Materials and Design 62 (2014) 361–366

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Short Communication

Development of a novel method for the backward extrusion

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ARTICLE INFO

Article history:
Received 17 March 2014
Accepted 15 May 2014
Available online 2 June 2014

Keywords:
Backward extrusion
Lower process load
Plastic strain
Strain homogeneity

ABSTRACT

In this study, a new method of backward extrusion using small diameter billet is proposed. In this new process, the die setup consists of three main parts of the fix-punch, the moveable punch and the matrix. The fix-punch has been used to decrease the cross section of applied billet and finally reducing the total force of the process. To investigate the capability of this process, experimental and finite element (FE) methods were used. The results showed that the first advantageous of the new process is that the load is reduced to about less than a quarter in comparison with the conventional backward extrusion process. This higher reduction in the required force is due to reduce of the cross section of the initial billet. EF results showed that while needing lower loads, the applied plastic strain through the processed sample is about two times higher than that in the sample processed via conventional backward extrusion. This is the second advantageous of the process. Eventually, the most important advantages of the novel method of backward extrusion are the lower process force, imposing higher effective strain and a better strain homogeneity through the tube length. This new process is also very promising for producing ultra fine grained (UFG) samples because the higher level of shear strains.

1. Introduction

Nowadays, the extrusion process has an important role in the manufacturing industries. Backward extrusion has been conventionally used for the production of hollow-shape symmetric and cylindrical products [1]. Bae and Yang analyzed the backward extrusion process of internally elliptic shaped tubes from round billets with using of upper bound method [2]. Shen et al. have proposed a method for estimating the value of shear friction factor using of a backward extrusion-type forging [3,4]. Lee et al. examined the extrusion of hexagonal shaped wrench bolts using of upper-bound method [5]. Cho et al. studied the process design of a forward and backward extruded axisymmetric part [6]. Fereshteh-Saniee et al. have performed several tests with different lubricants and friction conditions to find out the friction modeling of different bulk forming processes [7]. Bakhshi-Jooybari et al. have worked on reducing the deformation load in backward rod extrusion to optimize the die profile by both numerical and experimental approach [8]. Uyyuru and Valberg examined the material flow over the punch head in backward extrusion process by finite element simulation and physical modeling [9]. Saboori et al. have examined the extrusion energy of the two optimal conical and curved die in the forward and backward extrusion using of both finite element method and experimental investigation [10]. Kim et al. evaluated the effects of lubricants in backward extrusion of large aspect ratio rectangular aluminum case [11,12]. The effects of geometrical parameters such as die corner radius and gap height, as well as process condition such as friction on the radial-backward extrusion process were examined by Farhoumand and Ebrahimi [13]. Fatemi-Varzaneh and Zarei-Hanzaki proposed a novel severe plastic deformation process based on an accumulative back extrusion process [14]. Abrinia and Orangi analyzed the backward extrusion process of internally arbitrary-shaped tubes from circular billet using of finite element method. They examined tubes with elliptical, rectangular and circular shape [15]. Fatemi-Varzaneh et al. have studied the strain distribution and deformation behavior during accumulative back extrusion process on AZ31 magnesium alloy [16]. Orange et al. have carried out the analysis of backward extrusion process of aluminum tubes which have internally and externally shaped section using of finite element method [17]. Javanmard et al. have analyzed the backward extrusion process for circular shape hollow components from round billets by a computational method based on the natural element method [18]. Alihosseini et al. described a new process based on a cyclic forward–backward extrusion for producing ultrafine grains materials. They applied this new process to AA1050 aluminum alloy [19].

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http://dx.doi.org/10.1016/j.matdes.2014.05.022
0261-3069/

Faraji et al. [20] have investigated the effects of the accumulative back extrusion process on plastic deformation behavior and microstructure of an AZ91 magnesium alloy by finite element method and experimental investigations. Wang et al. have been observed that the effective strains at the produced part along both the axial and the radial directions were nonuniform [21]. Also, Chalay-Amoly et al. obtained the distributions of plastic strain were heterogeneous over the cross section of produced parts. They also studied the microstructure evolution of the backward extruded parts and their results indicated that inhomogeneously obtained microstructure was closely corresponded to the heterogeneous strain pattern that has been developed during deformation [22].

As revealed from the literature, the nonuniform distribution of the effective strain is one of the disadvantageous of the conventional backward extrusion process that extremely affected the microstructure and mechanical properties of produced part. The higher process load is also another important limitation of the conventional backward extrusion process. For the elimination of these limitations, a new backward extrusion process is proposed. To study the capability of this new process, experimental and finite element analysis were used.

2. Principle of the new backward extrusion process

In the new process, the die setup consists of three main parts of the fix-punch, the moveable punch and the matrix. Schematic illustrations of the conventional and new backward extrusion methods are shown in Figs. 1 and 2. In the conventional backward extrusion process, the billet has been initially placed in the matrix and then with the pressure of the punch, the material is compressed and flowed through the gap between punch and matrix. In the new backward extrusion, as shown in Fig. 2, small diameter billet is put in a cylindrical hole named billet chamber in the fix-punch. Then the moveable punch is pressed the billet into the gap between fix-punch and the matrix. So the compressed material is flowed through the gap between fix-punch and the matrix. The inner radius of fix-punch helped to material easily flowed through chamber of the billet and internal die. Also, the outer radius of fix-punch and radius of the matrix have been improved the material flow in the process.

3. Experimental and FE procedure

High-purity lead was used in the experiments. As-received lead metal ingot was melted and casted, then was extruded using of direct extrusion process to achieve a cylindrical sample with a distinct diameter. The diameter and length of the billet were 20 mm and 170 mm, respectively. The inner and outer radius of fix-punch, the radius of the matrix and the height of the edge for produced die selected as 7.5 mm, 10 mm, 10 mm and 5 mm, respectively. The length, outer diameter and thickness of the final product were designed to be 85, 63 and 3 mm, respectively. Compression test according to ASTM: E9-09 standard has been performed to obtain the mechanical properties. The physical and mechanical properties of the material were reported in Table 1. The main parts of the die setup including matrix, fix-punch, moveable punch, guide shafts and the holder plate of guide shafts were shown in Fig. 3(a). Different parts of the die were hardened to 50 HRC. The test has been carried out using of an INSTRON hydraulic press. The experiment was performed at 1 mm/s plunger speed at room temperature. Brinell hardness test with 30 kg force was used for hardness measurements according to the ASTM: E10-12 standard. The experimental setup including assembled die on the press was shown in Fig. 3(b).

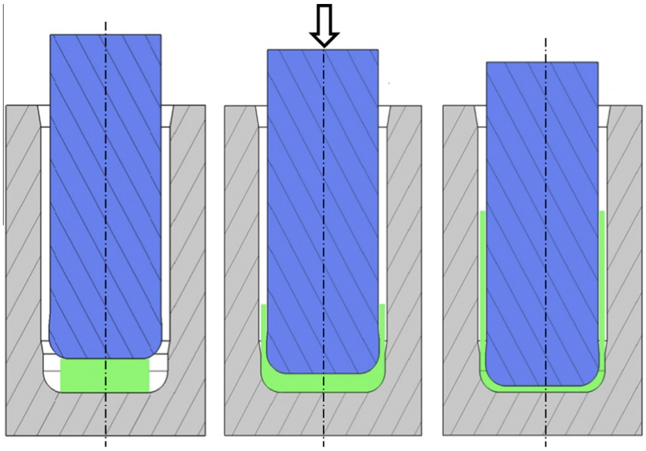

Fig. 1. The schematic view of backward extrusion.

The DEFORM 3D-6.1 software has been used for FE simulation. The material model was defined as elastic–plastic. The data of true stress–strain based on the results of compression test has been entered to the FE software. All the die parts have been considered as rigid bodies. The billet has been defined as deformable object during all analyses. The dimensions of all objects in the simulation perfectly matched with experimental ones in order to validate the results of the simulation. Tetrahedral element type was used, and the mesh sensitivity test has been carried out. Suitable mesh number reported as 25000. The friction type selected as shear. Because of the nature of the process, the friction factor (m) selected as 0.2 [7]. The type of simulation was Lagrangian Incremental. The global re-meshing was chosen and the type of interference depth selected as relative and its value considered as 0.7. The conjugate-Gradient has been chosen as the solver of simulation.

4. Results and discussion

The unprocessed initial billet and processed sample which is a closed-end tube were shown in Fig. 4(a and b), respectively. As shown, a 20 mm diameter billet was changed to 63 mm diameter cup shaped sound sample successfully via new backward extrusion process. It seems that most of the materials such as aluminum, copper and magnesium. and their alloys which can be processed via conventional method may be processed by the new method. Though, this statement needs experimental evidence; it is promising that the new process could be applied to a wide range of metallic materials.

The process force of conventional and novel method of backward extrusion obtained from FE method has been compared as shown in Table 2. Based on obtained results, the required force to produce a particular product with conventional backward extrusion was equal to 264.6 kN, while the required force to produce the same product using novel backward extrusion was equal to 61.1 kN. Consequently in the novel backward extrusion process the required force to produce a particular product was less than a quarter in comparison with conventional backward extrusion.

Hung and Chiang [23] investigated the influence of ultrasonic-vibration on Double Backward extrusion of aluminum alloy. In this method, the ultrasonic energy applied to the punch die and then the punch die deformed material. They reported that the required load for conventional method was 14.3 kN while it is 11.5 kN by imposing the ultrasonic energy to the punch. So by using of ultrasonic vibration, the extrusion force will be decreased about 20%. As was mentioned earlier with using of the novel method of backward extrusion, the extrusion load can be reduced about 75%. Uyyuru