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Finite Element Simulation Based Analysis of Rotary Forging of AXI-Symmetric Aluminium Disc

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Abstract: *The present economic situation in the world has been driving the forging industry even at more competitive environment. Finite element simulation became an important tool in the forging industries because of availability of high speed computers with low cost and even simulation softwares, not only for the purpose of R&D as well as being a daily tool in the work areas. FE simulation has been drastically increased and accompanied by the widespread high cost-performance workstations. The automatic re-meshing technology as well as the high cost- performance computer made the FE simulation software as a practical development tool in large size forging companies. 2-D FE simulations were used widely as a practical tool even in small and medium size forging industries, 3-D FE simulations have been also used since software equipped with automatic re-meshing capability introduced.*

Keywords*: axi-symmetric disc , effective strain, effective stress, effective displacement, total energy dissipated with forging time.*

I. Introduction

Development of FE simulation technology in forging area started in the late 1960s. During 1970s and early 1980s two dimensional steady state simulations such as drawing/extrusion of round bar and plane strain sheet rolling, which do not require re-mesh, were made available . 2-D non-steady state metal flow with manual re-meshing, which require much time to complete a simulation, were applied in limited forging areas especially in hot forging of aerospace part development.

Wang Guangchun, Zhao Guoqun.[1]A three- dimensional rigid plastic FEM analysis of rotary forging deformation of a ring work piece. The rotary forging process is analyzed using a three-dimensional rigid plastic finite element method. Velocity fields and stress strain fields of the ring work piece in the rotary forging deformation are obtained. The new metal flow demarcation model obtained in this paper is different from that ever provided before. The deformation mechanism of the rotary forging of the ring work piece is revealed thoroughly.

Shijian Yuan , Xiaohong Wang, Gang Liu, Decheng Cho.[2]The precision forming of pin parts by cold-drawing and rotary-forging. This paper introduces the cold-drawing and rotary-forging precision forming technology of pin parts used in locomotives and rail carriages. The determination of the drawing loads and the rotary forging loads, and the deformation mechanism and product quality are discussed. The deformation process is analyzed using the finite-element method.

D.Y. Jang , J.H. Liou.[3]Study of stress development in axi-symmetric products processed by radial forging using a 3-D non-linear finite-element method. The residual stress in these forged products directly affects the material stability, the resistance to deformation, the accuracy, and the fatigue life of products. In order to extend the operating life of products and satisfy the required quality of operation during customer usage, it is necessary to monitor the residual stresses during the forging operations. As a way to study residual stress formation due to radial forging, a three-dimensional theoretical model was developed using a non-linear finite-element method program. The work piece used in the calculations was alloy steel MILS 11595 and was assumed to have elasto-plastic behavior during forging. The Coulomb friction law was applied to simulate the contact behavior between the work piece and the mandrel and between the work piece and the die.

Wang Guangchun , Xue Kemin , Lu Yan .[4]Methods of dealing with some problems in analyzing rotary forging with the FEM and initial application to a ring work piece. In this paper the superiority and necessity of the finite element analysis method in rotary-forging is proposed after introducing all of the research methods of rotary- forging at present. In view of the characteristics of rotary-forging technology, the methods of resolving some key problems in the process of analyzing the rotary-forging process with the finite-element method are given.

Joseph P. Domblesky, Rajiv Shivpuri, Brett Painter.[5]Application of the finite-element method to the radial forging of large diameter tubes. In this paper, a model of the tube-forging process based on the rigidthermo visco plastic finite-element method is considered. The results that are presented include the effective strain, strain rates, and temperature distributions in the forged tube. The deformation was found to be uniform but sensitive to the axial feed- rate. Strain rates were found to be sensitive to the axial feed rate and were within the range typical for a mechanical press. Large temperature gradients across the wall thickness were predicted in the tube.

F. Capece Minutolo, M. Durante, A. Formisano, A. Langella . [6] Evaluation of the maximum slope angle of simple geometries carried out by incremental forming process. The aim of this study is the evaluation of the maximum slope angle of frustums of pyramid and cone carried out by incremental forming and the validation of a FE code in order to have an instrument able to evaluate the limits of the process as regards to the geometry of the manufacturing product. In the specific case, afterwards the mechanical characterization and the evaluation of the sheets formability, frustums of pyramid and cone, with different slope angles, have been carried out, up to the appearance of fractures in the sheet.

A. Ameli . M. R. Movahhedy.[7]A parametric study on residual stresses and forging load in cold radial forging process. In this work, a comprehensive study of radial forging process is presented through 2-D axi symmetric and 3-D finite element simulations while considering internal tube profile. The tube used in this investigation has four internal helical grooves along its length. The material is modeled with the elastic-plastic behavior, and sliding sticking friction model is utilized to model the die work piece and mandrel-work piece contacts. The numerical results in the 2-D case are compared with available experimental data. Residual stresses in the forged product, stress concentration around the grooves, pressure distribution on the hammers and mandrel and maximum forging load are studied.

Lin Hua , Xinghui Han.[8] 3-D FE modeling simulation of cold rotary forging of a cylinder work piece. Cold rotary forging is an advanced but much complex incremental metal forming process with multi-factors coupling interactive effects. Because of the limit of the experimental and analytical methods, many problems such as deformation mechanism, effects of processing parameters on the cold rotary forging process and so on need to be solved through an overall and detailed analysis with the FE modeling method.

Xinghui Han, Lin Hua.[9] 3-D FE modeling of cold rotary forging of a ring work piece. In the current work, in order to better investigate and understand the cold rotary forging process of the ring work piece, a 3D elastic–plastic dynamic explicit FE model of the process is developed under the ABAQUS software

environment.Some key technologies of modeling methods are dealt with reasonably and some key forming conditions are also determined properly. The reliability of the proposed 3D FE model is verified experimentally. Through simulation, the distributions and histories of different field-variables such as stress, strain and force and power parameters are investigated in detail. The research results provide valuable guidelines for better understanding the deformation characteristics of cold rotary forging of the ring work piece.

II. Finite Element Modeling For Rotary Forging

The simulation of rotary forging of axi- symmetric aluminium disc was performed using Deform ™ -3-D software, which is based on the implicit Lagrangian finite element code. The rotary forging dies were modeled as rigid bodies with required dimensions as shown in figure 2.1. In the coordinate system as shown in figure, the upper die is to rotate only about the axis while its other degrees of freedom are constrained. Similarly, the lower die is constrained to translate only along the axis while its other degrees of freedom are also constrained. The geometry of the axi-symmetric disc with required dimensions was also modeled in the software and material property was allocated from the available material library with properties as shown in table 2.1. The effective coefficient of interfacial friction was considered as 0.3. Tetrahedral elements were used to mesh the work piece and finer meshes were generated close to the face edges in order to better scope the forging process.

Table 2.1: Mechanical Properties of the AISI1020 Aluminium Work piece.

Sl. No.	Property	Value
1.	Density (Kg/m^3)	7800
2.	Young’s Modulus (GPa)	1053
3.	Poisson’s Ratio	0.33
4.	Initial Yield Stress (MPa)	210

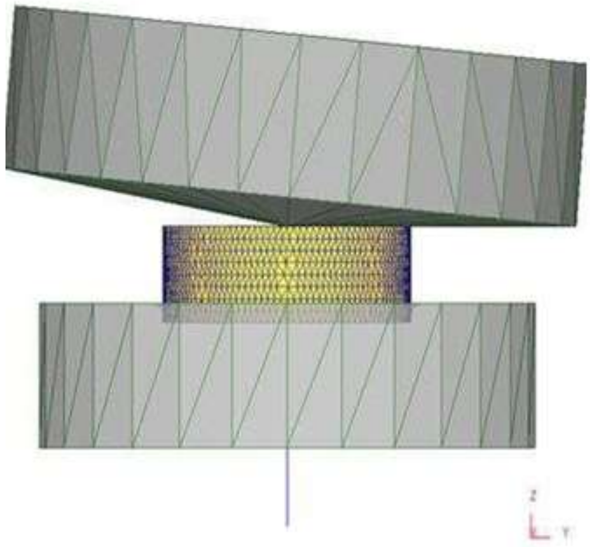

Figure 2.1: FEM Model of Rotary Forging Process

FEM Analysis

Axial velocity of 10mm/sec for lower die and angular velocity of 40rad/sec for upper conical die was considered during simulation of rotary forging process. The complete rotary forging simulation was performed in 10 steps having stroke movement of the die platens in each step equal to 0.21 mm. The lower die pushes the work piece vertically up at a constant feed rate of 10mm/sec until the axi-symmetric disc reaches its final desired height. The contact surface between the upper die and work piece is a portion of an Archimedes spiral surface. However, the feed amount per revolution is relatively smaller in rotary forging, therefore, the upper surface of the work piece can be approximately regarded as a plane during the rotary forging process. Table 2.2 shows the various processing parameters of 3-D finite element simulation of rotary forging process of axi-symmetric disc. The variation of effective strain, effective stress, effective displacement, total energy dissipated with forging time were recorded and respective graphs were plotted.

Table 2.2: Processing Parameters of 3-D FE Simulation of Rotary Forging Process.

Sl. No.	Parameters	Value
1.	Initial radius of cylinder workpiece (mm)	15
2.	Initial height of cylinder workpiece (mm)	40
3.	Reduction in height (%)	2.5
4.	Feed rate of the lower die ‘U’ (mm/sec)	3
5.	Rotational speed of the upper die ‘N’ (rpm)	4.4
6.	Inclination angle of the upper die (□)	5^0
7.	Friction coefficient between the dies and workpiece (□)	0.3
8.	Motion orbit of the upper die	Circle Line

III. Results & Parametric Discussion

During axial feed of the lower die the contact area between the dies and axi-symmetric aluminium disc increases from zero and attain a certain value rapidly, and then increases gradually with respect to the time. As the upper conical die rotates / oscillates about the axis of the die, the small indented contact area is swept over the entire disc surface leading to the decrease in the height of the disc. An illustration of the conical indented surface on the workpiece is shown in figure 2.2.

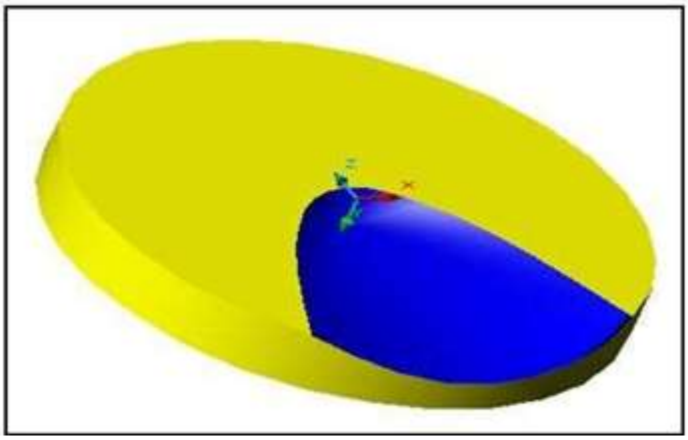

Figure 2.2: Illustration of Conical Indented Contact Area on Disc Top Surface.

Figure 2.3 shows the variation of the total energy dissipated with respect to stroke during rotary forging of axi-symmetric disc. It can be seen that energy dissipation, as well as the displacement increases gradually with the die stroke as the forging proceeds and becomes maximum at the end of the rotary forging process. This indicates that analysis of forging processes must be carried at the end of the process, when energy and load requirements for deformation is maximum so that forging system design are within the safe working limit. Figure 2.4 shows the contour plot of total displacement on the axi-symmetric aluminium disc during rotary forging. The result has been plotted arbitrarily at any instance of rotary forging process and it can be noticed that maximum displacement / deformation is at the central region of the disc that instant of time and this is due to the axial feed of the lower die. The maximum displacement observed is about 5.5 mm and this gradually decreases towards the periphery. As the process continues, the top surface will tend to become flat and the indented area will be swept over the entire preform top surface.

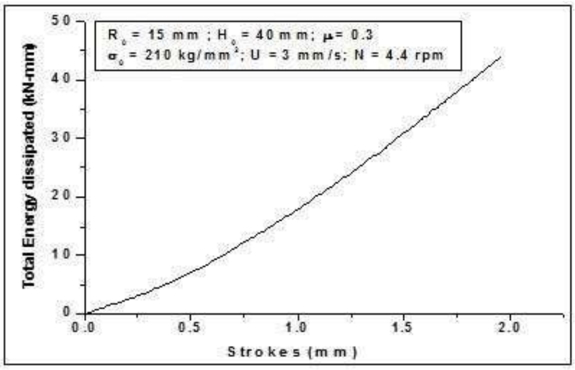

Figure 2.3: Variation of Total Energy Dissipated with Die Stroke.

aluminium preform respectively. It can be observed from figure 2.5 that effective strain of the magnitude 0.45 is present in the central region of the work piece, whereas peripheral regions are subjected to very small strains. The conical indented region has strain in the magnitude of 0.6. Figure 2.6 shows that the effective stress of the magnitude 90 N-mm^2 is generally found on all the top regions of the preform, whereas the conical indented region is subjected to maximum effective stress of about 107 N-mm^2. This confirms the variations as plotted in the above graphs. The region which is subjected to high strain and stress is the focal point of the investigations to study the nature of the effect of the rotary forging characteristics on the forging load and deformation. This validates again the theoretical analysis which focused on the estimation of the forging load on the conical indented area on the top surface of the axi- symmetric aluminum disc.

Figure 2.5: Contour Plot of Effective Strain (mm/mm) during rotary Forging.

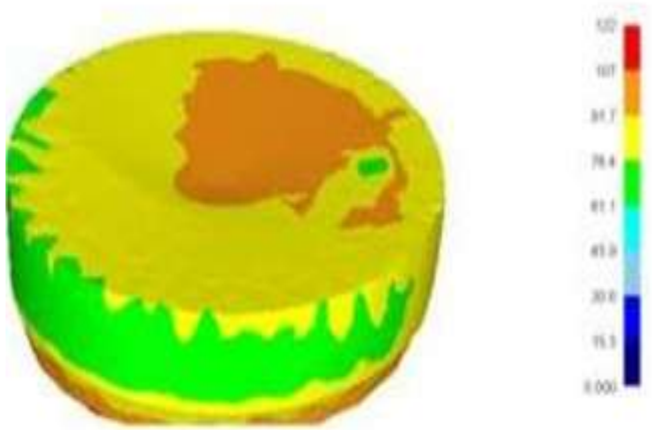

Figure 2.6: Contour Plot of Effective Stress (N-mm2) during rotary Forging.

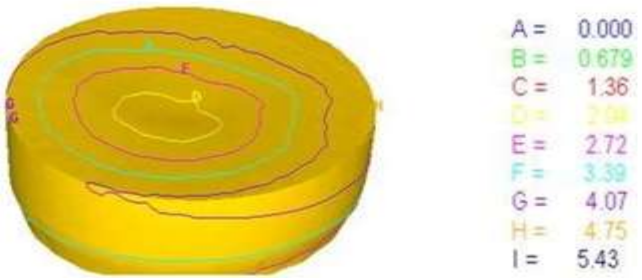

Figure 2.4: Contour Plot of Total Displacement (mm) during Rotary Forging.

Figure 2.5 and 2.6 shows the distribution of effective strain and effective stress on the axi-symmetric

IV. Conclusions

The finite element simulation of the rotary forging process was performed using DEFORM software. The effective strain and effective stress distribution were critically studied, which will help to understand the nature of the stress and strain involved in the indented contact area, as well as during sweeping of this indented contact area over the entire top surface of the work piece. It may be note that higher effective stress and strain were predominant over the indented contact area. It also gave the measure of the total energy dissipated during the forging process, which can be utilized to calculate the forging loads.

References

[1]. Wang Guangchun, Zhao Guoqun. "A three- dimensional rigid plastic FEM analysis of rotary forging deformation of a ring workpiece".Journal of Materials Processing Technology volume95 (1999),pp 112-115

[2]. Shijian Yuan , Xiaohong Wang, Gang Liu, Decheng Cho. "The precision forming of pin parts by cold-drawing and rotary-forging". Journal of Materials Processing Technology 86 (1999) 252–256p

[3]. D.Y. Jang , J.H. Liou. "Study of stress development in axi-symmetric products processed by radial forging using a 3-D non-linear finite-element method". Journal of Materials Processing Technology 74 (1998) 74–82p

[4]. Wang Guangchun , Xue Kemin , Lu Yan . "Methods of dealing with some problems in analyzing rotary forging with the FEM and initial application to a ring workpeice". Journal of Materials Processing Technology 7t ~1997) 299-303p

[5]. Joseph P. Domblesky, Rajiv Shivpuri, Brett Painter. "Application of the finite-element method to the radial forging of large diameter tubes".Journal of Materials Processing Technology.vol. 49 (1995).pp 57-74
[6]. F.Capece Minutolo, M. Durante, A. Formisano, A. Langella . Evaluation of the maximum slope angle of simple geometries carried out by incremental forming process. Journal of Materials Processing Technology
[7]. ,volume194 (2007) pp145–150
[8]. A.Ameli . M. R. Movahhedy. "A parametric study on residual stresses and forging load in cold radial forging process". Int J Adv Manuf Technol DOI 10.1007/s00170-006- 0453-2
[9]. Lin Hua , Xinghui Han. "3D FE modeling simulation of cold rotary forging of a cylinder workpiece". Materials and Design vol.30 (2009) 2133–2142p
[10]. Xinghui Han, Lin Hua. "3D FE modeling of cold rotary forging of a ring workpiece". Journal of Materials Processing Technology vol.209 (2009) 5353–5362p
[11]. Hung-Kuk.oh*. Seogou choi: "Plastic Deformation Behaviors of Cold Rotary Forging under Different Contact Patterns by 3D Elastic-Plastic FE Method". Journal of Materials Processing Technology (1997) PP1345-1349