

EFFECT OF STRUCTURE OF BORON STEELS ON THEIR RESISTANCE TO BRITTLE FRACTURE

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Abstract: Two grades of steels B27 and 28MCB5 called boron steels manufactured by two known companies were examined. The steels belong to the group of abrasion resistant steels and are intended to be hardened and tempered. However the steels are delivered in different states with different structure. Because the steels are used in construction of big machines, which are subjected to dynamic loading, it is important to know what is their resistant to brittle fracture in condition of work. Impact strength of the steels at different temperatures and with different structures was investigated. An exact fractographic analysis of examined steels along with impact test was carried out. Some structures of the steels show brittle fracture at relatively high temperatures.

Keywords: BORON STEEL, IMPACT STRENGTH, MICROSTRUCTURE, BRITTLE FRACTURE

1. Introduction

Low-alloy and low-carbon steels are widely used material. Special group of these steels are modern steels with boron called boron steels. The materials belong to very important wear-resistant structural materials for applying in many industries such as mining, auto industry, agriculture industry and many others [1,2]. Manufacturing of the steels requires advanced technology to produce materials of high properties. This kind of materials is produced, inter alia, by the well-known companies - Rautaruukki Corporation (Finland) [3] and Zeneri Acciai Company (Italy) [4] and others. Two grades of steels manufactured by the producers were examined. Usually producers show us basic mechanical parameters and the data can be not sufficient for many applications. Additionally the steels are manufactured with different structure after different treatment, so applying the steel with improper structure can lead to disaster construction. To obtain a material with high strength can cause not sufficient ductility of this material. It is very important for many applications of the materials to exhibit sufficient resistant to brittle cracking and safety transition temperature from ductile to brittle fracture, out of work temperature range. There are lack investigations of those kind real materials, which results can be very useful for customers. Despite rather high values of Charpy V-notch impact strength, brittle cracking can be observed in some structures at relatively high temperatures. In the present study alongside impact strength toughness measurements detailed fractographic investigations are presented.

2. Materials investigated

Two grades of boron steels – B27 (Rautaruukki Corporation) and 28MCB5 (Zeneri Acciai Company) have been tested. Chemical composition of the steels given by the manufactures is presented in table 1.

Tab. 1. Chemical composition steels tested

Steel grade	Content. %						
	C	Mn	Si	Cr	P	S	B
B27	0,7	1,2	0,25	0,3	-	-	0,002
28MCB5	0,25-0,30	1,0-1,30	0,15-0,35	0,20-0,50	0,030	0,030	0,0015-40

Al and/or Ti are used as micro alloying elements for binding of nitrogen.

Nominal chemical compositions of both steels are in the same range. Mechanical properties of the steels depend on heat treatment carried out. Mainly this steel is proposed to be used after quenching and mostly after tempering, but in other states can also be supplied. Company Rautaruukki for example, supplies its product after hot rolling, recommending the buyer an appropriate heat treatment, depending on your needs. Analyzed steels were tested in two states - in delivered state and in state of hardening and tempering at 200°C (the heat treatment was carried out by the authors of this paper). Structures of the steels in delivery state are seen in fig. 1 and 2. The

structure of both steels consists of a mixture of ferrite and pearlite, but with a different distribution of these components. There is a band structure in B27 grade, while in grade 28MCB5 pearlite colonies are surrounded by ferrite precipitates.

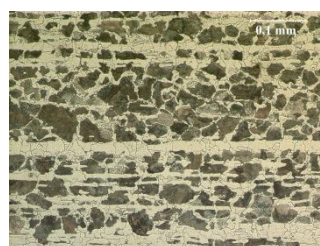


Fig. 1. Structure of B27 grade in delivered state. Light microscopy.

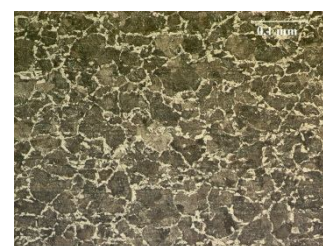


Fig. 2. Structure of 28MCB5 grade in delivered state. Light microscopy.

Structures of the steels, after hardening and tempering consist of martensite tempered.

3. Results of impact test

Average values of Charpy V- notch impact strength measured for the two steels studied, in two analyzed states, are presented in table 2. Various distribution of structure components – pearlite and ferrite - in delivered state, cause significant differences in the impact strength of the steels for the benefit of 28MCB5 one. Toughness of both steels in the state falls to relatively low values of 17 and 29 J/cm² at temperature of 0°C, and is reduced to even smaller values at minus temperatures.

Impact strength of the tested steels after hardening and tempering shows relatively high values at room temperature and the values decrease slowly with decreasing temperature, keeping the average values of 30 and 37 J/cm² at a temperature of – 40° C.

Tab. 2. Average values of toughness steels tested at temperature range of 20 ÷ -40°C

Grade of steels	As delivered				After hardening and tempering			
	Average values of Charpy V- notch impact strength [J/cm ²]							
	measured at different temperatures [°C]							
	20	0	-20	-40	20	0	-20	-40
B27	39	17	9	7	61	56	45	37
28MBC5	67	29	17	6	48	40	38	30

Notch toughness values determining transition from ductile to brittle fracture are accepted differently in different standards. Often for structural steels it is amount equal to 35 J/cm². Such defined ductile-to-brittle transition is present in the analyzed steels: in delivered state above 0°C, inside the range 20° - 0°C, while in the state after hardening and tempering below -20°, and even for the steel grade B27 less than -40°C.

3. Results of fractographic analyses

3.1. Delivered state

3.1.1. Grade B27 - temperature 20°C

Although minimum toughness of grade B27 at temperature of 20°C was equal to 38 J/cm² the fracture surface of the steel shows mainly brittle character (72% of entire fracture surface). Macroscopic view of the fracture surface is seen in fig. 3. Ductile narrow zone under mechanical notch means that this steel is characterized by low resistance to crack initiation at the temperature. Ductile lateral zones of a sample are also relatively narrow. Typical brittle fracture occurs in the central zone of the sample (fig. 4).

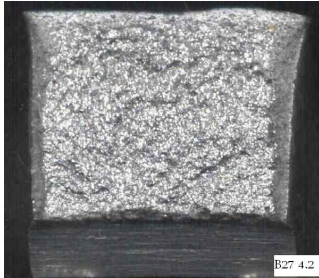


Fig. 3. Macroscopic view of the grade B27 fracture. 20°C. Delivered state.

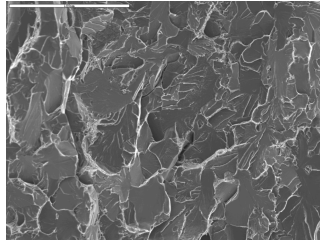


Fig. 4. Brittle fracture in the central zone of the sample B27 grade. 20°C. SEM. Delivered state.

3.1.2. Grade 28MCB5 - temperature 20°C

Minimum toughness of grade 28MCN5 at 20°C was higher than of grade B27 and equal to 53 J/cm². There is also less surface of brittle fracture in the grade (61%), but ductile narrow zone under mechanical notch is seen as well in steel 28MCB5 (fig.5 and 6).

3.1.3. Grades B27 and 28 MCB5 - temperature 0°C

At temperature of 0°C in both grade of analyzed steels almost all surface is occupied by brittle fracture. Toughness values are also low, pointing to crossing a ductile-brittle transition.

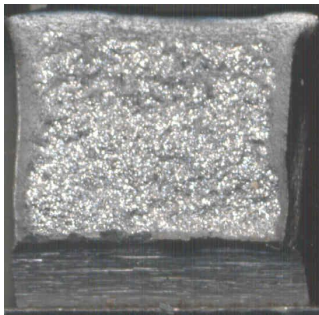


Fig. 5. Macroscopic view of the grade 28MCB5 fracture. 20°C. Delivered state.

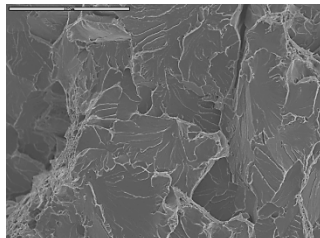


Fig. 6. Brittle fracture in the central zone of the sample 28MCB5 grade. 20°C. SEM. Delivered state.

3.2. The state after hardening and tempering

3.2.1. Grade B27 - temperature 20°C

Toughness of the steel grade B27 after hardening and tempering at temperature 20°C was equal 61 J/cm², so it is higher value than one for the a ductile-brittle transition. Fracture surface indicates on ductile-cleavage character of fracture, what is seen even in central zone (fig. 7).

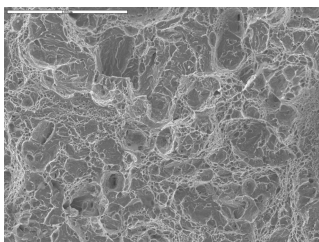


Fig. 7 Central zone of fracture in the sample B27 grade. 20°C. SEM. Hard./temper.

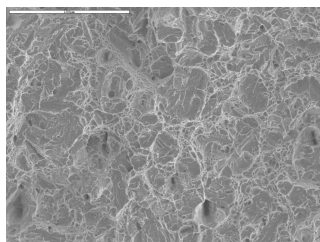


Fig. 8. Central zone of fracture in the sample 28MCB5 grade. 20°C. SEM. Hard./temper.

3.2.2. Grade 28MCB5 - temperature 20°C

Toughness of the steel grade 28MCB5 after hardening and tempering at temperature 20°C is also higher than applied to the ductile-brittle transition and it is equal to 48 J/cm². Grade 28MCB5 also shows ductile-cleavage character of fracture in the central zone of sample (fig. 8).

3.2.3. Grades B27 and 28 MCB5 - temperature -40°C

Fracture surfaces of both steel grades, even at a temperature of -40°C show a relatively wide lateral zones and zone under mechanical notch of ductile fracture. Macroscopic view of the fracture of grade B27 sample is presented in fig. 9. Central zone of the fracture in the analyzed steels at the temperature is different in comparison to samples in delivered state.



Fig. 9. Macroscopic view of the grade B27 fracture. -40°C. Hard./temper.

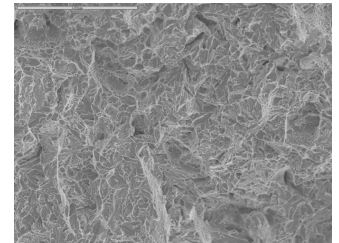


Fig. 10. Fig. 7 Central zone of fracture in the sample B27 grade. -40°C. SEM. Hard./temper.

Cleavage fracture with partially deformed facets and many areas of ductile fracture is seen in the zones (fig.10). That type of fracture allowed obtaining relatively high values of toughness in those minus temperatures.

4. Conclusion

Boron steels are delivered in different states with different structures. It is obvious that steel after suitable heat treatment with suitable microstructure should be used for particular application. Main properties attributed to boron steels are resistant to abrasion, weldability and high mechanical parameters. Those properties can be achieved by quenching and tempering to obtain a structure of tempered martensite. However the steels are supplied very often by manufactures only with a ferrite – pearlite structure, for example after hot rolling. In the presented research significant lower resistance to brittle cracking of the steel in delivered state in comparison to state after hardening and tempering is visible. Although values of impact strength of the former steels are relatively high at room temperatures, mainly brittle character of fracture occurs in the steels in delivered state. Temperature of ductile to brittle transition for the steels takes place already at positive temperatures. The steels after hardening and tempering retain both sufficient toughness values and sufficient resistance to brittle fracture up to temperatures of about -40°C.

5. References

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