Forming of Nanodimentional Structure Parts in Carbon Steels

A. Korchunov, M. Chukin, N. Koptseva, M. Polyakova, and A. Gulin

Abstract**—**A way of achieving nanodimentional structural elements in high carbon steel by special kind of heat treatment and cold plastic deformation is being explored. This leads to increasing interlamellar spacing of ferrite-carbide mixture. Decreasing the interlamellar spacing with cooling temperature increasing is determined. Experiments confirm such interlamellar spacing with which high carbon steel demonstrates the highest treatment and hardening capability. Total deformation degree effect on interlamellar spacing value in a ferrite-carbide mixture is obtained. Mechanical experiments results show that high carbon steel after heat treatment and repetitive cold plastic deformation possesses high tensile strength and yield strength keeping good percentage elongation.

Keywords**—**High-carbon steel, nanodimensional structural element, interlamellar spacing.

I. Introduction

ACHIEVEMENT of high quality and field reliability of metallic constructions is possible on the basis of knowledge-intensive technologies of getting materials with a new unique property package. Nowadays such technologies are those, which allow obtaining ultrafine and nanostructures, what considerably effects metals and alloys mechanical properties during production of hardware items of different purpose. This investigation actuality is stipulated by search of an effective complex of impacts on billets microstructure with major diameters (more than 10,0 mm) made from high-carbon steel to get the highest strength and ductility.

The aim of this work is studying peculiarities of getting nanodimensional structural elements in the billet from high-carbon eutectoid steel 80, updated by boron, after special kinds of thermal and deformation processing. The thin-platy pearlite structure, got by this, can be considered, as for modern material science perceptions, as a nanomaterial with structural constituents of platy form.

Interlamellar spacing in a ferrite-carbide mixture is a nanodimensional element of steel structure. The subject matter of the chosen thermal processing lies in isothermal holding in the field of minimal stability of overcooled austenite with further cooling in lead hot melt. The thermal processing task is forming, in major diameter billets, steel structure, providing the capability of the highest hardening during the following deformation effect with big total deformation degrees.

History of steel structural constituents fine crushing is known to be determined mainly by accumulation of sharing deformation in processing. Considerable steel structure fine crushing is achieved by big degrees of plastic deformation close to 1. To provide such processing conditions, repetitive cold plastic deformation was used. A differential characteristic of offered deformation effect is that operation modes are appointed so, that each deformation cycle initiates active dislocations sliding and it provides an additional fragmentation of microstructure and the highest hardening of thermally processed steel.

II. Experimental Analysis

The billet of diameter 16,0 mm was used to carry out the experiments. Thermal processing was realized with the following parameters: reheat temperature from 930^{0}C to 970^{0}C; isothermal holding temperature – from 470^{o}C to 550^{o}C. Holding time was chosen so that to provide finishing diffusional decay of overcooled austenite in the preset temperature. Cold plastic deformation was carried out with total deformation degree up to 60%. Herewith the billet diameter decreased from 16,0 mm to 10,0 mm. Scanning electron-microscope analysis of the bars was done on the electron microscope JEOL JSM-6490 LV with accelerating voltage 30 kW in modes of secondary and temporary reflected electrons in conditions of Nano Steel Research Studies Institute of Magnitogorsk State Technical University named after G.I. Nosov. Quality and quantity microanalysis was carried out on the metallographic microscope Meiji Techno using computer system of images analysis Thixomet Pro.

III. Measurements and Results

A steel structure in its initial state represents a ferrite-carbide mixture with interlamellar spacing from 0,22 μm to 0,28 μm (Fig. 1, a). Small sections of structurally free ferrite are present in microstructure (Fig. 1, b).

After thermal processing microstructure consists of a ferrite-carbide mixture and some quantity of structurally free

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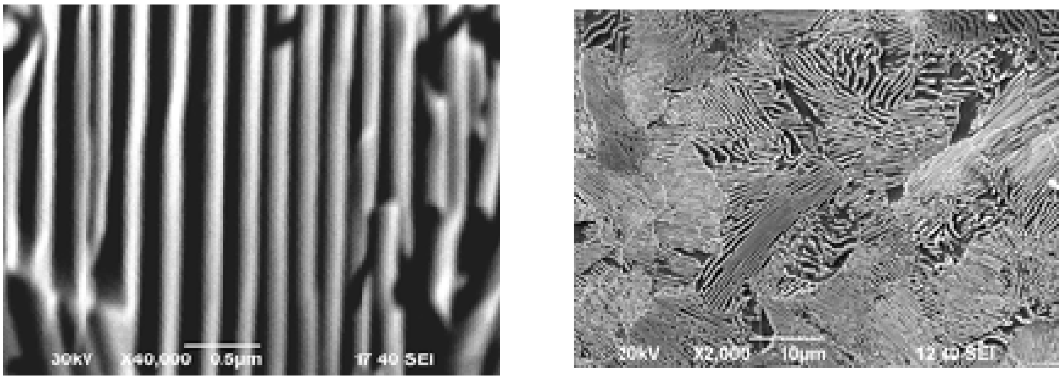
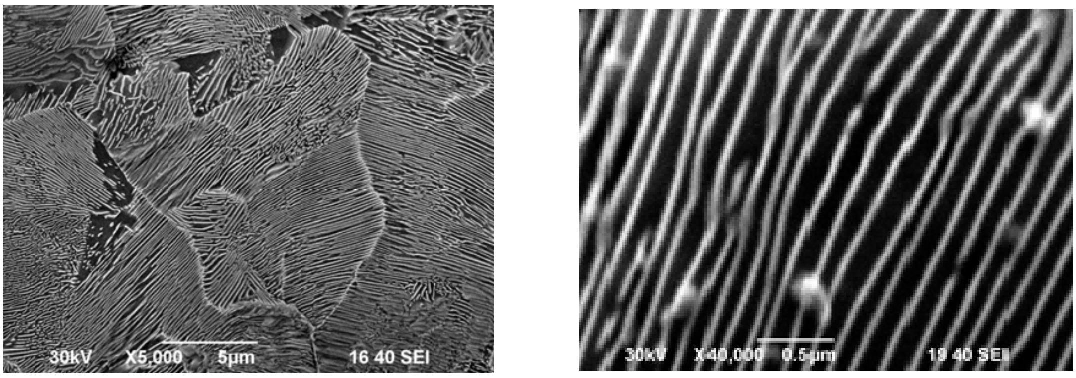
ferrite as small islands on grain junction lines (Fig. 2, a) with interlamellar spacing of ferrite-carbide mixture from 0,12 µm to 0,16 µm (Fig. 2, b).

As a result of carried out investigations it was determined that interlamellar spacing decreases with cooling temperature increase (Fig. 3). Got data show that interlamellar spacing value in ferrite-carbide mixture essentially depends on a cooling means temperature. The lowest interlamellar spacing values in ferrite-carbide mixture from 0,09 µm to 0,11 µm were observed at a cooling means temperature from 470^0C to 500^0C.



(a) (b)

Fig. 1 Steel microstructure in its' initial state



(a) (b)

Fig. 2 Steel microstructure after thermal processing

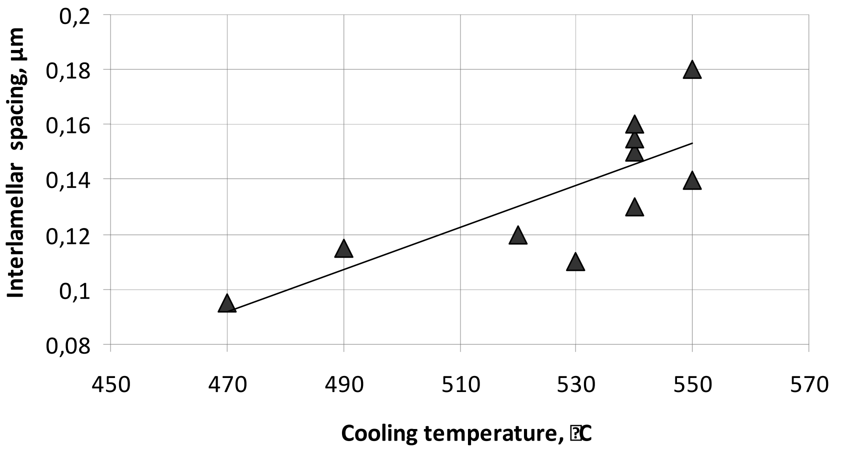


Fig. 3 Isothermal holding temperature effect on interlamellar spacing value in a ferrite-carbide mixture

However, a characteristic of the steel, obtained in such cooling modes was presence of fine pearlite and bainite sections in its structure, causing brittle behavior and making further deformation processing difficult.

Cold plastic deformation experiments showed that heat treated steel with interlamellar spacing in a ferrite-carbide mixture from 0,12 μm to 0,16 μm demonstrates the highest treatment and hardening capability. Further decrease of interlamellar spacing in a ferrite-carbide mixture is observed in repetitive deformation processing for heat-treated steel with such structure parameters (Fig. 4).

In Fig. 5 one can see interlamellar spacing value change in a ferrite-carbide mixture depending on total deformation degree.

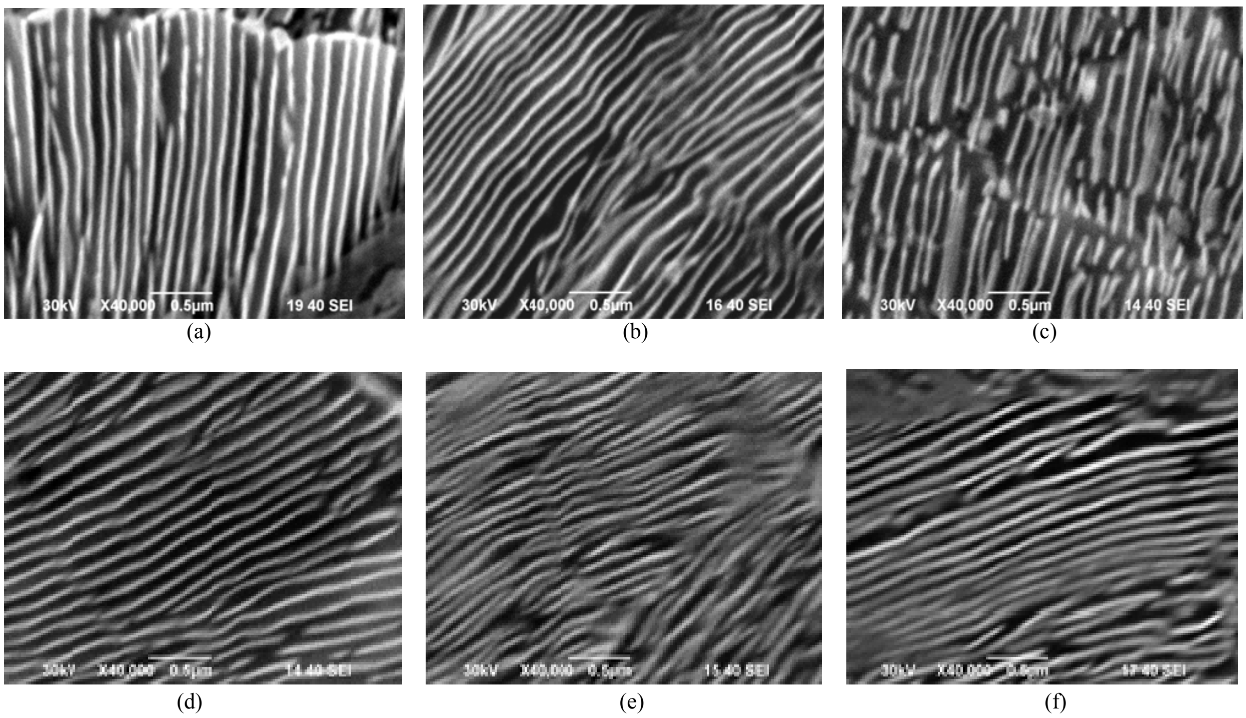


Fig. 4 Heat-treated steel microstructure at different total degree of cold plastic deformation: a – 21,8 %; b – 34,0 %; c – 43,3 %; d – 58,8 %; e – 56,3 %; f – 60,9 %

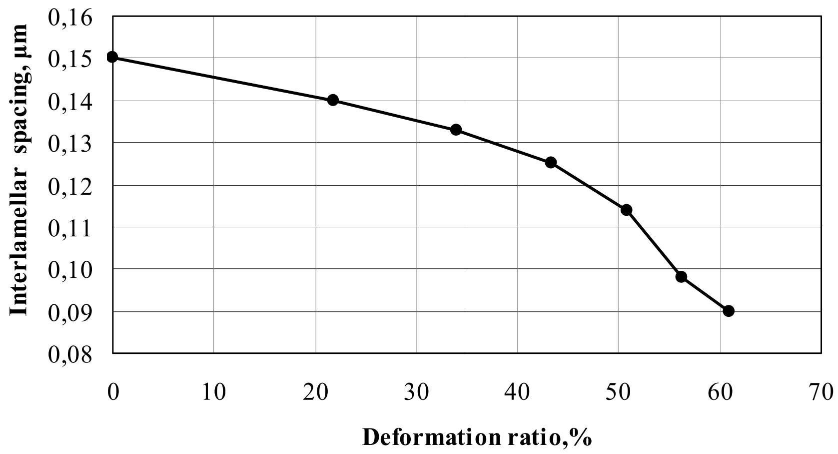


Fig. 5 Total deformation degree effect on interlamellar spacing value in a ferrite-carbide mixture

From the obtained data one can see that decrease of interlamellar spacing which is proportional to a diameter decrease of the billet, being processed, happens in the steel, being investigated, after heat treatment and further cold plastic deformation. The relationship of interlamellar spacing after heat treatment and cold plastic deformation amounts 1,66, the relationship of billet geometrical dimensions before and after deformation amounts 1,6. Thickness of cementite and ferritic plates in cold plastic deformation also decreases. Mechanical experiments results showed that steel after heat treatment and repetitive cold plastic deformation possesses the following mechanical properties: tensile strength from 1600 MPa to 1700 MPa, yield strength from 1450 MPa to 1500 MPa, and percentage elongation 5%.

IV. Conclusions and Perspectives

Thus, for high-carbon steel 80, updated by boron, one experimentally determined heat treatment modes, providing formation of a homogenous sliced ferrite-carbide mixture with nanodimensional interlamellar spacing in its structure. One determined isothermal decomposition temperature effect of overcooled austenite on steel microstructure parameters and its deformation effect and hardening capability. One defined structuring peculiarities in the process of repetitive cold plastic deformation, providing effective microstructure fragmentation of heat treated steel. At present, one considers the opportunity of realization of these processing kinds in hardware production of responsible purpose [1]-[3].

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