THE EFFECT OF SEVERE PLASTIC DEFORMATION ON THE MECHANICAL PROPERTIES AND STRUCTURE OF BRASS

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Abstract

Over the last few years, the great attention was paid to materials with grain size of diameter smaller than 1 µm. These materials were classified as Ultra-Fine Grained (UFG) materials with diameter of grains of the order of 100 to 1000 nm and nano-materials (NC) with mean diameters of grains smaller than 50 nm. This research concerned to the production of UFG materials, using Severe Plastic Deformation (SPD) process. One of the forming methods using the SPD process is the DRECE method. This method was used to achieve the UFG structure in brass strip sheet. In the present paper, the brass CuZn37 strip sheets were processed by severe plastic deformation by DRECE method. The mechanical properties and structure achieved in individual passes by the device at room temperature were analyzed. Deformation route "C" was applied, i. e. the sheets were rotated about 180° between subsequent forming passes. It was found that process SPD has a significant influence on the increase mechanical properties of forming materials. The obtained results are detailed analyzed in the final part of this paper.

Keywords: Dual Rolls Equal Channel Extrusion (DRECE), Cu - Zn based alloy CuZn37, microstructure, mechanical properties

1. INTRODUCTION

Modern technologies, which use high deformation for obtaining the fine-grained structure in non-ferrous sheets, are described namely by the following authors [1-20]. This research concerned the whole production of ultrafine-grained (UFG) materials, using Severe Plastic Deformation (SPD). Several types of SPD technologies serving for production of UFG metals were developed already at the beginning of the nineties. One of them is a new type of methods called DRECE, designated for obtaining UFG structure in a strip of sheets and rods. Research areas of SPD processes as ECAP and DRECE technology at the Department of mechanical technology VSB - Technical University of Ostrava are intensively developed. Strip with dimensions 58 × 2 × 1000 mm was fed into the working space and it was pushed by the feed roller with help of pressure rollers through the forming tool without change of its cross section. Severe plastic deformation realised in this manner brought substantial refinement of structure. During the trial operation the first experiments were made, followed by their evaluation. On the basis of these works some modifications of design were proposed. Effectiveness of this method is evaluated by using simulations. According to the results, appropriate adjustments by the forming tool have been designed to achieve a higher intensity of deformation to obtain the UFG structure. With use of the simulation process SPD is seen to increase the intensity of deformation after each pass to a value of 3.5 which is a region of small and medium deformations. The functionality of the forming device that uses a new forming method DRECE has been verified by experimental activities, namely on non-ferrous metals and steels [2-10, 15-19].

2. INVESTIGATION PROCEDURES

The study material using in this article was a commercial cold-rolled strip of sheets from brass CuZn37, which chemical composition is shown in **Table 1**.

Table 1 Chemical composition of investigate brass (wt. %)

Sn	Al	Zn	Mn	Si	Fe	Cu
0.43	0.15	36.80	0.45	0.10	0.06	rest

The initial brass samples with dimensions 58 mm × 2 mm - 2000 mm were subjected to DRECE processing. Specimens were processed by DRECE with a tool angle α = 108° at room temperature (RT). Route "C" was applied, i. e. the samples were rotated about 180° between subsequent DRECE passes. The extrusion velocity of DRECE process was 3 mm. s^{-1} and maximum number of passes was 3.

Microstructures were observed through optical (OM) using specimens taken from sliced discs from the samples processed by DRECE method. The samples for metallographic analysis were etched in a solution of $FeCl_3$ + HCl + Alcohol. A comparative method with the use of Plate III standards was also used. The analysis was performed on a microscope NIKON EPIPHOT 300.

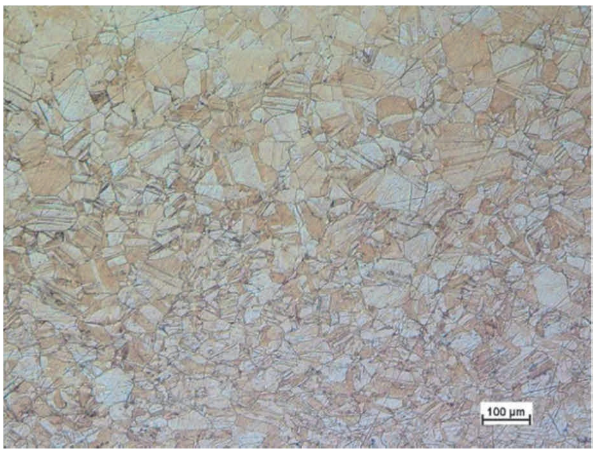
Hardness was measured using a vickers hardness tester al load of 10 kg for 20 s. Tensile tests were carried out using the tensile specimens with length 80 mm at the strain rate 1 s^{-1} at room temperature, the specimens for tensile testing were cuted from longitudinal (DRECE) direction.

3. INVESTIGATION RESULTS

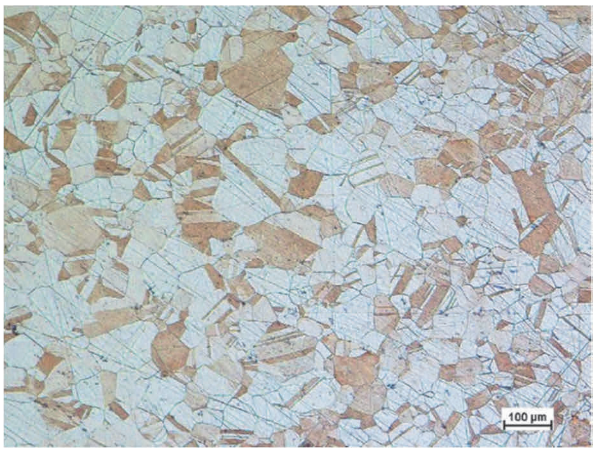
3.1. Microstructure evolution

All the samples have a microstructure formed by grains of α-brass with twins. The microstructures of the samples in the initial state prepared from different directions are show in **Figures 1 a, b**. The samples after the first and third pass through the forming tool show apparent slip lines and bands after plastic deformation (see **Figures 1 c - f**). All the samples have longitudinally elongated grains due to deformation, more so at the edges of the samples, in the centre, the deformation is sporadically not apparent. The average grain size after 3 passes reaches the values of 30 - 40 μm.

In the initial state the microstructure of the alloy CuZn37 consists of grains with prevailing average grain size 70 μm (G 4.7). After the first pass through the forming tool, a slight refining of grain with a predominant mean size of 50 μm (G 5.7) takes place. After the third pass, a further refinement takes place to a mean size of 40 μm (G 6). It is characterised by the accumulation of dislocations along the grain boundaries (dislocation reinforcement) and the beginning of the formation of sub-grains.

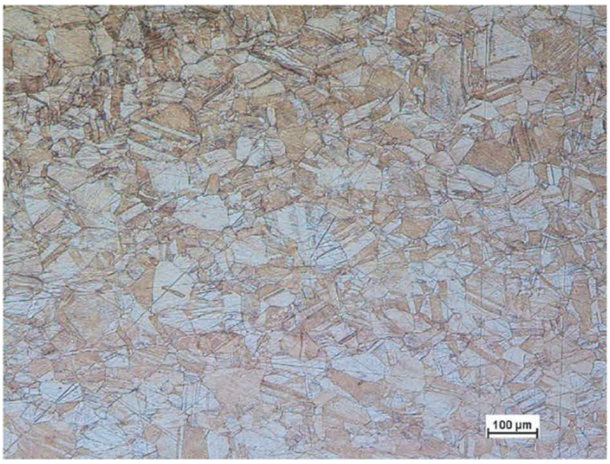


a) - transverse cut

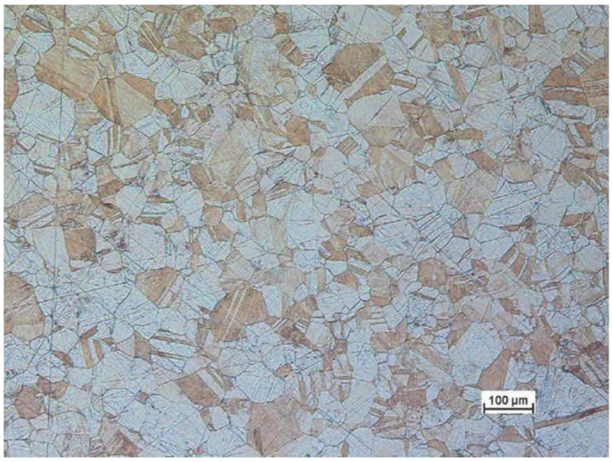


b) - longitudinal cut

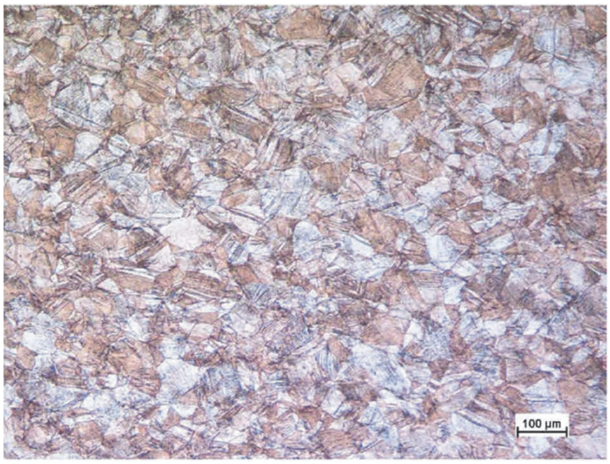
Figure 1 OM micrographs of investigated brass: Initial state (a - b); 1x DRECE (c - d) and 3x DRECE (e - f)



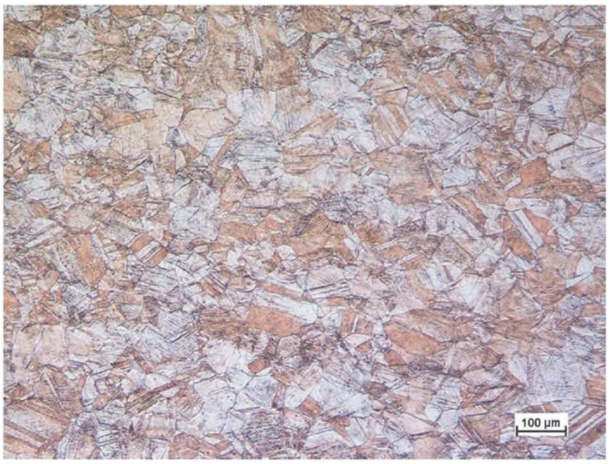
c) - transverse cut



d) - longitudinal cut

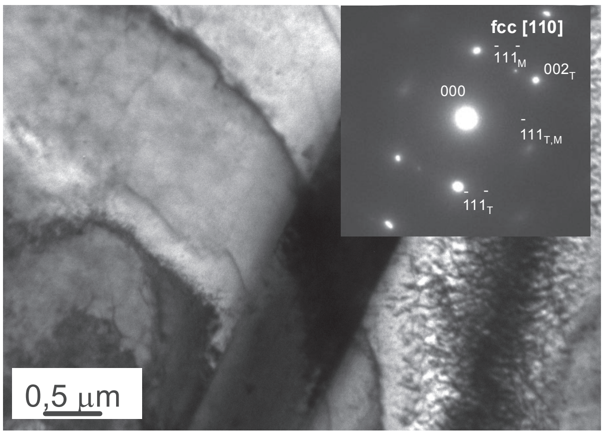


e) - transverse cut

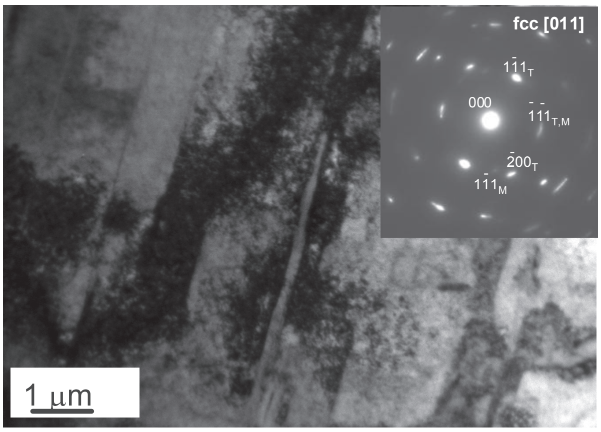


f) - longitudinal cut

Figure 1 OM micrographs of investigated brass: Initial state (a - b); 1x DRECE (c - d) and 3x DRECE (e - f)



a)



b)

Figure 2 TEM micrograph with corresponding SADP from the (a) 1x DRECE pass and (b) after 3x passes DRECE

Figure 2 shows the TEM micrograph from the sample which was passed 1 time through the DRECE device. One can see that the grain refinement is rather negligible, only growth of dislocation density and single twins can be observed. The presence of twin is confirmed in the diffraction pattern presented in **Figure 2b** (after third passes through forming device). As indicates the shape of the extinction contour, no formation of subgrain boundaries can be seen. Additional grove pressing repeated 3x causes formation of typical deformation twins and in addition formation of subgrain structure what causes splitting of diffraction spots in the direction of Debye Scherrer rings and causes contrast typical for the orientation changes. Similarly as in **Figure 2a** a relatively high dislocation density can be seen.

3.2. Mechanical properties

At the forming angle α = 108° we obtained the following results of mechanical properties (see **Table 2**). The original tensile curves of CuZn37 alloy are presented in **Figure 3**. **Figures 4** and **5** show a graphical representation of the influence of the number of passes through the forming tool to change the magnitude of the yield strength $R_{p0,2}$, ultimate strength R_m, ductility A and hardness HV10, respectively.

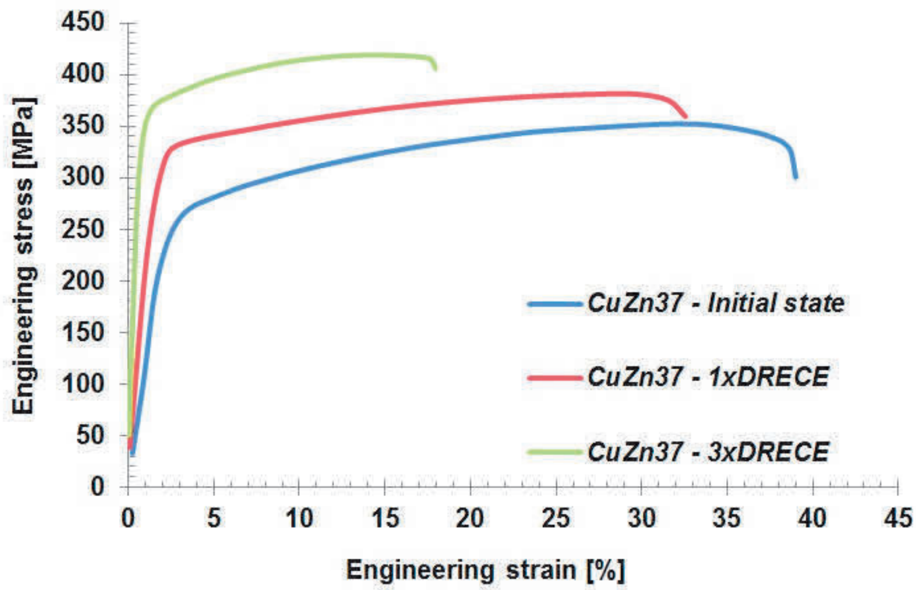


Figure 3 Tensile curves from samples: Initial state (a); 1x DRECE (b) and 4x DRECE (c)

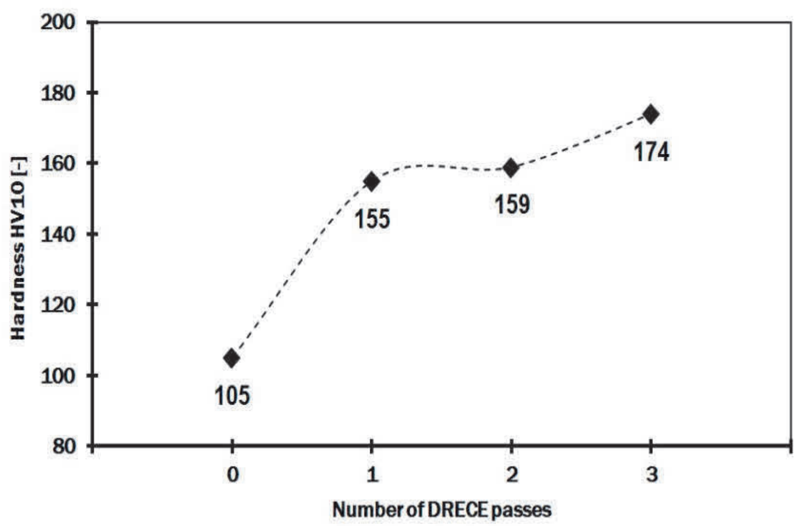


Figure 4 Vickers hardness HV10 evolution during DRECE processing

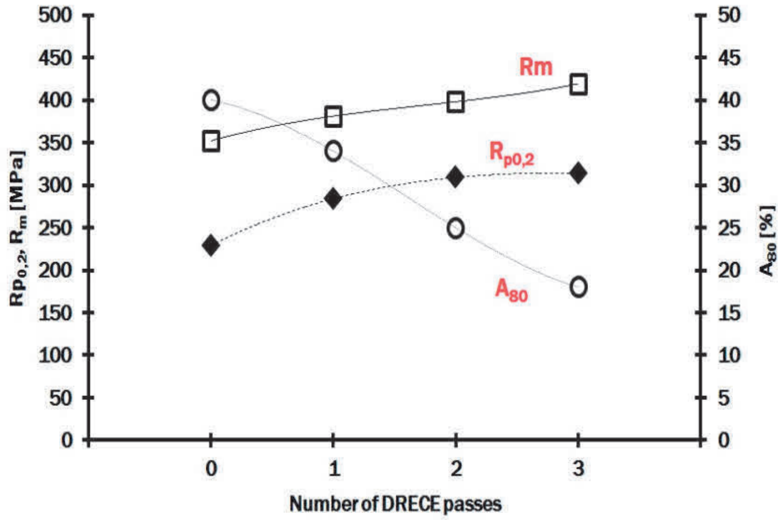


Figure 5 Tensile properties of CuZn37 with dependence of number of DRECE passes

Table 2 Mechanical properties of CuZn37 processed by DRECE method

	Yield stress $R_{p0,2}$ (MPa)	Ultimate tensile strength R_m (MPa)	Elongation to failure (%)	Vickers hardness HV10 (-)
Initial state	229	352	39	105
1st pass	284	381	33	155
2nd pass	309	398	25	159
3rd pass	314	419	18	174

When an angle α = 108° was used, the yield strength $R_{p0,2}$ increased by 24% already after the first pass through the forming tool, and after the second pass, it increased by 35% in comparison with the initial state. The ductility value decreased after the first pass by 5% in comparison with the initial state. Ductility decreased after the second pass by 8.5% to an acceptable value of 24.7% enabling subsequent forming operations. Ultimate tensile strength increases with dependence on number of passes. Maximal value of UTS was obtained in sample processed by 3 passes by tool with α = 108° (see **Table 2**).

4. CONCLUSION

Equipment for production of UFG structure in a strip of a sheet made of non-ferrous metals has been designed, with subsequent possibility of deformation also of steel sheets with a thickness of 2 mm. This process involves primarily creation of a sufficient number of shear systems with different orientation in the crystallographic lattice. Creation of UFG structure in the strip of the 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, the higher number of passes will bring a 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. The forming equipment is at the stage of verification and future works will verify the influence of technological parameters on the increase of efficiency of the SPD process for obtaining the UFG structure in non-ferrous metals. From the viewpoint of forming parameters, the higher number of passes will bring considerable grain refining and strengthening of the formed material. For the application of the achieved results in the industrial practice, it is very important to optimise the number of passes through the forming tool. From the viewpoint of achieving the maximum grain refinement, it is necessary to make a larger number of passes through the forming tool when no further strengthening of the material occurs anymore (alloy CuZn37) but to recovery of plasticity by its increase takes place. After the 3rd pass through the forming tool the yield strength $R_{p0,2}$ practically does not increase. A significant increase of $R_{p0,2}$ was achieved already after the 1st and 2nd pass through the forming tool. Drop in plasticity is minimal after the first pass - only 5%, and after the second pass it makes 14%, which allows next forming operations on a strip of the sheet, and thus a production of the final components (hinges, brackets, clips for car locks, etc.). The future works will investigate the influence of technological and forming parameters (the thrust of rolls, strain rate) on a further increase of efficiency of the SPD process.

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