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TREATMENT OF SAE 1006 STEEL BILLETS WITH AND WITHOUT BORON ADDITION

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ABSTRACT

This work aims at the development of low-carbon steel *SAE 1006* through the microalloying addition of boron. *Boron as alloying element is added in small amount, but it has significant effect on changes of properties of this kind of steel.*

The research is based on mechanical and microstructural testing of final product (wire) from the aspect of the influence of boron during hot rolling of billets into wire.

It is presented the technology of continuous casting and the process of hot rolling of wire for six heats based on low-carbon steel grades SAE 1006 with and without boron addition at the company ArcelorMittal in Zenica

The results showed that the addition of boron up to 0.01% can improve steel properties especialy drawability.

1. INTRODUCTION

Nowadays more than 95% of world steel production goes via continuous casting [1]. but the optimal amount of boron that will ensure maximal hardness of steel has not yet been investigated. Boron showed significant impact on toughness and plasticity of steel.

From 1970's, boron has been added to low carbon microalloyed steels. Today, with the development of the advanced analytical equipments, the understanding of the effects of boron is far better. Boron addition to steel a can have more or lees influence on steel properties. Today's steelmaking techniques have made it possible to closely control the effective boron content in steel [2].

Steel with boron addition has a wide application. In addition to the benefits of economy and alloy conservation, boron steels offer significant advantages of better extrudability and machinability compared with boron—free steels.

2. EXPERIMENTAL WORK

The aim of the present work is the investigation of the influence of boron addition on mechanical properties of steel grade SAE 1006.

The final stage of steel production *in ArcelorMittal Zenica* is continuous casting of steel. After the solidification of steel, the final products are made. In this case the final products were billets of the dimensions of 120x120 mm.. Each billet was cut to the lenght of 12 meters and afterward cooled at the air. At the Figure 2.1. is shown the continuous casting machine *in ArcelorMittal Zenica*.

Figure 2.1. *Continuous casting machine in ArcelorMittal Zenica*

In the following tables 2.1. and 2.2.are presented the nominal chemical compositions of steel grades SAE 1006 with and without boron addition based on standard ASTM A 510M. All tested heats comply with this standard. Mark +B indicates boron addition.

Table 2.1. *Nominal chemical composition of steel SAE 1006+B [3]*

C	Mn	Si	P	S	B
max 0.05	0.25-0.35	max 0.1	max 0.030	max 0.025	0.007-0.01

Table 2.2. *Nominal chemical composition of steel SAE 1006 [3]*

C	Mn	Si	P	S
max 0.08	0.25-0.40	-	max 0.040	max 0.050

At the wire rod mills starting materials are semi-finished cast billets which are transformed into hot-rolled wire of diameter range 5.5-12 mm. The production of wire is similar for the various steel grades, with the difference in adjustment of production parameters.

Wire rod mill consists of 25 roll stands divided into three sections:

- the roughing mill is created by seven roll stands
- the intermediate mill is created by eight roll stands
- the finishing mill is equipped by monoblock Morgan, created by 10 roll stands.

At the Figure 2.2. is shown the process of rolling.

Figure 2.2. *Rolling mill in ArcelorMittal Zenica*

Stelmor process is one of the most important part of wire production, because it defines the final microstructure and by that means mechanical properties of steel. It is actually the process for controlled wire cooling which consists of two parts:

- water boxes for cooling wire by water
- Stelmor conveyor for controlled cooling by air.

The aim of water cooling is decreasing temperature of the wire in order to prevent the growth of crystallite. The aim of controlled Stelmor air cooling is getting microstructure of ferrite. The aimed microstructure was ferritic with the low amount of pearlite. At the Figure 2.3. is shown the Stelmor conveyor.

Figure 2.3. *Glowing coil at Stelmor conveyor*

3. THE RESULTS

Mechanical properties were measured by Avery machine both for steel with and without boron addition. In the Tables 3.1. and 3.2. are presented the average results of mechanical properties for heats: H1+B, H2+B, H3+B from SAE 1006+B steel grade and the heats: H4, H5, H6 from SAE 1006 steel grade. The sample was hot-rolled wire of 5.5 mm diameter.

Table 3.1. *The average results of mechanical properties of SAE 1006+B [4]*

Heat	R_{eH} N/mm^2	R_m N/mm^2	R_m/ R_{eH}	A_{gt} %	Ovality mm
H1+B	251.17	346	1.38	34.5	0.32
H2+B	241.33	346.67	1.44	34.0	0.25
H3+B	257.33	350.17	1.36	35.5	0.29

Table 3.2. *The average results of mechanical properties of SAE 1006 [4]*

Heat	R_{eH} N/mm²	R_m N/mm²	R_m/R_{eH}	A_{gt} %	Ovality mm
H4	277.83	385.33	1.39	31.5	0.30
H5	273.83	385.33	1.41	32.5	0.27
H6	273.83	384.5	1.41	32.0	0.31

At the Figure 3.1. is shown the diagram of tensile strength for steel grade SAE 1006+B. From the Figure 3.1. it can be seen that all the values of tensile strength are bellow maximum allowable tensile strength that is 375 N/mm^2. For testing were used three coils of each heat.

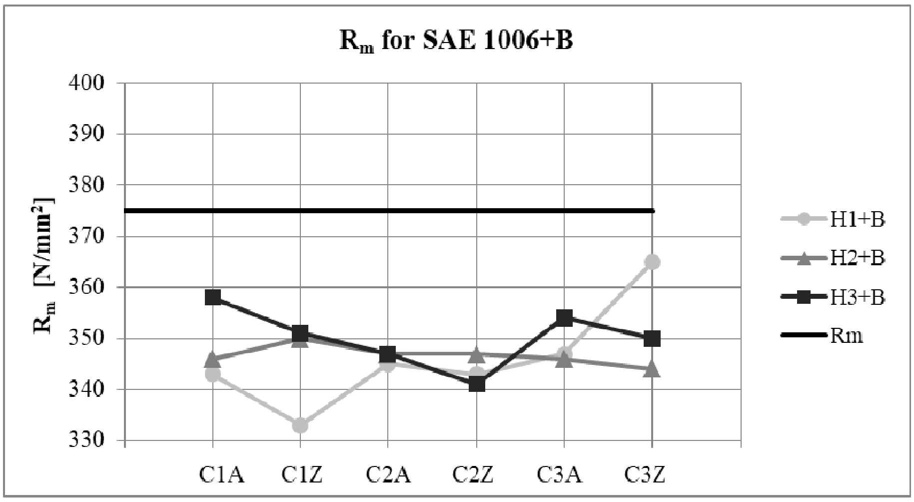

Figure 3.1. *Rm value for steel grade SAE 1006+B [4]*

At the Figure 3.2. is shown the diagram of tensile strength for steel grade SAE 1006. From the Figure 3.2. it can be seen that all the values of tensile strength are bellow maximum allowable tensile strength that is 400 N/mm^2. For testing were used three coils of each heat.

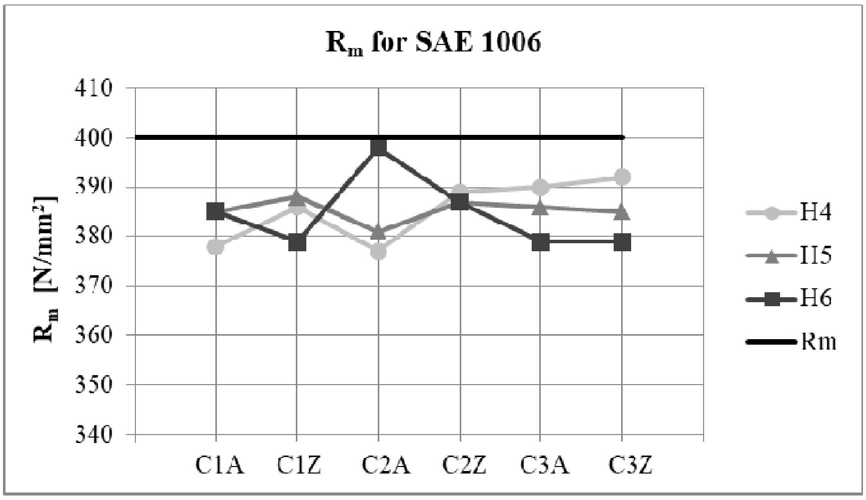

Figure 3.2. *R_m value for steel grade SAE 1006 [4]*

At the Figure 3.3. is shown the diagram of yield strength for steel grade SAE 1006+B. It can be seen that the values of the yield strength are different for every coil, as for the every heat.

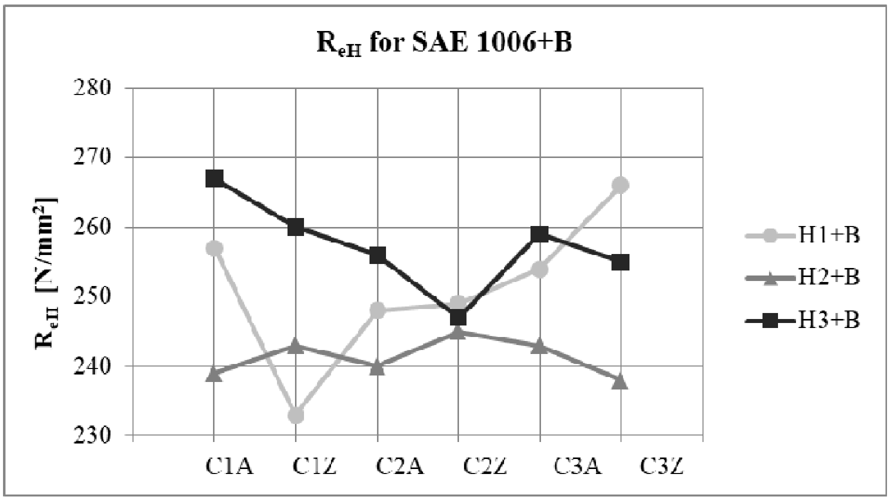

Figure 3.3. *R_{eH} value for steel grade SAE 1006+B [4]*

At the Figure 3.4. is shown the diagram of yield strength for steel grade SAE 1006.

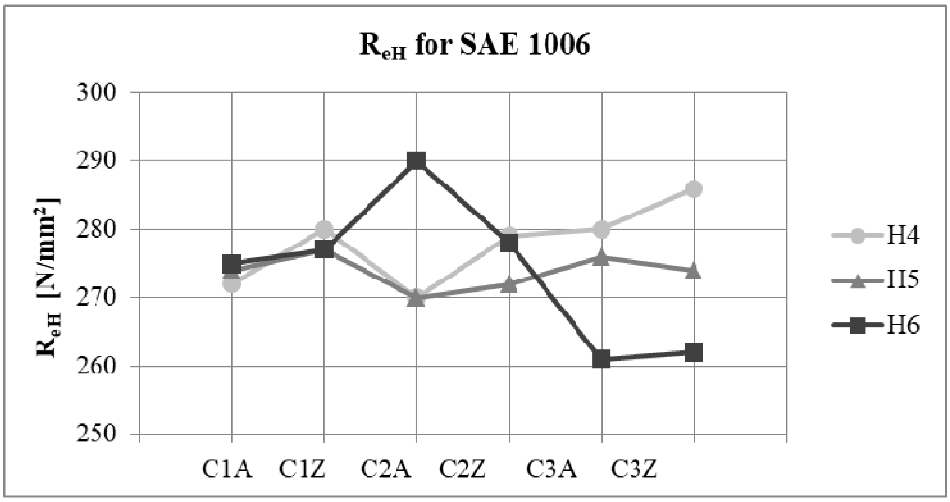

Figure 3.4. *R_{eH} value for steel grade SAE 1006 [4]*

At the Figure 3.5. can be noticed that the average values of tensile strength R_m and yield strength R_{eH} of tested wire samples made from steel with boron addition are lower than the ones without boron.

For the steel with boron addition the average value of tensile strength was 347 N/mm^2, and yield strength was 250 N/mm^2. However, the average value of tensile strength for steel without boron addition was 385 N/mm^2, and yield strength was 275 N/mm^2.

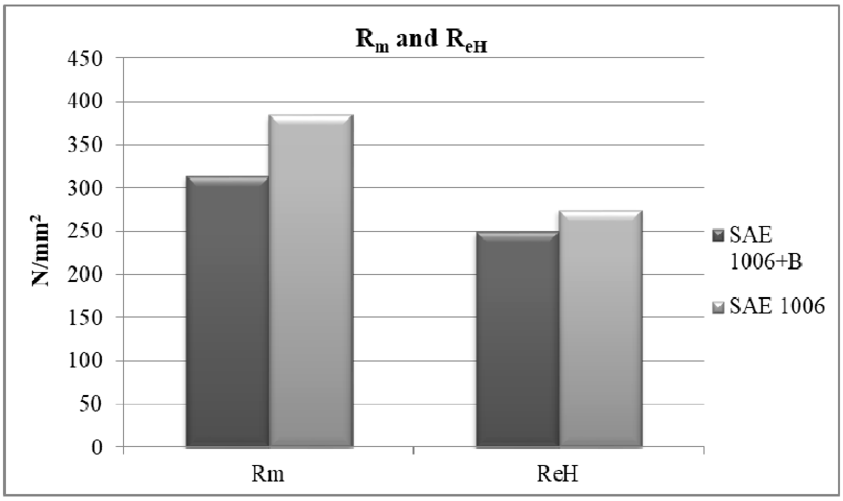

Figure 3.5. *Comparation of R_m and R_{eH} values for steel grades SAE 1006+B and SAE 1006[4]*

The average value of relative elongation for the tested heats of SAE 1006+B was 34.5% and for the heats of SAE 1006 steel was 32% which is presented at the Figure 3.6. Relative elongation A (%) is larger for the steel with boron adition, which indicates that boron has a beneficial impact on plastic working of steel.

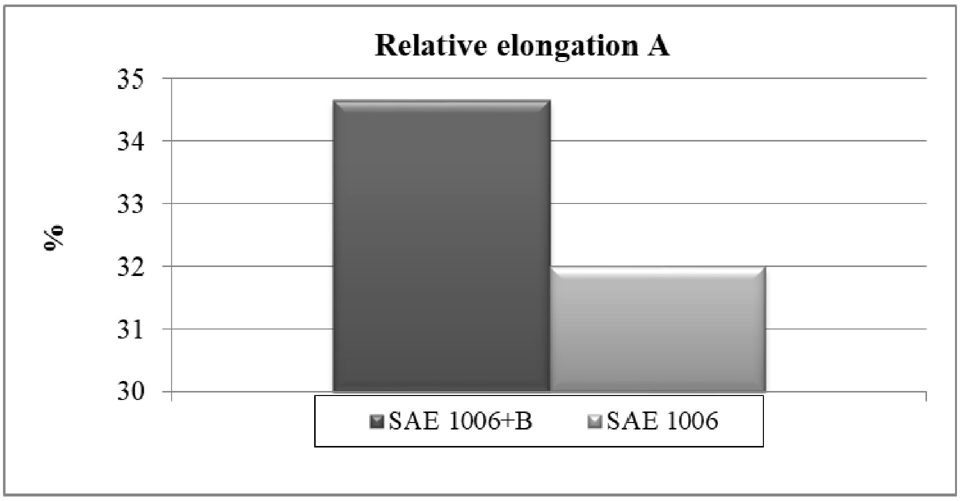

Figure 3.6. *Comparation of relative elongation values for steel grades SAE 1006+B and SAE 1006 [4]*

Boron addition in the range from 0.007 to 0.01% in the low-carbon steel grade SAE 1006 showed influence on mechanical properties of tested hot-rolled wire. It caused the growth of ferritic grain [5] which led to decreasing of tensile strength and yield strength, so that the drawability of steel grade SAE 1006 has been improved by addition of boron.

4. CONCLUSION

Boron addition in the range from 0.007 to 0.01% in the low-carbon steel grade SAE 1006 showed influence on mecahnical properties of tested hot-rolled wire.

The values of tensile strength and yield strength for the tested heats with boron addition towards the heats without boron addition were lower. The reason for that is reflected through the influence of boron in steel SAE 1006 in increasing grain size and in decreasing strength parameters.

The same can be explained for the values of relative elongation along with the growth of ferritic grain. For the tested heats with boron addition, these values were higher then the values of tested heats without boron addition. In this case the boron addition to the tested grade of low-carbon steel improved the drawability proces.

REFERENCES

[1] Zoran Glavaš, Anita Štrkalj, *Sekundarna metalurgija i kontinuirano lijevanje*, University in Zagreb, Faculty of Metallurgy, Sisak, 2015.

[2] Yu Lu, *Effect of Boron on Microstructure and Mechanical Properties of Low Carbon Microalloyed Steels*, McGill University, Department of Mining, Metals and Materials Engineering, Montreal, Canada, June 2007.

[3] Technical documentation of ArcelorMittal Zenica, 2018-19.

[4] Alma Puljić, *Čeličansko i valjaoničko tretiranje konti gredica SAE 1006 kvaliteta čelika sa i bez dodatka bora,* undergraduated work, Zenica, November 2019.

[5] Puljić Adna, *Proizvodnja niskougljeničnog čelika SAE 1006 sa i bez dodatka bora*, undergraduated work, Zenica, November 2019.