Steels are the most used engineering material in many industrial fields, due to their relative low cost, availability and excellent properties. Development of new metal forming processes such as severe plastic deformation (SPD) makes it possible to extend the range of steels application. However, the SPD can be an effective method of producing ultra fine-grained with submicron and nanocrystalline structure, even in steel bulk semiproducts, as well as increasing in mechanical properties [1]. Thus, some products of high-alloy steels might be replaced by carbon steel or low alloy ones. For that reason, at the Department of Production Engineering, an attempt was made to develop one discontinuous SPD method for upsetting square shaped billet by V-shape dies, Fig.1(a). The V-shape die compression is multistage process in which, after single compression stage, sample is removed from the dies and rotated for 90° in anti-clockwise direction and returned into the dies.

Experimental application of the compression by the V-shape dies was conducted using a normalized carbon rod steel CK15 with 0,14%C and ferrite-pearlite microstructure, Fig.1(b). The samples of 14x14x70 mm were compressed in eighteen turns, without any lubrication on hydraulic press. The influence of the processing parameters was evaluated by TEM microstructure analysis using FEI Tecnai F20. For TEM sample preparation FIB (Quanta 3D FEG) TEM sections of the carbon steel upsetting specimens were prepared with in-situ, lift-out technique, Fig.1(c).

TEM micrographs and corresponding diffraction patterns of the ferrite region in the as-compressed samples are present in Fig.2(a-d). After the second turn, Fig.2(a), the ferrite microstructure mainly consisted parallel bands of elongated grains having width 0,2-0,3 μm. The band boundaries are predominantly in low-angle misorientations. It is also apparent that inside the band, the interior dislocation cell boundaries are also present. This kind of boundary microstructure is typical in heavily deformed metals.

The TEM microstructures and corresponding ring patterns, after eight, twelve and eighteen turns are shown in Fig.3(b-d) respectively. Equiaxed grains with an average size of 0,15-0,3 μm were formed in all three samples. The presence of equiaxed grains, i.e. the grains with high angle boundaries confirmed by ring patterns with large number of reflections and a TEM contrast at the grain boundaries.

Moreover, the grain refinement during the eighteenth turn is not significant compared to twelfth. In addition, from the results presented it can be concluded that multistage compression by V-shape dies might be used as a severe plastic deformation method for the steels.


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Fig. 1: a) V-shape die b) as-received microstructure c) FIB sample preparation

Fig. 2: TEM micrographs of as-compressed low-carbon steel after: a) second b) eight c) twelve d) eighteen turns