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Investigation of the Effect of the Particles $Ti(C_x, N_{1-x})$ on the Properties of Structural Steel

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The effect of the titanium carbonitride particles on the emergence and development of brittle cracks during the destruction of microalloyed steels with different alloying systems is observed in the article. Possible applications of high-strength mill products in construction are shown.

Keywords: TITANIUM NITRIDE, ACICULAR FERRITE, DESTRUCTION

Introduction

Currently, the construction industry of Ukraine is badly in need of new materials, including high-strength metal-roll, which is widely used in building construction. After reaching a certain height of a building, high-strength metal is the only material that allows increasing the number of floors of buildings at accepted loads on the foundation.

Wide application of metal in construction is limited by the obsolete regulatory system (СНиП-II-23-81), which restricts the use of new grades of steel in the construction industry. In this situation, from our point of view, the most promising is the use of steel included in the СНиП (Construction Rules and Regulations, e.g. Ст3) with an increased number of properties, which provide an additional increase in the number of floors of the object at lower loads on the foundation. The improvement of the set of properties can be achieved through the use of heat treatment and/or modification of steel. An example of such material may be Ст3, a modified system of Al+Ti+N with the structure of acicular ferrite in the heat treated condition. A lot of works are devoted to the study of the structure of acicular ferrite in steels. This can be explained by an attractive combination of high strength and toughness at low temperatures, what is achieved through the features of the acicular ferrite morphology [1, 2]. The toughness can also be affected by nonmetallics in steel. This work is dedicated to the evaluation of impact of particles $Ti(C_x, N_{1-x})$ of a modified system Al+Ti+N on the toughness of the steel Ст3.

The chemical composition of the investigated steels is presented in the **Table 1**.

Table 1. The chemical composition of the investigated steels of JSC «Днепроспецсталь» production

Smelting №	Elements composition, %										
	C	Mn	Si	P	S	Cr	Ni	Cu	Al	Ti	N
166215	0,20	0,71	0,30	0,016	0,010	0,22	0,13	0,18	0,028	0,016	0,018
166908	0,19	0,63	0,28	0,015	0,014	0,18	0,13	0,20	0,029	0,003	0,019

The studies of titanium carbonitride particles and fractures of samples of these steels were performed in a scanning electron microscope Karl Zeiss. Determination of the chemical composition of the particles was performed using an additional attachment EDX + WDX of company EDAX. The photo of the microscope is shown in **Figure 1**.

Specifications of the microscope Karl Zeiss:
- Resolution - 1 nm;
- Zoom up to 900,000 times;
- EDX + WDX detector of company EDAX, which distinguishes oxygen, nitrogen and carbon;
- Pt cathode in the ZrO tube;
- Multimode STEM detector for analyzing thin layers.

Figure 1. Scanning electron microscope Karl Zeiss with EDX+WDX detector EDAX

Results and Discussion

It is well known that the presence of high heat particles in the steel structure leads to the refinement of austenite grain and improvement of the complex of material properties. In the case of formation of acicular ferrite structure high heat particles (titanium carbonitrides and aluminum nitrides in our case) are origination centers for acicular ferrite and have a decisive influence on the morphology (packet bainite or acicular ferrite) of bainite phase [3, 4]. At the same time such hard and brittle particles can be the sites of cracks during deformation. In some studies [5-7] there are given the data on the passivation of titanium carbonitride particles as origination centers of brittle fractures in the presence of acicular ferrite in the steel structure. At the same time in other studies [8, 9] titanium carbonitride particles are estimated as the main point of initiation of brittle fracture in the temperature range of tests from +10°C to -80°C.

Our conducted detailed studies of more than 40 particles of $Ti(C_x, N_{1-x})$ in steel Ст3+Al+Ti+N with the structure of acicular ferrite showed that the destruction of the particles themselves is not observed in contrast to the titanium carbonitride particles in X85 steel as shown in **Figure 2**.

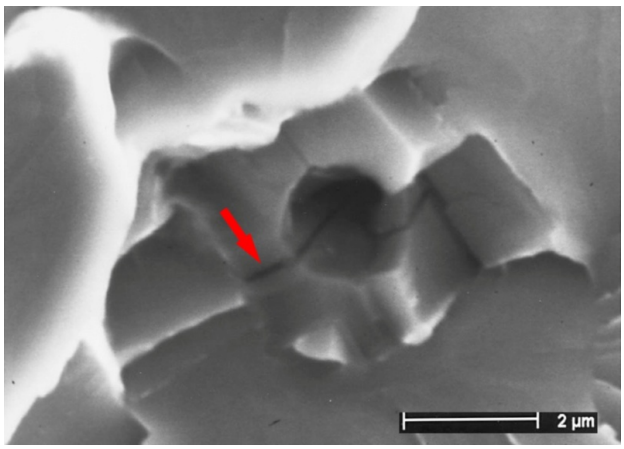
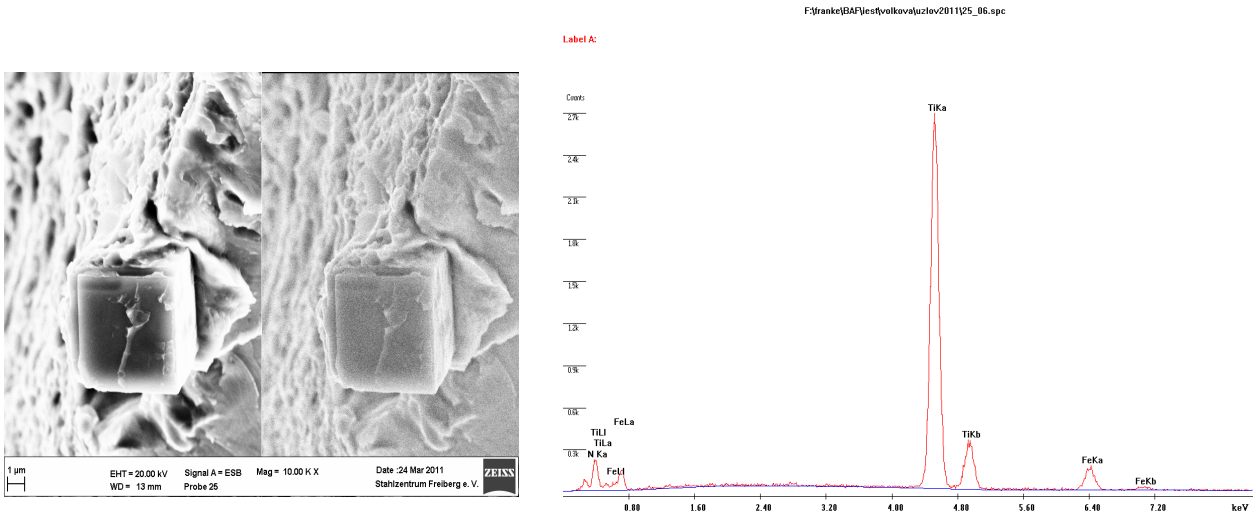


Figure 2. Particle TiN which is the origination center of a brittle crack, x 12000, [8]



a **b**

Figure 3. a) titanium carbonitride particle in the investigated steel with a fragment of the matrix on the surface, x 10,000, b) EDX spectrum of a given particle.

In the investigated steel the particles are sufficiently tightly bound to the matrix and spalling or cracking on the particles themselves are not observed (**Figure 3**).

Moreover, in many cases, the particles Ti(C_x, N_{1-x}) in the studied steel are surrounded by areas of ductile fracture, whereas in general there is mostly brittle fracture in the structure (**Figure 4**).

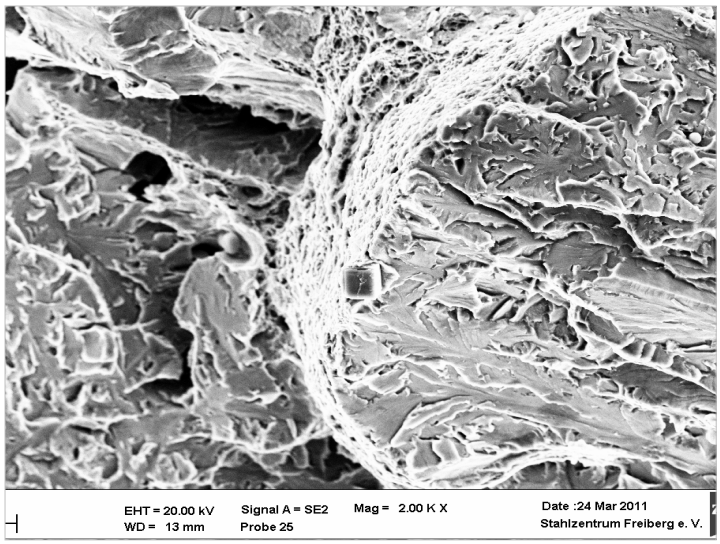


Figure 4. General view of fracture of the studied steel sample, SEM x 2000

This fact can obviously be connected to the chaotic orientation of the structure of acicular ferrite and local depletion of the matrix on carbon near the inclusions. According to the results of further research it will be possible to estimate more clearly. But even now the following conclusions can be made.

Conclusions

1. Particles Ti(C_x, N_{1-x}) in steel Ст3+Al+Ti+N with the structure of acicular ferrite show no tendency to spalling and separation from the matrix during destruction.

2. Particles Ti(C_x, N_{1-x}) in the investigated steel are not the origination centers of brittle fracture during the temperature range of tests from +20°C to -80°C.

3. The combination of heat treatment of steel Ст3 with its modification with non-deficient for Ukraine elements Al, Ti and N can provide inexpensive high-strength metal-roll with high toughness for the construction industry.

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Исследование влияния частиц $Ti(C_x, N_{1-x})$ на свойства строительных сталей

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В статье рассмотрены особенности влияния частиц карбонитрида титана на возникновение и развитие хрупких трещин при разрушении микролегированных сталей с различными системами легирования. Показаны возможные пути применения высокопрочного проката в строительстве.