

# Micro structural Study of Equal-Channel Angular Pressing (ECAP) performed and Ultra Fine Grained of Nickel Reinforced Aluminium 7075 Alloy Composites

Vitala HR<sup>1</sup>, Dileep BP<sup>2</sup>, Ravi kumar V<sup>2</sup>

<sup>1</sup> Department of Mechanical Engineering, SJBIT, Bengaluru, India <sup>2</sup>Department of Mechanical Engineering, Amrita University, Bengaluru, India

E-mail: vitala.hr@gmail.com

**Abstract.** Microstructure and mechanical properties of equal-channel angular pressing (ECAP) processed and ultrafine grained (UFG) of nickel reinforced aluminium 7075 alloy composites were investigated. The composites were prepared using liquid metallurgy technique. The content of nickel in the composition was varied from 2 to 8% (by weight) in steps of 2%. The ECAP processing was carried out using die with an intersecting channel angle of 120°. Pin-on disc equipment was used for wear testing and X-Ray Diffraction Technique (XRD) was used to confirm the percentage of reinforcement of in the composites. This study shows that severe plastic deformation has significantly improved the mechanical properties of nickel reinforced aluminium 7075 alloy composites compared to an alloy.

## 1. Introduction

Aluminium (Al) and its alloys [1] exhibit numerous advantages such as low specific weight, better strength-to-weight ratio and comparably low cost. Metal matrix composites [2] (MMC) have gathered much importance because of their enhanced mechanical, micro structural properties [3] and comparatively low cost, also they show isotropic [4] properties in compare to the fibre reinforced [5] MMCs. SiC particles as reinforcements [6] are harder than tungsten carbide; this is one of the reason why SiC is recommended by more researchers as a reinforcement material. Ultra grained (UFG) metals [7] produced by severe plastic deformation (SPD) techniques have been identified to process better mechanical properties [8], such as better strength with high ductility and good super plasticity [10] at very lower temperature. More metals and alloys, including Aluminium [12], Cu, Ni, Ti and its alloys, and steels have been successfully produced by the ECAP technique [13]. For Al alloys ECAP effort have been used on work strengthening [14] Al-Mg alloys.

## 2. Preparation of Composites :

Chemical composition of Aluminium 7075 alloy series is given in Table 1 was used here as the matrix material. The nickel is used as reinforcement material which is hard material with better resistance to wear property. The MMC's were fabricated by liquid metallurgy technique. Nickel particles (0%, 2%, 4%, 6% and 8% by weight) were added into the vortex of the effectively degassed molten alloy Al

<sup>1</sup> To whom any correspondence should be addressed.



7075. The stirrer blade was designed such a way that while rotating the nickel particles move up in molten metal and distributed thoroughly, equally in the casting.

Table 1 Composition of Al-7075 alloy

Elements	Cu	Mg	Si	Fe	Mn	Zn	Ti	Cr	Al
% by weight	1.58	2.25	0.063	0.833	0.014	5.84	0.033	0.20	Remaining

### 2.1. ECAP specimen preparation

The die consists of one channel and it turned through an angle of  $120^\circ$  on to the sides of the die. The billets (with 10mm of diameter and 50mm length) were produced at a pressing rate of 20mm/min, by using a ram fixed to a hydraulic press capacity of 50 ton. All the passes were conducted using A route in which the billet is not allowed to rotate after each and every successive pass. The molybdenum disulphide is coated on billets as a lubricant to minimize the friction between the die walls and billets. Then processed specimens were machined into required size in a direction perpendicular to the pressing direction.

### 2.2. Wear test:

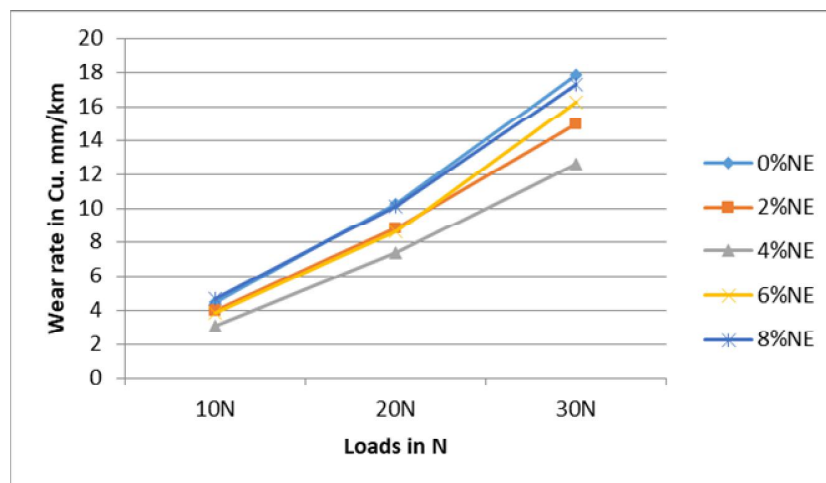
The wear tests were carried out according to ASTM G99 standards by using a pin-on-disc wear testing machine. Steel EN24 disc of diameter 250mm is used for this test. The weight loss method was used in this study where pins of the material under study were 20mm in length and 6mm in diameter.

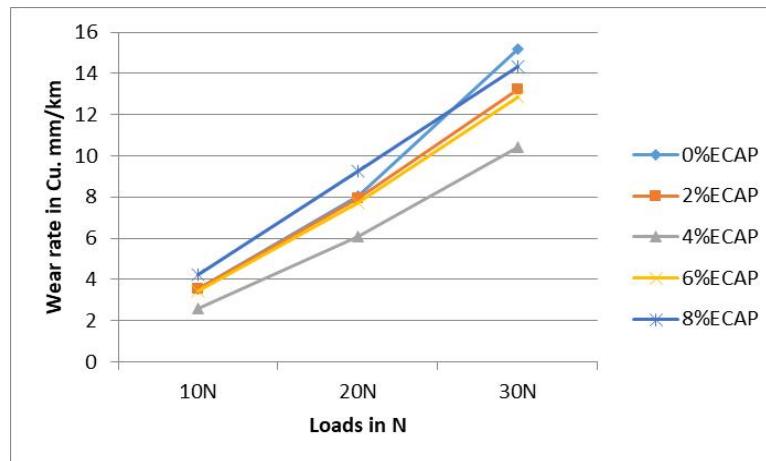
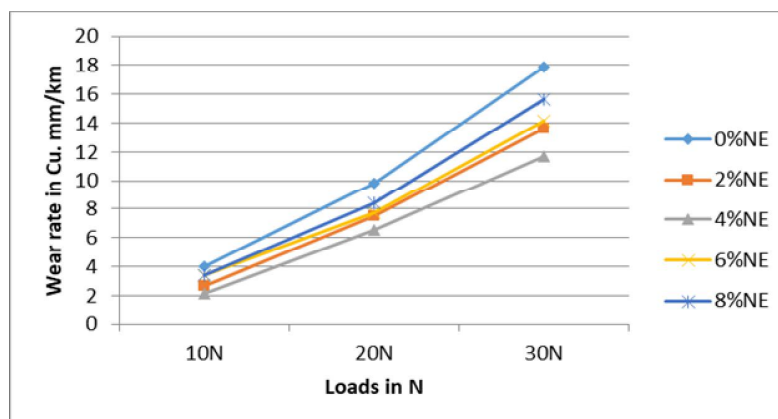
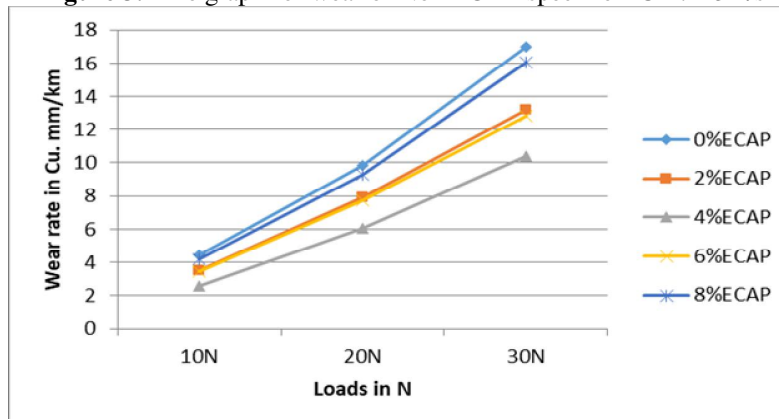
## 3. Results and Discussions:

### 3.1. Wear Test:

Wear tests were performed by using pin-on-disc test set up for all wt. % of Ni for both non ECAP and ECAPed specimens. The variables considered during testing are velocity and loads. In the present work, loads of 10-30N in step of 10N were used. The rotational speed used was 200rpm and 300rpm, at a tract radius of 45mm which gave corresponding liner speed of 0.9424m/s and 1.413 m/s, respectively.

The method adopted for analysis is 'weight loss' method and the wear volume was determined by ratio of weight to theoretical density and for wear rate was found by sliding distance in kilometers (km) and volume in cubic millimeters (Cu.mm).



**Figure 1.** Line graph for wear of Non ECAP specimen @ 0.9424m/s**Figure 2.** Line graph for wear of ECAPed specimen @ 0.9424m/s**Figure 3.** Line graph for wear of Non ECAP specimen @ 1.413m/s**Figure 4.** Line graph for wear of ECAP specimen @ 1.413m/s

The results were presented graphically for velocity of 0.9424m/s in figure 1. and figure 2. and for velocity of 1.413m/s in figure 3. and figure 4.

### 3.2. Effect of load

From graph it is evident that rate of wear of both Non ECAPed and ECAPed specimen increased with load. For Non ECAP and ECAP specimen wear rate reduces with increase in reinforcement up 4 wt. % of Ni. There after addition of reinforcement to 6 and 8 wt. % of Ni increase in wear rate. Also observed in graph that at certain load there is increase in wear rate, that load is known as transition loads. Transition loads observed ECAPed specimens are higher than that of Non ECAP specimens. Transition load for Non ECAP specimen was 20N for 6 and 8 wt. % Ni at velocity of 1.143m/s but, same was observed for ECAP specimen at 20N only for 8 wt. % Ni. This shows the effect of ECAP on Al7075-Ni composition.

### 3.3. Effect of Nickel on wear

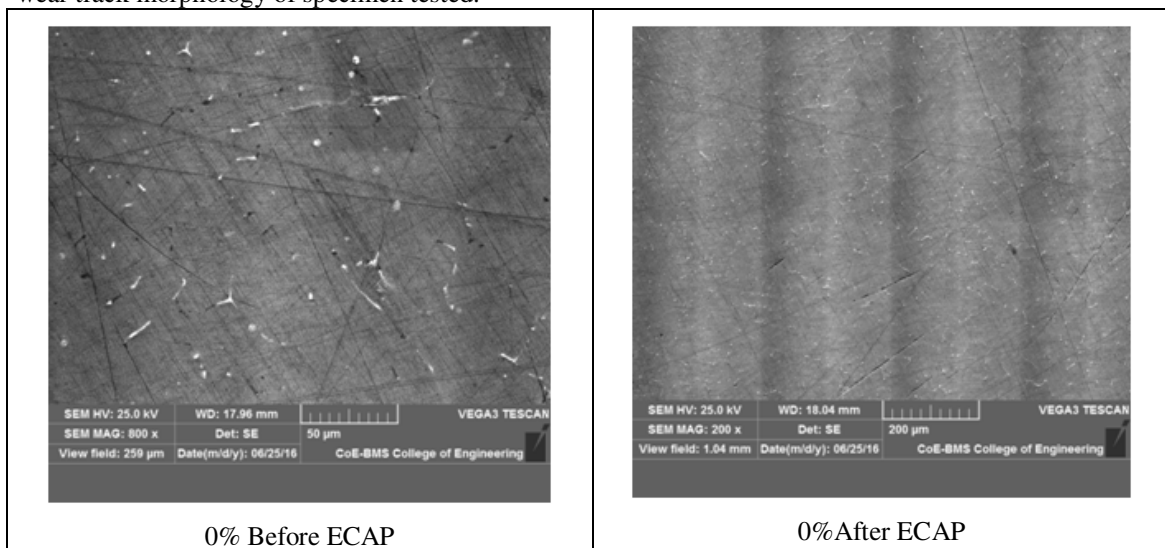
From observation the nickel particles plays a strong role in reducing the effect of wear rate in the composites. The released nickel particles on to sliding surface show resistance to because nickel is harder than that of matrix material (Al7075). The resistance to material removal is because of nickel particles shows the capacity of the reinforcement to get stuck to the sliding surface gives the effectiveness in increasing the wear resistance of Al-Ni composite material.

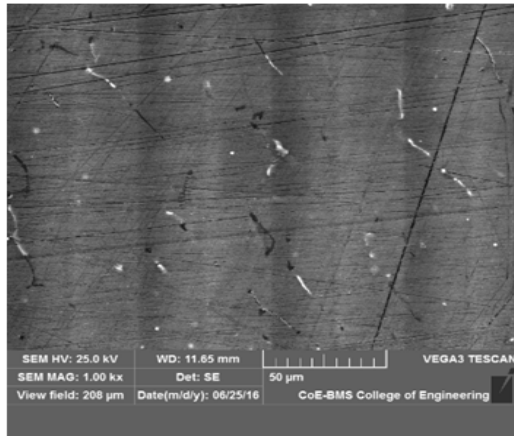
### 3.4. Effect of ECAP on wear

ECAP is a grain refinement process uses special die and specimen passed through the die under huge loads. As graph in figure 1. shows there is significant improvement in wear resistance on addition of reinforcement particles. By processing through ECAP shows further increase in wear resistance. This is due to grain refinement at microstructural level of the specimens. But in both non-ECAP and ECAP specimen wear rate is reduced with increase in Ni percentage upto 4wt. % of Ni, there onwards wear rate is gradually increased.

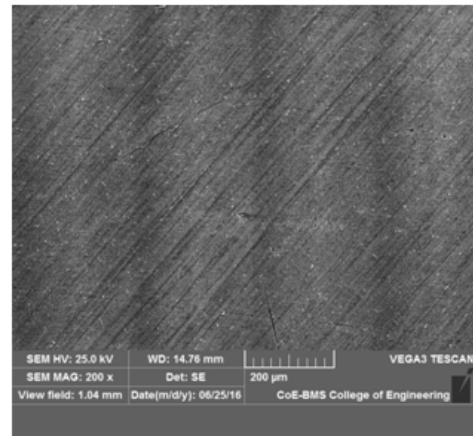
### 3.5. SEM analysis for wear tracks

Wear micrographs of work surface at 30N load and 1.413m/s speed are present in figure 4.) Showing wear track morphology of specimen tested.

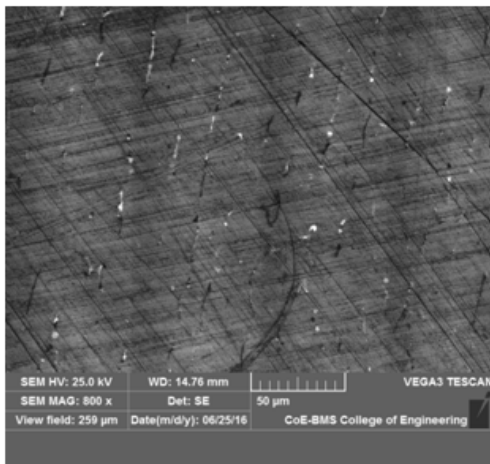




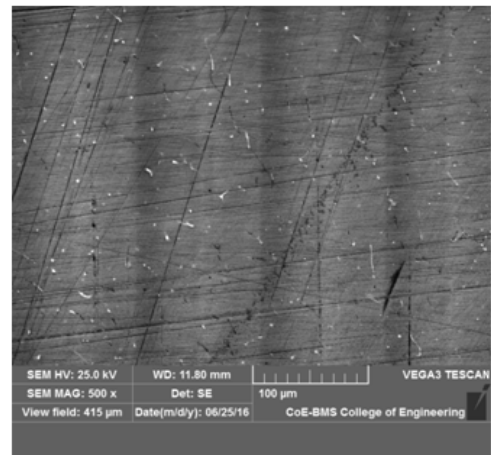
2% Before ECAP



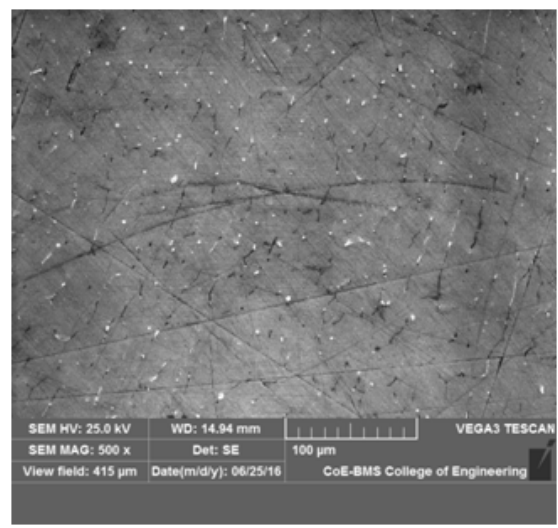
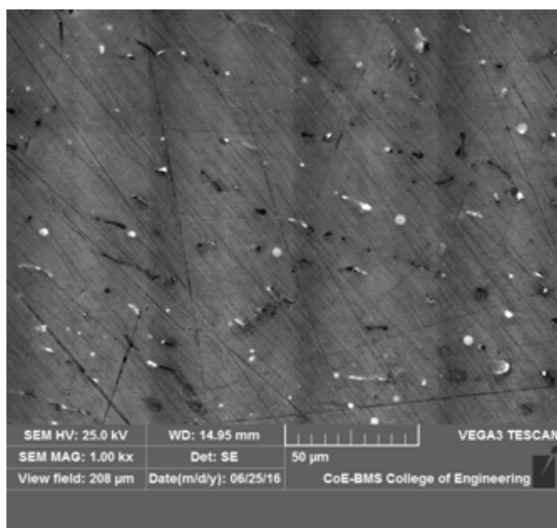
2% After ECAP



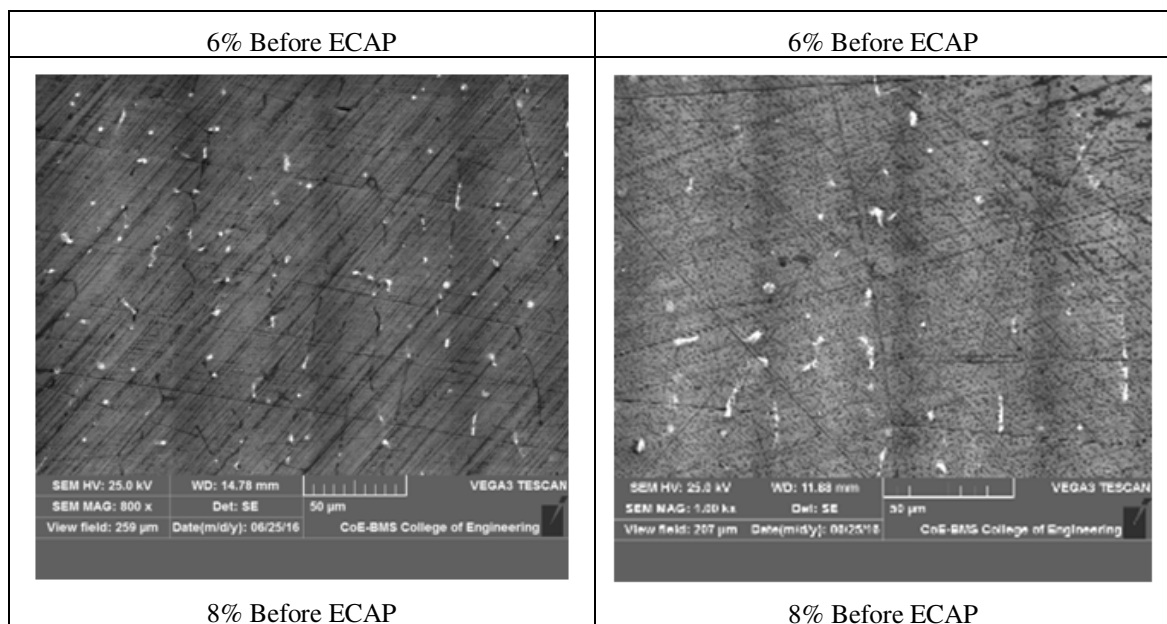
4% Before ECAP



4% Before ECAP







**Figure 5.** Wear track morphology for 0%, 2%, 4%, 6% and 8% Nickel reinforcement; Before ECAP specimens and after ECAP specimens.

There are lot of parallel, continuous and deeply ploughed grooves seen on wear surface. Comparing all 0%, 2%, 4%, 6%, and 8% Ni after and before ECAP the small micro cracks in composite before ECAP were almost closed after ECAP, there exist a smeared due to penetration of Nickel particles into a soften matrix surface. This is one of the main reasons for wear. Due to severe compressive forces applied during ECAP process the smearing due to penetration of Nickel was reduced. Hence the wear rate for ECAP specimen has reduced.

#### 4. References

- [1] Strite S and Morkoc H 1992 *J. Vac. Sci. Technol. B* **10** 1237
- [2] Jain S C, Willander M, Narayan J and van Overstraeten R 2000 *J. Appl. Phys.* **87** 965
- [3] Nakamura S, Senoh M, Nagahama S, Iwase N, Yamada T, Matsushita T, Kiyoku H and Sugimoto Y 1996 *Japan. J. Appl. Phys.* **35** L74
- [4] V. Ravi Kumar, B. P. Dileep, and H. R. Vital; Tribological and mechanical characterization of Al-Ni-SiC metal matrix composites, AIP Conference Proceedings 1859 (2017), 020020.
- [5] O'Leary S K, Foutz B E, Shur M S, Bhapkar U V and Eastman L F 1998 *J. Appl. Phys.* **83** 826
- [6] Qian Z G, Shen W Z, Ogawa H and Guo Q X 2002 *J. Appl. Phys.* **92** 3683
- [7] Guo Q X, Okada A, Kidera H, Tanaka T, Nishio M and Ogawa H 2002 *J. Cryst. Growth* **237–239** 1032
- [8] Aderhold J, Davydov V Yu, Fedler F, Klausing H, Mistele D, Rotter T, Semchinova O, Stemmer J and Graul J 2001 *J. Cryst. Growth* **222** 701
- [9] Mamutin V, Veskin V, Davydov V, Ratnikov V, Shubina T, Inanov S, Kopev P, Karlsteen M, Soderwall U and Willander M 1999 *Phys. Status Solidi* **176** 247
- [10] Jenkins D W and Dow J D 1989 *Phys. Rev. B* **39** 3317
- [12] Tansley T L and Egan R J 1992 *Phys. Rev. B* **45** 10942

- [13] Wessel R, Koch C and Gabbiani F 1996 Coding of time-varying electric field amplitude modulations in a wave-type electric fish *J. Neurophysiol.* **75** 2280–93
- [14] M. V. Phanibhushana, Dileep, B. P., RaviKumar, V. and Prashanth Mrudula, “Effect of zinc coating on mechanical properties of Al 7075”, in *Applied Mechanics and Materials*, 592-594, 2014 pp, 255-259
- [15] V. Ravi Kumar, B. P. Dileep, S. Mohan Kumar, and M. V. Phanibhushana, Effect of metal coatings on mechanical properties of aluminium alloy, *AIP Conference Proceedings* 1859 (2017), 020037-1 – 020037-6.
- [16] Akasaki I, Sota S, Sakai H, Tanaka T, Koike M and Amano H 1996 *Electron. Lett.* **32** 1105