

CARBON CONTENT INFLUENCE ON THE PERITECTIC REACTION PATH IN STAINLESS STEELS

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An important role for the peritectic reaction path in castings of stainless steel play small changes in a carbon content (e.g. from 0,02 to 0,06 % C), at maintaining constant chromium and nickel values. An influence of the carbon content on the peritectic reaction stages constitutes the subject of studies. The calculations of the steel solidification pathways in the four-component system, of a constant chromium and nickel content of 18 % and 9 % – respectively and of various carbon content from 0,01 to 0,06 %, were performed. It was proved by means of the PANDAT program that the carbon concentration increases the Cr segregation and thereby changes the solidification path under actual conditions.

Key words: peritectic reaction, stainless steel, carbon content, segregation, simulation of solidification.

INTRODUCTION

Investigations of the behaviour of the Fe-Cr18-Ni9 system during the peritectic reaction occurrence were performed by means of the PANDAT program. Regardless of several studies concerning the peritectic reaction [1 – 8] it is still a not well known effect. In order to understand better the processes occurring during this reaction several calculations of the system, allowing the visualisation of this change, were performed. This reaction is of an essential meaning in modern casting, since it is considered to be the cause of surface defects such as cracks and deformations, especially in thin casting walls. An occurrence of longitudinal cracks on casting surfaces is related to volumetric changes and fractions of ferrite and austenite phases, while transverse cracks to the formation of austenite grains [1]. The peritectic reaction [1 – 4] described many times, divides the peritectic change into three stages: the main reaction, phase transformation and solidification. Mechanisms of the reaction and transformation were characterised in detail by H. Kerr [4].

Investigations of the solidification of austenitic Fe-Cr-Ni steels will allow differentiating four solidification forms, which depend on the initial phase and on further transformations in the solid phase [5]. The total solidification of the regular face-centred cubic phase, fcc, is called the A type, while the AF type [6] starts the solidification process of the primary fcc phase, up to the final stage of the eutectic reaction (fcc + bcc).

The solidification period of the primary body-centred cubic phase, bcc, up to the end of the eutectic reaction (bcc + fcc) is called the FA type. The total solidification of the bcc phase is marked as the F type. The total

solidification of the regular face-centred cubic, fcc (A type), phase depends on nickel, which stabilises this phase, whereas in case of the regular body-centred cubic, bcc (F type), phase chromium is the stabilizing element. For the A and AF solidification types, at the primary solid phase growing, chromium contained in the alloy enriches interdendritic liquid causing an occurrence of the eutectic reaction (fcc + bcc) in the final solidification stage. The bcc phase is contained in the interdendritic zones of the formed eutectic in the retained, different morphology. For the FA and A solidification types the interdendritic liquid is enriched in nickel, which causes the eutectic reaction occurrence (bcc + fcc), and the formed microstructure consists of the bcc phase dendrites surrounded by the fcc phase [6].

EXPERIMENTAL PART

Calculations of the Fe-Cr-Ni system were performed for the constant chromium (18 %) and nickel (9 %) content, at the variable carbon content (from 0,01 to 0,06 %). The preformed examinations of the system were based on previous estimations made by Luoma [9], Hillert and Qiu [10] and Kundrad and Elliot [11]. The main aim of the investigations was the verification in what way a small carbon content influences the four-component system. The influence of chromium on the three-component Fe-Cr-Ni system in the peritectic reaction area is presented in Figure 1. This is the temperature range, specially considered in the paper.

From among several calculated systems – solidifying within the peritectic reaction temperature – the following temperatures were selected for the analysis: 1 515 °C, 1 500 °C, 1 490 °C, 1 480 °C and 1 475 °C. In the first of these temperatures: 1 515 °C, for lower carbon

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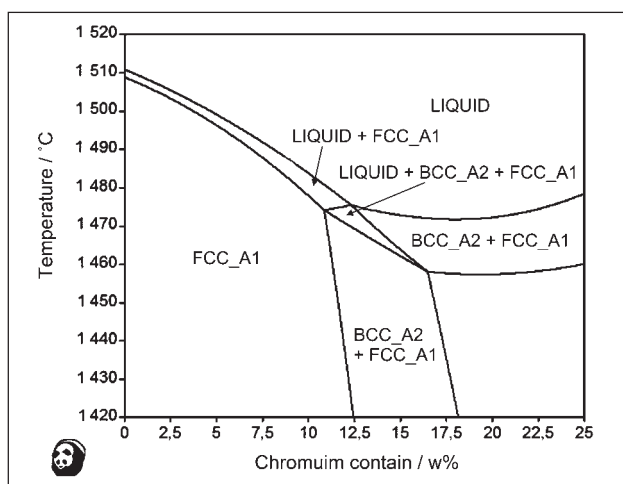


Figure 1 Influence of chromium content on solidification mode in Fe-Cr-Ni ternary system

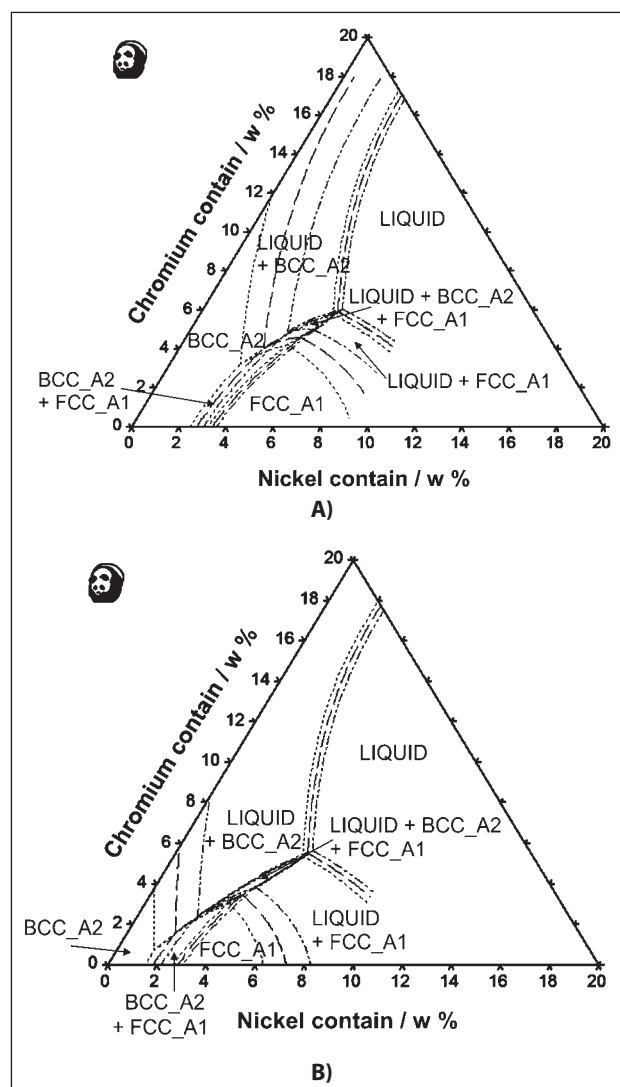


Figure 3 Solidification course in temperature 1 500 °C of Fe-Cr18-Ni9 system: A) 0,01 - 0,03 % C, B) 0,04 - 0,06 % C

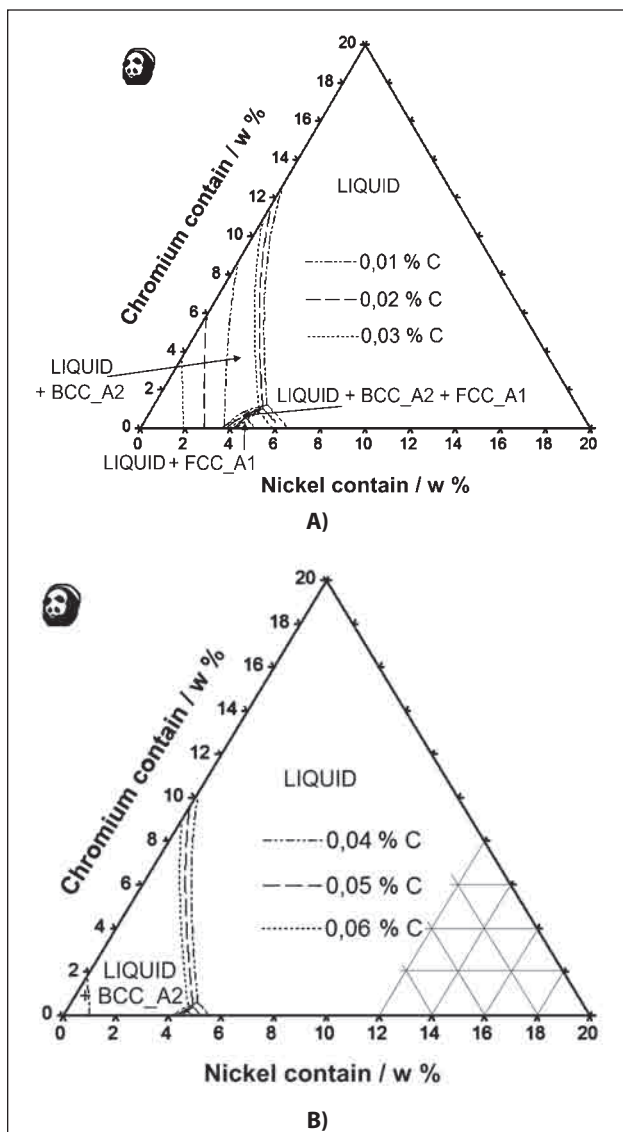


Figure 2 Solidification course in temperature 1 515 °C of Fe-Cr18-Ni9 system: A) 0,01 - 0,03 % C, B) 0,04 - 0,06 % C

content (Figure 2 A), the visible, initial area of three phases (LIQUID + BCC_A2 + FCC_A1), i.e. the peritectic reaction, occurs at 6 % of chromium and 4 % of nickel, while for higher carbon content (Figure 2 B) – at approximately 5 % of chromium and above 4 % of nickel.

In a lower temperature: 1 500 °C and for 0,01 – 0,03 % C (Figure 3 A), the peritectic reaction starts already at app. 11 % of chromium and 6% of nickel. However, lower carbon content the smaller BCC_A2 crystallisation area, which – in turn – decreases the peritectic reaction area (LIQUID + BCC_A2 + FCC_A1) and its further transformation. The three-phase area for 0,04 – 0,06 % C has a wider range, in a similar fashion as the transformation via the secondary FCC_A1 phase, while the high-temperature BCC_A2 range decreases (Figure 3 B).

A successive shifting to higher chromium concentrations occurs during the solidification at a temperature of 1 490°C (Figure 4 A and B). The three-phase area decreases, in an analogous way, with the decreasing carbon content in the system and with increasing the high-temperature is also visible at a temperature of 1 480 °C (Figure 5 A and B). The larger this area BCC_A2 phase,

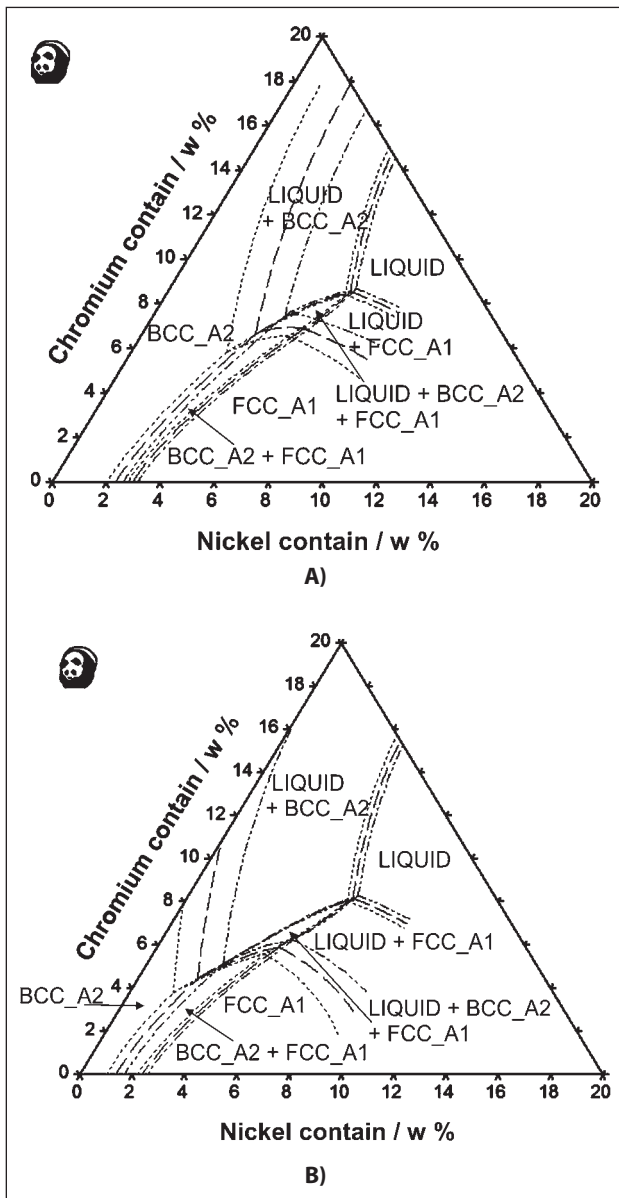


Figure 4 Solidification course in temperature 1490 °C of Fe-Cr18-Ni9 system: A) 0,01 - 0,03 % C, B) 0,04 - 0,06 % C

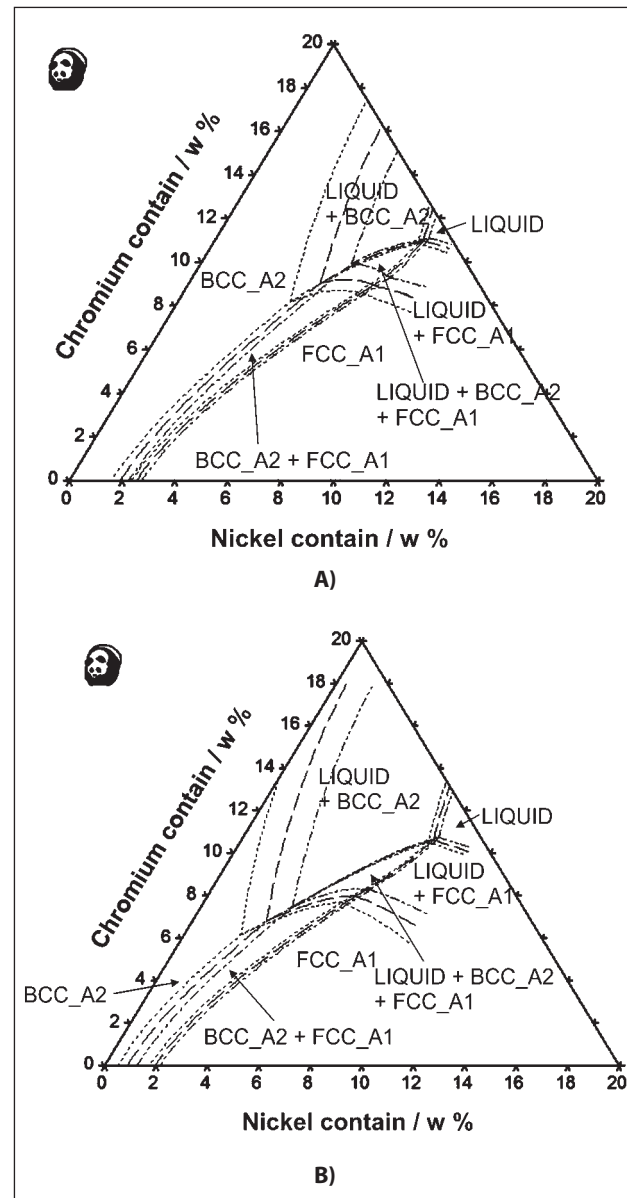


Figure 5 Solidification course in temperature 1480 °C of Fe-Cr18-Ni9 system: A) 0,01 - 0,03 % C, B) 0,04 - 0,06 % C

as a result of diffusion via the FCC_{A1} phase. This decrease causes that the alloy has worse corrosion resistant and strength properties, especially in case of castings of diversified wall thickness. It also leads to the increased segregation of carbon and chromium and to the formation of brittle phases, such as σ .

The change of the peritectic transformation area the smaller the high-temperature BCC_{A2} phase. The peritectic reaction area in Figure 5 A decreases and the FCC_{A1} phase crystallising from the LIQUID surrounds the primary BCC_{A2} phase. As a result of that, the LIQUID phase in the system disappears as a component of the peritectic reaction. Figure 5 B presents the area of two phases occurrence: LIQUID + BCC_{A2} for higher carbon concentrations. During the peritectic reaction the increased FCC_{A1} phase fraction causes the decrease of the high-temperature BCC_{A2} phase.

In a still lower temperature (1 475 °C), Figure 6 A, the LIQUID phase disappears and the areas of the LIQ-

UID + BCC_{A2} and LIQUID + FCC_{A1} occurrence decrease. Thus, the slow disappearance of the three-phase peritectic reaction takes place. However, the diffusion of carbon still occurs in the FCC_{A1} phase and due to it, the three-phase peritectic area, but much smaller in size, still occurs in liquid containing from 0,04 % to 0,06 % of carbon (Figure 6 B). It can be noticed, that at 0,06 % of the carbon content the BCC_{A2} area narrows to below 1 % of chromium and 1 % of nickel. This is the reason that after the finished crystallization this phase is – in the alloy microstructure – in the retained form only. The content of components stabilizing ferrite and austenite in the alloy decides on its size.

CONCLUSIONS

The peritectic reaction occurring in the Fe-Cr-Ni alloy is of a special meaning for the final microstructure

and properties of cast steels. Several strength and corrosion resistant properties depend on its pathway. This reaction mainly depends on the alloying elements content and also – as it was shown in the presented here study – on the carbon content. It is worth emphasizing that such strong influence, on the three-phase area of the peritectic reaction and its further transformation, is exerted by such small differences in the carbon content (calculations were performed every 0,01 % of C). It was noticed, that the higher carbon content the wider area of the peritectic reaction occurrence. However, the following transformation of the BCC_A2 phase into FCC_A1 increases its range. Unfortunately the BCC_A2 phase amount after the alloy solidification depends on the peritectic reaction range. The BCC_A2 phase is very important due to its influence on corrosion resistance properties and formation of brittle phases.

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Note: The responsible translator for English language: “ANGOS” Translation Office, Kraków, Poland

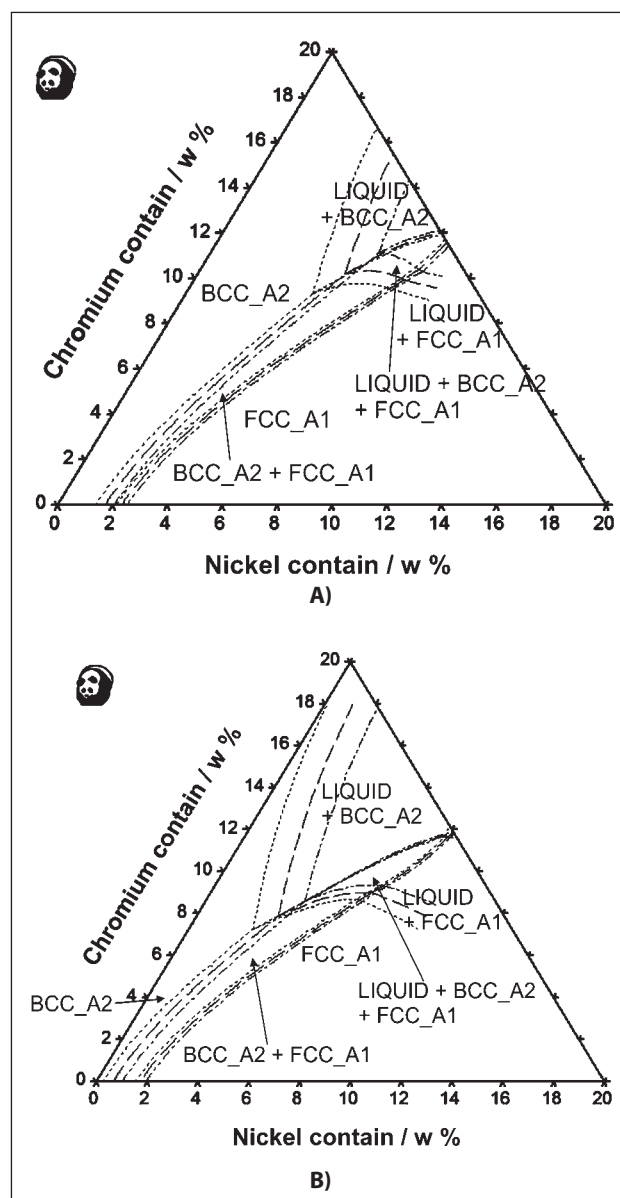


Figure 6 Solidification course in temperature 1475 °C of Fe-Cr18-Ni9 system: A) 0,01 - 0,03 % C, B) 0,04 - 0,06 % C