STUDY OF STRUCTURE AND PROPERTIES OF BRASS AFTER REPEATED DRECE PROCESSING COMBINED WITH HEAT TREATMENT

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Abstract

During last two decades great attention was paid to materials with grains of diameter smaller than 1 μm. These materials were classified as Ultra Fine Grain (UFG) materials with diameter of grains of the order of 100 to 1000 nm and nano-materials with mean diameters of grains smaller than 50 nm. This research concerned the whole production of UFG materials, using Severe Plastic Deformation (SPD) method. One of them is new type of equipment DRECE (Dual Rolling Equal Channel Extrusion), designated for obtaining UFG structure in strip of sheet.

Experiments with use of brass were made on the DRECE machines to achieve grain refinement in the strip of sheet with dimensions 58 x 2 x 1 000 mm. A prototype of this equipment used has been put on Department of Mechanical Technology, VSB-Technical University of Ostrava, Faculty of Mechanical Engineering. On the part of brass strip sheets after the first DRECE processing next heat treatment 400°C/15min/air has been made to obtain the behavior of that materials after heat treatment with aim the next DRECE processing with changing conditions namely with obtaining grain refining.

Metallographic analysis of structure was made on optical microscope NEOPHOT 2 and mechanical properties of studied samples by tensile test and Vickers hardness method were tested.

Key words: DRECE machinery, brass, heat treatment, hardness, structure

1. INTRODUCTION

In many technical processes of forming the deformation is substantially greater than conditions at the tensile test. In this case a torsion tests have already been used for a long time at investigation of strengthening behavior and development of material structure. These new activities demonstrated at the beginning of the nineties, that it is possible to manufacture nano-crystalline metallic materials by very high plastic deformation at low homological temperatures. It is possible to achieve on ductile metallic materials at the tensile test a deformation from 30% to 70%. At the torsion test it is possible to achieve on the same materials several hundreds percent. Obtaining of nano-crystalline structures requires typical magnitudes of deformation of the order from 100 to 1000%. High deformation at comparatively low homological temperatures is an efficient method for manufacture of ultrafine grained (UFG) massive materials. News technologies, which use high deformation for obtaining of fine-grained structure, comprise namely the following authors [1-6].

This research concerned the whole production of UFG materials, using Severe Plastic Deformation (SPD). These new technologies for production of semi-finished products with ultra-fine grained structure differ from conventional technologies. While in classical technologies change cross-section of the processed material, the cross-section of material processes by SPD remains unchanged. Several types of SPD technologies serving for production of UFG metals was developed already at the beginning of the nineties. One of them is
new type of equipment DRECE (Dual Rolling Equal Channel Extrusion), designated for obtaining UFG structure in strip of sheet.

1.1 Technologies for production of UFG materials

Most frequently used and new developing methods for production of UFG materials comprise the following technologies [1-8]:

- High Pressure Torsion
- Equal Channel Angle Extrusion
- Cyclic Channel Die Compression
- Cyclic Extrusion Compression
- Continuous Extrusion Forming
- Accumulative Roll Bonding
- Constrained Groove Pressing
- Thixoforging
- HPT – High Pressure Torsion
- DRECE

1.2 DRECE Machinery

Equipment DRECE is based on process CONFORM, modifying for sheet forming. During 2009 a prototype of this equipment was put into trial operation at the working site of the VŠB-TUO. Fig. 1 shows a principle and overall view of the prototype of this equipment. It consists of the following main parts: gear of the type Nord with electric drive, disc clutch, feed roller and pressure rollers with regulation of thrust, forming tool made of the steel grade Dievar. Strip of sheet with dimensions 58 x 2 x 1000 mm fed into the working space and it is pushed by the feed roller with help of pressure rollers through the forming tool without change of its cross section. Next pass is realized after rotation of sheet with angle 180°. Repeated plastic deformation realised in this manner brings substantial refinement of structure. During the trial operation first experiments were made followed by their evaluation. On the basis of these works some modifications of design were proposed. It is not possible to publish more detailed technical data as this equipment is patent protected [9].

2. EXPERIMENTAL METHODS AND MATERIAL

Experiments with use of the formed structural material - brass were made on the DRECE machines in order to achieve grain refinement in the strip of sheet with dimensions 58 x 2 x 1000 mm (brass Cu-Zn 65/35 weight %).

Altogether 6 passes were made through the DRECE tool. The heat treatment (450°C/15min/air) of part of sheet was applied after DRECE processing. The extruded samples of brass after all passes were then cut from sheets into individual series for manufacture of individual testing specimens for metallographic evaluation and mechanical tests. They were marked on the surface of sheets by symbols MoX, (number of passes X = 1-6) for the samples without heat treatment and MoHTX for the samples with heat treatment. Sample of initial state is marked MoI [9].

Experimental and mathematical simulation achieved parameters at DRECE processing:

Mathematical simulation: Intensity of deformation after first pas is $e_1 = 0.411$, and after six passes $e_6 = 1.720$

Experimental results: Intensity of deformation after first pas is $e_1 = 0.398$, and after six passes $e_6 = 1.704$

As it is seen the mathematical simulation and experimental results are in a good agreement.
2.1 DRECE Machinery

Mechanical properties of studied samples were tested by Vickers hardness method on the HPO 250 testing device and tensile test on the Inova TSM 50 testing machine. Results of Vickers hardness test for samples without heat treatment are shown in the Table 1, and for samples with heat treatment in the Table 2. The hardness of the sample of initial state MoI is 93HV5.

Table 1 Average values of hardness of brass on the samples without heat treatment

<table>
<thead>
<tr>
<th>Sample</th>
<th>Hardness HV5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo2</td>
<td>127</td>
</tr>
<tr>
<td>Mo4</td>
<td>150</td>
</tr>
<tr>
<td>Mo6</td>
<td>160</td>
</tr>
</tbody>
</table>

Table 2 Average values of hardness of brass on the samples with heat treatment

<table>
<thead>
<tr>
<th>Sample</th>
<th>Hardness HV5</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoHT2</td>
<td>95</td>
</tr>
<tr>
<td>MoHT4</td>
<td>101</td>
</tr>
<tr>
<td>MoHT6</td>
<td>136</td>
</tr>
</tbody>
</table>

Average values of hardness in Table 1, 2 from five measurements were calculated. As it can be seen from Table 1 for samples without heat treatment, these values rapidly increase from the 1st to 4th passes. After the 4th pass the value of hardness stays nearly the same.

It may be assumed from this dependence, that the biggest increase of hardness caused by dislocation strengthening in the course of plastic deformation occurs till the 4th pass and subsequent passes do not contribute substantially to further increase of strengthening (Table 2). In the case of the samples after heat treatment a decrease of hardness occurs as a result of re-crystallisation process. Values of hardness are in all cases higher than in initial state and they also increase in the samples with an increasing number of passes.
2.2 Tensile test

Results of tensile test are shown in Fig. 2

![Graph showing tensile test results](image)

**Fig. 2. Tensile test - brass**

As it is seen from this figure the yield stress and ultimate tensile stress after DRECE processing are increased to 4th pass while the elongation is decreased. After heat treatment the significant increasing the yield stress and ultimate tensile stress against initial state were occurred while the elongation stays nearly the same.

2.2 Metallographic analyze

Metallographic analysis was made on light microscope NEOPHOT 2. After usual metallographic preparation the samples were chemically etched. Results of selected micrographs are shown in Fig. 3. Microstructures of brass samples are shown in Fig. 3. Fig. 2a shows microstructure of initial state sample of brass. This microstructure consists of grains in agreement with the fact that this material was formed before the DRECE processing. Grain size reached the value G4 according to ASTM. Microstructures of brass samples without heat treatment after passes through the DRECE tool are shown in Figs. 3b,d. As it can be seen from these micrographs, refining of grains after each pass was only small. Grain size reached the value from G5 to G6 according to ASTM. Microstructures of brass samples with heat treatment after passes through the DRECE tool are shown in Figures Figs. 3e,f. As it can be seen from these micrographs, refining of grains is much bigger than in case of the samples without heat treatment. Grain size reached the value G8 – G9 according to ASTM.
Prototype equipment for production of UFG structure in a strip of sheet made of non-ferrous metals has been designed, with subsequent possibility of deformation also of steel sheets with thickness of 2 mm. This process involves primarily creation of sufficient number of shear systems with different orientation in crystallographic lattice. Creation of UFG structure in the strip of sheet is closely connected to the design of suitable geometry of the forming tool, appropriately dimensioned power unit and control system enabling setting of various values of peripheral velocities. From the viewpoint of forming parameters higher number of passes will bring considerable strengthening of the formed material. According to the degree of the obtained results of extrusion of the sheet made of brass it is possible to state that the equipment is fully functional.

3. CONCLUSION
The equipment DRECE is at the stage of verification and future works will verify influence of technological parameters on the increase of efficiency of SPD process for obtaining the UFG structure in non-ferrous metals.

From the viewpoint of forming parameters higher number of passes will bring considerable grain refining and strengthening of the formed material.

It may be assumed from dependence mechanical properties on number of passes, that the biggest increase of hardness caused by dislocation strengthening in the course of plastic deformation occurs till the 4th pass and subsequent passes do not contribute substantially to further increase of strengthening.

Heat treatment applied after passes through the DRECE tool significantly contributes to intensification of grain refinement procedure caused by running re-crystallisation process. It may be assumed on the basis of these results that in such fine-grained material further grain refinement can be achieved after subsequent the DRECE processing.

The results reached after heat treatment show the necessity next experiments with changing conditions of heat treatment parameters.

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