THE INFLUENCE OF Cr, Mn AND Mo ELEMENTS ON CRACKS OCCURENCE IN LOW-ALLOYED Cr-Mo STEELS

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Abstract
The low – alloyed Cr-Mo based steels are very sensitive to internal crack occurence especially in cases when they are hot rolled from round continuously cast blooms. The scope of the paper is therefore dedicated to the study of microscopic crack mechanism of 25CrMo4 steel variant. We have demonstrated that the crack presence after hot rolling strongly depends on the microstructure composition as well as on the segregation of chromium, manganese and molybdenum content. The main conclusions are supported by the metallographic analysis that was performed on the surface and in the center of the investigated billet and also the microchemical line analysis carried out with the energy - dispersive X - ray spectroscopy (EDX) to precisely determine the internal segregation behavior of above mentioned elements. Moreover we have also utilised the microhardness determination of Cr-Mo steels.

Keywords: segragation, steels, rolling, microstructure

1 Introduction

The defect incidence such as internal crack occurence in Cr – Mo steels is still the scope of great interest. There are many scientific articles and monographies published so far that explain cracking in low – alloyed steels from different points of view mainly based on content of molybdenum [1, 2], improper microalloying process with respect to the high level of vanadium and niobium [3-10], segregation of copper, stannum or manganese sulfide (MnS) along the grain boundaries [11, 12], inappropriate steel casting speed and overheating above the liquidus curve [13, 14], insufficient deformation degree in central billet area or unsuitable rolling temperature range [2, 15]. It is evident that all of mentioned mechanisms are closely related to the preparation and/or post – preparation process. However, the Cr-Mo steels have been successfully employed in fabrication of mounted wheels, sleeper screws or air pressure duct pipelines. Therefore, the aim of presented paper is to emphasise the conditions which cause the internal crack initiation and propagation in hot rolled billets from continuously cast low alloyed Cr - Mo steel.

2 Material and experimental methods

The experiments were carried out on low - alloyed 25CrMo4 steel variant in form of the square billets with the dimensions of 280 x 280 mm. The billets were air cooled immediately after hot rolling. The chemical composition of presented Cr-Mo steel is given in the **Table 1**.

Table 1 Chemical composition of the steel (wt %)

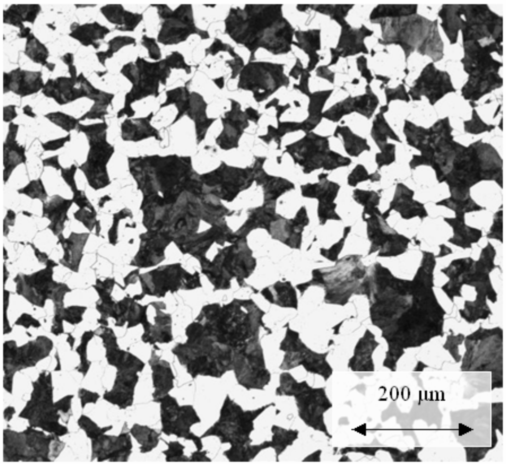
Steel	C	Mn	Si	P	S	Cr	Ni	Mo	V
25CrMo4	0,25	0,74	0,25	0,013	0,004	1,18	0,25	0,20	0,044

Additionally, the samples were etched in Nital (4 % solution of alcohol and nitric acid). The microstructure observations were performed by the light microscope (Hitachi S3500N) and by the scanning electron microscope (SEM - JEOL JSM 5510). We also included the microhardness determination ($HV_{0,1}$). The microchemical line analysis was made by Thermonoran microprobe 445a (EDX). Due to the ultrasonic analysis we noticed that most of the analysed samples contained the void in central area of the billet. Therefore we decided to investigate the void in detail with respect to the element composition.

3 Results and discussion

3.1 Microstructure

It is shown (**Fig. 1**) that the surface and the central part of the billet consist of the two constituents, ferrite and pearlite. One can also see that the ferrite and pearlite grain size in central parts is much bigger in comparison to the surface, mainly due to different temperature gradient between the inner and outer region of the sample during cooling processes.



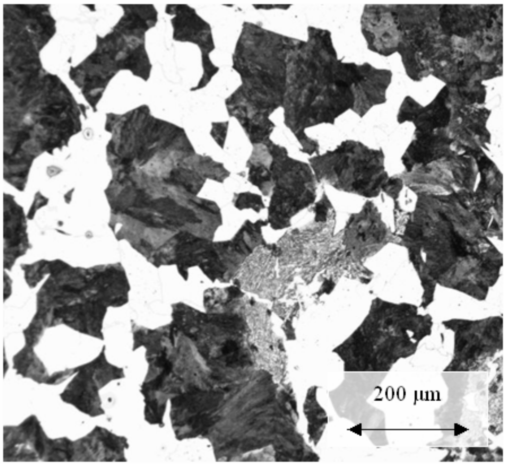


Fig.1 Microstructure of 25CrMo4 steel variant. The left image was taken from the surface of the billet, whereas the right image was taken from the void

Although the regions close to the void are known to be coarse grained with respect to the surface, it was possible to examine the bainite occurence in the structure. The bainite origination is therefore coupled with the segregation of the elements that increase the hardenability, i. e. manganese, chromium, molybdenum. The segregation is responsible for elevating the resistance to deformation in central parts of the billet. It also creates undesirable deforming strain field that leads to the potentiality of the crack initiation.

3.2 Microchemical line analysis

The area, that was chosen for precise microchemical analysis, is depicted on the **Fig. 2**. The chemical data were collected by scanning the sample (300 μm) with the step of 3 μm (100 points). We have compiled two graphs (**Fig. 3**) which illustrate the relation between the element content (wt. [%]) and distance (μm - line scan).

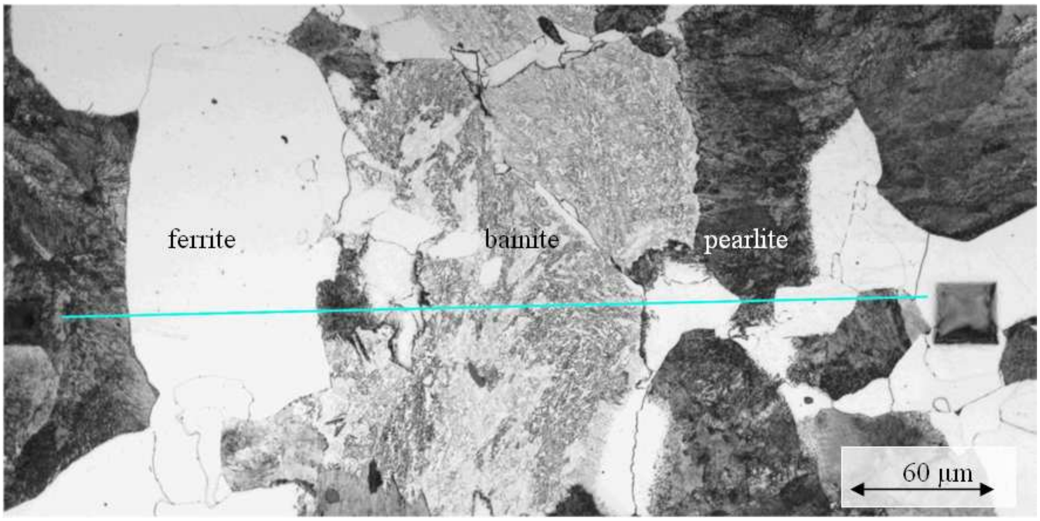


Fig.2 Selected area of 25CrMo4 steel sample (close to the void) . The microchemical analysis interval is depicted by line

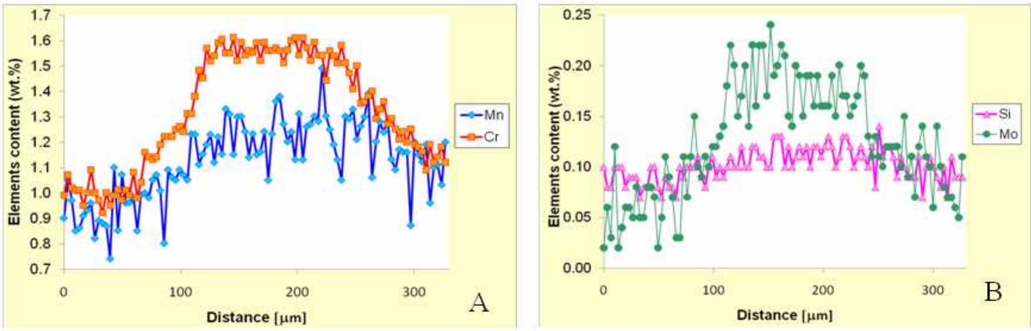


Fig.3 The microchemical line analysis performed through the bainite grain. Subplots A resp. B denote the relation between the element content of chromium, manganese resp. molybdenum, silicon and the distance (microprobe motion interval)

It can be clearly seen, that the content of elements demonstrated on Fig.3 (A - manganese, chromium) is evidently lower crosswise the ferrite and pearlite grain as compared with the bainite grain (see Fig. 2). This fact suggests that the crack initiation and deformation resistance are closely related to the locations of increased concentration of chromium, molybdenum and manganese.

3.3 Microhardness evaluation

The samples were investigated in twenty randomised places to obtain complex microhardness measurements ($HV_{0,1}$). The microhardness behaviour is depicted in Fig. 4A resp. B (close to the void - central part, outer region - outer part).

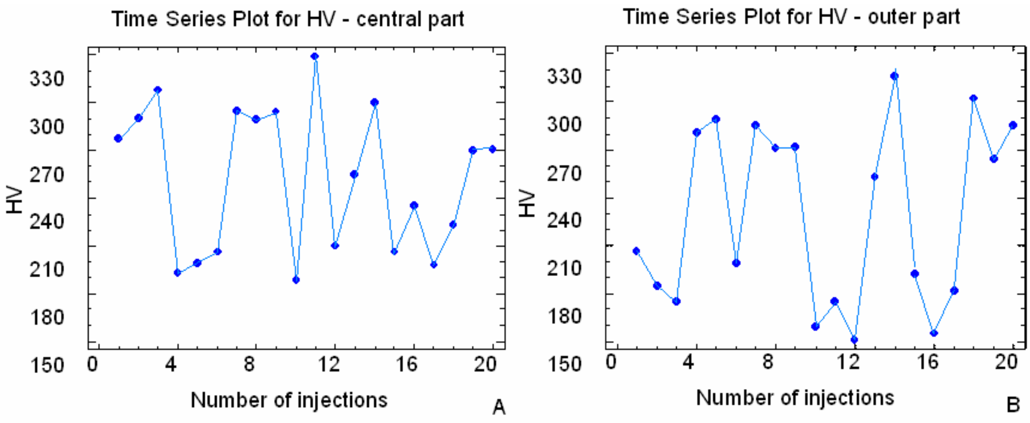


Fig.4 The microhardness evaluation. Subplots A. resp. B. denote the central resp. outer part of measured sample

The values that were collected during the microhardness evaluation in central part of the sample (**Fig. 4**) appear to be bit higher than those in outer part. We can conclude that statistical tests did not approve any significant differences at all. Mean values, median or error variances as well as distributions are statistically equal. It means that values of microhardness measured close to the void are almost the same as those which were collected in outer region of the sample. However, quantitatively is this relation not valid.

4 Conclusions

The scope of experimental activity consists of microstructure analysis and chemical study of 25CrMo4 steel variant with respect to the microcracking mechanism. We demonstrated that bainite-based structure in surrounding area of central void contains elevated volume of chromium, molybdenum and manganese in comparison to the surface, that is cooled down faster due to the preparation and/or post – preparation process. The bainite occurence in central area of the billet suggests that void initiation and its propagation during hot rolling of square billets from round continuously cast blooms is caused by higher resistance to deformation. The tensile stress that is introduced during first few passes through the rolling mills is caused by a small contact area between rolling mills and the bloom. The microhardness determination is not statistically significant in comparison to central respectively outer parts of the sample.

The internal crack occurence can be lowered due to keeping the manufacturing processes under the rigorous conditions such is low overheat of steel in tundish, higher casting speed or application of mould electromagnetic stirring. Another point that has to be taken into account is reduction of bloom passes through rolling mills.

Acknowledgements

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