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INFLUENCE OF NANOSTRUCTURATION ON THE SOUND VELOCITY IN ALUMINUM AL_99.50

Alin Marian CAZAC[1], Mihai Adrian BERNEVIG-SAVA[1],
Andrei Victor SANDU[2], Costica BEJINARIU[1*]

[1] Technical University "Gheorghe Asachi" of Iasi-Romania, Department of Materials Engineering and Industrial Safety, Blvd. Mangeron, No. 69, 700050, Iasi, Romania
[2] Technical University "Gheorghe Asachi" of Iasi-Romania, Department of Technologies and Equipments for Materials Processing, Blvd. Mangeron, No. 51, 700050, Iasi, Romania

Abstract

The paper aims to determine the influence of nanostructure on sound velocity, to severe plastic deformation by cold multiaxial forging of aluminum. The deformation process is discontinuous and comprises deformation processes defining a severe plastic deformation cycle. Thus, a number of 7 determinations were performed for each sample, corresponding to the first 12 cycles of severe plastic deformation. As a result of the analysis of the results, it can be deduced that the area of passages 3, 4 and 5 represents, in fact, precisely the transition zone between micrometric granulation and mesoscopic (ultrafine) granulation, which is only an intermediate area between micrometric granulation and nanometric granulation.

Keywords: *aluminum, sever plastic deformation, stress.*

Introduction

Severe plastic deformation (SPD) is a generic term describing a group of metal processing techniques involving very high stresses without including significant changes in the overall dimensions of the model or workpiece [1-3].

Another defining feature of SPD techniques is that shape retention is achieved due to the special geometries of the die, which involve the material semi free flow and thus produces significant hydrostatic pressure [4-6].

The presence of high hydrostatic pressure in combination with high shear stress is essential for producing a high density of crystalline mesh defects, especially dislocations, which can lead to significant grain finishing [7,8].

Because the workpiece dimensions do not change during SPD processing, the process can be repeatedly applied to impose extremely high stresses [4-6]. Optimizing SPD pathways and regimes can eventually induce a very fine microstructure in the workpiece, which extends homogeneously along the blank [9,10].

Sound speed is one of the parameters that describe the propagation of sound through an environment. This velocity depends on the properties of the medium propagation, in particular its elasticity and density.

Ultrasounds are elastic waves that propagate in solid, liquid and gaseous environments, and whose frequency exceeds the audibility limit of 20 kHz.

Corresponding author: costica.bejinariu@tuiasi.ro

In solid environments two types of elastic waves can be propagated - longitudinal and transverse. Each waveform corresponds to its own oscillation velocity. The velocity of the longitudinal waves is determined using ultrasound generating devices by means of transducers which transmit such waves reflecting the opposite surface of the sample relative to the surface on which the touch probe is placed.

Materials and Methods

Multiaxial forging is a discontinuous deformation process consisting of a series of deformation processes defining a severe plastic deformation cycle, with the consequence of nanostructuring the deformed material to a certain number of passes [1-3, 11-15].

The shape and dimensions of the blank and piece obtained at one pass remain unchanged [6]. This is possible by correlating these parameters with the configuration and dimensions of the deformation tools [3].

The shape and dimensions of the workpiece are preserved after each pass, as shown in Fig.1 at the *"i"* pass (SPD_i), where the deformation scheme is also shown.

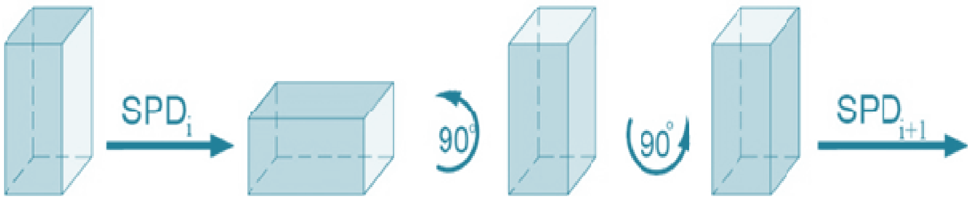

Fig. 1. Deformation scheme at pass *"i"*.

For the next deformation, the specimen obtained after deformation rotates with 90° in the vertical plane and then with 90° in the horizontal plane.

This cycle is repeated n times until the nanometric structure is obtained. The value of parameter n (number of passes) is determined experimentally.

Ultrasound generating and receiving is done with ultrasound transducers (piezoelectric sensors).

The material used is 99.50% pure aluminum having the chemical composition shown in Tab. 1, composition determined on the GNR Metal Lab 75/80 V spectrometer.

Table 1. Chemical composition of aluminum Al_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

Workpiece. Parallelepiped shaped semiproducts were used with a square base of a = 10 mm and the height of h = 16 mm, so with a dimensional factor h / a = 1.6, Fig.2.

Preparation of the specimens included grinding and polishing operations on all surfaces.

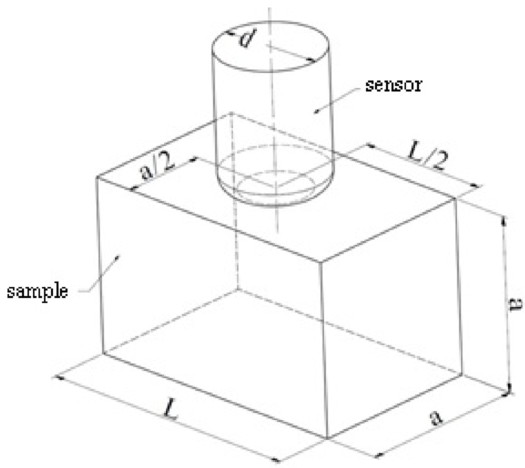

Fig. 2. Sound velocity measurement scheme.

The propagation velocity of the ultrasonic waves is determined by the material after it has been subjected to a cycle of 12 multiaxial forging, based on two calibrated dimensions present on the sample, namely *a* and *L*. The propagation velocity is automatically stored. The finished surface should be carefully cleaned before the measurements begin.

Results and Discussion

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

N is pass number (deformation), *[-]*;

L - semiproduct length, *[mm]*;

l - semiproduct height, *[mm]*;

$\bar{v}_{Al99.50}$ - the average of the sound velocity for the samples in Al_99.50, $\left[\frac{m}{s}\right]$.

Based on the values in Tab. 2, was plotted the variation of the sound velocity according to the number of passes, Fig. 3.

Table 2. Average sound rate values for the 12 passes of the Al_99.50 semiproducts.

N [-]	*L* [mm]	*l* [mm]	$\overline{V}_{Al_{99,50}}$ [m/s]
0			6400
1			6230
2			6080
3			5930
4			5820
5			6040
6	16	10	6180
7			6350
8			6370
9			6450
10			6530
11			6540
12			6550

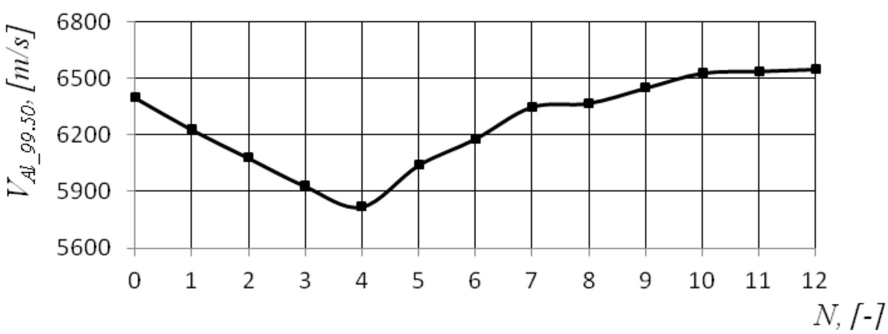

Fig. 3. Variation of the sound velocity according to the number of aluminum passes, Al_99.50.

From figure 3. It is noted that the variation of the sound velocity for Al_99.50 shows a minimum in the passes area 3, 4 and 5.

Following the microstructural analysis, a grain size of 250 to 500 nm is observed at pass 4.

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 merely an intermediate area between micrometric granulation and nanometric granulation.

Conclusion

The paper studies the influence of granulation finishing to nanostructure, the speed of sound in material as the physical property of semifinished materials by applying multiaxial forging.

Thus, it can be seen that the variation of the sound velocity for Al_99.50 shows a minimum in the area of passes 3, 4 and 5, at the pass of 4 severe plastic deformed materials having a grain size of 250 to 500 nm. 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 merely an intermediate area between micrometric granulation and nanometric granulation.

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