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The Evaluation of Structure and Destruction of Ribbed Bars as a Result of Processing and Heat Treatment

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Abstract. In this paper the images of steel microstructures (on elements taken from ribbed bars were rolled using QTB technology) have been presented. The observation has been carried out on two types of steel which are most commonly used for ribbed bars, 34GS, BSt500S and 16, 25 mm in diameters. The observations on the structure of materials have been performed on samples perpendicular and parallel to the rolling direction (after surface nital etching). The analysis of a macro- and microstructure gave the possibility to approximate the causes of non-conformity of finished products, as a major problem in ribbed bars production and processing.

Introduction

Together with emerging investments and building highways, modern construction shows a great demand, among others, for ribbed bars for concrete reinforcement. Constructions of these bars connected with concrete allow for significant savings of steel, aggregates, cement, wood and shortening of construction time [1]. Ribbed bars in reinforced concrete structures guarantee better adhesion of reinforcement to concrete due to a special shape in which humps (ribs) are applied to the round core. Recipients of the ribbed bars demand that they have high strength and ductility, corrosion resistance, good weldability and high fatigue strength [2, 3].

Ribbed bars, like other metallurgical products, must meet relevant requirements resulting from standards and specified by customers in their orders. The following dimensions of ribbed bars are specified in the standards: nominal diameter and their permissible deviations, mass range of 1 m of a ribbed bar, core diameter, rib height, width and length of ribs longitudinal. For individual steel grades, their chemical composition is also defined. Requirements regarding mechanical properties, plasticity and weldability are also specified [4]. These properties are obtained due to their properly carried out production process [5-6].

The purpose of the article is to assess the structure of ribbed bars in terms of their production process. The samples for the analysis were obtained from one of the rolling mills in Poland.

Experimental

The strength and technological properties of steel are primarily related to its microstructure which depends on heat treatment. Due to physicochemical phenomena occurring while heating and cooling steel, it is possible to create the desired structural components, and thus, to give specific strength properties [7, 11].

To illustrate the diversity of the research material, a microstructure of selected steel grades was analyzed. The observation has been carried out on two types of steel which are most commonly used for ribbed bars, 34GS, BSt500S and 16, 25 mm in diameters. These bars were rolled with the use of QTB technology.

The observations on the structure of materials have been performed on samples perpendicular and parallel to the rolling direction (after surface nital etching). The metallographic analysis was carried

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out using an Axiovert 25 optical microscope cooperating with a Mavica MVC-FD87 digital camera from Sony.

The size of ferrite grains was evaluated on the basis of the PN-EN ISO 643: 2005 standard [8] and determined by comparison of the scale model with a sample zoomed 100x. With the use of standardized scale models, the grain size standard was indicated, which in the best way approximated the size of the sample grain in the three analyzed areas of the sample. The average grain diameter $\bar{d}$ was taken form Table C.1. and included in the standard in which for individual grain size numbers from the scale model, the average grain diameter $\bar{d}$ [mm] corresponds to it.

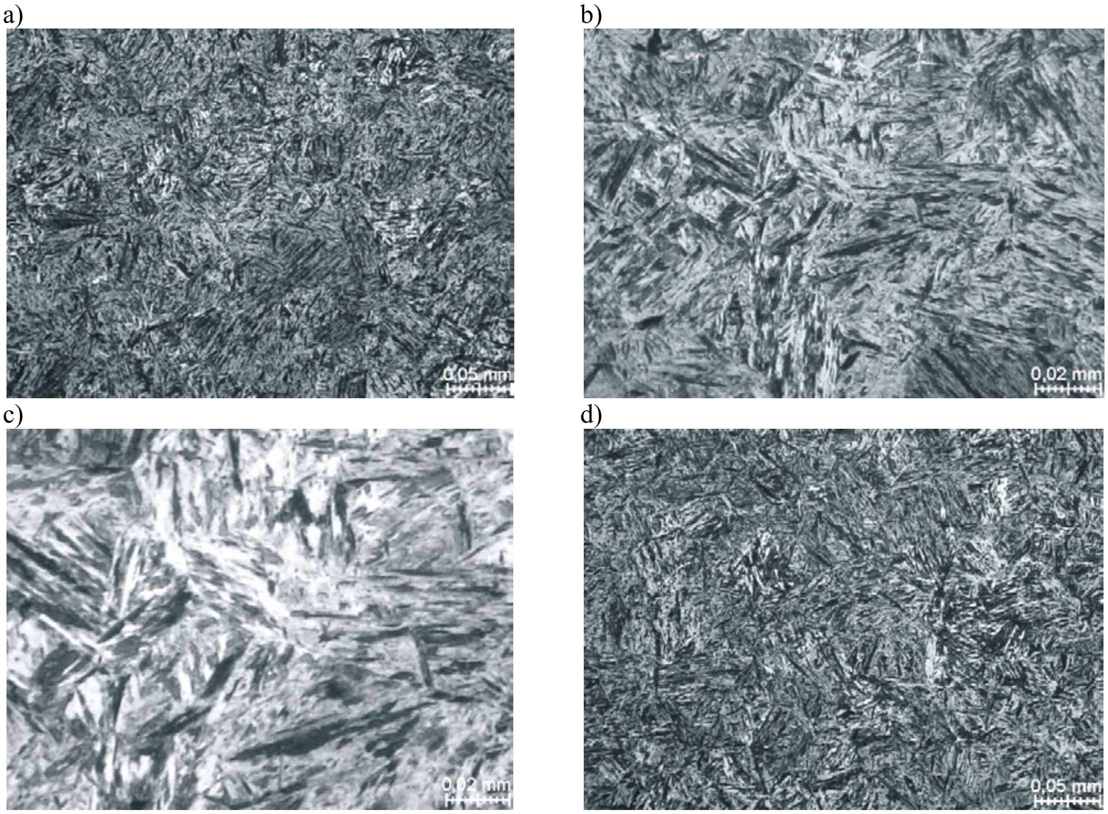
In case of the metallographic sections which are parallel to the rolling direction, a banded microstructure was evaluated according to the PN-63/H-04504 standard [9], i.e. on the basis of a comparison of the scale models with two worst structures found on a given microsection, separately in each of the bar thickness zones.

Widmannstätten ferrite [10] was evaluated according to the PN–63/H–04504 standard [9] by comparison with the scale models in at least three fields of view from ten observed fields.

Results

Figure 1 presents the characteristics of the microstructure which occurs in the ribbed bars with a diameter of 16 mm from steel 34GS.

a) b) c) d)



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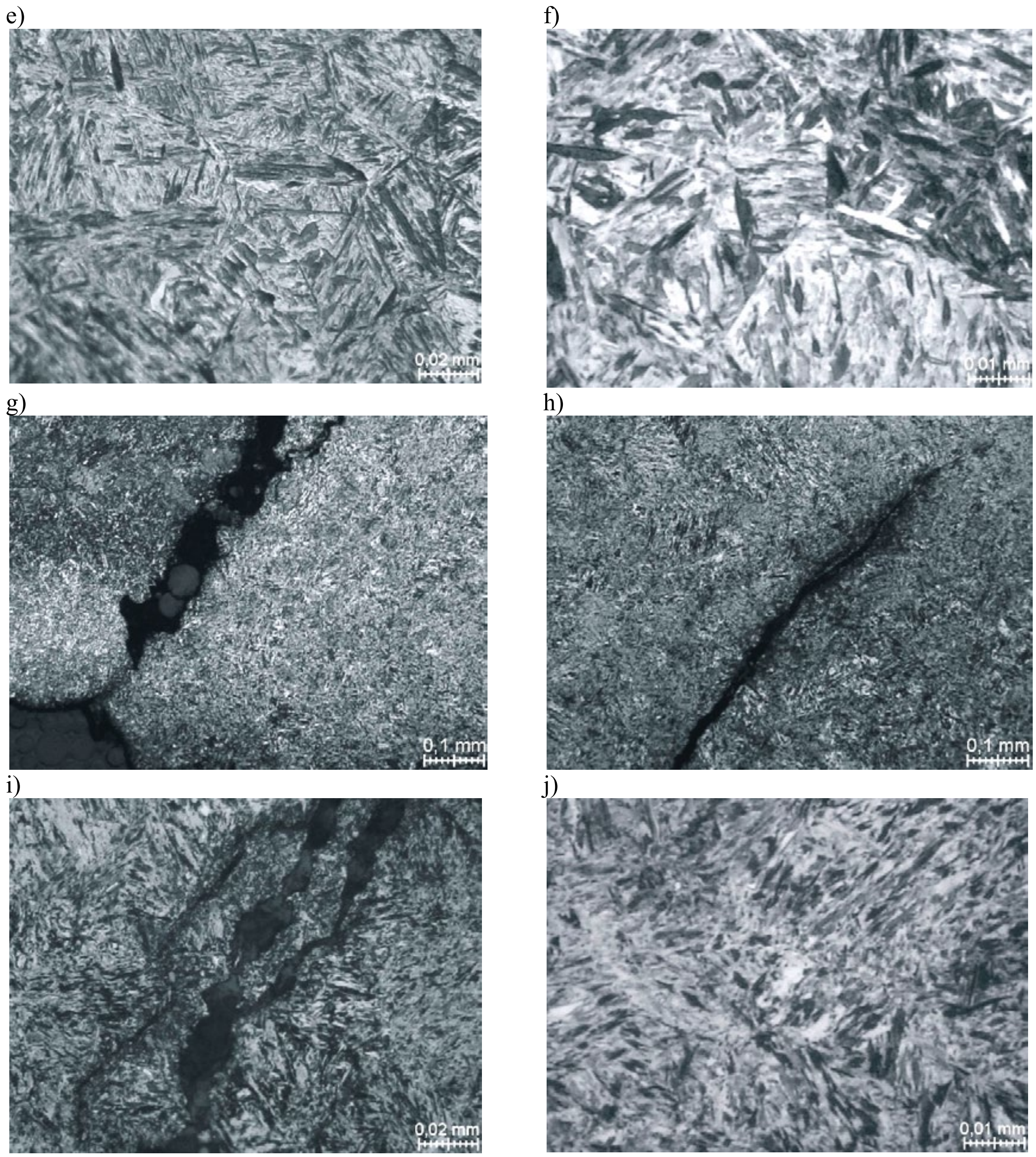

Fig. 1. Microstructure of the ribbed bar with a diameter of 16 mm from steel 34GS. After surface nital etching [4]

a) in the middle of the bar, zoom 200x, parallel metallographic section; b) in the middle of the bar, zoom 500x, parallel metallographic section; c) in the middle of the bar, zoom 1000x, parallel metallographic section; d) near the surface of the bar, zoom 200x, parallel metallographic section; e) near the surface of the bar, zoom 500x, parallel metallographic section; f) near the surface of the bar, zoom 1000x, parallel metallographic section; g) near the surface of the bar, zoom 100x, perpendicular metallographic section, crack near the surface of the bar – inlet; h) near the surface of the bar, zoom 100x, perpendicular metallographic section – end of the crack; i) near the surface of the bar, zoom 500x perpendicular metallographic section – crack of the bar; j) near the surface of the bar, zoom 1000x, perpendicular metallographic section

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In the sample made of steel 34GS, the presence of bainitic-martensitic structures is observed (Fig. 1a-1g). In areas corresponding to the center of the bar thickness, the extent of the bainitic structure in the bainitic-martensitic structure has been noticed (Fig. 1c, 1j).

In the ribbed bar made of steel 34GS, cracks occurred starting from the surface of the bar until the end of the crack almost in the middle, i.e. a depth of about 10 mm (Fig. 1g-1i). No decarburization at the crack surface (Fig. 1g-1i) and the nature of its course (Fig. 1i) allow for making a conclusion that it is a crack which occurred during cooling of the bar from the austenitizing temperature. The visible particles (Fig. 1g, 1i) are most likely pressed into the crack during the preparation of the metallographic section from the abrasive papers. The cracking in the sample is shown in Figure 2.

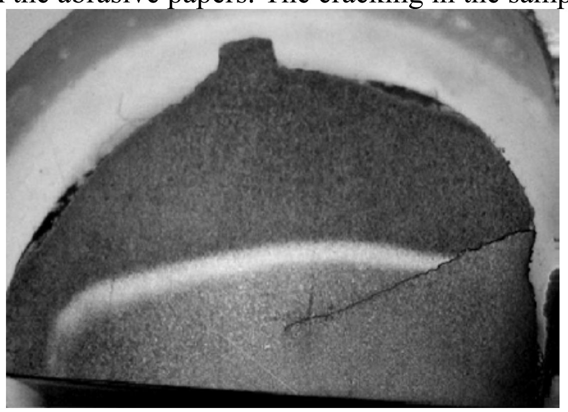
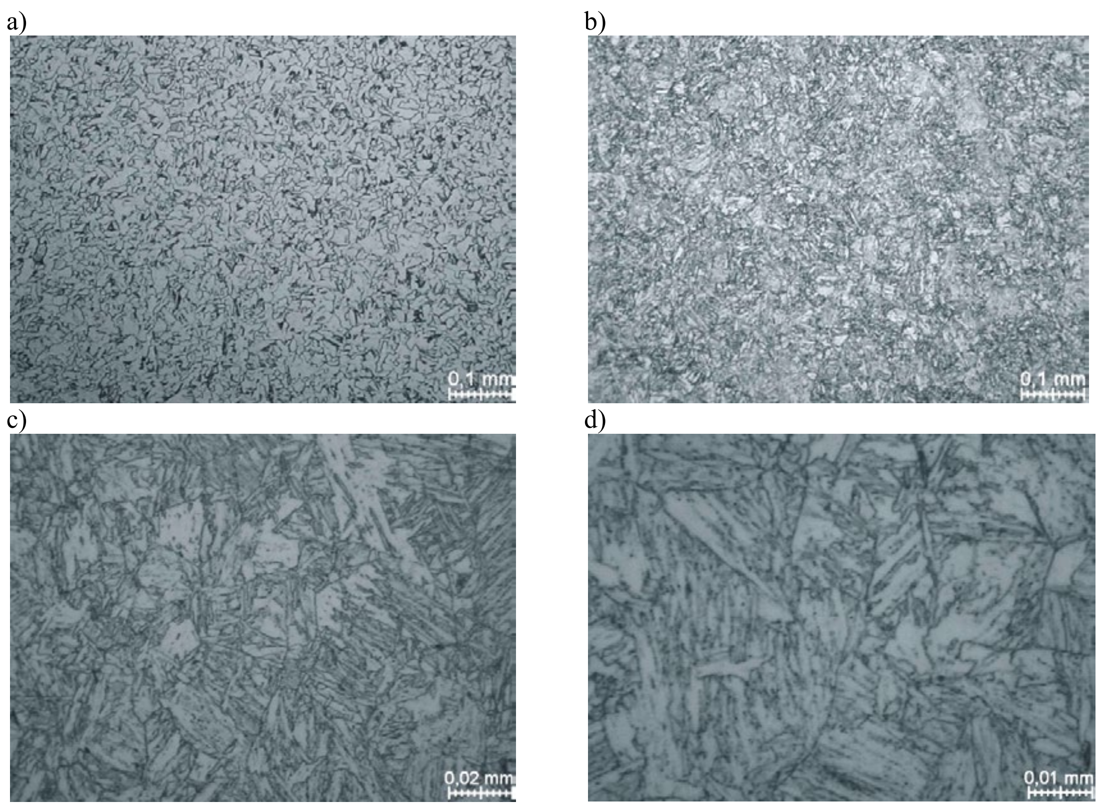


Fig. 2. Crack of the ribbed bar with a diameter of 16 mm from steel 34GS. After surface nital etching. A photo of the whole sample *[4]*

Figure 3 presents the characteristics of the microstructure which occurs in the ribbed bars with a diameter of 25 mm from steel BSt500S.



e) f)

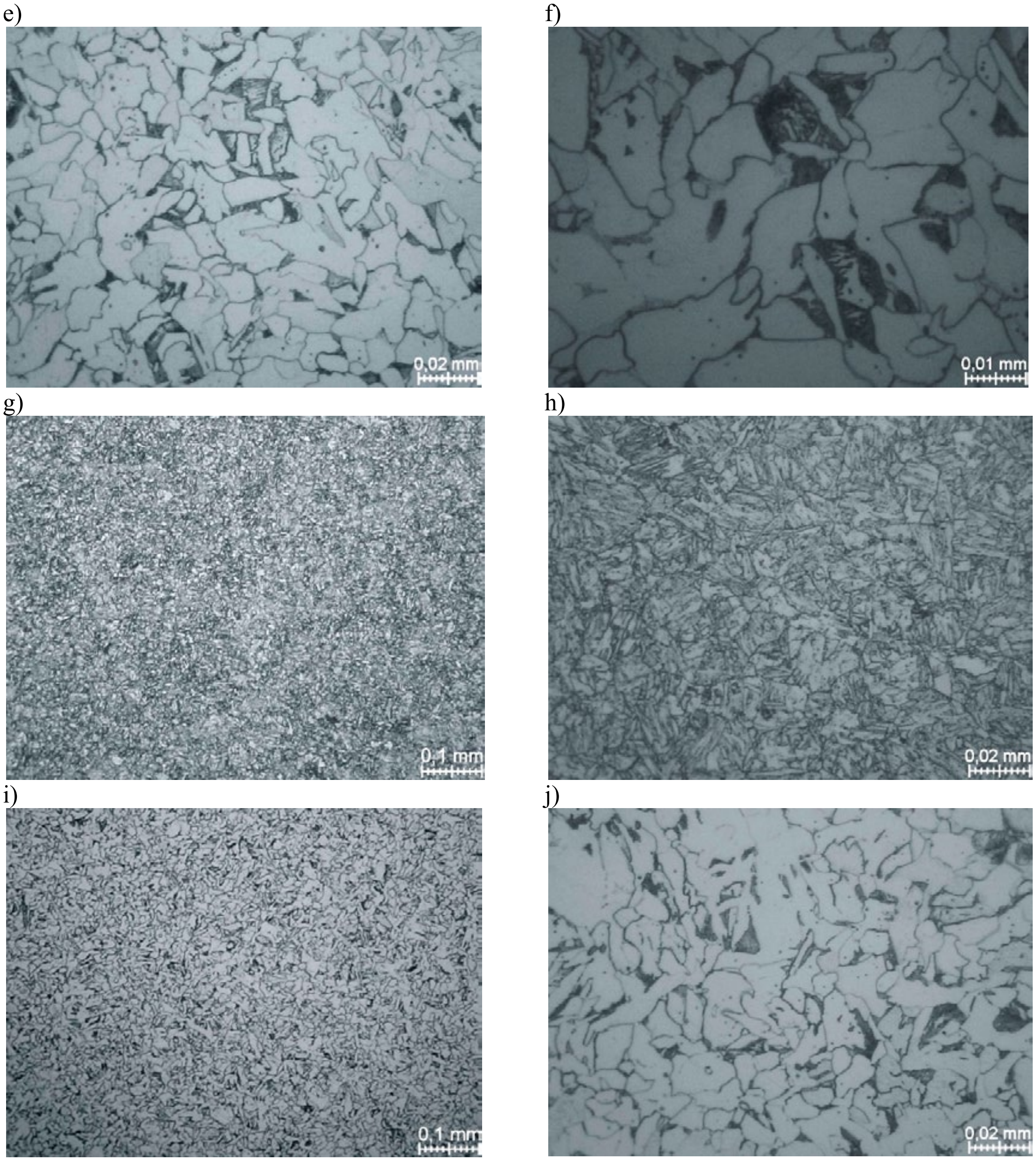


Fig. 3. Microstructure of the ribbed bar with a diameter of 25 mm from steel BSt500S. After surface nital etching [4]

a) in the middle of the bar, zoom 100x, parallel metallographic section; b) near the surface of the bar, zoom 100x, parallel metallographic section; c) near the surface of the bar, zoom 500x parallel metallographic section; d) near the surface of the bar, zoom 1000x, parallel metallographic section; e) in the middle of the bar, zoom500x, parallel metallographic section; f) in the middle of the bar, zoom 1000x, parallel metallographic section; g) near the surface of the bar, zoom 100x, perpendicular metallographic section; h) near the surface of the bar, zoom 500x, perpendicular metallographic section; i) in the middle of the bar, zoom 100x, perpendicular metallographic section; j) in the middle of the bar, zoom 500x, perpendicular metallographic section

In the sample made of steel BSt500S at a distance of about 5 mm from the surface, occurrence of bainitic structures and ferrite grains with carbide precipitates have been observed (Fig. 3b-3d). In the middle of the bar there is a ferritic-pearlitic structure (Fig. 3a) with locally occurring bainite areas

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(Fig. 3e-3f). The ferrite grain size (Fig. 3a, 3i) was assigned to standards 8.5 and 9 of the scale models, which corresponds to the average grain diameter of $\bar{d} = 0{,}0186 \div 0{,}0156$ mm. The banded microstructure corresponded to model 0 on the A scale, which means no banding occurrence. The increase in the occurrence of Widmannstätten ferrite (Fig. 3i) corresponded to model 2 on the A scale.

Summary

On the basis of microstructure image observations, the effect of heat treatment and use of QTB technology on the structure of 34GS, BSt500S steels which are most commonly used for ribbed wire has been determined. It has been noticed that after the production process, 34GS steel is characterized by a bainitic-martensitic structure, where in the areas corresponding to the center of the bar thickness, the bainitic structure in the bainitic-martensitic structure was found. On the other hand, BSt500S steel is characterized by a bainitic structure with the area of occurrence of ferrite grains with carbide precipitates, where in the areas corresponding to the center of the bar thickness, the ferritic-pearlitic structure with locally occurring bainite areas was found. The occurrence of Widmannstätten ferrite was also confirmed.

References

[1] B. Golis, Z. Błażejowski, J.W. Pilarczyk, Z. Muskalski, Stalowe druty, pręty i wyroby z drutów do zbrojenia betonu, Series: Metalurgia nr 21, first ed., Wydawnictwo WIPMiFS Politechniki Częstochowskiej, Czestochowa, 2002.

[2] A. Almsallam, Effect of degree of corrosion on the properties of reinforcing steel bars, Constructions and Building Materials 15 (2001), 361-368. https://doi.org/10.1016/S0950-0618(01)00009-5

[3] V. Danchenko, H. Dyja, L. Lesik, L. Mashkin, A. Milenin, Technologia i modelowanie procesów walcowania w wykrojach. Series: Metalurgia nr 28, first ed., Wydawnictwo WIPMiFS Politechniki Częstochowskiej, Czestochowa, 2002.

[4] M. Konstanciak, Analiza strat w produkcji prętów żebrowanych, Praca doktorska, WIPiMFS, Częstochowa Politechnika Czestochowska, 2010.

[5] P. Sygut, Theoretical analysis of unit friction force working on the metal contact surface with the roll change during feedstock with non-uniform temperature distribution rolling process, Archives of Metallurgy And Materials, 61/2(2016), 927-932. https://doi.org/10.1515/amm-2016-0157

[6] P. Sygut, D. Klimecka-Tatar, S. Borkowski, Theoretical analysis of the influence of longitudinal stress changes on band dimensions during continuous rolling process, Archives of Metallurgy And Materials, 61/1(2016), 183-188. https://doi.org/10.1515/amm-2016-0032

[7] N. Toropov, D. Bajare, G. Shakhmenko, A. Korjakins, J. Justs, Effect of thermal treatment on properties of high strength concrete, Civil Engineering '13, PT I, Civil Engineering-Jelgava, 4/1 (2013), 129-133.

[8] PN-EN ISO 643:2005.

[9] PN-63/H-04504.

[10] R.P. Todorov, K.G. Khristov, Widmanstatten structure of carbon steels, Metal Science and Heat Treatment, 46/1-2 (2004), 49-53. https://doi.org/10.1023/B:MSAT.0000029601.58461.bd

[11] P. Szataniak, F. Novy, R. Ulewicz, HSLA steels - comparison of cutting techniques, 23rd International Conference on Metallurgy and Materials, METAL (2014), 778-783.