FEM Analysis of Copper Using Equal Channel Angular Pressing

Abstract: *The Severe Plastic Deformation (SPD) is an effective approach for producing bulk nanostructured material. Equal Channel Angular pressing (ECAP) processes provide an efficient procedure for achieving ultra fine grained material with excellent mechanical properties. The objective is to achieve high and homogeneous deformation in the work piece. In this work an optimized design of the channel die is presented which improves deformations obtained in materials using standard dies. This is a very useful process which can help in the reuse of bulk materials. It can convert the used bulk material to Ultra fine grained material. Ultra-fine grained materials exhibit superior mechanical properties such as high strength and ductility. In this work, three dimension finite element of ECAP process was carried out for Billet Material Copper with channel angle of 120° for Strain harding Copper using Forge 2007 software. The Simulation results clearly depict the Evolution of Strain on body of work piece. The FE simulation greatly help to design the experimental condition to produce good material die for forging. The process parameter of ECAP influences the effect on properties of material. In the present study FEM modeling of ECAP process using Copper for 10 mm round billet is attempt the effect of various process viz. channel intersection angle, friction at die billet and punch velocity are studied. The FE simulations greatly help to design the experimental condition to produce good quality products in manufacturing industries.*

Rajnish Saxena
Department of Mechanical Engineering
FET, MRIU, Faridabad, India
rajnish.fet@mriu.edu.in

Neeraj Saraswat
Dayalbagh Education Institute
Agra, India
neeraj7946@gmail.com

Keywords: *Severe Plastic Deformation (SPD), ECAP, Ultra-fine grained Materials, FE Simulation*

1. INTRODUCTION

The grain size of polycrystalline materials plays a critical role in determining the mechanical behaviour of the material. At low temperatures the strength increases with decreasing grain size through the Hall- Petch relationship [1, 2].
FORMULA

$$\sigma y - \sigma o + \frac{ky}{\sqrt{d}}$$

Where σy is the yield stress, σo is a materials constant for the starting stress for dislocation movement (or the resistance of the lattice to dislocation motion), ky is the strengthening coefficient (a constant unique to each material), and d is the average grain diameter. At high temperatures, when diffusion becomes important, the material flows more rapidly when the grain size is reduced [3]. Thermo- mechanical processing is generally used in industrial operations to achieve a range of acceptable grain sizes for different applications but the smallest grain sizes attained in this way are typically of the order of a few micrometers. Two different types of processing technique have been developed in attempts to achieve exceptionally small grain sizes in the sub micrometer and nanometer range [4]. There are two types of approaches are used for grain refinement.

1.1 SEVERE PLASTIC DEFORMATION (SPD)

Severe plastic deformation (**SPD**) is a generic term describing a group of metal-working techniques involving very large strains which are imposed without introducing any significant changes in the overall dimensions of the specimen or work-piece. A further defining feature of SPD techniques is that the preservation of shape is achieved due to special tool geometries which prevent the free flow of material and thereby produce a significant hydrostatic pressure. The presence of a high hydrostatic pressure, in combination with large shear strains, is essential for producing high densities of crystal lattice defects, particularly dislocations, which can result in a significant refining of the grains. As the dimensions of the work-piece practically do not change in an SPD operation, the process may be applied repeatedly to impose exceptionally high strains. Optimization of routes and regimes of SPD can eventually introduce an extremely fine microstructure into the processed material which will extend, reasonably homogeneously, throughout the bulk..

1.2 EQUAL-CHANNEL ANGULAR PRESSING (ECAP)

Equal channel angular pressing (ECAP) was invented by Segal in 1977 in Russia. This technique in- volves pressing a billet through a die with the billet constrained within a channel which is bent through an abrupt angle within the die. Although the principles of ECAP processing were first introduced approximately twenty-five years ago, it is only very recently that the ECAP procedure has been applied to the processing of single crystals.

1.3 PRINCIPLES OF EQUAL CHANNEL ANGULAR PRESSING

The basic principle of the ECAP process is to press a sample through a die having two intersecting channels, where the two channels have identical cross-sections so that the cross-section of the sample experiences no change during pressing. A specially-designed die is used in ECAP and two internal angles Φ and Ψ are defined as the curvature associated with the two channels where Φ corresponds to the angle between the two intersecting channels and Ψ is the angle at the outer arc of curvature of the two intersecting channels as shown in Figure.1.

2. MATERIAL & METHOD

2.1 FINITE ELEMENT SIMULATION

Finite Element (FE) Simulation results for Copper materials

1	Billet	=	Circular in cross section (10*100)
2	Billet Material	=	Copper
3	Lower die	=	Square in cross section
4	Upper die	=	Circular in cross section
5	Ψ	=	0
6	Φ	=	120
7	N	=	Single pass
8	Friction	=	High
9	Thermal Exchange	=	Adiabatic
10	Temperature	=	20 (Constant)
11	Press	=	Hydraulic
12	Velocity	=	1 mm/s

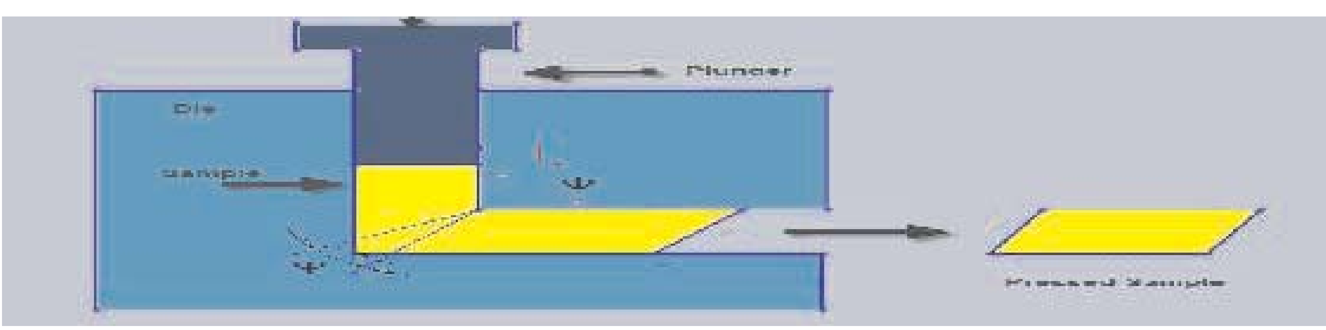
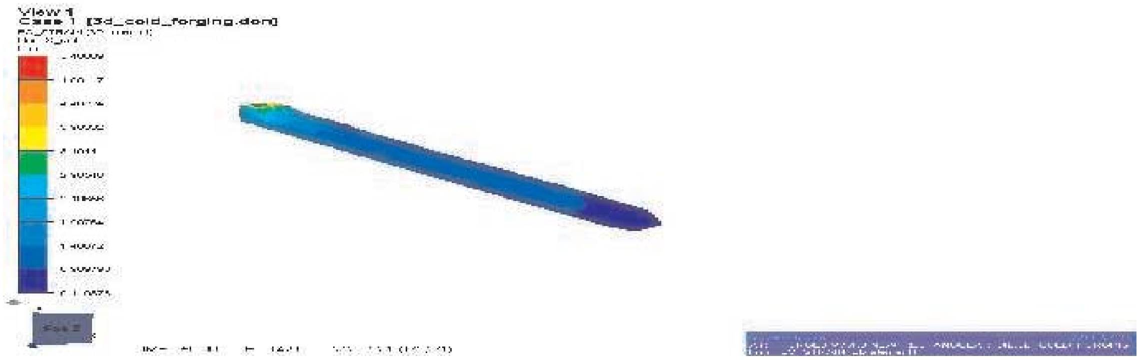


Fig. 1. Designed Die used in ECAP

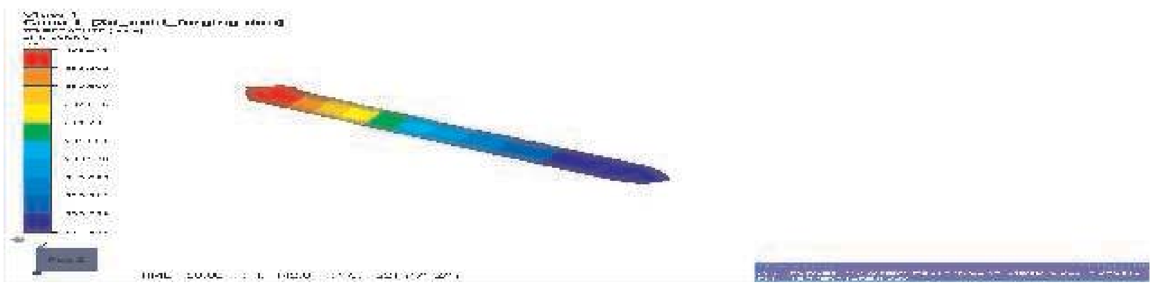
Equivalent Strain generated in Equal Channel Angular Pressing (ECAP)



We can see value of equivalent strain is 1.4.

Fig. 2.

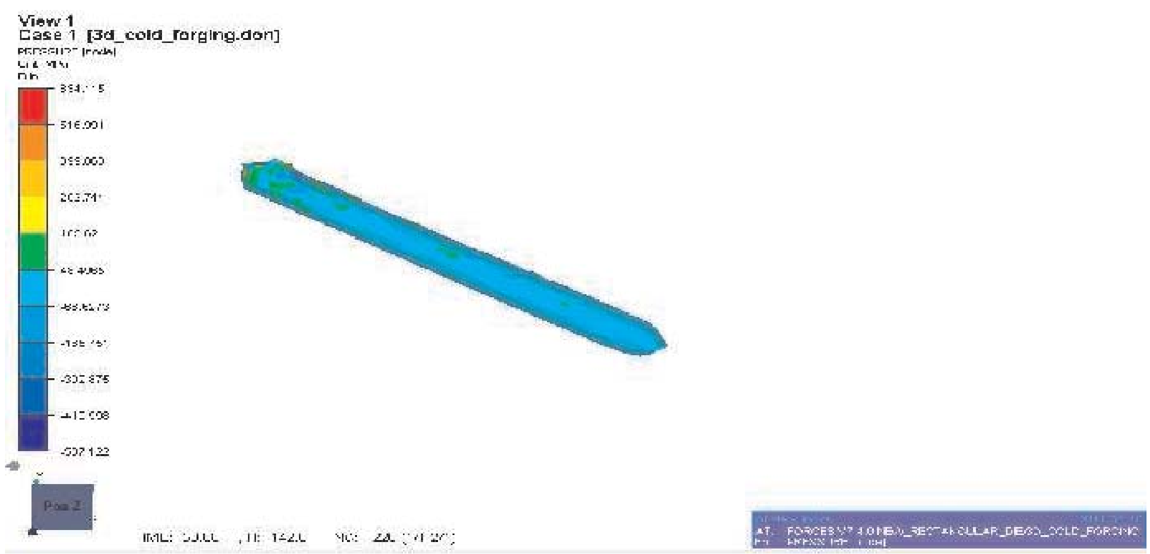
Temperature distribution in Equal Channel Angular Pressing (ECAP)



We can see that value of temperature distribution in ECAP process is 406 ^{o}C.

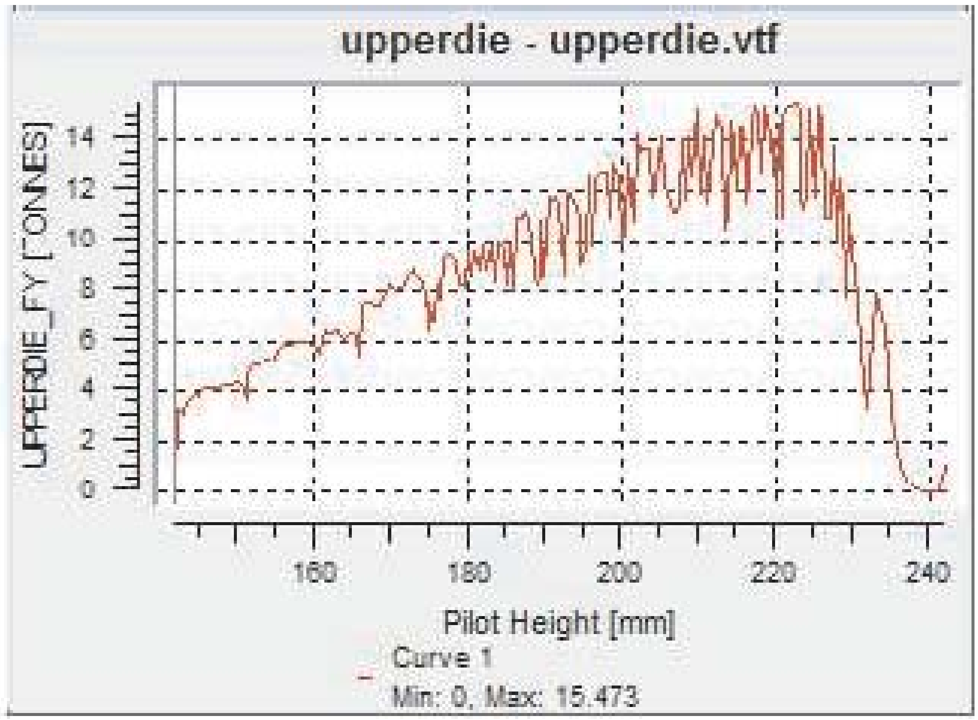
Fig. 3

Pressure generated in Equal Channel Angular Pressing (ECAP)



As shown in figure, Pressure generated in ECAP process is 48.49 MPA.

Fig. 4



Graph-1

As shown in graph, force required for passing the billet in ECAP is 15.47 Tones

3. RESULT

Force (Tones)	Equivalent Strain	Pressure (MPa)	Temperature (^{O}C)
15.47	1.4	48.49	406

4. CONCLUSION

1. Among all the SPD techniques, ECAP is the most developed and can so far produce the largest bulk Nano structured materials. However, ECAP is a discontinuous technique, which makes it a labour-intensive and relatively expensive process.

2. In ECAP, it is possible very large deformation strain can be obtained after repeated passes without changing the shape of billets. Very uniform and homogeneous deformation can be applicable throughout the cross section of the Billet. In ECAP because input billet and end billet both have same cross section. so same lower die can be use for multiple times for the sake of larger strain generation.

3. Single crystalline and polycrystalline both types of metal can be treated with ECAP Can be conducted at room temperature.

4. ECAP processed UFG alloys have significantly enhanced properties

5. Result obtained from FEM simulation is very useful for designing of Die.

6. ECAP Process is useful for industrial application it can be use in mass production.

REFERENCE

1. E.O Hall 1951 " Effect of deformation mode on the strength ofdeformation process" Material Science Forum, 53-57, B64 .

2. N.J.petch 1953 " cleavage strength of polycrystals" journal of iron andsteel institute 174, page no 25-28.

3. T.G.Langdon 1993 "Solute and Dispersed combined effects onmechanical properties of ultrafine grained Al alloy produced

by frictionstir processing" page no 410-411, Material science engineering.

4. Iwahashi, Y., Wang, J., Horita, Z., Nemoto, M. and Langdon, T.G.,1996 "Principle of Equal-Channel Angular Pressing for the Processing of Ultra-Fine Grained Materials," *Scripta Materialia*, 35, 143-146.

5. Birringer, R., Gleiter, H., H. P. Klein, Marquardt, P., 1984 "Nanocrystalline materials: an approach to a novel solid structure withgas-like disorder", *Physics letters*, 102 A, 365-369.

6. Erb, U., 1995 "Electrodeposited nanocrystals: Synthesis, properties andindustrial applications", *Nanostructured Materials*, 6(5-8), 533-538.

7. Koch C. C. and Cho**,** Y. S., 1992 "Nanocrystals by High Energy BallMilling", *Nanostructured Materials*, 1**,** 207**–**212**.**

8. Koch, C.C.,2003 "Top-down synthesis of nanostructured materials: Mechanical and thermal processing methods", Review of Advance Material Science, 5, 91–99.

9. Furukawa, M., Horita, Z., Nemoto, M. and Langdon, T.G., 2002 "The Use of Severe Plastic Deformation for Micro structural Control," Materials Science and Engineering, 324 A, 82-89.

10. Iwahashi, Y., Horita, Z., Nemoto, M. and Langdon, T.G.,1998 "TheProcess of Grain Refinement in Equal-Channel Angular Pressing," ActaMaterialia, 46, 3317-3331.

11. Langdon, T.G., Furukawa, Z., Nemoto, M. and M., Horita, 2000 "Refining Grain Size through Severe Plastic Deformation," Journal of Materials Science, 52(4), 30-33.

12. Rosochowski A., Olejnik L., Richert M., 2004 "Metal formingtechnology for producing bulk nanostructured metals", Journal of Steel and Related Materials - Steel GRIPS, vol. 2, Suppl. Metal Forming2004, 35-44.

13. Segal, V.M.2002 "Severe Plastic deformation : simple shear versus pureshear", Material science and Engineering (A) vol.2.,331-344.

14. Langdon,T.G 2010. "The impact of Bulk Nanostructured Materials in Modern Reasearch," Rev. Adv. Mater. Sci. Res 25, 11-15.

15. Valiev, R.Z., Langdon,T.G, 2011 "Achieving Exceptional Grain Refinement through Severe Plastic Deformation: New Approches for Improving the process Technology" Mettalurgical and Material transaction A, 42, 2942-2951.

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