

Influence of Nanostructuration on the Sound Velocity in Aluminum Al_{99.50}

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Abstract. The paper proposes is a multidisciplinary study on the influence of nanostructured material obtained by cyclic closed die forging process, in this case the aluminum with a purity of 99.50% (Al_{99.50}), on the sound velocity. The study of nanomaterials is a branch of material science on the basis of which nanotechnology can be approached. Severe plastic deformation (SPD) is a generic term describing a group of metal and alloy processing techniques involving very high stresses without including significant changes in the overall dimensions of the model or workpiece. The sample is of a regular quadrangular prism shape with the side square of $a = 10$ mm and the height of $h = 16$ mm, so with a dimensional factor $h/a = 1.6$. For each sample, a number of 7 determinations were performed to establish a mean value for the sound velocity. As a result of the microstructure analysis, it is observed that at the deformation cycle 4 the grains have an average size between 250 and 500 nm.

1. Introduction

The paper proposes a multidisciplinary study on the influence of the nanostructuring of a material obtained by the cyclic closed die forging process, in this case the aluminum with a purity of 99.50% (Al_{99.50}), on the sound velocity. The process was patented by A.K. Ghosh in 1988 [1] and is schematically represented in the Figure 1.

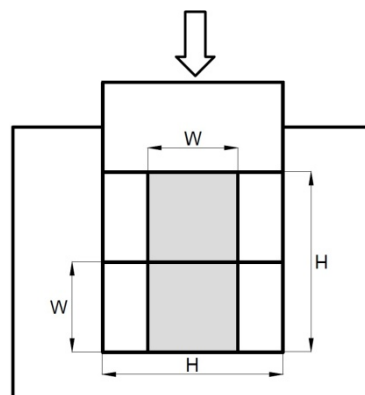


Figure 1. Gosh scheme for multiaxial forging [2].

where: W is the side of the initial square section of the blank;

H is the initial height of the blank.

Plastic deformation is the method of machining where permanent deformation of solid materials without macroscopic cracking is achieved in order to obtain semi-finished products or finished parts [3]. Multiaxial forging is a discontinuous deformation process consisting of a series of deformation processes defining the severe plastic deformation cycle, with the consequence of the nanostructure of the deformed material at a certain number of passes [4-11].

The shape and dimensions of the blank are kept after each pass, as shown in the Figure 2 at the pass " i " (SPD _{i}), where the deformation scheme is presented.

2. Materials and methods

The deformation process is discontinuous and comprises deformation processes defining a severe plastic deformation cycle [12].

Figure 2 shows the phases of multiaxial forging at a passage of the parallelepiped blank.

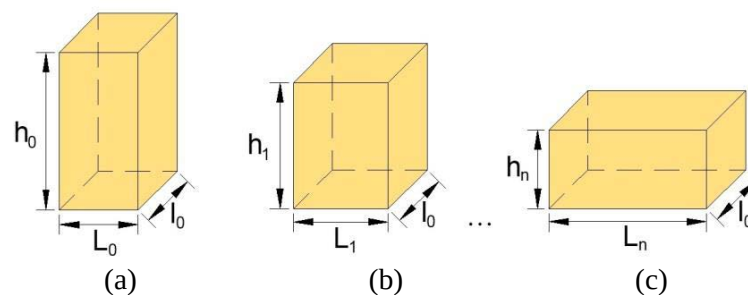


Figure 2. Stages of multiaxial forging for a single passage:
(a) blank; (b) blank deformation; (c) deformed part.

in which: h_0	este initial height of the blank, $h_0=20\text{ mm}$;
L_0	– initial length of the blank, $L_0=10\text{ mm}$;
l_0	– initial width of the blank is kept constant throughout the deformation, $l_0=10\text{ mm}$;
$h_1, h_2, \dots, h_{n-1}$	– current height of the workpiece deformed values $h_i[\text{mm}] \in (10, 20), i = \overline{1, n-1}$;
$L_1, L_2, \dots, L_{n-1}$	– current length of the workpiece deformed values $L_i[\text{mm}] \in (10, 20), i = \overline{1, n-1}$;
h_n	– height of the piece at the end of severe plastic deformation process, $h_n=10\text{ mm}$;
L_n	– length of the piece at the end of severe plastic deformation process, $L_n=20\text{ mm}$.

The samples were subjected to 12 deformation cycles by cyclic closed die forging process. We used the device designed on the principle of A.K. Ghosh, (Figure 1). It was mounted on a hydraulic press of 750 kN. The press is equipped with a force transducer of 1000 kN and a displacement one having a stroke of $0 \div 100\text{ mm}$.

The nanostructure device for metallic materials, Figure 3, was designed and made on the Ghosh principle, the blank and the piece having the same shapes and dimensions, Figure 2a.

The device according to figure 3 consists of an active plate (1), placed on a pressure plate (2), the assembly being guided on the inner surface of the support (3).

The blank (4) is centred in the recess of active plate over a counterpunch (5) placed in turn on a tablet pressure (6) positioned in the holder (3).

The deformation of workpiece is achieved by applying a force over the punch (7) moving with the given value of stroke limiter (8).

The deformation force applied is dynamically registered with an acquisition system, not shown, by means of a load cell (9) mounted between the holder (3) and a pressure plate (10).

After deformation, the pressure plate (6), counterpunch (5) and limiter (7) are eliminated and the punch is pressed (7) using another stroke limiter until the extraction of the deformed workpiece. The workpiece is rotated by 90° vertical and 90° horizontal, and introduced into the initially described device in order for the next pass and so on until nanostructuring the blank material.

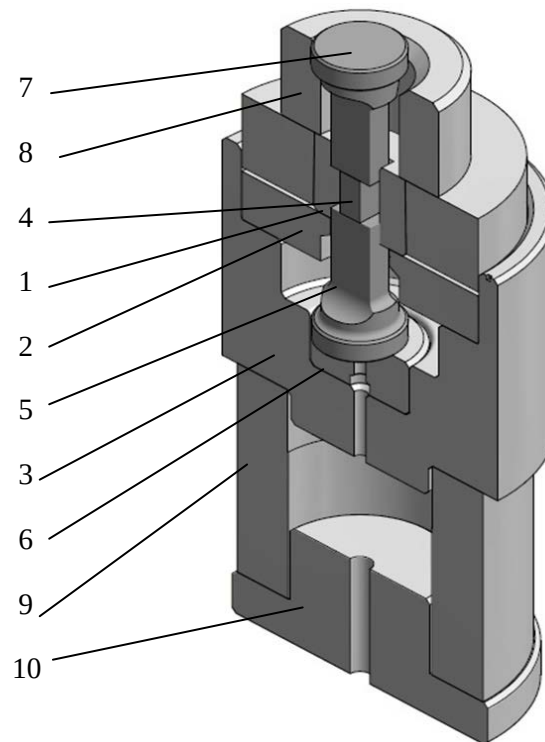


Figure 3. The constructive functional scheme of multi-axial forging device [2].

2.1. Material

To determine the chemical composition of the sample material used in the investigations, we performed the chemical analysis test with the GNR Metal Lab 75/80 V spectrometer, as shown in Table 1.

Table 1. The chemical composition of the aluminum 99.50.

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ni	Ti
Percent	0.143	0.213	0.021	0.004	0.050	0.003	0.021	0.008	0.006

Element	Pb	Sn	B	Ca	Co	V	Na	P	Al
Percent	0.005	0.011	0.000	0.003	0.002	0.011	0.004	0.000	99.495

The sample is of a regular quadrangular prism shape with a square base of $a = 10$ mm and a height of $L = 16$ mm, so with a dimensional factor $L / a = 1.6$, Figure 4.

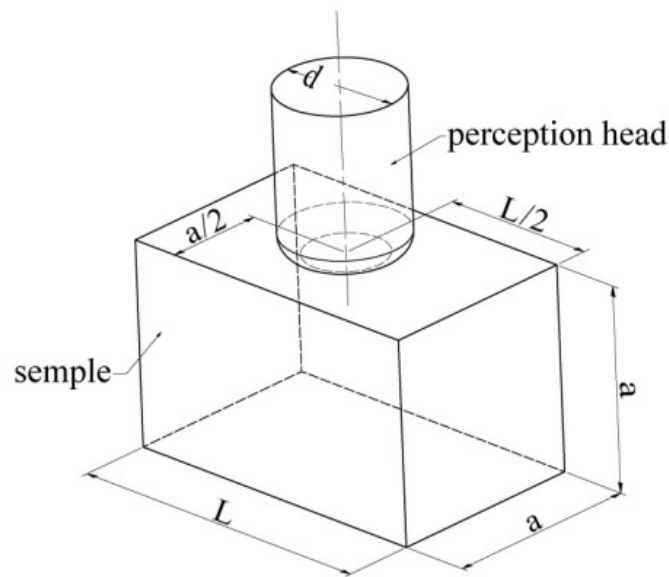


Figure 4. Sound rate measurement scheme.

3. Results and discussions

On each sample we performed 7 determinations and in Table 2 we present the average values of the sound velocity, where:

- N is the number of passes (deformation), [-];
- L - length of the blank, [mm];
- l - width of the blank, [mm];
- $V_{Al_99.50}$ - the average of the sound velocity for Al_99.50 samples, [m/s].

Table 2. Valorile medii ale vitezei sunetului pentru cele 12 treceri a semifabricatelor din Al_99.50.

N [-]	L [mm]	l [mm]	$V_{Al_99.50}$ [m/s]
0	16	10	6400
1			6230
2			6080
3			5930
4			5820
5			6040
6			6180
7			6350
8			6370
9			6450
10			6530
11			6540
12			6550

Based on the values in Table 2, we have plotted the variation of the sound velocity according to the number of passes, Figure 5.

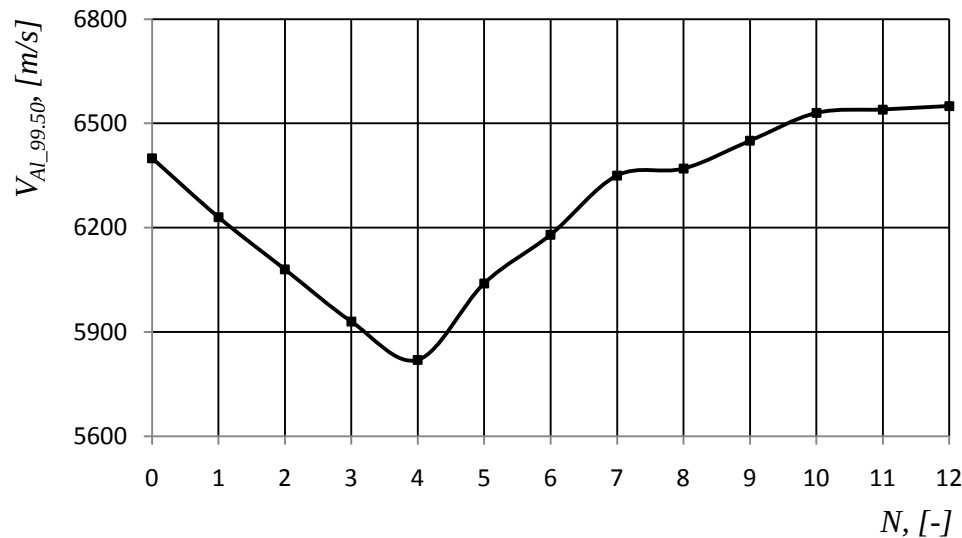


Figure 5. Variation of the sound velocity according to the number of passes for aluminum Al_99.50.

4. Conclusions

The variation of the sound velocity was plotted against the number of deformation cycles, a variation describing a convex line having a minimum in the area of the deformation cycle number 4.

As a result of the microstructural analysis, it is observed that at the deformation cycle 4 the grains have an average size between 250 and 500 nm.

On the basis of the above, it can be deduced that the area of passes 3, 4 and 5 is, in fact, precisely the transition zone between micrometric granulation and mesoscopic (ultrafine) granulation, which is nothing but an intermediate area between micrometric granulation and nanometric granulation.

5. References

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