15th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2011, Prague, Czech Republic, 12-18 September 2011

SEM-EDS MICROCHEMICAL ANALYSIS OF THE MnS NONMETALLIC INCLUSIONS AND METAL MATRIX INTERFACE IN THE CARBURISED 20MnCrB5 STEEL

Ph.D. Nađija Haračić
University of Zenica
Fakultetska 1, Zenica
Bosnia and Herzegovina

Ph.D. Fuad Ćatović
University"Džemal Bijedić"
Mostar
Bosnia and Herzegovina

ABSTRACT
The results of investigation of 20MnCrB5 steel for carburisation and direct quenching are given in this paper. This is very important steel for motor's industry. Beside some usual factors that affect the strength and toughnes is also demanded the carburised layer depth, carbon content (%) on the surface of carburised steel and special fracture toughnestest for this quality of the steel. Research and explanation of SEM-EDS microchemical analysis of the MnS nonmetallic inclusions and metal matrix interface in the carburised 20MnCrB5 steel was conducted in the aim of achiving demanded special fracture toughnes.

Keywords: Boron steels, Electron microscope metallographic testing, non-metallic inclusions

1. INTRODUCTION
Existed data's about boron and his influence on the steel properties are very dispersed in the literature. In this study are described some of the most important properties of the boron and the boron microalloyed steels concerning reliable worlds literature data bases such as results owner microstructure examinations of the steel for carburisation and direct quenching 20MnCrB5 and low alloyed steel for carburisation 16MnCrB [1.].

Boron elementary influence in the steel is encountered, in the inhancement of hardenability which is evident already at very small concentration, of the degree of 0,0010% of boron[2.]. It is added to unalloyed and low allooyed steels for the hardness level enhancement through the hardenability. Iven in the small quantity of the degree of size up to 100 ppm, boron give the same effect of the hardenability enhancement, suh as others more expensive elements which must be added in much more quantity. An addition of 30 ppm of boron in steel which contains approximately 0,15%C, 1%Mn and 0,9%Cr shows a clear increase in hardness of almost 50% to a larger depth from the surface than in the case of a steel of identical composition, but free from boron. According the same authors, there′s no difference in hardness on the surface between the boron - containing and the boron-free steel. Accordingly, the incipient hardness is therefore determined not by boron, but by the martensitic structural state influenced by the carbon content. The hardness-enhancing effect of boron comes into play only below the surface. The operative mechanism which is decisive for the enhancement of hardenability by boron derives from a delay in the transformation to the bainite, ferrite and pearlite

structures, which are softer than martensite, taking place over cooling from the austenitisation temperature after annealing or from the hot working temperature.
J.W.Spretnok investigated if it is possible that boron make a film surrounding austenitic grain in the steel and concluded on the basis of the geometrical cosiderations that it is impossible. Instead, they discovered point Fe_2B precipitation at the grain boundaries. In the steel boron can be dispersed in matrix in the forme of Fe_2B, boride with size of 20 to $30x10^{-8}$ cm and free which segregates predominantly surounding primary austenite grain boundaries. This small amount of the soluble boron arranged along grain boundaries, evidently retards γ-α transformations by diffusion, namely it prevents feritic reaction and on this manner enhances hardenability of the steel. Boron optimale quantity which have must be added in the steel for the atchivement maximal hardenability, on the base experiances data is about 0,0003 to 0,0030% B [2]. Boron addition up to menthioned values deteriorates hardenability because boron precipitation of the exede quantity suh as face centered cube $Fe_{23}(B,C)_6$ borocarbide which can be a ferrite nucleation prefferential place.

2. MATERIALS AND METHODES

The rule of sulphide nonmetallic inclusions on the carbon layer microstructure of the $20MnCrB_5$ pack carburised and direct quenched steel, for the gear box is described in this paper. Chemical composition of the experimental steel was: 0,16% C; 0,325%Si; 1,125%Mn; 0,015%P; 0,027%S; 1,25% Cr; 0,020% Mo; 0,065%Al; 0,0035%B. The samples with size of ϕ25x5mm were carburised at 940^0 C over different periods from 0,5 to 8 hours in the compound CMD070. After heat treatment, detailed up-to date metallographic investigations of the carburised steel microstructure were made.

3. RESULTS AND DISCUSSION

Results obtained by electron spectroscopy confirmed [5.], that the present sulphide nonmetallic inclusions can be a source of oxidation over the carburising proces, which can cause the formation of microstructure inhomogenity of the carburised layer with negative effects on the mechanical properties of the carburised steel.
On the figure of the carburised specimens microstructure it is viseable white spot around sulphide nonmetalic inclusions (fig.1). The carbon layer structure consists of the martensite, retained austenite, and sulphide nonmetallic inclusions with evident inhomogeneity (white areas) round them (fig.2.).

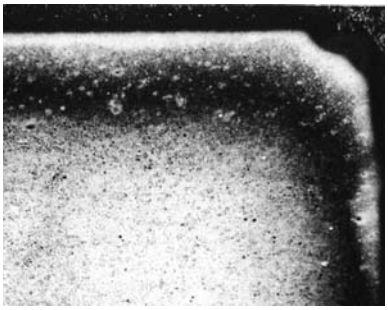


Figure 1. Macrostructure of the carburised layer 20MnCrB5 steel (carburized : 940°C, 8h)

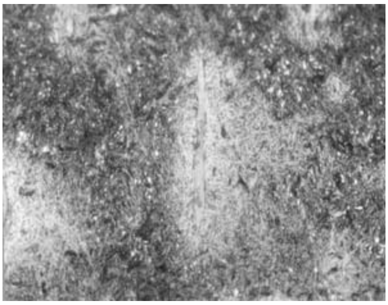


Figure 2. Microstructure of carburised layer 20MnCrB5 steel (carburized : 940^0 C, 8h)

Microstructure of the correct carbon layer of the 20MnCrB5 steel consists of the martensite, retained austenite and the mixed crystal phase. Detailed up–to date metallographic investigations of the microstructure of carburised steel are made in the purpose of the origine of menthioned anomalies explanation.

Qualitative scaning electron SEM-EDS microchemical analysis is made acros on the dark and light part of the nonmetalic inclusions on the fig.2, such as in the matrix, far from the nonmetalic

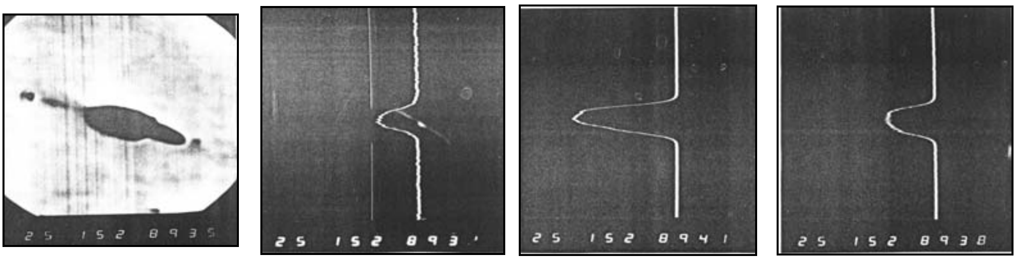
CONTENTS AUTHORS

inclusions. Results of the SEM-EDS microanalysis made on the nonmetalic inclusions in the light and the dark areas, are presented in table 1. and fig.3.

Table 1. Results of Scaning electron microanalysis (SEM-EDX)

20MnCrB5 steel	Identified chemical components		
	Light part of inclusion	**Dark part of inclusion**	**Metal matrix**
Noncarburised	**S, Mn**	**Al, O, S, Mn, Ca**	**Fe, Cr, Mn**
Carburised: 940^0 C, 8h	**S, Mn, Ca, Al, O**	**Al, S, Mn, O, Ca**	
Carburised: 1020^0 C, 8h	**S, Mn, O**	**Al, S, Mn, O**	

Beside carbon diffusion, this results show local diffusion of the present chemical elements across nonmetallic inclusions (the most evident of Ca and Al), such as diffusion batwen nonmetalic inclusion and matrix.



Alined acros inclusion | *Line of analyse Al-Kα* | *Mn- Kα* | *S- Kα*

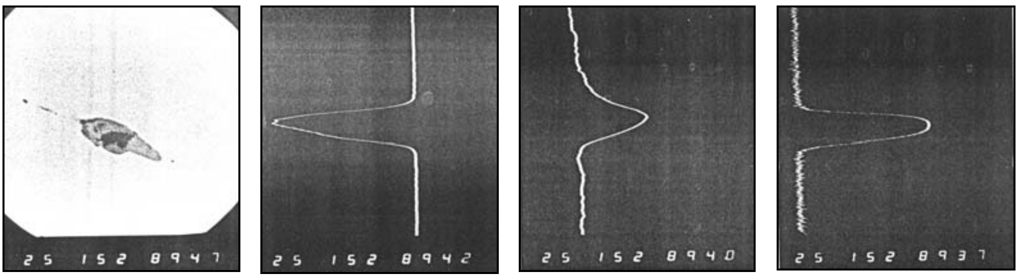


Image topographic(BSE) | *Ca - Kα* | *Cr - Kα* | *Fe - Kα*

Figure 3. Linear electron microscopy (SEM) and with wave length dispersive spectrometre -WDS analysis of the Steel 20MnCrB5 (magnification 1500)

On the fig.3 are presented results of the qualitative microchemical, linear analysis. Intensitat of the present elements flow linies in the complex nonmetallic inclusions have specific view which shows existance of the diffusion changes over the pack carburisation process (940^0 C, 8h).

4. CONCLUSIONS

Steel 20MnCrB5 for carburisation and direct quenching is very important steel for motor's industry which contains 0,0010 to 0,0030 % of alloyed element bore (B) as the difference from the commonly used carburizing steels. Samples for the carbon layer gradient with size of ϕ25x5 mm were machined from bar stock with diameter of 32 mm. The specimens were pack carburized in the compound CMD070 on the temperature of the 940^{0}C over different periods (0,5 to 8 hours), oil quenched, tempered and tested.

Results of the optical microscopy investigations showed that the structure of the carbon layer consists of the martensite, retained austenite, and sulphide nonmetallic inclusions with evident inhomogeneity (white areas) round them.

Results of the qualitative electron SEM-EDS microchemical, linear analysis showed that intensity flow lineas of the present elements in the complex nonmetallic inclusions have specific view which shows exystance of the diffusion changes over the pack carburisation process (940^{0} C, 8h).

Results obtained by these investigations could be used as a base about carburisation technological process optimisation in the aim of solving the existing dilemmas about chemical composition, type of microstructure and mechanical properties of the low alloyed steel 20MnCrB5 for carburisation and direct quenching.

5. REFERENCES

[1] Haracic N.: A Contribution to study of the Carbon Transfer During the Pack Carburisation Process of Steel by Means of the Case-Hardening Compound, Ph.D. Thesis, Faculty of Mechanical Engineering, Zenica 2000.

[2] Dietrich H. Werner: Bor und borlegirte Stahle (Boron and Boron containing Steels, Verlag Stahleisen mbh, Dusseldorf 1995.

[3] Hong- Rong Lin, Gwo-Hva Cheng: Analysis of hardenability effect of boron, Materials Science and Technology, August 1990.Vol.6

[4] Jiang, Kun Cui: Quantitative study by calcium and its effect on the impact toughness of a resulfurised alloy steel, Steel Research 68(1997)No4

[5] Kurzydlowsky J., B.Ralph: The Quantitative Description of the Microstructure of materials, Brunel University, United Kingdom 1995., 1410p.

[6] Handbook of Analitical Methods, Materials Evaluation and Engineering.Inc.

[7] http://www.mee-inc.com/gsem6.jpg

[8] *** Boron treated engineering steels for quenching and tempering ISO/TR11637; 1997

[9] *** Standard Practice for determining the Inclusions or Second-Phase Constituent of Metals by Automatic Image Analysis, ASTM E 1245-95