HARDNESS AND WEAR EFFECT ON ALUMINIUM 6063 SUBJECTED TO CRYO ECAP AND RT ECAP FOLLOWED BY AGING

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ABSTRACT:

Effects of cryo ECAP and followed by aging on Aluminium 6063 were studied in the present work. Two sets of samples of 9.5 X 9.5 mm Aluminium square 6063 T6 were chosen for Equal Channel Angular Pressing (ECAP). Before going to ECAP operation the samples were subjected to solution treatment at 520^0C. One set of samples were subjected cryo ECAP, by keeping the samples in liquid nitrogen for 20 minutes before each pass and die is kept at room temperature during the process. Other set of samples were subjected ECAP operation with the samples, which are at RT. Like this ECAP operation was done up to 4 passes for both set of samples. These samples were subjected aging treatment at 180^0 and Vickers hardness values were taken for every 15 minutes and for these values aging curves were drawn for both cryo ECAPed and RT ECAPed samples. Change in peak aging time was observed for both curves and obtained at 90 minutes, which is 8 hours for normal Aluminum 6063. Several points were chosen on these curves for wear testing, some points before peak aging point and some points after peak aging point. For these times both sets of samples were aged and wear testing performed using dry sliding wear testing machine. Wear testing is done each sample for 2 hours and for every half an hour change in weight readings values were taken. Curves were plotted for both cryo ECAPed and RT ECAPed samples loss of weight verses aging time at constant sliding distance. Microscopy studies are carried out on these both sets of samples for comparison. These Vickers hardness and Wear testing curves of shown that up to peak aging point RT ECAPed specimens showed good values i.e upto 90 minutes and after peak aging point cryo ECAPed specimens showed good hardness and wear resistance.

Key Words: Aluminum 6063, wear, Vickers hardness, cryo ECAP, Aging

1. Introduction

SPD has received enormous interest over the last two decades as a method capable of producing fully dense and bulk sub micro crystalline and nanocrystalline materials. Significant grain refinement

obtained by SPD leads to improvement of mechanical, micro structural and physical properties [1].

Equal Channel Angular Extrusion (ECAE) is a process, which is developed by Segal, is one of the prominent procedures among the various severe plastic deformation techniques. This technique allows obtaining ultra – fine grain in larger volumes, moreover without change of its original cross sectional area. The materials thus obtained can be used in automotive, military and aerospace industries.

The most widely controlled geometric parameters are the channel angle _ and the corner angle of ECAP dies. Equivalent strain generated in the work piece after one pass based on the geometric analysis from Iwahashi Equation.

$$\varepsilon = \frac{1}{\sqrt{3}}\left[2\cot\left(\frac{\Psi}{2}+\frac{\Phi}{2}\right) + \Psi\mathrm{cosec}\left(\frac{\Psi}{2}+\frac{\Phi}{2}\right)\right].$$

The effective strain during ECAP can decrease from the maximum of 1.15 to the minimum of 0.907 with changing the corner angle from 0 to 90^0 [2]

Aluminium alloy 6063 is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish, high corrosion resistance, is readily suited to welding and can be easily anodised. Most commonly available as T6 temper, in the T4 condition it has good formability [3].

In commercial Al–Mg–Si alloys have been reported in numerous works, much less information has been given on dynamic precipitation during ECAP. In this work, precipitation behaviors during SPD by ECAP at room temperature and 175^0C in an Al–Mg–Si alloy have been investigated. The precipitation process during ECAP was compared with that in conventional static aging[4]. Dynamic precipitation was in fact observed from the solutionized alloy after ECAP at both room temperature and 175 °C. The interaction between precipitates and dislocations was investigated and the strengthening mechanisms and reasons for the dynamic precipitation were briefly discussed and because of the widespread use of these alloys, it is important to understand their mechanical behaviour when exposed to different loading conditions, strain rates and temperatures, and to be able to model their behavior and later, to predict the behaviour for any of these conditions [5-7].

Presently studies interested as deep cryogenic dipping drastically changes the properties of materials. Deep-cryogenic treatment drastically changed the mechanical properties of Al alloys by refining the grain size and altering the distribution of fine precipitates. The overall effect of partial grain refinement, dislocation hardening, and dynamic aging during cryorolling and warm rolling resulted in increased strength and partially improved ductility in AA6061 alloy [8].

Wear properties effect, in the present study, we are interested in finding the properties Aluminum 6063, when it is subjected to ECAP after (i) Solution treatment and (ii) After Solution treatment, dipped in liquid nitrogen. After the ECAP operation is over, aging done on the different time intervals. Find the aging behavior at different time intervals followed by wear at different points on the aging curve, before and after the peak points.

2. MATERIALS AND METHOD

The material chosen was Aluminium 6063 T6 grade of cross section 9.5 mm X 9.5 mm square. The chemical composition is analyzed by optical emission spectrometer and the composition is shown in tableI.

The samples were given solution treatment at 520^0C followed by water quenching for obtaining super saturated solid solution. The die was chosen for Equal Channel Angular Pressing (ECAP) has channel angle of 108^0, with outer curvature angle of 36^0 (FigI & FigII) . One set of samples were soaked in liquid nitrogen for 20 minutes before ECAP and another set for RT ECAP. ECAP extrusion of samples was done using UTM. Normal samples have taken 70 KN load, where as liquid nitrogen samples have taken 75 KN load (Fig III & Fig IV). The ECAP done samples were cut into p2ieces by water submerged cutting in order to not take any changes in the properties during cutting. On these samples hardness and wear tests were conducted.

2.1 Hardness Test

After getting the samples from ECAP in both conditions, these samples were aged till 500 minutes. This time is taken because, it is well known that after ECAP, peak aging point decreases for the normal Aluminium 6063 samples which is almost 8 hours. Hardness test was done using load of 300g and dwelling time 15 seconds as per specifications on the micro Vickers

Hardness Tester. Readings are taken during the aging at 180^0C, for every 15 minutes and returning the samples to the furnace.

2.2 Wear testing

Obtaining the aging curves, by selecting certain points before and after peak aging point on the curve, where wear test has to be conducted were selected. After selecting the points, wear samples were aged for that time. Wear testing was done using Pin on Disc wear testing machine on these aged samples for both the cryo ECAP and RT ECAP samples. The parameters were taken as speed 300 rpm 20 KN load, which were constant and weight loss due to wear for each sample were taken for every half an hour and test conducted for 2 hours for each sample. Graphs were drawn weight loss verses aging time by keeping remaining parameters constant that is the total sliding distance is 22000 meters constant.

2. 3. Tables and Figures

TABLE1

Al	Cu	Mg	Si	Fe	Mn	Zn	P
98.6	0.049	0.63	0.43	0.15	0.054	0.03	0.005

Fig I. Die

Fig II. ECAP Process

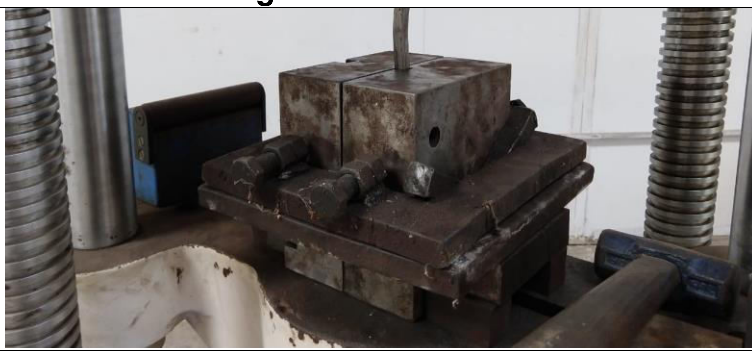


Fig III .As received Al 6063 and cryo ECAPed specimens

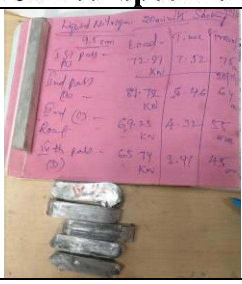
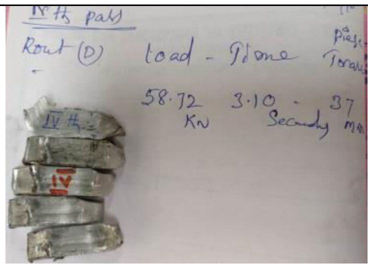


Fig IV. RT ECAPed specimens

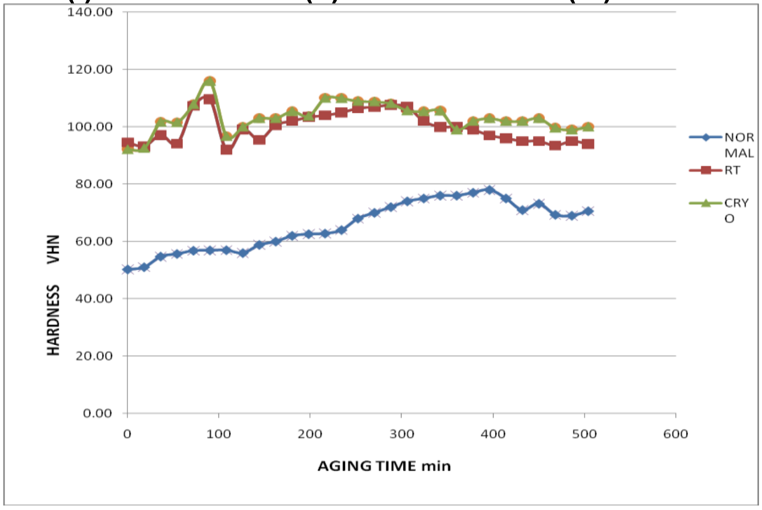


3.RESULTS AND DISCUSSION

3.1 HARDNESS

Aging curves for both CRYO ECAP and RT ECAP shown peak aging point dropped to 90 minutes. In the beginning of aging CRYO ECAP samples shown poor hardness and after that it gradually increased to peak aging point. After peak aging point CRYO ECAP samples shown good hardness over RT ECAP samples. Nearly at 200 minutes, there is slight increase in both conditions (Fig 4). These values were compared with normal without ECAP samples, which has peak aging point nearly 8 hours.

Fig V Aging Curves for (i) CRYO ECAP (ii) RT ECAP and (iii) Without ECAP samples



3.2 WEAR

Wear loss of the samples, when graphs were drawn, in the initial condition CRYO ECAP samples showed poor wear resistance means huge wear loss. It decreased gradually till peak aging point and after that peak aging point CRYO ECAP samples shown good wear resistance with respect aging time(Fig VII). Wear surfaces for both the conditions at different aging times can be seen in the diagrams, at magnification (1000X) (Fig VI).

FigVI. Optical microscopic images of Wear surfaces at 1000x when aged at (i) 0 min (ii) 30 min (iii) 90 min (iv)180 min

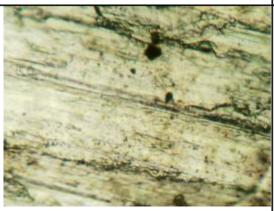
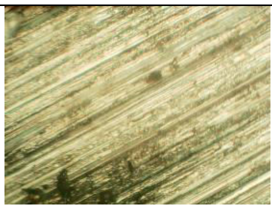
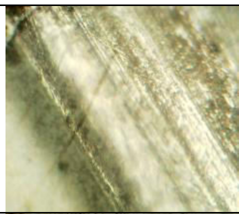
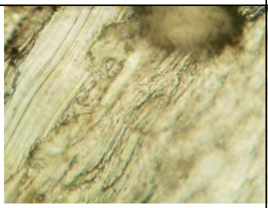
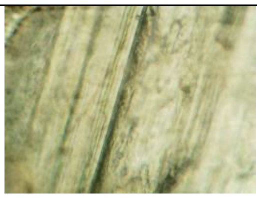
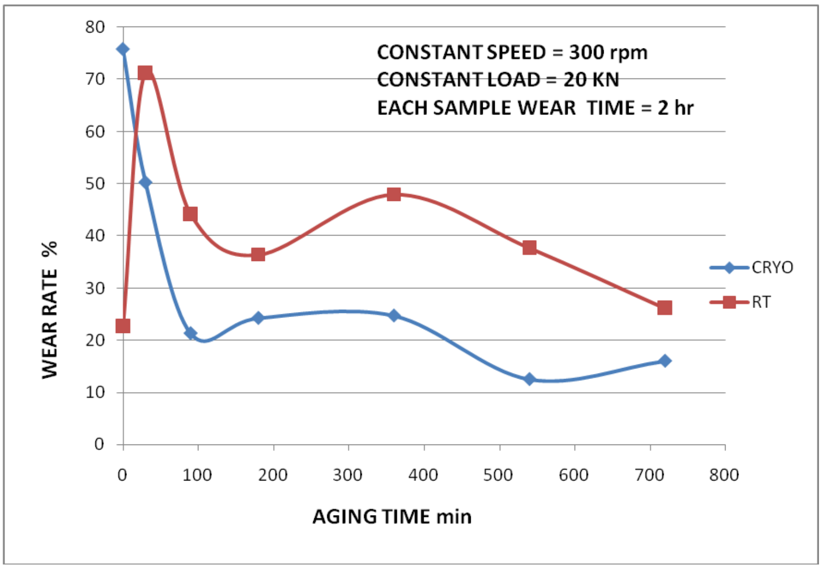
	0 MIN	30 MIN	90 MIN	180 MIN
CRYO				
RT				

FIG VII WEAR RATE VS AGING TIME



4. CONCLUSION:

1. In the initial conditions of aging, CRYO ECAP samples shown less hardness and wear resistance properties.
2. Till peak aging point, gradual domination of properties of CRYO ECAP samples can be seen over RT ECAP.
3. After Peak aging point, good wear resistant and hardness properties can be observed.
4. Microstructures reveal good wear resistance surfaces with aging time increases.

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REFERENCES

[1]Investigations and applications of severe plastic deformation. T.C. Lowe, R.Z. Valiev (eds.), Kluwer, Dordrecht, 2000.

[2] Process Modelling of Equal Channel Angular Pressing for Ultrafine Grained Materials Hyoung Seop Kim1, Pham Quang1, Min Hong Seo1, Sun Ig Hong1, Kyeong Ho Baik1, Hong Rho Lee1 and Do Minh Nghiep2

1 [3] FINITE ELEMENT ANALYSIS OF EQUAL CHANNEL ANGULAR PRESSING USING A ROUND CORNER DIE
Hyoung SeopKim

[4] Dynamic precipitation during severe plastic deformation of an Al–Mg–Si aluminium alloy Hans J. Roven ∗, Manping Liu, Jens C. Werenskiold

[5]. *R. Sterie, N. Panait, P. Moldovan*, Study and research concerning the quality of cast billets of
6XXX aluminium alloys, U.P.B. Sci. Bull., Series B, Vol. 70, 2008, 4, 85-92

[6]. *N. Panait, M. Ciurdas, R. Stephan*, Microstructural characterization of AA - 7050 alloy slabs
(part I), U.P.B. Sci. Bull., Series B, Vol. 71, 2009, 3, 147-151

[7]. *N. Panait, M. Ciurdas, R. Stephan*, Microstructural characterization of AA - 7175 alloy slabs,
U.P.B. Sci. Bull., Series B, Vol. 71, 2009, 2, 93-99

[8] Influence of over-aging and sub-zero temperature rolling on strengthductility balance in AA6061 alloy Souriddha Sanyal a,b,⇑ , Subhranshu Chatterjee c , Sumit Chabri c,d , Nandagopal Bhowmik c , Arijit Sinha a,⇑

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