Achievements in Mechanical and Materials Engineering

COMMENT Worldwide Congress on Materials and Manufacturing Engineering and Technology
16th - 19th May 2005 Gliwice-Wisła, Poland

COMMITTEE OF MATERIALS SCIENCE OF THE POLISH ACADEMY OF SCIENCES, KATOWICE, POLAND
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13th INTERNATIONAL SCIENTIFIC CONFERENCE
ON ACHIEVEMENTS IN MECHANICAL AND MATERIALS ENGINEERING

The quantitative analysis of ferritic-pearlitic structure wire rod C20D steel

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Abstract: The quantitative analysis of ϕ5,5mm wire rod structure of C20D steel has been presented in this work. The size of the grains of ferrite and pearlite was quantified in the longitudinal and transverse directions of rolling for two different heats. Appointed values the averages of chord of the ferrite and pearlite grains equal respectively 3,7÷4,6 μm and ~2,0 ÷ 3,6 μm. On the basic of average values and standard deviations the changeability coefficient of the wire rod structure was counted.

Keywords: Wire rod, Quantitative analysis, Conformance λ Kołomogorow's test, The changeability coefficient.

1. INTRODUCTION

One of the steel used for the production of the wire rods designated for further cold plastic working is C20D grade with addition of boron. The wire rod should possess uniform and fine-grained structure which assures good strength properties, according to the dependence Hall-Petch [1]. One of the technique of the quantitative metallography is the computer image analysis with quantitative analysis. It permits on quick analysis of the considerable number areas (the areas of microstructures). Due to the large population of the objects (grains), obtained results are more probable. And for this reasons the test of structure analysis of C20D steel with computer technique was taken up.

2. INVESTIGATED MATERIAL

The rolled rods (wire rod about diameter 5.5 mm) from low carbon steel C20D were investigated in this work, the chemical composition is given in Table 1. Test specimens were taken from two heats 30502 and 30503, with longitudinal and transverse direction. The wire rod was made from continuous casting billets. The process of the production of this steel was described in work [2]. In paper [3] the detailed profile of grain size in individual zones of the continuous casting billet was introduced . The maximum dimension of the dendritic grains equals 2800μm. The other structure was fine-grained with the average diameter of grain ~ 80μm.

Table 1.
The chemical composition of steel examined.

Element	C	Mn	Si	P	S	Al	B
Contents [%]	0,2	0,9	0,17	0,011	0,021	0,004	0,004

3. THE QUANTITATIVE ANALYSIS AND STATISTICAL DESCRIPTION OF STEEL STRUCTURE

The microscopic investigations were performed on the optical microscope Zeiss Axiovert 25 at magnification 1000x. The metallographic specimens were made along and across the axis of rod rolling. The received ferritic-pearlitic structures (Figure 1-2) were subjected the image computer analysis and then metallographic quantitative analysis with help of the Image Pro Plus 3.0 program. The stereologic parameters which are describing the real structure of the examined wire rod i.e. minimum D_{min} and maximum D_{max} chord of grain were established. On this basic the average of the chord of grain and the extension index D_{max} / D_{min} were counted. Those results are shown in Table 2.

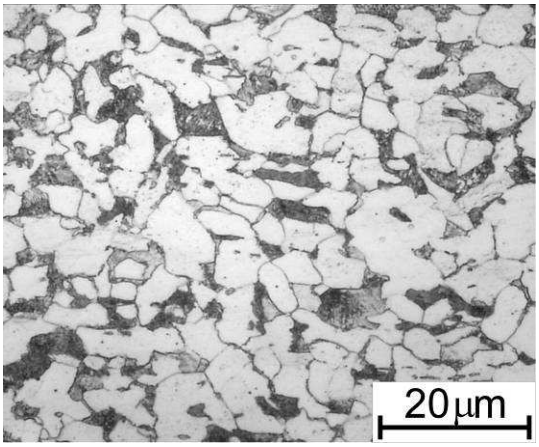

Figure 1. The ferritic-pearlitic microstructure of wire rod, longitudinal direction, no. of heat 30503

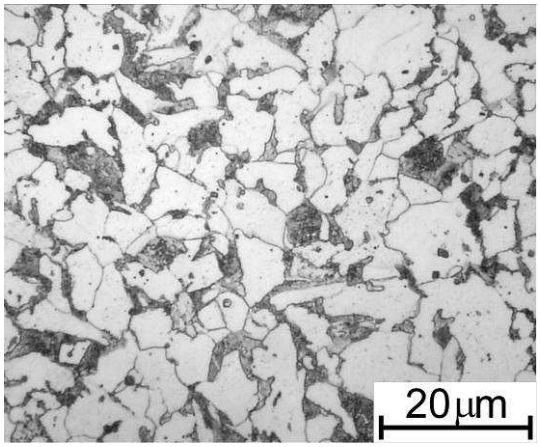

Figure 2. The ferritic-pearlitic microstructure of wire rod, transverse direction, no. of heat 30503

Distributions of the average chord of the ferrite and pearlite grain were shown in Figure 3 and 4. From comparison of the schedules with normal distribution (black line) which are shown in Figures 3a, b and 4a, it results that they are approximate to the normal distribution and schedule in Figure 4b has the most distant character from normal one. That confirmed the later investigations of the normality distribution with λ Kołomogorow's test.

In the Table 2 the average values and the standard deviation of chords and the extension index for the ferrite and pearlite grains in individual heats are presented. The volume fraction of the pearlite in the structure carried out $36{,}5^{\pm 5}\%$.

On the basic of the results from the metallographic investigations and the computer image analysis of the ferrite and pearlite chords measurements of the conformance test λ was executed. Results were put in Table 2. The level of the confidence equals α=0,05 for which the critical value λ_α equals 1,358 [4]. According to the conformance test it could be affirm that not every distributions of the average chord values and extension index of the grains had the normal character, they are shown in histograms (Figure 3 and 4).

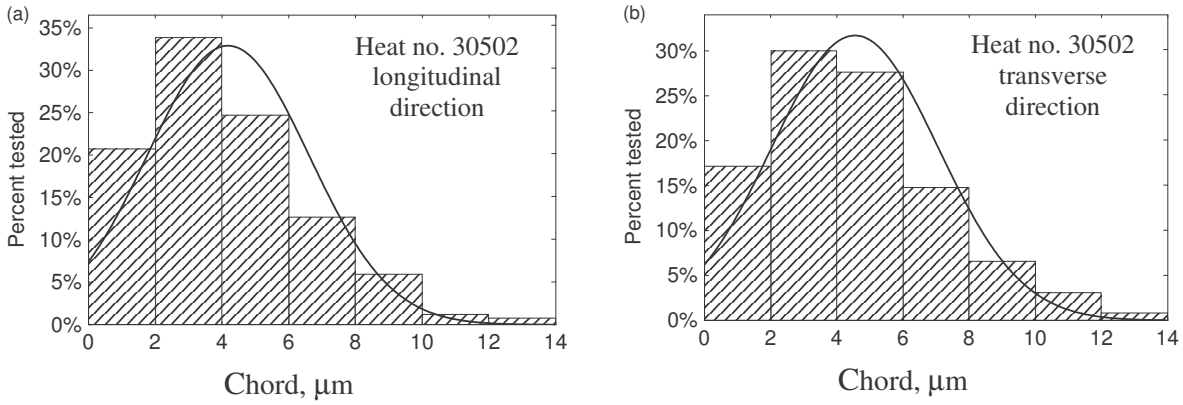

Figure 3 The distribution of average chord of ferrite grain, longitudinal (a) and transverse (b) direction, heat no. 30502

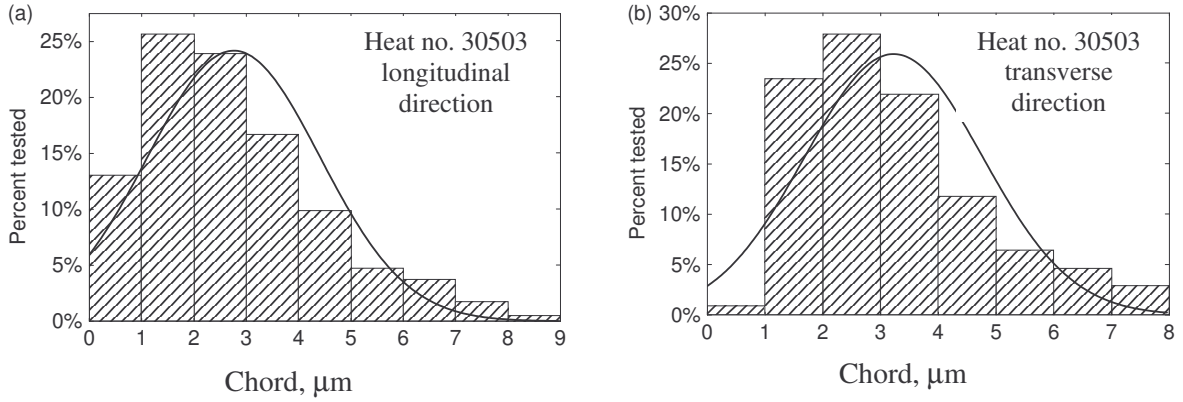

Figure 4. The distribution of average chord of pearlite grain, longitudinal (a) and transverse (b) direction, heat no. 30503

Table 2.
The conformance λ Kołomogorow's test on level of confidence α=0,05 for average chord $D_{śr}$ and the extension index D_{max} / D_{min} of ferrite and pearlite grains.

Specimen (direction)	Heat	Average chord $D_{śr}$			D_{max}/D_{min}		
		average	standard deviation	λ	average	standard deviation	λ
FERRITE							
transverse	30502	4,282	2,184	1,277	2,879	1,533	1,080
	30503	3,700	-	-	2,799	1,569	1,138
longitudinal	30502	4,183	2,425	1,057	2,823	1,833	1,010
	30503	4,581	2,573	1,219	2,885	1,620	0,687
PEARLITE							
transverse	30502	3,621	1,925	1,123	3,535	1,633	0,992
	30503	3,226	-	-	3,768	-	-
longitudinal	30502	1,969	0,700	1,321	3,097	-	-
	30503	2,046	0,906	1,325	3,372	1,869	1,190

For identification of the uniform structure of the wire rod the changeability coefficient was used. This coefficient was calculated as the relation of the average chord to the standard deviation. It has been presented graphically in Figure 5. It was notice that the grains of ferrite in contrast to pearlite grains characterize smaller dispersion of the changeability coefficient which equals respectively $1{,}86^{\pm 0{,}12}$ and $2{,}26^{\pm 0{,}45}$. The larger dispersion of the changeability coefficient value was confirmed additionally in longitudinal samples than in transverse (particularly for pearlite).

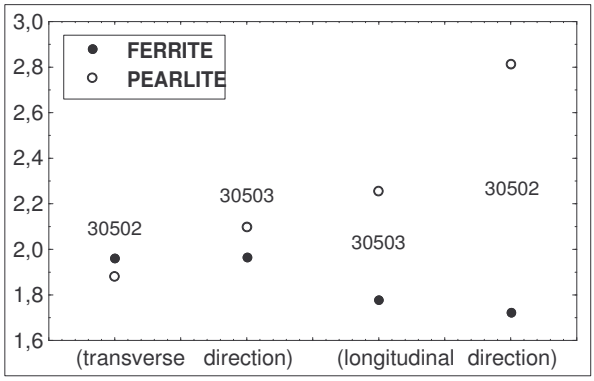

Figure 5. The changeability coefficient of the ferrite and pearlite grains in dependence of the type of the cross-section

4. SUMMARY

The analysis of the ferritic-pearlitic structure was executed in this work. The averages of the grains of ferrite and pearlite were quantified (Table 2). It was confirmed that the grains of ferrite have similar averages as well as the extension index in both directions of the investigation. Achieved the averages of stereologic parameters values shown that the grains of pearlite are imperceptibly diverse. However the microscopic investigations do not show essential differences in morphology of pearlite. The grains in the structure according to uniform and non-uniform of the ferrite and pearlite grains in the transverse direction have the larger chords, what was confirmed by the quantitative investigations (Table 2 and Figure 3-4).

The calculation of the changeability coefficients for the grains of ferrite and pearlite permitted to differentiate grains in structure. The lower average coefficient of changeability for ferrite grains shows on larger differences in the size of grains, what is visible as well on histograms (Figure 3). However the small deviation from average shows on large similarity in structure of these grains independently of the heat as well as kind of cross-section. In case of pearlite it was confirmed that the transverse section grains are more diverse than the longitudinal section (particularly for heat 30502).

According to the results of the average chords and the standard PN EN ISO 2624:1997 the studied steel structure is 12 in grade number and belong to the fine-grained group.

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