STRUCTURE AND MECHANICAL PROPERTIES OF ROLLED BARS FROM STEEL 42CrMo4

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Abstract

The paper presents the results of evaluation of the macro and microstructure as well as mechanical properties of rolled bars made from steel 42CrMo4 from continuously cast stock. The macrostructure was examined using Baumann's method and deep etching. Based on the examination of the macro and microstructure, it was shown that discontinuities and internal defects may occur during initial plastic processing of ingots by rolling. For high degree processing, a fine-grained structure is obtained, while for large bar diameters and low degree processing, there may be variations in the grain size in the cross-section. Mechanical properties determined from the static tensile test, impact test and hardness measurements indicate a greater influence of the sampling site than of the degree of plastic processing, which may results from both the quality of ingots and the rolling conditions.

Keywords: Structural steels, rolling of long products, plastic working

1. INTRODUCTION

The quality and properties of semi-finished products made by the rolling process depend on a number of factors, such as: the method of steel production and its post-furnace treatment, steel casting, plastic working and, possibly, heat treatment [1]. Despite using additional methods in the process of steel casting whose purpose is to improve the homogeneity of steel, ingots obtained for rolling still have internal defects, such as: axial porosity, central porosity, cracks, pinholes and blisters. Therefore, obtaining long products of good quality, i.e. of the desirable shape and dimensions, with the required strength and plastic properties and their uniform distribution across the cross-section, and without external and internal defects, requires a properly designed technological process, especially a properly selected degree of plastic processing [2]. Most often, the degree of plastic processing by rolling is equivalent to the elongation factor λ and is calculated as the ratio of the initial cross-sectional area of the ingot (stock), S_o, to the cross-sectional area of the strip (product), S_i, after i^{th} deformation. In this paper, the results are presented of the evaluation of the macro and microstructure as well as mechanical properties of rolled bars made from steel 42CrMo4 from continuously cast ingots.

2. RESEARCH MATERIAL

For macro and microstructure studies as well as for mechanical tests of the 42CrMo4 steel, two sections of 250 mm in length were sampled from round bars with diameters of ϕ90, ϕ150, ϕ180 and ϕ200 mm, and a 20 mm thick disc. The chemical composition of the steel verified with a spectrometer meets the requirements of the PN-EN 10083-2:2008 standard. The ϕ90 mm and ϕ150 mm bars were made from a 270 x 320 mm ingot, which corresponds to processing degrees of 13.6 and 4.9 respectively; the ϕ180 mm bars were made from a 390 x 283 mm ingot, which corresponds to a processing degree of 4.3; and the ϕ210 mm bars of a ϕ410 mm ingot, corresponding to a processing degree of 4.2. Specimens were taken from one section to determine the mechanical properties (static tensile test, impact test) according to the scheme shown in **Figure 1**. Specimens for the microstructure examination were cut out from the head of a specimen for the tensile test.

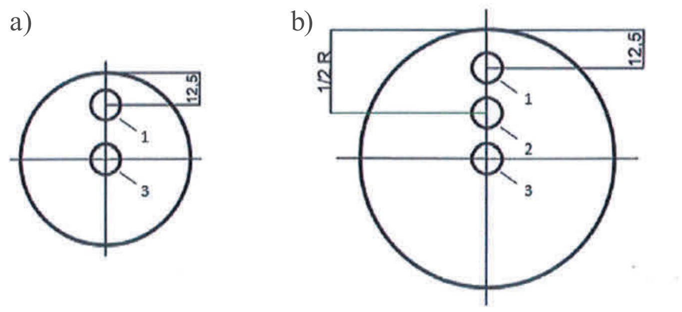
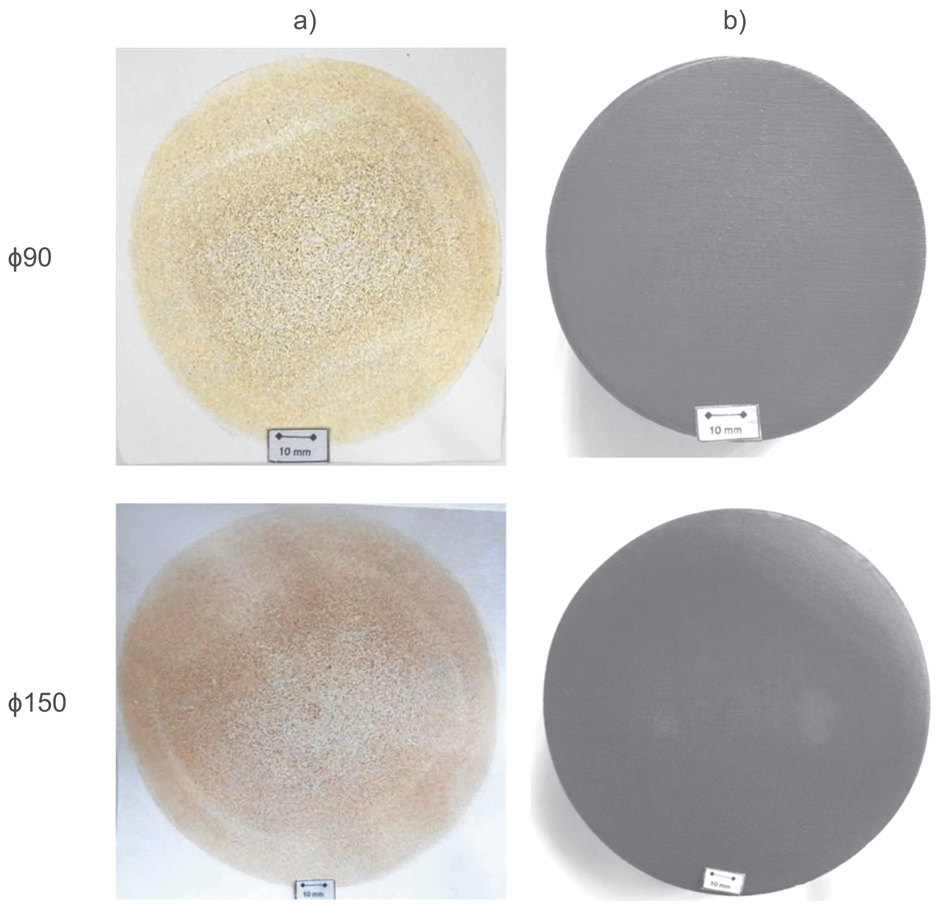


Figure 1 Diagram of sampling locations for tensile and impact tests: a) from the ϕ90 mm bar, b) from the ϕ150, ϕ180 and ϕ200 mm bars

A disc was sampled in order to perform a Baumann's test and deep etching, while hardness tests were performed on specimens prepared for the microstructure examination. The heads from impact tests, after analysis of their chemical composition, were used to determine the size of the primary austenite grain.

3. MACROSCOPIC TESTS

Macroscopic examination included a Baumann's test, performed in accordance with the PN-H-04514:1987 standard, and deep etching as per standard PN-H-04501:1957. The tests were carried out on transverse specimens and were aimed to detect internal defects of the obtained bars by rolling from continuously cast ingots. Examples of the macroscopic test results for the investigated steel 42CrMo4 are shown in **Figure 2**.



ϕ200

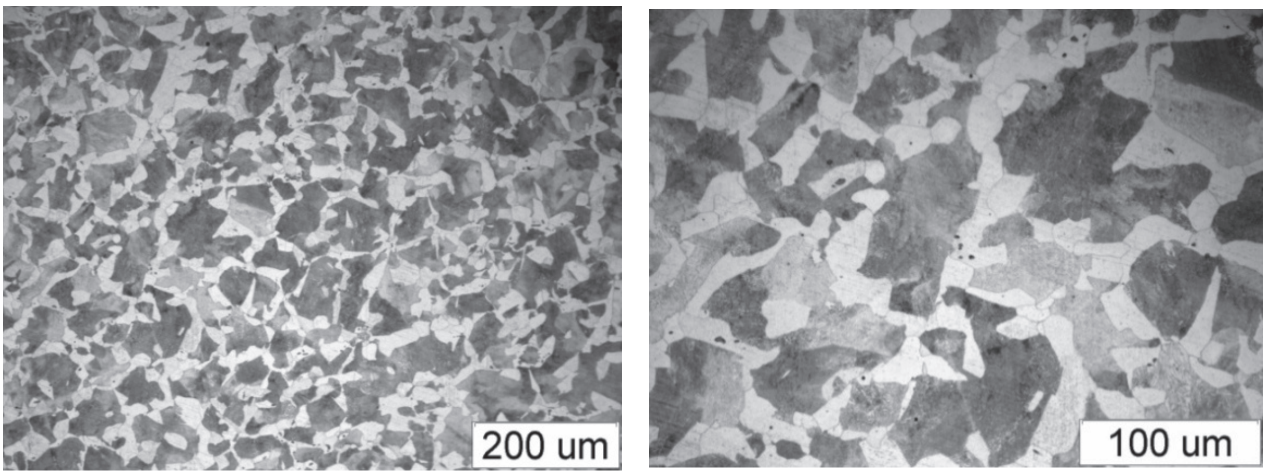
Figure 2 Macroscopic tests of steel 42CrMo4: a) Baumann's print b) deep etching test

The results of Baumann's test show the presence of axial porosity within a 1mm area for the ϕ180 mm bar, and central porosity for the ϕ90 mm, ϕ150 mm and ϕ180 mm bars. A dendritic structure was found for the ϕ180 mm bar, while numerous pinholes occurred in the ϕ90 mm bar only. For the ϕ200 mm bar with the lowest processing degree, no internal defects were observed. The deep etching tests performed for steel 42CrMo4 practically did not reveal any internal defects. The only exception was the ϕ90 mm bar, where central porosity was observed within an area of 70 mm.

4. MICROSCOPIC TESTS

Microstructure tests were performed on transverse microsections using an Olympus GX51 microscope, at magnification of 50x÷1000x. Additionally, the analysis of the microstructure of the investigated steels was complemented by examination carried out on the Hitachi S-3400N scanning microscope. Examples of the microstructures of the bars of steel 42CrMo4 are presented in **Figure 3**. For the 42CrMo4 steel microsections, a pearlitic structure with the presence of a cementite lattice was found. In the case of the bars with smaller dimensions, i.e. ϕ90 and ϕ150 mm, the structure was finer and homogeneous, and for large bar diameters ϕ180 and ϕ200 mm, the refinement of the structure depended on the sampling location. A finer structure was characteristic of the specimens sampled at the surface of the bar, and the deeper into the bar axis, the larger the grain size.

Light microscope



Scanning microscope

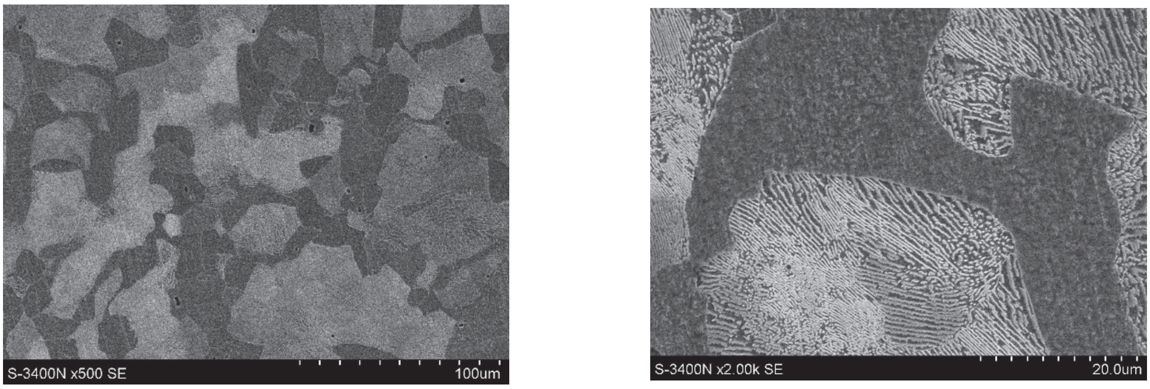


Figure 3 Examples of the microstructures of steel 42CrMo4S4 - ϕ150 mm bar

Assessment of the primary grain size of austenite was performed according to the ASTM E112 scale. No correlation was found between the degree of processing and the grain size. All results fall within a narrow range of the grain size from 8 to 9. The determination of the surface and linear fraction of structural components in the steel was carried out using the Met-Ilo application [3]. In the specimen taken from the ϕ90 mm bar, the linear fraction of ferrite amounted to 15.2 % and the linear and surface fraction of pearlite was 84.8 %. In the specimen taken from the ϕ200 mm bar, the fraction of ferrite was smaller and amounted to 5.2 %, with a pearlite fraction of 94.8 %.

5. MECHANICAL TESTS

A static tensile test was carried out in accordance with standard PN-EN ISO 6892-1:2016 using the AMSLER 60ZD 1368 strength testing machine with a measurement range from 10 to 500 kN. Mechanical properties (R_m, $R_{0,2}$, A_5 and Z), depending on the bar diameter and sampling location, are presented in **Figure 4**.

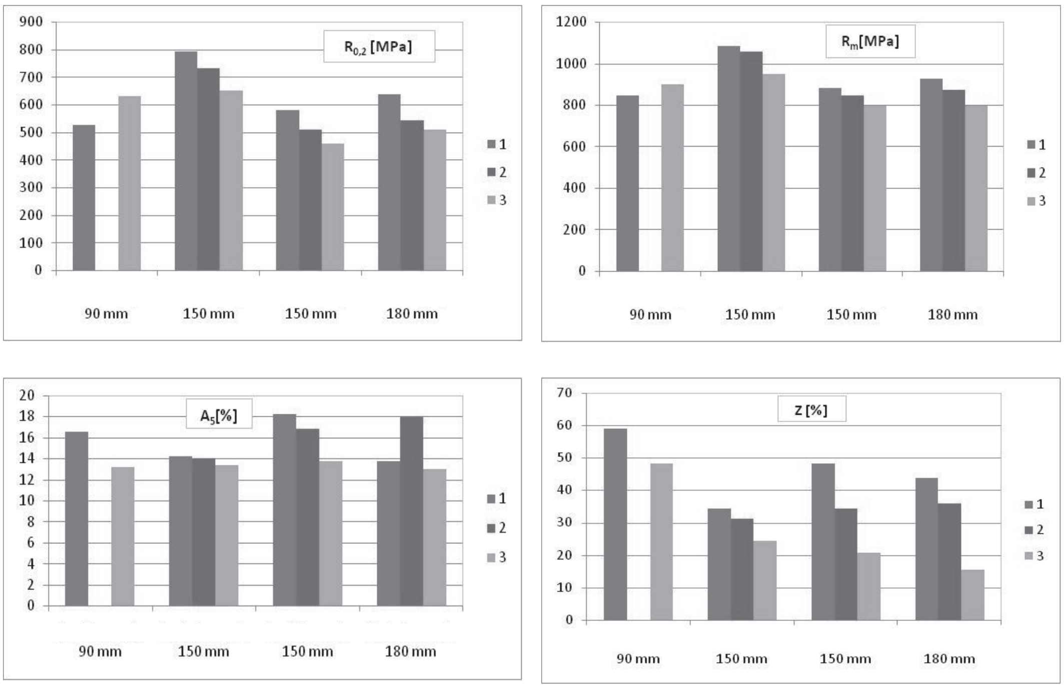


Figure 4 Collation of the results of mechanical properties tests for steel 42CrMo4S4:
a) yield stress, b) tensile strength, c) elongation, d) reduction of area

The results of the tensile test show significant differences in strength properties, independent of the degree of plastic processing. Yield point $R_{p0.2}$ changes from 516 to 726 MPa, and tensile strength R_m changes from 869 to 1034 MPa, where the highest values refer to the ϕ150 mm bar. Elongation A falls within the range from 13.9 to 16.3 %, and reduction of area Z from 29.9 to 53.6 %, with the highest values for the ϕ90 mm bar, for which the degree of plastic processing is the highest. Impact strength tests were performed on specimens with a V-notch using a Charpy pendulum machine, Zwick/Roell RKP 450, in compliance with standard PN-EN ISO 148-1:2017-02. Results of the impact tests, depending on the bar diameter, are presented in **Figure 5**. The highest impact strength KV of 38J was obtained for the specimen taken from the ϕ90 mm bar at a distance of 12.5 mm from the surface, while in the axis of the specimens, the impact strength is 14J and is comparable to that of the specimens sampled from the other rods.

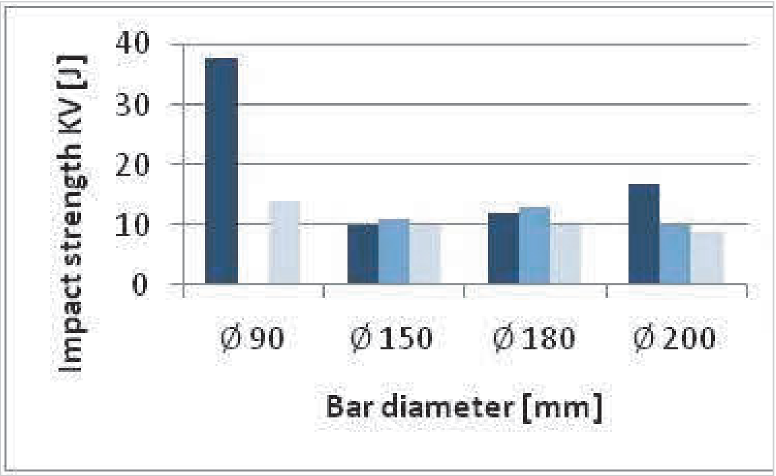


Figure 5 Impact strength KV of steel 42CrMo4 depending on the diameter of the rolled bar
12.5 mm from the surfec, 1/2 radius , axis

Hardness of the steel was examined by means of the Brinell method, with a Rockwell-Brinell KP 15002 P hardness tester, using a 5mm steel ball at a load of 250 kg. The hardness ranges from 208 to 248 HB, with the highest hardness value for the ϕ150 mm bar, for which also the highest strength was demonstrated. Similarly to the impact test, the sampling location had a greater influence on the obtained results than the dimensions of the bar.

6. CONCLUSIONS

1) Visual examination of the discs cut out from rolled 42CrMo4 steel bars after Baumann's test revealed the presence of central porosity in the material, as well as a dendritic structure and numerous pinholes in the edge region.

2) It was found in the microstructure tests that steel 42CrMo4 had a pearlitic structure with the presence of a cementite lattice. Bars with a smaller cross-section had a homogeneous fine-grained structure. Large diameter bars were characterized by diverse cross-sectional structures, with the grain size increasing the closer to the bar axis.

3) No influence was found of the bar diameter on its mechanical properties. Both the results of tensile and impact strength tests, and hardness measurements indicate the significance of the place from which specimens are sampled. Significantly higher strength and hardness were obtained for the ϕ150 mm bar in relation to ϕ180 and ϕ200 mm bars, with a comparable degree of plastic processing. The quality of stock and rolling conditions should be considered to have an effect on the mechanical properties of the product.

ACKNOWLEDGEMENTS

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