Nanostructural Formation in Steel Material by ECAP

Tibor Kvackaj[1,a], Michal Zemko[1,b], Tomas Kuskulic[1,c], Robert Kocisko[1,d],
Michal Besterci[2,e], Sergej V. Dobatkin[3,f], Maria Molnarova[1,g]

[1]Technical University in Kosice, Letna 9, 042 00 Kosice, Slovak republic
[2]Institute of Materials Research of SAS, Watsonova 47, 043 53Košice, Slovak Republic
[3]Moscow State Institute of Steel and Alloys, Leninsky prospect, Moscow, Russia
Corresponding author: tibor.kvackaj@tuke.sk

Abstract

In the present research work was searched the influence of severe plastic deformation (SPD) realized by ECAP (equal-channel angular pressing) on structural, mechanical and plastic properties of IF (interstitial free) steel. For physical simulation ECAP process with right angle channels (90°) was used. The ECAP process was numerical simulated (namely its course of temperature, strain and stress fields and deformation forces) by FormFEM software, too.

Keywords : nanostructure, IF steel, material properties, ECAP, numerical simulation

At the present time the topic of intense research is the refining of various type material microstructures, which have the low value of the basic deformation resistance in the volume deformation processes by severe plastic deformation (SPD) at the room temperature. The aim of SPD is to obtain from the initial grain sizes at m level, after several ECAP passes, ultrafine microstructures diameter at the nm level, usually less than 500 nm [1, 2]. There are some ways of SPD realization [2]: Equal-channel angular pressing – ECAP, and High-pressure torsion – HTP realized by the high stress, equal-channel angular rolling – ECAR [3], and rolling + rolls shifting [4]. Materials with the ultrafine microstructure in SPD are characterized by high value of strength, hardness, elongation, fatigue facilities and increasing of superplasticity. Achievement of listed facilities is conditional by nanocrystalline microstructures, its distribution in volume, internal intensity, texture and other characteristics of microstructure. Opposite possibilities are also describing for ultrafine powders compactation [5]. From point of view incoming material to SPD process it can be divided on compactation ultrafine grained powder materials and grains fragmentation in compact materials. The paper deals about influence of SPD realized in ECAP die on the mechanical facilities, the microstructure, stress and strain material analysis in channel passes of IF steel.

Commercial quality IF steel was used for experiment. Local chemical analysis investigated steel is shown in **Table 1**. The three passes were made in ECAP die on experimental material. Pressed materials were rotated before input to next pass by 180°. Short examinational bars (d_o=5 mm, l_o=10 mm) were machined from died samples after ECAP process for static tension test at room temperature. Micro-hardness was measured by Vickers method on Hanemann device. TEM analysis was made on thin foils. Mathematical simulations were made by FormFem2D software.

Table 1. Chemical analysis of IF steel [wt.%]

C	Mn	Si	Al	S	P	Ti	Cu	N_2
0,005	0,128	0,005	0,027	0,009	0,007	0,074	0,032	0,003

The initial values of mechanical properties before ECAP were $R_{P0,2}$=182 MPa, Rm=275 MPa, elongation A=71% and mean grain size 21 μm.

The stress – strain curves from static tensile test are represented in **Fig.1**.

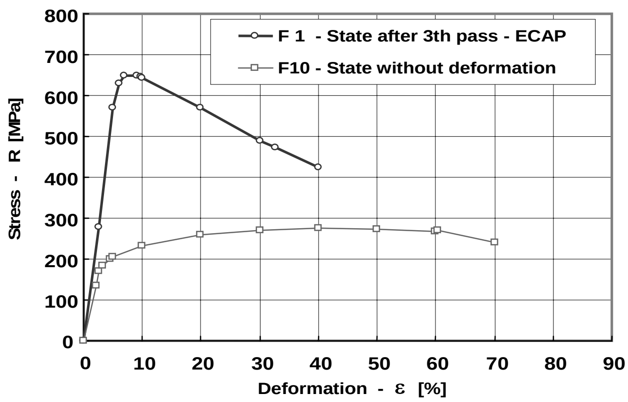

Fig. 1. Stress – deformation diagrams.

The three pass curve has form typical for superplastic material behavior. The initial grains were equiaxed. Steel microstructure analyzed by TEM after SPD is characterized as mixed cell-subgrain and submicrocrystalline substructure with the mean grain size was from 120 to 150 nm and heterogeneity in samples cross section.

Microstructural cross section heterogeneities were occasioned with non-uniform plastic deformation in ECAP channel. The influence deformation heat resulting from channel angular deformation on strength was tested, too. Mathematical simulation temperature field in ECAP die shown, that maximal samples temperature was 63°C, as resulting from **Fig. 2**.

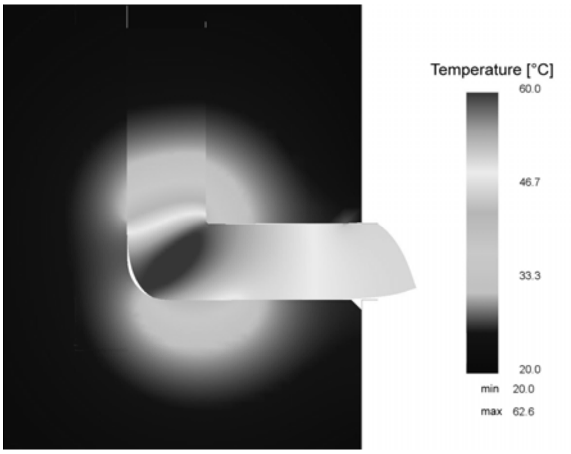

Fig. 2. Sample temperature field.

Temperature effect during ECAP has not any influence on microstructure development. If sample after the third pass was warming, so microhardness measurements in dependence on temperature referred on fact, that materials strength begins have significant changes from starting temperature 400°C, as it resulting from **Fig. 3**. This process could be related with polygonization.

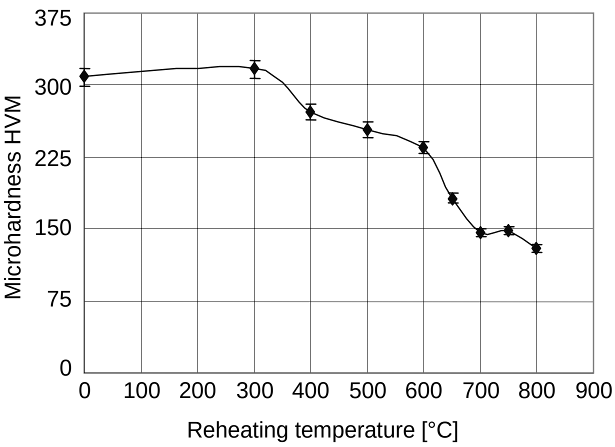

Fig. 3. Microhardness after three ECAP passes in dependence on reheating temperature.

The following conclusions based on achievement own experimental results and also on literature, were made:

- for IF steel material we obtained the following properties with compare to initial annealing state by application of SPD by ECAP:
  - yield strength increased by 3,5 times
  - tensile strength increased by 2,4 times
  - elongation decreased by 2 times
  - mean grain size was reduced from 19 μm to 135 nm level
  - each ECAP pass represent very intensive plastic deformation of material at which summary deformation after three ECAP passes was 97%
  - temperature development in ECAP process has not any influence on strength and microstructure

Acknowledgements

The research was supported by Slovak Grant Agency for Science-VEGA: (project No. 1/1072/04 and No.2/2114/25).

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