, left corner and the right corner. The OM observations showed the microstructure of the as annealed state, and the changes in the microstructure appearance after TE. More variations occurred in the first two stages

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of the cut sections such as P-P and Q-Q, which is evident from fig. 7.

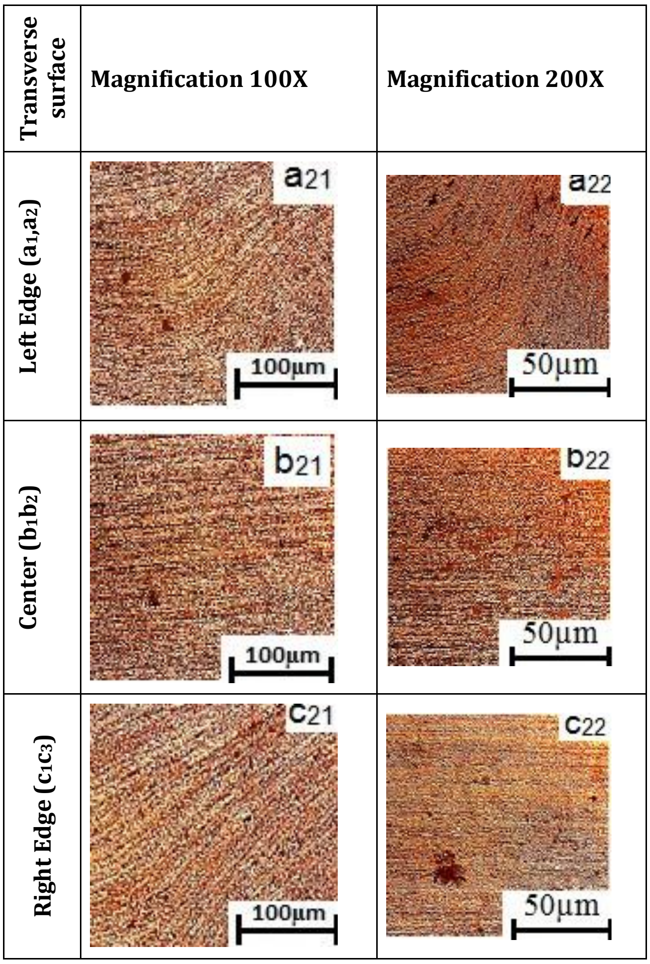

Fig.11 OM of AA 7075 microstructure (a_1,a_2) left edge, (b_1b_2) center region& (c_1c_3) right edge of cut section Q-Q during TE

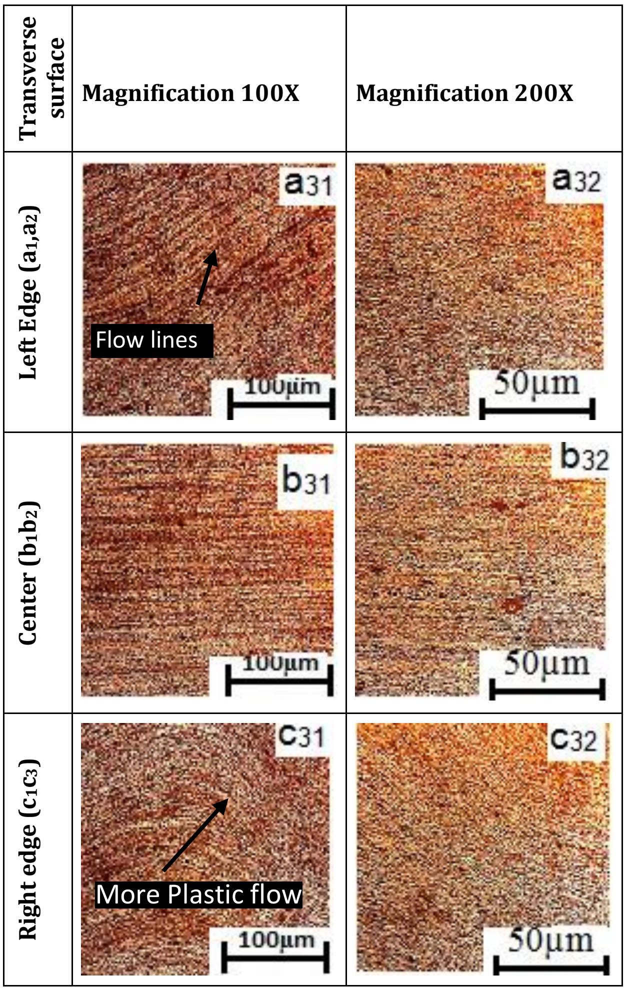

Fig 12 OM of AA 7075 microstructure (a_1a_2) left edge, (b_1b_2) center region& (c_1c_3) right edge of cut section R-R during TE

CONCLUSION

The appraisement of microstructure and micro hardness was studied in AA 7075 Aluminium alloy by the twist extrusion (TE) process at room temperature and the micro hardness value is found to be 136Hv.The hardness variations reflected the enhancements of properties by employing the one pass twist extrusion.In the microstructure, the orientation of the plastic flow has been determined by employing TE from the entry zone to the exit zone at three different cut sections.The TE process increases the average hardness value and decreases the average grain size throughout the section at the entry zone of P-P cut section of the sample, which is found to be 100 Hv.5.2 % deformation occurs in the corner, which is compared to the center of a TE sample due to twist direction in the twist channel die.Hardness was achieved in the range of 136 Hv in the peripheral area of the sample and 129 Hv in the center region of the extruded sample.Hardness distributions were identified due to enhancement of the grain refinement. More strain distribution was found in a corner of the TE sample.Strain increases by twisting the direction from the center to the corners, and its distribution throughout the section is heterogeneous.Hardness was increased by 53.5 % as compared to the initial state of the specimen.

REFERENCES

1. *SAE Manuel on Shot Peening, 3rd edn., SAE HS-84, Warrendale, PA, 1992.*
2. *Shot Peening Application, Metal Improvement Company, New Jersey, USA, 1997.*
3. *E.S. Campbell, MCIC Report, MCIC, Columbus, OH, USA, 1971.*
4. *Satoki Matsumura &NaojiHamasaka , High Strength and Compactness of Gearsby WHSP (Double Hard Shot Peening) Technology , 2006 ② VOL. 52 NO.158*

IJESMR
International Journal OF Engineering Sciences &Management Research

5. *Wagner L, Mueller C. Effect of shot peening on fatigue behavior in Al-alloys.Mater Manuf Processes 1992; 7(3):423–40.*
6. *Dorr T, Hilpert M, Beckmerhagan P, Kiefer A, Wagner L. Influence of shotpeening on fatigue performance of high-strength aluminum and magnesiumalloys. In: International conference in shot peening – 7. 1999. p. 153–60.*
7. *Obata M, Sudo A. Effect of shot peening on residual stress and stress corrosionCracking for cold worked austenitic stainless steel. In: International conference in shot peening – 5. 1993.*
8. *T. Hong, J.Y. Ooi, B. Shaw, A numerical simulation to relate the shot peening parameters to the induced residual stresses, Eng. Fail. Anal. 15 (2008) 1097–1110.*
9. *T. Hong, J.Y. Ooi, B.A. Shaw, A numerical study of the residual stress pattern fromsingleshot impacting on a metallic component, Adv. Eng. Softw. 39 (2008) 743–756.*
10. *R. Shivpuri, X. Cheng, Y. Mao, Elasto-plastic pseudo-dynamic numerical model forthe design of shot peening process parameters, Mater. Des. 30 (2009) 3112–3120.*
11. *A.T. Vielma, V. Llaneza, F.J. Belzunce, Shot peening intensity optimization toincrease the fatigue life of a quenched and tempered structural steel, Proc.Eng. 74 (2014) 273–278.*
12. *L. Trško, O. Bokůvka, F. Nový, M. Guagliano, Effect of severe shot peening on ultrahigh cycle fatigue of a low-alloy steel, Mater. Des. 57 (2014) 103–113.*