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THE INFLUENCE OF MICRO COOLERS ON THE PHYSICAL-MECHANICAL CHARACTERISTICS OF THE STEELS USED IN MAKING RAILWAY MONOBLOCK WHEELS

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Original scientific paper

The paper introduces the possibilities of improving mechanical characteristics of the steels used in making railway monoblock wheels, by using micro coolers on steel casting. The laboratory experiments are aimed at studying the control of round cross-section steel ingot solidification by adding crystallization germs in their central area, in order to influence the internal structure and the mechanical characteristics of the steel. The stimulation of heterogeneous germination on the surfaces generated by the particles introduced in the center of the ingot, while it was in a liquid state, leads to the formation of a second solidification front and heat absorption in this area. The data we obtained during the research have been processed in Excel, in order to obtain the correlation equations that express the variation of the steel mechanical characteristics as a function of the chemical structure both for the experimental samples and for the reference ones.

Keywords: *improvement, micro coolers, physical-mechanical characteristics, railway monoblock wheels, steel*

Utjecaj mikro rashlađivača na fizkalno-mehaničke karakteristike čelika korištenih u izradi željezničkih monoblok kotača

Izvorni znanstveni članak

U radu se razmatraju mogućnosti poboljšanja mehaničkih svojstava čelika koji se koriste u izradi željezničkih kotača iz jednog bloka, korištenjem mikro rashlađivača kod lijevanja čelika. Cilj je laboratorijskih eksperimenata bio proučavanje skrućivanja čeličnih ingota kružnog presjeka dodavanjem kristalizacijskih klica u njihovo centralno područje kako bi se utjecalo na unutarnju strukturu i mehanička svojstva čelika. Stimulacija heterogenog klijanja na površinama, generiranog česticama umetnutima u središte ingota dok je bio u tekućem stanju, dovodi do stvaranja drugog ukrućenog sloja i apsorpcije topline u tom području. Podaci koje smo dobili tijekom istraživanja obrađeni su u Excelu da bi se dobile korelacijske jednadžbe kojima se izražavaju varijacije mehaničkih karakteristika čelika kao funkcije kemijske strukture za eksperimentalne kao i za referentne uzorke.

Ključne riječi: *poboljšanje, mikro rashlađivači, fizikalno-mehančke karakteristike, željeznički monoblok kotači, čelik*

1 Introduction

Railway monoblock wheels are subjected to particularly complex strains, so they have to meet highly exigent quality criteria both in terms of material and surface quality and dimensional accuracy. In the case of monoblock wheels, there are several materials that qualitatively correspond to the high quality carbon steels [1].

The values of the mechanical characteristics depend on the quality of the material. These characteristics can be improved by controlling the solidification of the steel cast into ingots meant for manufacturing monoblock wheels.

The basic problem that has to be solved when casting steel consists in obtaining ingots as homogeneous as possible chemically, structurally and mechanically. In order to dim out the flaws in ingot solidification in the case of classical casting, it is necessary to approach an efficient method of releasing the heat from the steel in the course of solidification [2]. A quick removal of heat is granted by the creation of an abrupt temperature gradient in the solidifying parts, as well as in the ingot liquid phase. In this case, besides the overheating temperature, the physical cooling temperature of the solidified steel will have to be transferred for the most part. In the case of casting circular cross section ingots meant for manufacturing monoblock wheels, as compared to the square cross section ones, (let aside the rectangular ones), for the same ingot cross section, the lateral surface of the round ingots is smaller than that of the square ones, so heat transfer is lower.

The intensity of the heat transfer in the process of liquid steel solidification influences the casting structure (the extension of solidification areas), the grain size, the segregation and through these, the mechanical characteristics. A particular importance during the solidification process, particularly in the case of the ingots under study, is to be given to the generation of crystallization germs into the mass of the steel, which also determines the control of the solidification process. The control of the crystalline structure can be achieved by means of the temperature gradient (considered to be a basic parameter) in the liquid phase neighbouring the ingot solidification front.

The research done upon the possibilities of controlling the solidification process, has brought forth the fact that the basic parameters are: the temperature gradient in the liquid and solid phases, the length of the bi-phasic zone, the kinetics of solid phase separation in the solidification interval as function of the balance diagram and the thermal-physical properties of the steel [3].

In order to control the solidification, we used the addition of micro-coolers in the form of metallic powder or grains, which reduce the temperature quotient and influence the circulation of the non-solidified steel. The use of micro-coolers leads to the reduction of shrinkage extent, of segregation, and to an improvement of the solidification structure and of the physical and mechanical characteristics.

2 Laboratory experiments

On the European Union railway network the steel grade most widely used is R7T [4], as it is non-alloyed, corresponding to the chemical composition of OLC 55, steel used in the laboratory experiments.

Taking into consideration the effects of micro-coolers, we carried out laboratory experiments aiming at improving the quality of the steel. Within these experiments, steel grade 1C55, according to SREN 10083-2, has been elaborated into a 10 kg induction furnace and was cast into circular cross section ingots of 2,5 kg each, and as micro-coolers we used grains obtained from steel wire having the diameter of 0,6 ÷ 1mm and 1 mm length.

Out of the four ingots cast on every charge, two were cast with micro-coolers and the other two without addition of micro-coolers (reference samples). We cast 12 charges in all. The addition of micro-coolers was of 1 ÷ 4 g/kg of cast steel. The introduction of micro-coolers into the steel in the mould (the cast steel) was done when the mould was filled 30 %, 60 % and 90 % in equal quantities. We established these filling levels taking into consideration the research on a local level as well as the works of reference literature [4 ÷ 8]. After having filled the moulds, the end of the ingot was covered with anti-shrinkage dust.

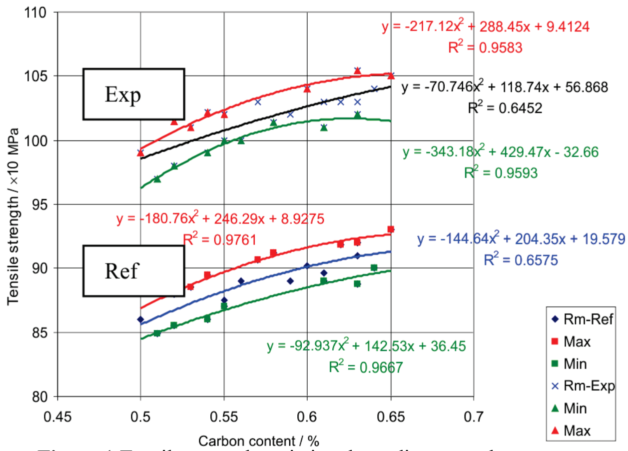

Figure 1 Tensile strength variation depending on carbon content

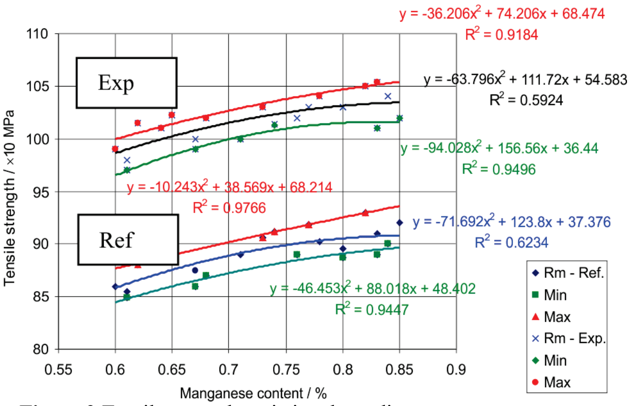

Figure 2 Tensile strength variation depending on manganese content

We sampled all the ingots that were cast, both those in which micro-coolers were used and those without micro-coolers (3 samples/semi-finished part, corresponding to the foot, the middle and the top of the ingot) in order to determine the physical-mechanical characteristics ($R_{p0,2}$ – yield strength, R_m,- tensile strength, KU - resilience).

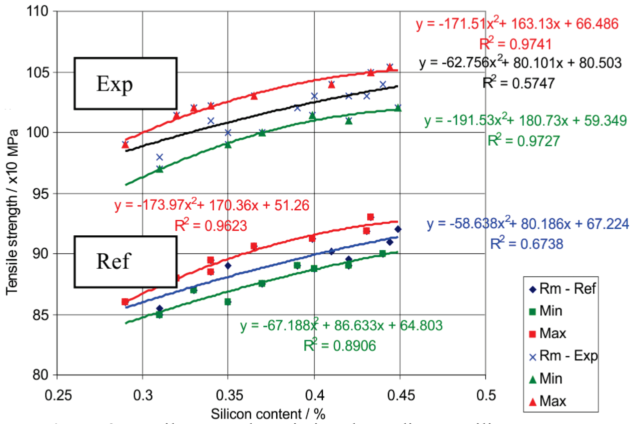

Figure 3 Tensile strength variation depending on silicon content

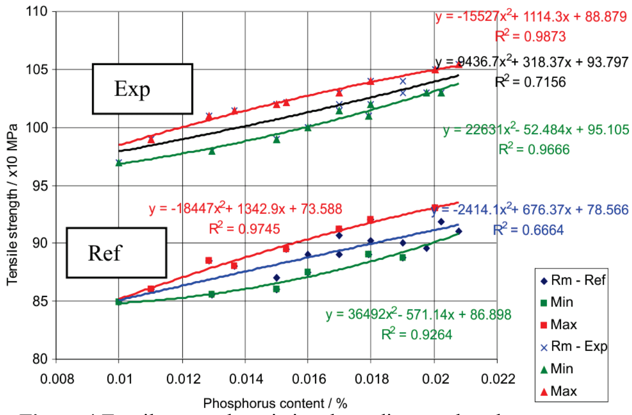

Figure 4 Tensile strength variation depending on phosphorus content

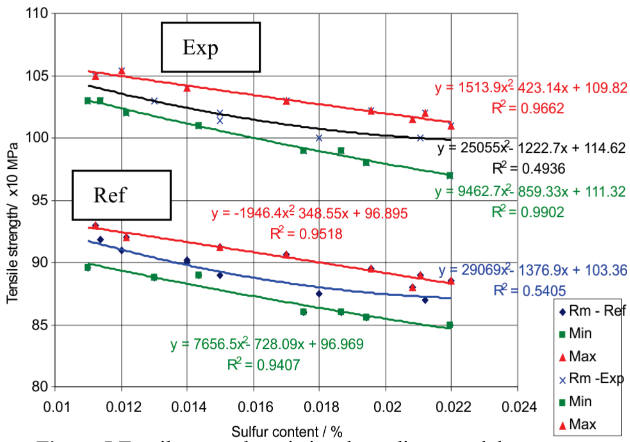

Figure 5 Tensile strength variation depending on sulphur content

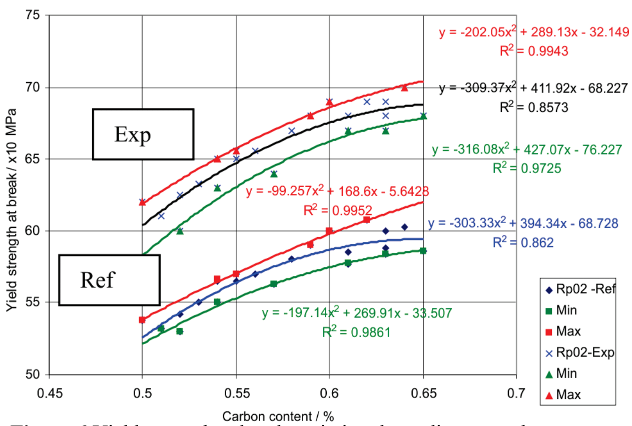

Figure 6 Yield strength at break variation depending on carbon content

The resulting data consisting in the mean values of the physical-mechanical characteristics were processed in

EXCEL, and we obtained both graphic and analytical correlations, which are shown in Figs. 1 ÷ 18. We presented the variations of the mechanical characteristics as function of the chemical composition for the experimental samples (Exp) alongside with the reference samples (Ref).

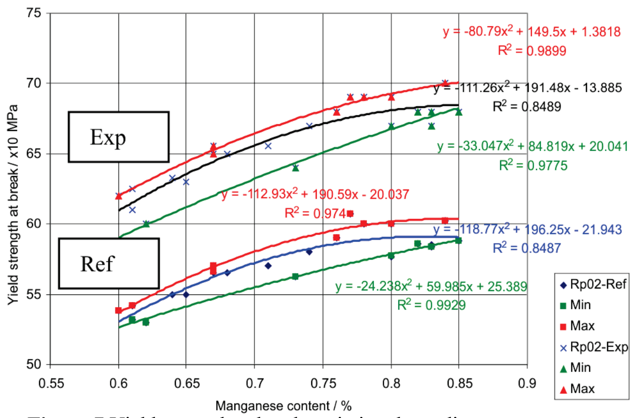

Figure 7 Yield strength at break variation depending on manganese content

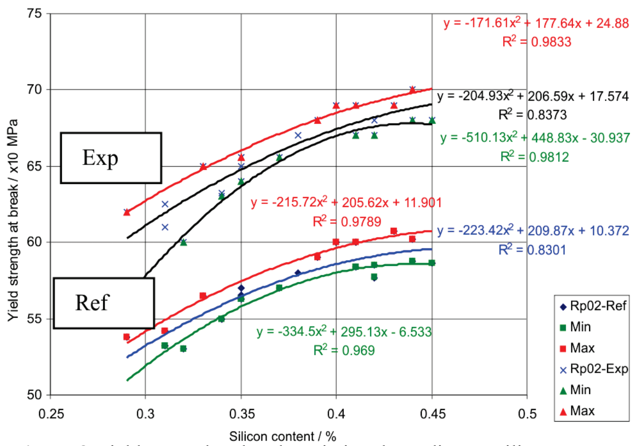

Figure 8 Yield strength at break variation depending on silicon content

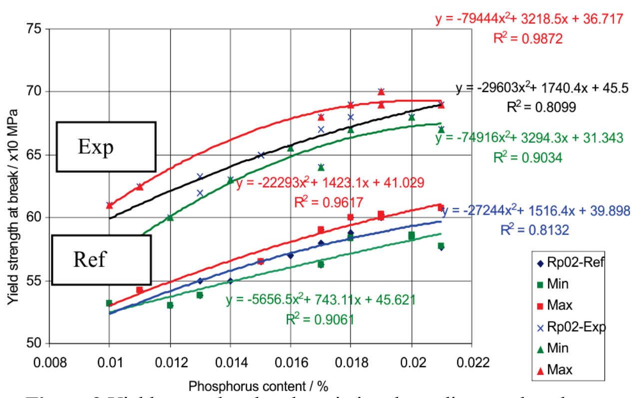

Figure 9 Yield strength at break variation depending on phosphorus content

The results of the research in graphical and analytical form prove the fact that the use of micro-coolers leads to an improvement of the physical-mechanical characteristics. The shape of the curves and the variation limits for the dependent parameters have the same tendency as in the reference samples.

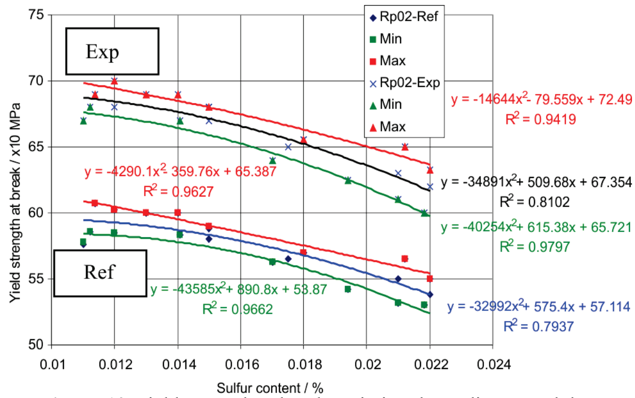

Figure 10 Yield strength at break variation depending on sulphur content

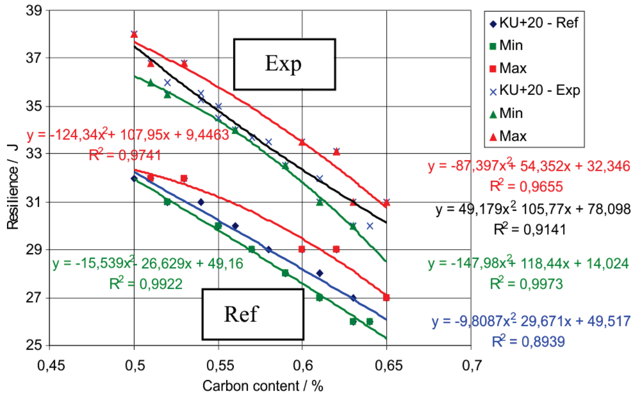

Figure11 Resilience at +20° variation depending on carbon content

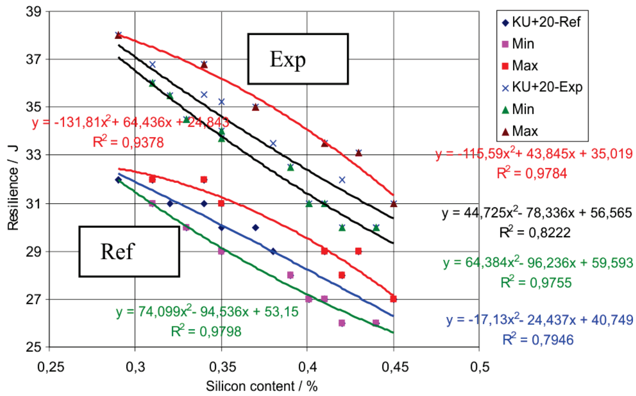

Figure12 Resilience at +20° variation depending on silicon content

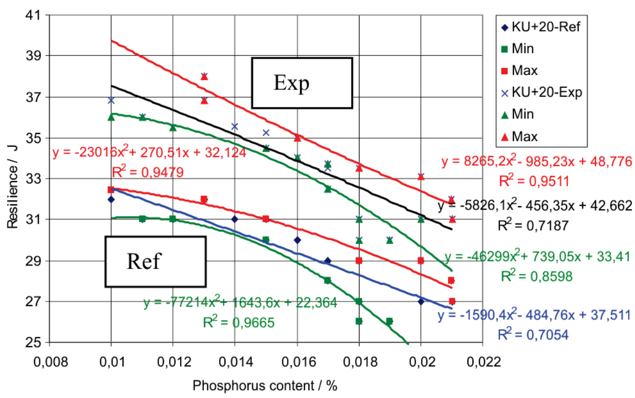

Figure 13 Resilience at +20° variation depending on phosphorus content

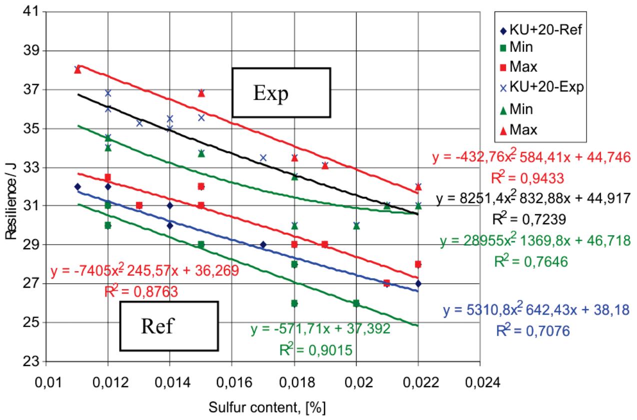

Figure 14 Resilience at +20° variation depending on sulphur content

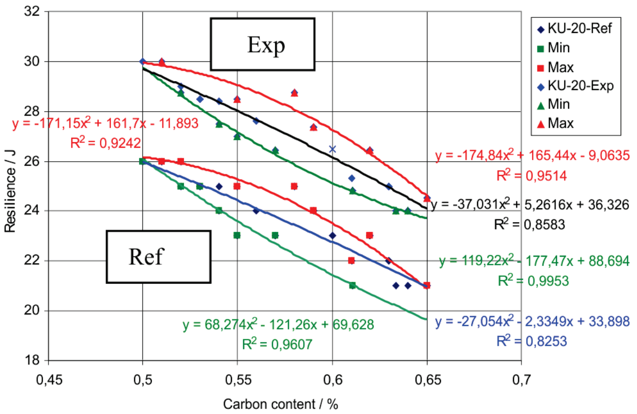

Figure 15 Resilience at –20° variation depending on carbon content

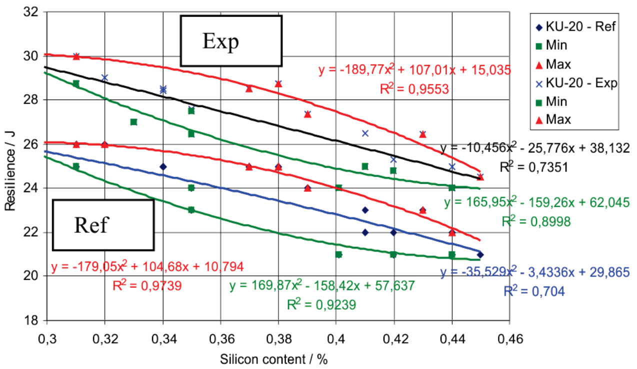

Figure 16 Resilience at –20 degrees variation depending on silicon content

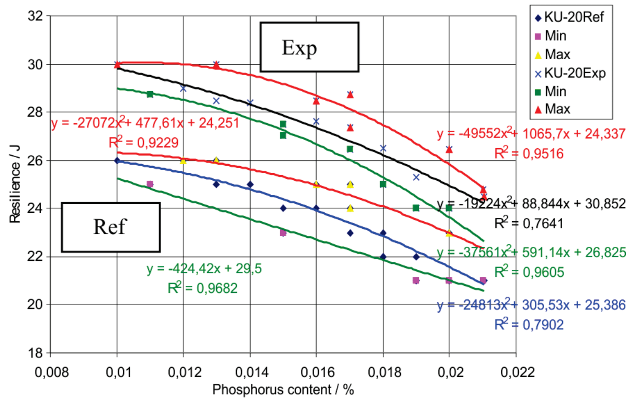

Figure 17 Resilience at –20° variation depending on phosphorus content

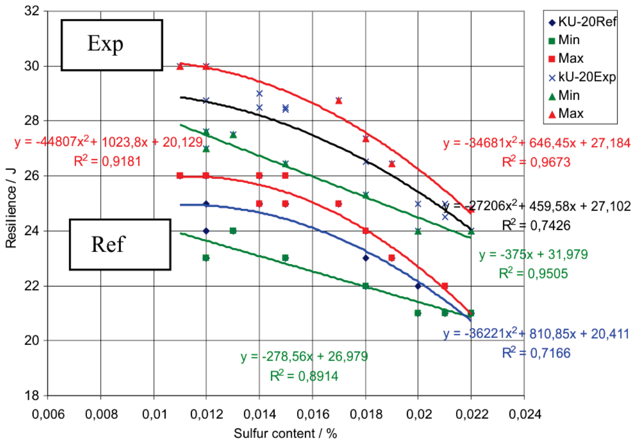

Figure 18 Resilience at –20° variation depending on sulphur content

Considering that in the case of railway monoblock wheels the chemical composition of the steel varies within very narrow limits, the addition of micro-coolers on steel casting improves the quality of the steel in terms of physical and mechanical characteristics, for the same chemical composition.

The use of micro-coolers in casting steel for railway use brings the physical-mechanical values of the steel within the variation domains required by the standard.

3 Conclusions

As a result of the experiments and after having processed the data, we have come to the following conclusions:

- the casting structure is finer in the ingots cast with addition of micro-coolers than in the classically cast ingots;
- an increase of metal strip by 1 ÷ 2 % for ingots cast with micro-coolers, as a result of the reduction of the shrinkage;
- an improvement of the resistance and plasticity values in the products resulting from ingots cast with micro-coolers, the increase ranging within 12 ÷ 18 %;
- on the basis of the results and correlations we obtained, we will continue the research in the sense of establishing the optimal addition of micro-coolers (g/kg) and their grain size.
- the correlations we have obtained allow the choice of an optimal grain size domain (mm) respectively the specific addition of micro-coolers (kg/t) in view of obtaining the desired values for the physical and mechanical characteristics.

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