V. A. ANDREYACHSHENKO, M.K. IBATOV, D.A. ISSAGULOVA

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INITIAL POROSITY IMPACT ON EQUAL CHANNEL ANGULAR PRESSING (ECAP) OF TI–6AL–4V POWDER MATERIAL

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Preliminary Note – Prethodno priopćenje

There is studied the technology of processing Ti-6Al-4V powder material with various initial densities using the method of equal channel angular pressing. The device with the 90, 120 and 135 degree angled joint channels was used for the study. The deformation was carried out at the room temperature. It was found that the most favorable stressed-and-strained state was formed in the instrument where the angle of channel joints was equal to 135 degrees. The maximum compression in the instrument is reached at 90 degree angle of the channel joints, but it needs a larger deformation force. To obtain pressed material it is recommended to use a high ECAP cycle for any configuration.

Key words: powder material, ECAP, Ti-6Al-4V alloy, stress-strain state

INTRODUCTION

ECAP is an effective method of hardening a wide number of materials, obtaining subultrafine-grained structure and consolidation of powder materials. In addition, ECAP is used as an intermediate or a final procedure when obtaining the material with the set properties and structure.

Equal channel angular pressing has a number of important technological characteristics, peculiarities and advantages in comparison with traditional metalworking processes. It permits to realize simple shear as a unique industrial operation for the structure and texture formation that develops new opportunities for the technology of advanced materials. There are a lot of potential and promising applications of this deformation method in the materials synthesis and processing [1].

Besides, the use of a multi-cycle ECAP when processing compact materials permits to obtain subultrafine-grained materials with mainly high-angle boundaries of grains [2].

Despite the latest active development of special methods of equal channel angular presssing, such as Tubular channel angular pressing (TCAP) [3], Equal channel angular pressing–conform [4], Equal channel multiangular pressing (ECMAP) [5], Rotary-die equal channel angular pressing (RD-ECAP) [6], ECAP using a bevel-edge punch [7], Three-dimensional flow in multipass equal channel angular pressing [8], Modification of the ECAP process by incorporating twist channel [9], Tube Channel Pressing (TCP) [10], the interest in the classical version of the ECAP realization is still very significant. The ECAP efficiency is shown both for ferrous and even for nonferrous metals and alloys [11-15].

However at this it is noted that both on the parameters of mechanical characteristics and on the extent of crushing the grains under the deformation by the ECAP method there has significant effect not only the geometry of the tool, but also the chemical composition of the processed workpieces and the way of the previous processing, in particular the deformation way [5].

Even more often ECAP is used for compacting powder materials for producing products or parts from hardly deformed metals and alloys, or made for responsible purpose. At this the process of ECAP is, as a rule, carried out after the preliminary processing by pressure. As a result of the preliminary processing by pressure a workpiece acquires a certain form, volume and density. Most often when realizing the classical ECAP, there are used the angles of channel joints of the tool equal to 90, 120, 135°. The value of the angles of channel joints defines the efficiency of the process of compaction, the level of the deformation force and the parameters of the stressed-and-strained state of the workpiece. Besides the geometrical factor, the boundary conditions and the temperature parameters an essential role when obtaining high-quality workpieces is played by the extent of the accumulated deformation directly depending on the number of cycles of deformation and the selected route.

In this work there is studied the ECAP process of powder materials based on titanium with varying angle of channel joints 90, 120, 135 degree, as well as with varying the initial densoty from 10 to 90 %.

MATERIAL AND METHODS OF STUDYING

The assessment of the ECAP efficiency of powder material was carried out by means of the program DE-

V. A. Andreyachshenko, D. A. Issagulova Faculty of Nanotechnology and Metallurgy, Karaganda state technical University, Karaganda
M. K. Ibatov Karaganda state industrial University, Karaganda, Kazakhstan

FORM 3D complex. As the material of a deformable workpiece there was selected the Ti – 6 Al – 4 V alloy. It is used in aerospace industry and mechanical engineering. The coefficient of friction was selected for deformation conditions with the use of lubricants (0,3). When realizing the method of finite elements a workpiece with sizes 10 x 10 x 60 mm was broken into 50 000 finite elements of the octahedral form. There was selected a rigid type of objects of the equipment and punch, for workpieces it was porous. There was set the task of non- isothermal type with the possibility of accounting heat removal from the workpiece to the equipment and the surrounding atmosphere. At deformation the initial temperature of the workpiece corresponded to the ambient temperature (20 ºC). The tool was selected with the rounding off of the channel joints.

First of all there was carried out the ECAP modeling of porous workpieces with the initial densoty 50 %. After identification of the most rational angle of the channel joints there was studied the process of compaction in this configuration with varying initial density of porous workpieces from 10 to 90 %.

RESULTS AND DISCUSSION

When deforming by the ECAP method and selecting the geometry of the tool the prime role is played by the distribution of the stressed-and-strained state on the workpiece section. Besides stressed-and-strained state the character of the current of the workpiece material is also important. When realizing ECAP, the existence of the dead zone in the field of channel joints of the tool is characteristic. The use of the rounding off of channel joints of the tool permits to reduce the vacancy of this zone. At this the size of the dead zone directly depends on the angles of channel joints of the tool. As it is presented in Figure 1, the maximum dead zone belongs to the tool with the angle channel joints equal to 90 degree. The minimum dead zone is inherent in the tool with the angle of channel joints equal to 135°. For all three configurations of the tool the dead zone is present only at the initial stages of deformation. When moving the worlpiece to the output channel of the tool the volume of the dead zone decreases to zero. It is connected with the impact of contact friction forces. The forces of contact friction are directed against the workpiece movement that leads to filling the dead zone at the stabilized deformation stage.

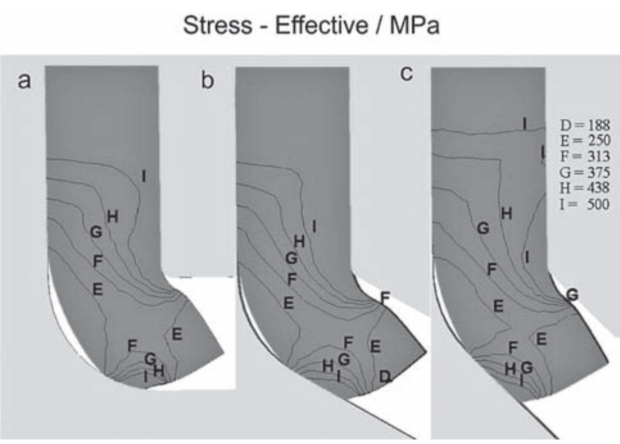

Figure 1 Stress intencity dfistribution on the workpiece section at ECAP with the angle of channel joints 90 degree (a), 120 degree (b) and 135 degree (c)

At the initial timepoint there takes place the compaction of the workpiece zone that is directly under the punch. Then the workpiece begins to pass to to the zone of the channel joints of the tool, and there comes the stabilized deformation stage. The center of deformation serves the zone of the channel joints of the tool. At the stage of the forward end of the workpiece passing the zone of channel joints of the tool and its transition to the output channel for all three configurations of the tool there is characteristic unifrom distribution of stress intensity with numerical values from 190 to 250 MPa in the deformation center. The similarity of values of stress intensity for all three configurations is caused by a high share of free surfaces of the workpiece at this stage of deformation. At the places of contact stress intensity values 500 MPa. In the process of reducing the angle channel joints of the tool the value of stress intensity decreases.

At the stabilized deformation stage the field of shear stress is not homogenous (especially for cangles channel joints of the tool 90 и 120 degree). At this when using the angle of channel joints of the tool equal to 135 degree the center of deformation degenerates to the line connecting the internal and external radiuses of the tool. The shear stress distribution on the workpiece section is more favorable for the angle of channel joints of the tool equal to 135 degree.

The form of the forward end of the workpiece is closer to the initial one for the tool with the 135 degree angle of channel joints. With increasing the angle of channel joints the distortion of the workpiece form amplifies that increases the trimming volume.

At this increasing the angle of channel joints of the tool intensifies the process of the powder material compaction that is a very important factor. In Figure 2 there is presented the diagarm of distribution of the workpiece density on its longitudinal section at the time of the workpiece full transition to the output channel of the tool. It is seen that for the tool with the angle of channel joints 90 degree the largest volume has density equal to 1. For two other configurations of the tool the main volume of the workpiece has density 0,9…1. At this there characteristic the existence of zones which density has dispersion from 0,55 to 0,9 for all three considered configurations.

At this the maximum force of deformation is observed at the channel joints of the tool 90 degree which reaches 220 kN at the stabilized process stage. With increasing the angle of channel joints of the tool the force decreases and for the tool with 120 degree it corresponds to 170 kN and 150 kN for the tool with 135 de-

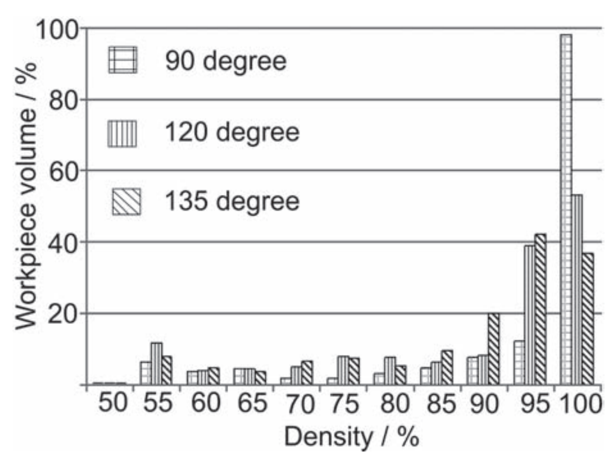

Figure 2 Diagram of density distribution on the workpiece volume

gree. Thus, for the further studies there was selected the angle of channel joints 135 degree.

The next step was studying the impact of the initial density value on the process of compaction of porous workpieces. The ECAP process for a range of values of initial density from 10 to 90 % with a step of 10 % was studied.

When studying there were considered such parameters as the average value of the workpiece final density, a deviation from the average value of density, an absolute difference of initial and final density of the workpiece Δρ and relative consolidation which was calculated as the ratio between the absolute difference of initial and final density of the wprlpiece and the initial value of density. In Figure 3 it is shown that the final density increases with increasing the initial density, and this dependence is logarithmic.

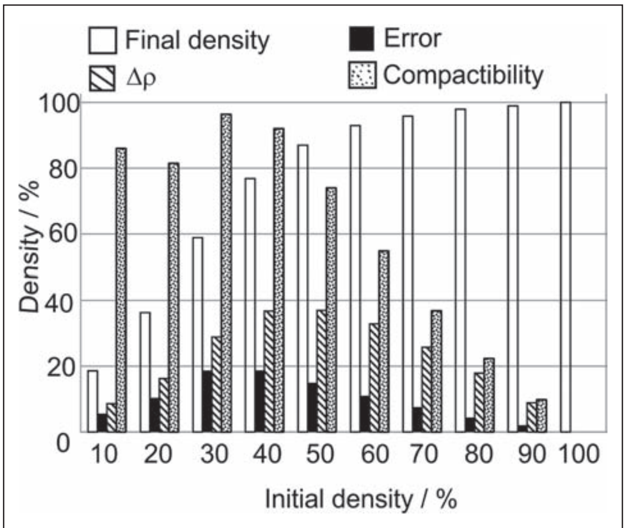

Figure 3 Final density dependence on the value of the initial density

The greatest dispersion of the values of density is observed at the initial density 30…40 %. With increasing the values of the initial density, dispersion of the values for samples decreases. It is characteristic that the maximum compactibility of the workpiece corresponds to the initial density 30…40 %. At this the absolute difference of values of density before and after ECAP corresponds to 50 % of the initial density. Thus, the most fast there is consolidation at the minimum initial density of the workpiece when the distance between the material particles is rather large. With increasing the and respectively the final density of the workpiece there is observed decreasing compactibility for one ECAP pass, at this dispersion of the values of the workpiece density on the volume also decreases. Increasing the workpiece density is provided with reducing its volume. The maximum reduction of the workpiece volume for one ECAP cycle falls on the workpiece with the initial density 40 % and makes 3 250 mm^3. In ECAP there takes place primary reduction of the workpiece length with insignificant decreasing the sizes of cross sections.

CONCLUSIONS

There was studied the technology of processing powder materials by the ECAP method. It was revealed that with increasing the angle of channel joints of the tool the homogeneity of stressed-and-strained state distribution increases, at this numerical indicators decrease. The size of the dead zone at initial stages of deformation decreases that is a positive factor. However, even at 90 degree angle in the workpiece volume there are zones which densobtaining compact materials from samples with the initial density 50 % there os recommended carrying out a multi-cycle ECAP for any configuration of the tool. At deformation in the tool with the angle of joint 135 degree there is observed maximum consolidation at the initial density 30…40 %. With increasing the initial density of the workpiece, the density achieved as a result of carrying out one ECAP cycle also increases.

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Note: The translator for the English language is N. Drak, Karaganda, Kazakhstan.