DEVELOPMENT OF METHODS OF SEVERE PLASTIC DEFORMATION AND RESEARCH METHODS OF ULTRAFINE STEELS

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Introduction

Modern processing technologies possess to increase mechanical characteristics and to improve properties of real materials. One of the important directions of investigation is the ultra-fine grained and nanostructural materials. The application field of such materials is very wide, from the nanoelectronics before reception of volumetric constructional elements of various purposes.

Volumetric ultra-fine grained and nanomaterials have the unique structure and high mechanical characteristics. These materials can be used as responsible structural element of construction. Now some methods of reception of such materials are developed. One of the effective methods of making metals with ultra-fine grained structure is the equal channel angular pressing (ECAP). ECAP permits to obtain a nanostructural volumetric metal workpiece by refining its grain structure [1].

ECAP has been developed by V.M. Segal with colleagues in 1970th years. In the beginning of 1990th years this method has been applied by R.Z. Valiev as a method of reception of structures with ultra-fine and nano-size grains. At realization ECAP the workpiece is repeatedly pressed through the special pressform having two equal channels which are intersected under the certain angle [2]. Thus, at the process of workpiece pressing through the pressform there is a grain refinement of a material.

Steel subjected ECAP have very high mechanical characteristics. For example, yield stress of low carbon steels after ECAP increases to 2÷3 times and to achieve ~1000 MPa [3]. However, strengthening steel by ECAP attract to decrease of plasticity. For the increasing of ductility necessary to applied thermal treatment of steel subjected ECAP. The goal of present work is investigation of thermal treatment influence on steel cold brittle resistance after ECAP. In the present work investigated low carbon steel Fe360.

Experimental

Materials

The chemical composition of the Fe360 steel was 0.15 wt % C, 0.2 wt % Si, 0.52 wt % Mn, 0.17 wt % Cr, 0.13 wt % Ni, and 0.25 wt % Cu. Mechanical characteristics of steel Fe360 in initial condition are the yield strength 330 MPa and ultimate strength 500 MPa. A microstructure is ferritic-perlitic, average size of grains consist 18,5 microns, a microhardness - 1,37 GPa. The cylindrical workpieces with diameter of 0.02 m and length of 0.1 m from the Fe360 steel were subjected to ECAP at the routs C and B_c. The angle between channels of the pressform is equal to 120°. Number of cycles of pressuring *n* was 2 and 8.

Results and Discution

Steels subjected to ECAP possess high strength characteristics. For example, the yield strength and ultimate strength of steel Fe360 after ECAP 825 MPa and 835 MPa, respectively. At the Figure 1 presented standard deformation diagram of steel Fe360 after ECAP by the route C at 8 cycles of pressure. At it is seen, the yield strength and ultimate strength after ECAP have noticeably risen. Difference between the yield strength and ultimate strength for the steel subjected ECAP is too small (Fig. 1).

The photos of a microstructures received by optical metallographic, are given in Figure 2. As it is shown in photos 2 and 3 after ECAP the texture is formed and ferrite phase become of more elongate shape on a direction of pressing.

The average grain size after ECAP by the route B_c at 2 and 8 pressure cycles is 11.0 μm and 7.5 μm, respectively; by the route C at 2 and 8 cycles it is 10.6 μm and 6.6 μm, respectively.

The smallest grain size and the highest strength are obtained by the route C at 8 cycles of pressure.

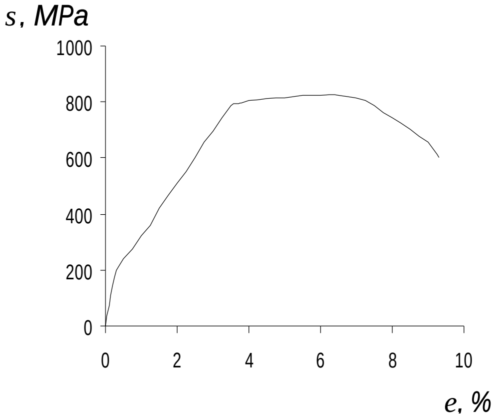

Fig.1. Deformation diagram of steel Fe360 after ECAP by the route C at 8 cycles of pressure verses elongation.

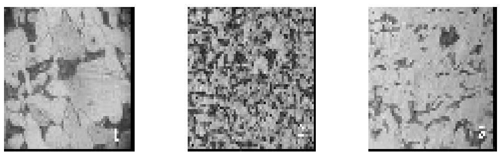

Fig. 2. Phase metallographic component explored structural conditions became Fe360:1 – initial condition; 2 - after 2 cycles ECAP 450 ^{0}C; 3 - after 8 cycles ECAP 450 ^{0}C.

Application by the ECAP allows improving strength characteristics of steel. But the impact test data at room temperature have shown that the impact toughtness has considerably decreases. For example, the impact toughtness at the test temperature +20° C for the steel Fe360 in initial condition is 121×10^4 J·m^{-2} and after ECAP is 25×10^4 J·m^{-2} only. It is associated with decries of material plasticity. Then, low carbon steel subjected ECAP possessed low brittle fracture resistance.
However, impact toughness can be increased by using thermal treatment. In the Table 1 presented impact test data of steel Fe360 after ECAP with thermal treatment at low temperature. The best result is achieved at preliminary quenching at 860° C in water (before ECAP), then ECAP and employed post-deformational tempering. Then, the brittle fracture resistance can be improved using thermal treatment at insignificant decreases of strength characteristics.

Table 2

Impact toughness of steel Fe360 at the temperature of test -60°C after ECAP and ECAP + thermal treatment

Type of ECAP and thermal treatment	Impact toughness, $KC\times10^4$ J·m^{-2}
Steel Fe360 in initial state	24
ECAP by route «B_c» at T=450 °C, n=4	10,1
Quenching at T=860 °C + ECAP «C», T=450 °C, n=4 + tempering	183

Conclusions

Application by the ECAP allows improving strength characteristics of steel. But the brittle fracture resistance has considerably decreases. That effect is result of plasticity decreasing of strengthened steel. However, the brittle fracture resistance can be improved using thermal treatment at insignificant decreases of strength characteristics. The best result with high strength and brittle fracture resistance is obtained by the route C at 8 cycles of pressure with at preliminary quenching at 860 °C in water (before ECAP) and employed post-deformational tempering (after ECAP).

Acknowledgements

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