14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

STRUCTURE AND PROPERTIES OF COPPER AFTER DRECE PROCESSING

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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 material Cu 99.5% were made on the DRECE machines in order to achieve grain refinement in the strip of sheet with dimensions 58 x 2 x 1 000 mm. For orientation information, whether grain was refined preliminary metallographic analysis was made on optical microscope NEOPHOT 2. Structure was analysed on the surface in longitudinal direction in respect to direction of rolling, and also in cross section and longitudinal section. Altogether to 10 passes were made through the DRECE tool. Comparison was made for initial state and for the state after the third pass. According to the degree of the obtained results of extrusion of the sheet made of Cu (99.5%) it is possible to state that the equipment is fully functional.
Keywords: Manufacturing and Processing, DRECE Machinery, Structure and properties

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.

2. 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**

3. 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. Figure 1 and 2 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].

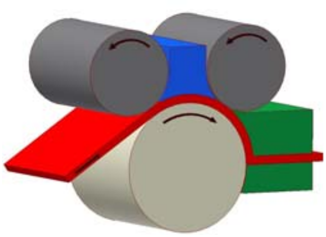

Figure 1. Principle of DRECE process

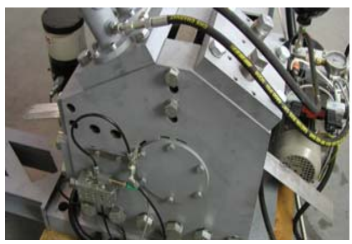

Figure 2. Front view of the equipment DRECE

4. EXPERIMENTAL METHODS AND MATERIALS

Experiments with use of formed structural material Cu 99.5% were made on the DRECE machines in order to achieve grain refinement in the strip of sheet with dimensions 58 x 2 x 1 000 mm [10]. Chemical composition of copper shows Table 1 and properties in Table 2.

Altogether 10 passes were made through the DRECE tool. The extruded samples of Cu after all passes were then cute from sheets into individual series for manufacture of individual testing specimens for metallographic evaluation and mechanical tests on the surface in longitudinal direction in respect to direction of rolling and in parallel and upright direction oriented to deformation marked by symbols MX1, MX2 and MX3 (number of pass X = 1-10).
Mechanical properties of studied samples by Vickers hardness method were tested. Results of these tests are showed in Table 3.

Table 1. Chemical composition of copper

Cu	Al	As	Bi	Fe	O	Pb	Sb	Sn
99,5	0,05	0,1	0,01	0,05	0,1	0,1	0,08	0,15

Table 2. Selected properties of copper

Properties	
Tensile strength R_m	220 [MPa]
Young modulus E	130000 [MPa]
Yield point R_e	60 [MPa]
Elongation	50 [%]
Density	8.940 [g/ cm^3]
Melting temperature	1083 [°C]

Table 3. Chemical composition of copper

Pass	Hardness HV5		
	MX1	MX2	MX3
0	81,8	88,7	83,6
2	105,0	94,8	97,3
4	112,6	102,6	100,6
6	114,2	102,9	108,2
8	111,9	113,9	109,0
10	117,2	114,4	119,4

For structure investigation the metallographic analysis was made on optical microscope NEOPHOT 2. Comparison was made for initial state and for the state after selected passes. This analysis was making more precise on TEM microscope.
After usual metallographic preparation the samples were electrolytically etched. Figures 3, 4 and 5 show the obtained results of analysis of selected samples.

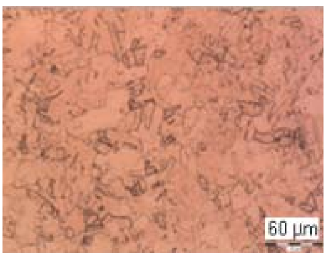

Figure 3. Structure of the sample M01 – initial state

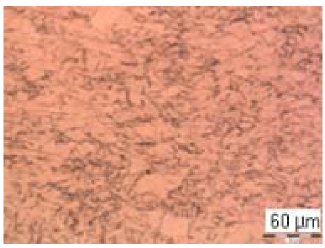

Figure 4. Structure of the sample M101 – after 10th pass

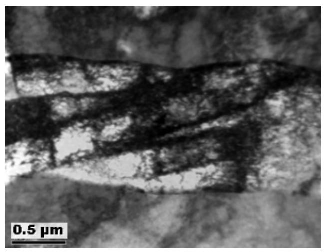

Figure 5. TEM of the sample M101 – after 10th pass

5. DISCUSSION OF RESULTS

Average values of hardness in Table 3 from five measurements were calculated. These values in all cases of cuts do not showed significant differences.
As it is seen from Table 3 these values rapidly increase from 1st to 4th passes. After fifth pass this value increase slightly and reached up 119 HV5 in the case of M103.
Microstructure of initial state samples of Cu is shown on the Figure 3. This microstructure consists from grains in agreement with fact that material was formed before DRECE machining.
The microstructure of sample M101 after 10th pass through DRECE tool is showed in Figure 4. Refining of grains after each pass was only small as it is seen on Figure 4 of the last passes. More information by TEM analysis was acquired as it is seen in Figure 5. This picture shows increasing dislocations density and slip band occurrence. This fact is in agreement with hardness measurement.

6. SUMMARY

It has been designed as prototype equipment for production of UFG structure in strip of sheet made of non-ferrous metals with subsequent possibility of deformation also of steel sheets with thickness 2 mm. This process involves primarily creation of sufficient number of shear systems with different orientation in crystallographic lattice. Creation of UFG structure in strip of sheet is closely connected to the design of suitable geometry of forming tool, appropriately dimensioned power unit and control system enabling setting of various values of peripheral velocities. It is also necessary to optimise the pressure force and thus also pressure on pressure rollers so that only extrusion occurs, but not the rolling. 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 Cu (99.5%) it is possible to state that the equipment is fully functional.

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

ACKNOWLEDGEMENTS

The authors would like to acknowledge gratefully that the Ministry of Trade and Commerce financed project MPO No. 2A-1TP1/124

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