Effect of Cyclic Extrusion and Compression Process on Impact Behavior of Aluminum Alloy AA6060

Madhu H J[1,a)] and Shantharaja M[2,b)]

[1,2]Department of Mechanical Engineering, UVCE, Bangalore University, Bengaluru 560 001, Karnataka, India.

[a)]Corresponding author: madhuhj6@gmail.com, [b)]shantharajam@gmail.com

Abstract: The fabrication of ultrafine-grained (UFG) materials has attracted a great deal of attention in recent years because of the recognition that these materials offer several engineering advantages such as high strength and good ductility at ambient temperature. In this work the effect of severe plastic deformation (SPD) during Cyclic Extrusion and Compression (CEC) on impact toughness of aluminum alloy 6060 is studied. An attempt is made to get an ultrafine grained material using specially designed CEC die. Charpy impact test result shows that the CEC processed samples absorbs more energy compared to sample of base material and also it is found that the impact strength of samples gets incremented upto 3rd cycle of CEC process. After 4th cycle there is not much appreciable increment in impact strength.

Key words: Severe Plastic Deformation (SPD), Cyclic Extrusion and Compression (CEC), Impact Strength.

1. INTRODUCTION

Severe Plastic Deformation (SPD) is one of the methods used to make ultra-fine grained (UFG) bulk metals and alloys. This is done by introducing very high plastic strains to the metal material, resulting in improved mechanical properties that enable the development of light weight components with high strength [1]. Developing a finer grain size, with the increase in strength, also provides higher fracture toughness and the potential for superplasticity. SPD has an advantage over the other metal forming process because it enables overcoming of certain problems that occur in other Nano-Structured Material (NSM) techniques, e.g. residual porosity problems that occur in compacted samples or impurities from processes such as ball milling.

Various SPD process such as Cyclic Extrusion and Compression(CEC), Equal Channel Angular Pressing(ECAP), Accumulative Roll Bonding, Repetitive Corrugation and Straightening(RCS), Severe Torsion Straining(STS), High Pressure Torsion(HPT), Cyclic Closed-Die Forging(CCDF), Super Short Multi-pass Rolling(SSMR), Cyclic Channel Die Compression(CCDC), Mechanical alloying, Asymmetric Rolling, Surface Treatments, Mechanical Milling have been developed[2].

The ultra-fine grained metals created by the SPD processes exhibit high strength and thus they may be used as ultra high strength metals with environmental harmony. The yield stress ‘σ_y’ of polycrystalline metals is related to the grain diameter‘d’ by the following Hall–Petch equation:

$$\sigma_y = \sigma_0 + K_y d^{-1/2} \qquad (1)$$

Where σ_0 is the friction stress and K_y is a constant. Eq. (1) indicates that the yield stress increases with decreasing square root of the grain size. The decrease of grain size leads to a higher tensile strength without reducing the toughness, which differs from other strengthening methods such as heat treatment [1].

2. CYCLIC EXTRUSION AND COMPRESSION (CEC) PROCESS

Cyclic Extrusion and Compression (CEC) process belongs to unconventional methods of forming metals, alloys and powder materials, with plastic strains as large as needed. In CEC process, a billet contained within a die chamber is extruded and compressed simultaneously forward and backward. During this process the billet extrudes from the chamber diameter (D) to channel diameter (d) meanwhile, the lower ram compresses the extruded material to chamber diameter simultaneously thus completing the first cycle of CEC process and the process is repeated. By repeating this process, a very large amount of plastic strain is accumulated in the billet without changing its initial dimensions and as a result an ultrafine grained structure is obtained.

The accumulated equivalent strain is approximately given by the Eq. (2).

$$\Delta\varepsilon = 4.n.\ln (D/d) \qquad (2)$$

Where 'D' is the chamber diameter'd' is the channel diameter and 'n' is the number of deformation cycles [3]. This process is better suited for processing soft materials such as magnesium and aluminum alloys.

3. EXPERIMENTAL PROCEDURE

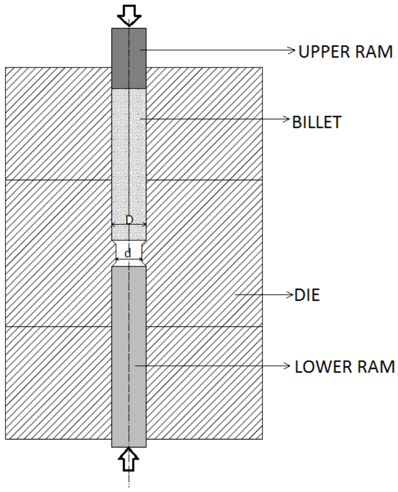
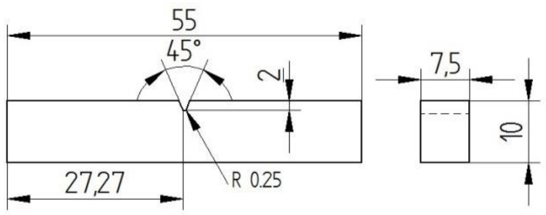


FIGURE 1. Experimental procedure of Cyclic Extrusion and Compression Technique

The material used in the present study was Aluminum alloy 6060. It was received in the form of rod with a diameter of 16 mm and turned it to 15 mm then cut into pieces of length 90 mm. The dies were lubricated using graphite paste to reduce friction between work material and the die. A billet of 15 mm diameter with 90 mm length is placed in the lubricated die and the upper ram is moved in downward direction through a displacement rate of 10 mm/min so the material gets extrude through the channel diameter of 12.5 mm and the billet is subjected to CEC upto four cycles as shown in Fig.1 and the material obtained after each cycle is used to prepare specimen for Charpy V- Notch impact test as per IS 1757 (Equivalent to ASTM standard E23) as shown in Fig.3.

4. CHARPY V-NOTCH IMPACT TEST

After each cycle of cyclic extrusion and compression process of material, the Charpy V-Notch Impact Test specimens are tested according to IS 1757 with specimen geometry: 10mm × 7.5 mm × 55 mm as shown in Fig.2.



All dimensions are in mm

FIGURE 2.Geometry of Charpy impact toughness test specimen

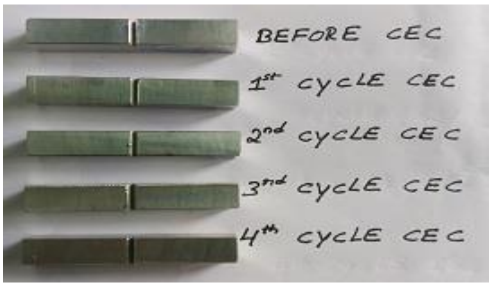


FIGURE 3. Charpy V- Notch impact test specimens after each cycle of CEC process

5. RESULTS AND DISCUSSION

Impact properties like absorbed energy and Impact Strength for specimens before and after each cycle of CEC process are studied and the results are discussed as follows:

a) Absorbed Energy

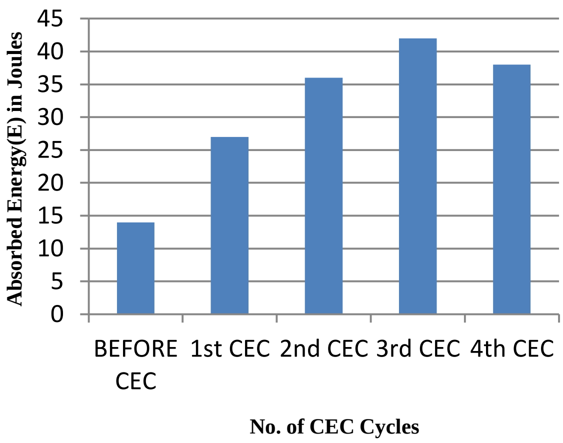


FIGURE 4. Variation of absorbed energy for AA6060 with number of CEC cycles

Fig.4 shows the variation of absorbed energy before and after CEC process for Aluminum Alloy 6060. It can be observed that there is a gradual increase in energy absorbed by the material after each cycle of CEC process upto 3rd cycle. This may be due to grain refinement in the material after each cycle of CEC and also it is noticed that after 4th cycle, the absorbed energy gets reduces this may be because of structure softening of material at the end of 4th cycle of CEC process.

b) Impact Strength

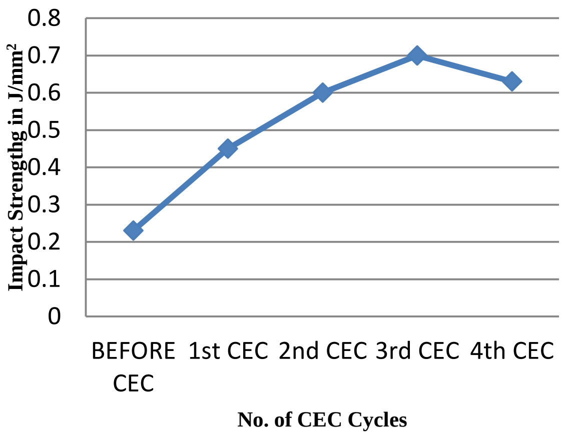


FIGURE 5. Variation of Impact strength for AA6060 material with number of CEC cycles

Fig.5 shows the distribution of impact strength for aluminum alloy 6060 material before and after CEC process. The impact strength of AA6060 gets incremented upto 3rd cycle of CEC, this may be due to grain refinement after each cycle of CEC process. It is also found that after 4th cycle of CEC, there is not much appreciable improvement in impact strength this may be due to reduction in grain refinement mechanism after 4th cycle.

6. CONCLUSIONS

From this study it can be concluded that with increase in the number of CEC cycles the impact property of the material gets improved and the Charpy V-Notch impact test result shows that the impact strength of Aluminum Alloy 6060 gets improved.

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