INFLUENCE OF NANOSIZED SILICON NITRIDE ADDITION DURING CASTING ON THE MICROSTRUCTURE OF X210Cr12 STEEL

ВЛИЯНИЕ НА ДОБАВЯНЕТО ПРИ ОТЛИВАНЕТО НА НАНОДИСПЕРСЕН СИЛИЦИЕВ НИТРИД ВЪРХУ СТРУКТУРАТА НА СТОМАНА X210Cr12

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Abstract: *The objective of this study is to investigate the effect of modification and nitrogen alloying of X210Cr12 tool steel by addition of nanosized* Si_3N_4 *during the casting process. This is an air hardening, high-carbon, high-chromium tool steel which displays an excellent wear resistance and has good dimensional stability and high compressive strength. Of great importance for the tools fabrication of this steel is the ledeboritic structure after casting and the influence of its characteristics on the next processes of forging. machining and heat treatment for obtaining of optimal properties. In this case a modification at the cast process and obtaining of finer structure is a precondition for better results on the next stages of tool manufacture. The role of nitrogen for obtaining of fine grained structure is already proved for many types of steels and the alloying process is precise developed.* Si_3N_4 *is one of the most suitable nitrogenous alloying agents for production of alloyed with nitrogen steels because of its high nitrogen content and stability. The investigations show a considerable improvement of the cast structure of X210Cr12 tool steel after the addition of small amount of nanosized silicon nitride during the casting process.*

Keywords: MODIFICATION, NANO-DYSPERSED SI_3N_4, X210CR12 STEEL, HEAT TREATMENT

1. Introduction

The alloying of tool steels with nitrogen is a perspective direction for improvement of their wear resistance, hardness, tribological characteristics and for better performance. The advances of nitrogen addition in these steels is connected with grain size refining, significant increasing of strength without restriction of ductility, formation of nitrides and carbonitrides with high hardness in the structure. The nitrogen can be introduced in the steel by remelting in nitrogen atmosphere at higher pressure or by addition of high-nitrogen ferroalloys and nitrides such as nitrided ferrovanadium, ferrochromium, ferromanganese or silicon nitride. In the case of high-carbon, high-chromium cold work tool steels with ledeboritic as-cast structure the addition of nitrogen as a stable silicon nitride with about of 30 % nitrogen content will modify and refine the structure, stabilize the austenite, increase the strength, wear resistance and resistance to tempering. The role of nitrogen for obtaining of finer grained structure is already proved for many types of steels and the alloying process is precise developed. Si_3N_4 is one of the most suitable nitrogenous alloying agents for production of alloyed with nitrogen steels because of its high nitrogen content and stability [1].

2. Materials and Procedure

The material for the experiments was a standard tool steel X210Cr12, with or without addition of nanosized Si_3N_4 at the casting process. The chemical composition of the prepared samples is shown in Table 1. Steel 2 is modified with nanosized silicon nitride added in the mould before casting.

Table 1: *Chemical composition of the studied steel samples*

Element, wt. %	C	Si	Mn	P	S	Cr		Ni	Mo	Cu	V	As	Al	N
Steel 1	1.91	0.51	0.46	0.031	0.046	11.60		0.23	0.077	0.10	0.052	0.031	0.006	-
Steel 2 (+N)	1.98	0.51	0.46	0.031	0.045	11.38		0.33	0.076	0.10	0.053	0.031	0.11	0.061

The two types of steel were obtained by remelting in induction furnace and casting in graphite molds with a conical shape, shown in Figure 1, left. The samples used for the study were cut vertically from the ingot and after that prepared according to the standard methods. The dimensions of the samples are shown in Figure 1, right.

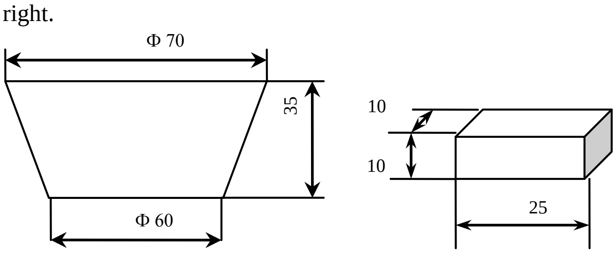

Fig. 1. *Shape and dimensions of the cast ingots(left) and of the cut samples (right)*

After casting some of the samples were 25 % hot deformed by stamping at temperature of 1150ºC and after that heat treated by quenching from 1100 ºC in oil with followed double high temperature tempering at 520 ºC for obtaining of secondary hardness. In table 2 and Figure 2 are shown the heat treatment parameters for the samples from the both steels.

Table 2: *Heat treatment parameters*

Steel type	1	2
Quenching (temperature, [°C] and medium)	1100, oil	1100, oil
Hold, [min]	40	40
Hardness after quenching, HRC	61	62
Tempering (temperature, [°C] and medium)	520, air	520, air
Hold, [min]	120	120
Hardness after Ith tempering, HRC	63	60
Hardness after IIth tempering, HRC	58	57
Hardness after casting, HRC	46	50

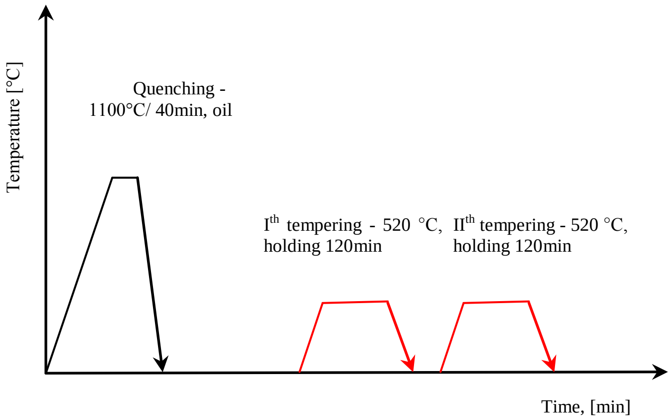

Fig. 2. *Heat treatment of the both types X210Cr12 steel*

3. Results and Discussion

Booth steels 1 and 2 have the typical chemical composition of X210Cr12 tool steel according to the producers and standards [2, 3].

The measured hardness of the as-cast samples shows that the modified with nanosized Si_3N_4 steel has hardness higher than HRC 50 and the hardness of non-modified steel is about HRC 46. The added nanosized silicon nitride refines the coarse dendrite structure of the cast steel and creates more homogeneous distribution of the ledeburitic eutectic. The presence of complex carbides and carbonitrides into the microstructure has the same effect. The as-cast microstructures of steels 1 and 2 are shown in Figure 3 and Figure 4. The non-modified as-cast steel 1 has a coarse dendritic structure, which can not be observed in Figure 4 for the modified with nanosized silicon nitride steel 2, and higher amount of ledebourite between the longer austenitic dendtites.

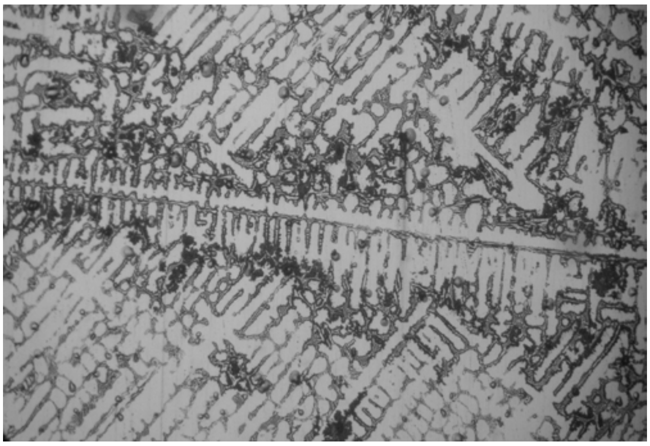

Fig. 3. *As-cast microstructure of steel 1: Primary dendrites from partially transformed alloyed austenite (white zones) and ledeburite eutectic (dark zones). Optical micrograph of an etched sample, magnification 100x*

The deformation in this case of stamping is not enough to break up the ledebouritic eutectic and it remains in the structure of bouth steels in about the same amount – Figure 5 and 6.

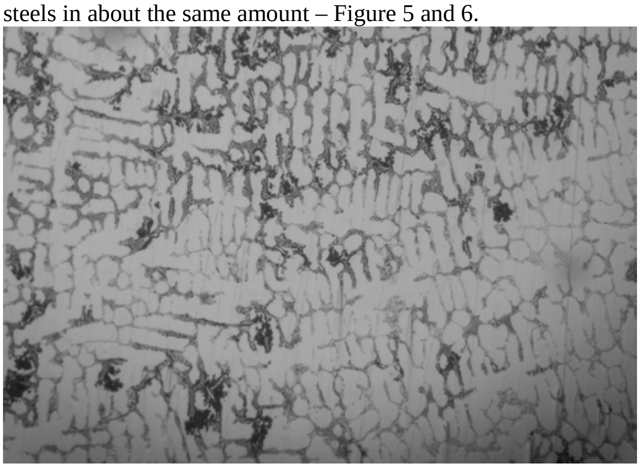

Fig. 4. *As-cast microstructure of steel 2. Optical micrograph of an etched sample, at magnification 100x*

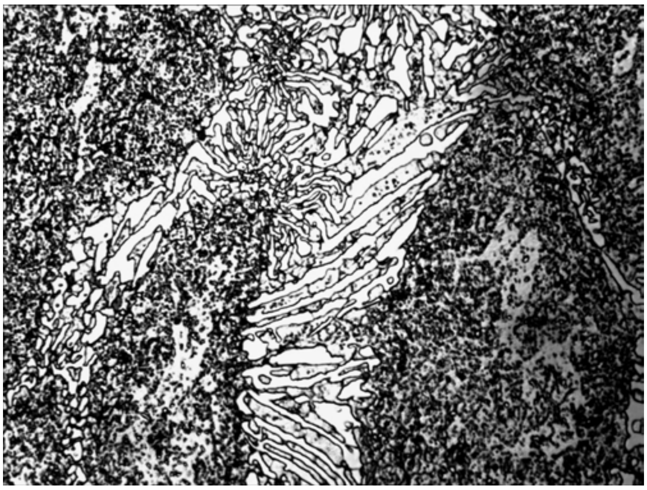

Fig. 5. *Ledebouritic eutectic in steel 1 after stamping, 800x*

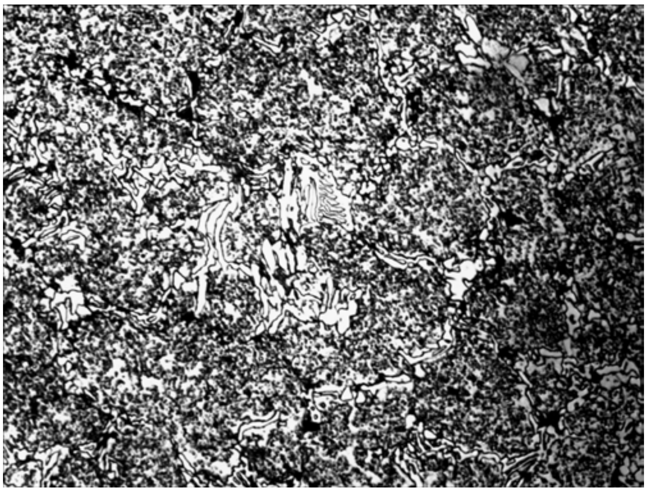

Fig. 6. *Ledebouritic eutectic in steel 2 after stamping, 800x*

Figures 7 and 8 show optical micrographs of heat treated samples from X210Cr12 steel which are not modified with nanosized Si_3N_4. The microstructure of the sample quenched in oil from 1100 °C is shown in Figure 7 and the microstructure of the same sample after double tempering at 520 °C for 180 min is shown in figure 8.

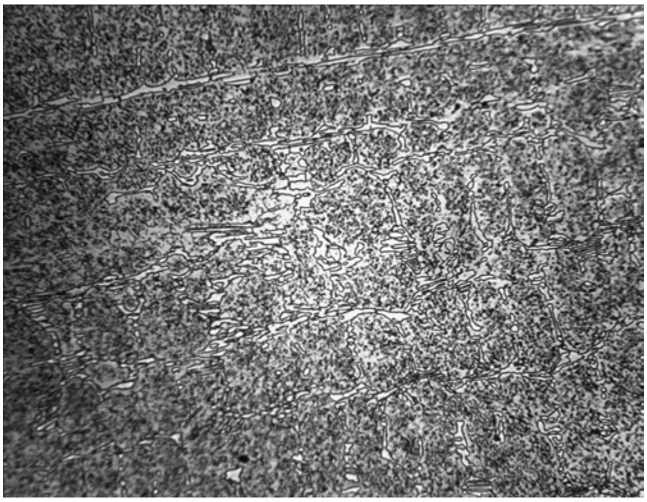

Fig. 7. *Non-modified with Si_3N_4 microstructure of steel 1 after quenching from 1100ºC. Optical micrograph of etched sample at magnification 400x.*

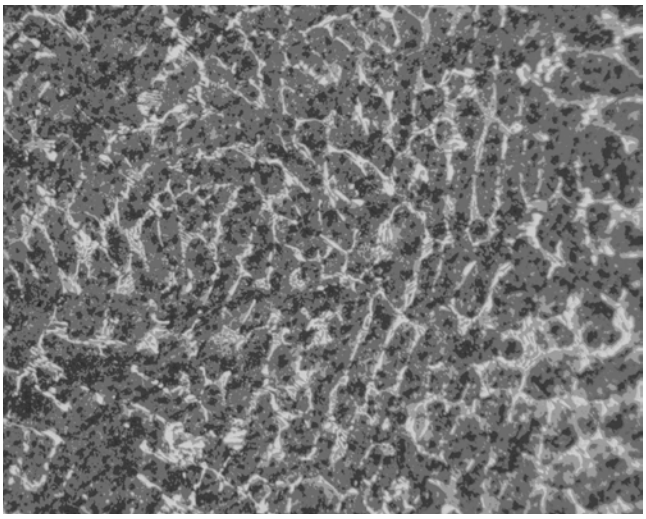

Fig. 8. *Non-modified microstructure of steel 1 after quenching from 1100ºC and double tempering at 520 ºC. Optical micrograph of etched sample at magnification 320x.*

In Figure 7 can be seen the microstructure of steel 1 consisting of martensite, retain austenite and ledeburitic eutectic surrounding the martensitic grains. It can be also seen by higher magnifications carbides which are homogeneously distributed in the grain structure [4-6]. The tempered microstructure, shown in Figure 8, consists of tempered martensite, ledeburitic eutectic and secondary carbides. It can be observed that the dendritic structure remains in approximately same type.

Figure 9 and Figure 10 show the microstructures of steel 2 after quenching in oil from 1100ºC and double tempering at 520 ºC. It can be observed the finer ledebouritic net around the martensitic grains.

In Figure 11 are shown the values of measured hardness of investigated steels in the discussed conditions. After casting and quenching the modified with nanosized silicon nitride samples of steel 2 have higher hardness than those of steel 1. After tempering at 520 °C the modified structure is with lower hardness, because of finer ledebouritic net and smaller amount of retain in the structure eutectic.

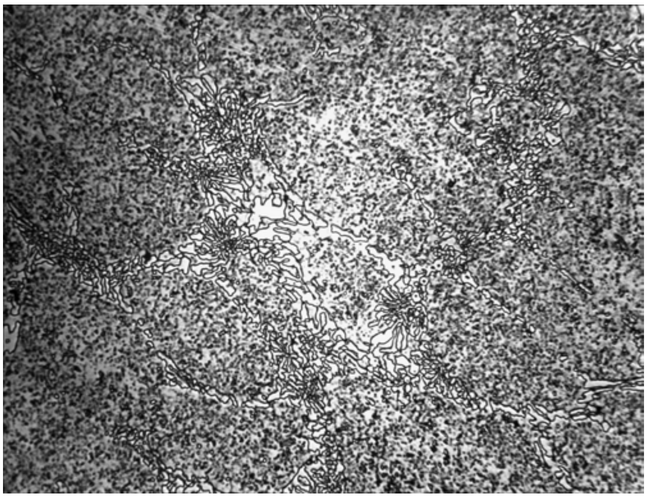

Fig. 9. *Si_3N_4-modified microstructure of steel 2 after quenching from 1100 ^oC. Optical micrograph of etched sample at magnification 400x.*

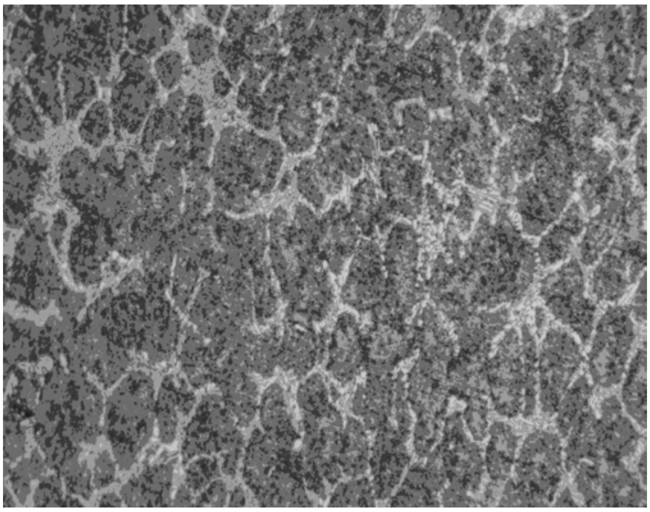

Fig. 10. *Si_3N_4-modified microstructure of steel 2 after quenching from 1100 ^oC and double tempering at 520 ^oC. Optical micrograph of etched sample at magnification 320x*

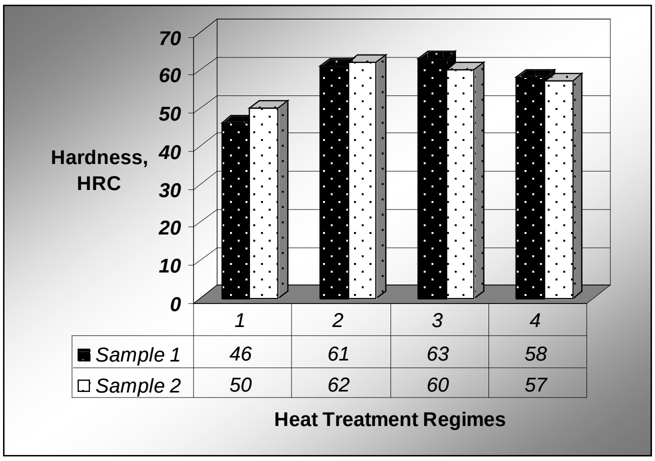

Fig. 11. *Hardness of samples from steels 1 and 2 after: 1- casting; 2- quenching from 1100 °C; 3- I^th^ tempering at 520 °C ; 4- II^th^ tempering °C.*

4. Conclusions

The modification of steel X210Cr12 with nanosized silicon nitride gives more homogeneous distribution of the phases (ledeburitic eutectic, alloy martensite, retain austenite and dispersed carbides) after casting, plastic deformation, oil quenching from 1100°C and double tempering at 520 °C. The applied heat treatment can not remove the dendritic structure remained after the applied plastic deformation. It can be observed more homogeneous distribution of the ledeburitic eutectic and its finer structure in the samples from modified with silicon nitride steel.

5. References

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