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# Characteristics of centrifugally cast GX25CrNiSi18-9 steel

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## Abstract

The paper presents the results of microstructural examinations of the industrial heat-resistant centrifugally cast GX25CrNiSi18-9 steel characterised by increased content of Cu. The study included changes in the microstructure of base cast steel respective of the steel held at a temperature of 900 and 950°C for 48 hours. Based on the results obtained, an increase in microhardness of the examined cast steel matrix with increasing temperature was stated, which was probably caused by fine precipitates enriched in Cr, Mo, and C forming inside the matrix grains.

The layer of scale formed on the tested cast steel oxidised in the atmosphere of air at 900 and 950°C was characterised by an increased tendency to degradation with increasing temperature of the conducted tests.

**Keywords**: Metallography, Heat resistance 18Cr-9Ni cast steel, Microstructure,

## 1. Introduction

Cast austenitic GX25CrNiSi18-9 steel belongs to the group of heat-resistant steels used for castings operating at temperatures of up to 900°C in an oxidising environment, and up to 700°C in a reducing environment containing sulphur compounds [1÷4]. It is used, among others, for heat recuperators, muffles, tubes and stacks. This cast steel is the starting material for the development of many other heat- and creep-resistant alloys based on different Cr/Ni ratios. Introducing to these materials, besides Cr and Ni, also the additions of elements like Ti or Nb increases the creep resistance of the Cr-Ni cast steel, while Cu as an alloying addition, whose maximum solubility in $Fe_\gamma$ is approximately 9% (at 1094°C), improves the resistance to atmospheric corrosion, and at a level of 3÷4% increases the resistance of high-alloyed Cr-Ni cast steel to the effect of HCl, $H_2SO_4$ and $H_2PO_4$. Additionally, Cu in these materials "strengthens" the effect of Ni [5,6].

Cast GX25CrNiSi18-9 steel is relatively rarely used for the centrifugally cast tubes. Therefore, metallographic examinations were carried out on the material when cast under industrial conditions.

## 2. Methods investigation

The object of this study was tube centrifugally cast from the heat-resistant GX25CrNiSi18-9 steel (Table 1). From the tube wall of 24mm thickness, specimens were cut out for microstructural examinations in as-cast state and after holding at 900 and 950°C for 48 hours. The specimens were oxidised for 24 hours at a maximum operating temperature of this material.

Metallographic studies were performed on polished sections etched in the Mi15Fe reagent. Microstructure was examined under a scanning electron microscope and light microscope. The chemical composition of the matrix and of the detected precipitates was determined by X-ray microanalysis. The scale was analysed under the scanning electron microscope equipped with an EDS system for X-ray microanalysis made by IXRF. For microhardness measurements, a light microscope Neophot 32 and Hanemann's attachment were used.

Based on the results of the chemical analysis of the investigated cast heat-resistant steel, it was showed that as regards the Cu content this cast steel grade does not correspond to the steel 1.4825 according to Polish Standard PN-EN 10295.

Table 1.
Chemical composition of the examined cast steel

| Cast steel type (PN-EN 10295)/ designation | Chemical composition, wt% | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | Si | Mn | Cr | Ni | Mo | P | S | Cu | Nb | other |
| GX25CrNiSi18-9 [1] | 0,15<br>0,35 | 0,5<br>2,5 | max<br>2,0 | 17,0<br>19,0 | 8,0<br>10,0 | max<br>0,5 | max<br>0,04 | 0,03 | max<br>0,25 | max<br>0,6 | 0,12V<br>1,0Co |
| A | 0,26 | 0,9 | 1,60 | 19,8 | 8,6 | 0,2 | 0,005 | 0,017 | 1,22 | 0,06 | 0,03V<br>0,17Co |

# 3. Results and discussion

Centrifugally cast steel tubes retain the typical casting macrostructure composed of chill grains, both columnar and equiaxial (Fig. 1). In as-cast state, the equiaxial grains occupy about 2/3 of the tube wall cross-section.

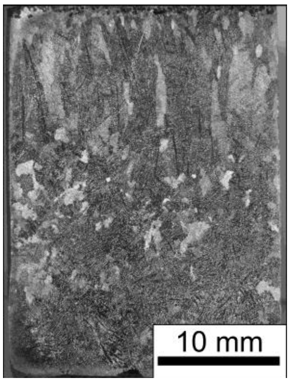



Fig. 1. Macrostructure of the examined casting wall

The tested cast GX25CrNiSi18-9 steel was characterised by an austenitic structure, the microhardness of which in as-delivered state was $219 \div 226 \mu HV_{20}$. After holding at 900°C for 48 hours, the microstructure showed the presence of precipitates rich in Cr, Mo and C, occurring mainly at grain boundaries (Fig. 2b, 3). Raising the temperature of holding to 950°C additionally led to the formation of fine precipitates inside the grains (Fig. 2c, 4). As in the case of precipitates observed at grain boundaries, also these precipitates showed enrichment in Cr, Mo and C (Fig. 5, 6). The analysis of chemical composition of both the matrix and precipitates in as-cast state and after holding at 900 and 950°C showed the presence of Cu only in the alloy matrix because, like nickel, copper also belongs to the elements dissolving in austenite.

a)

b)

c)

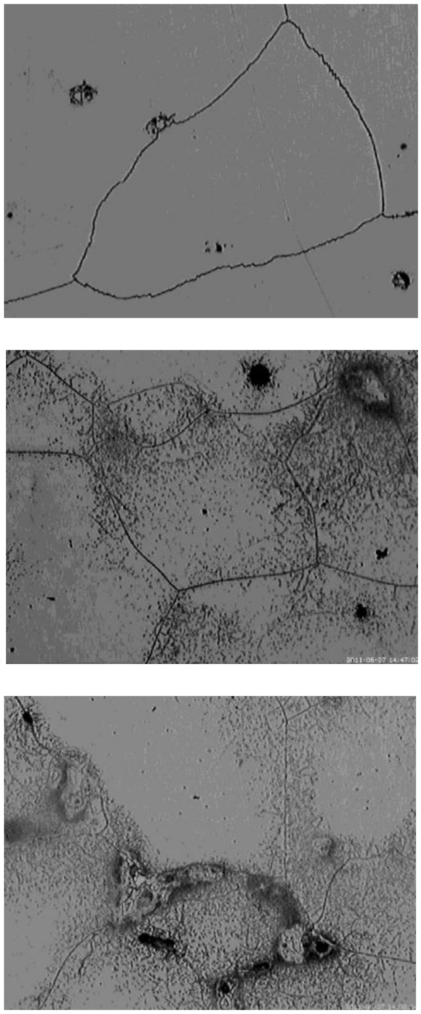
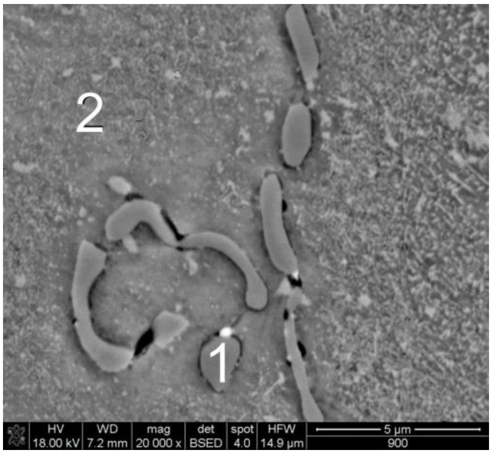


Fig. 2. Microstructure of GX25CrNiSi18-9 steel in base state - a), after holding for 48 hours at 900°C – b), after holding for 48 hours at 950°C – c), magnification of 1000x

Matrix microhardness in samples held at 900 and 950°C for 48 hours was comparable. Its values ranged from 253÷261$\mu HV_{20}$ and were higher by about 35$\mu HV_{20}$ than the hardness of the matrix in as-cast samples.

On the other hand, the results of microhardness measurements at the grain boundaries in samples held at a temperature of 900°C averaged 266$\mu HV_{20}$, thus showing an increase by about 10÷15$\mu HV_{20}$ compared to the matrix. The values of microhardness at the grain boundaries in samples held at a temperature of 950°C were still higher and amounted to 280÷295$\mu HV_{20}$. Compared with the matrix, an increase by 23÷38$\mu HV_{20}$ was achieved. For this increase of microhardness in the areas adjacent to grain boundaries are most probably responsible the precipitates rich in Cr, Mo, and C.

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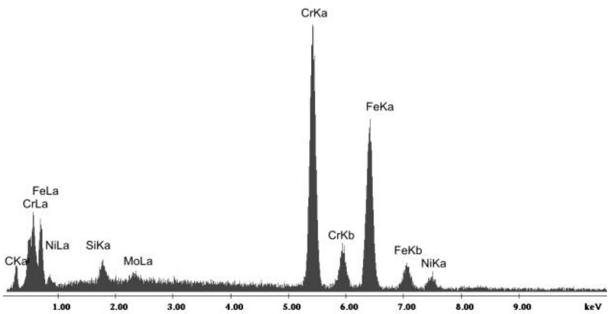


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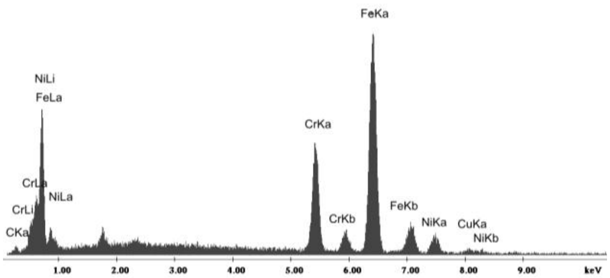
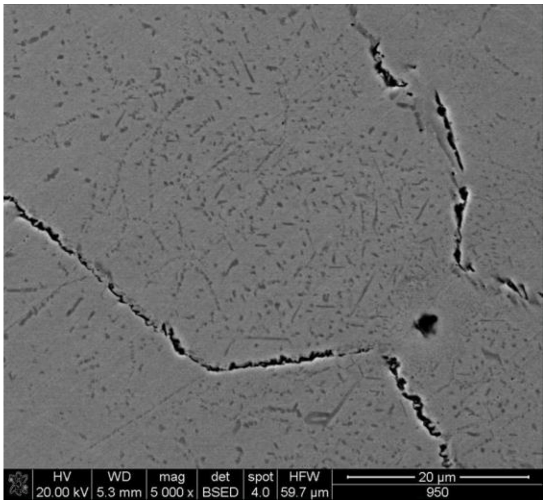
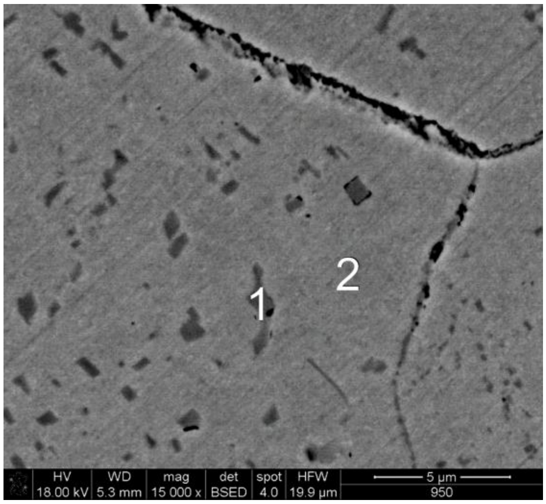



c)

Fig. 3. Microstructure of cast GX25CrNiSi18-9 after holding for 48 hours at 900°C – a) and energy dispersive X-ray spectra (EDS) of the precipitates 1 – b) and matrix in the examined cast steel – c)




a)




b)

Fig. 4. Microstructure of cast GX25CrNiSi18-9 after holding for 48 hours at 900°C, SEM

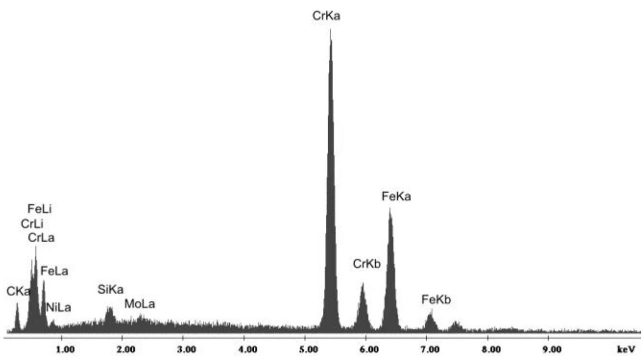



Fig. 5. Energy dispersive X-ray spectrum (EDS) of the examined cast steel matrix shown in Fig. 4b

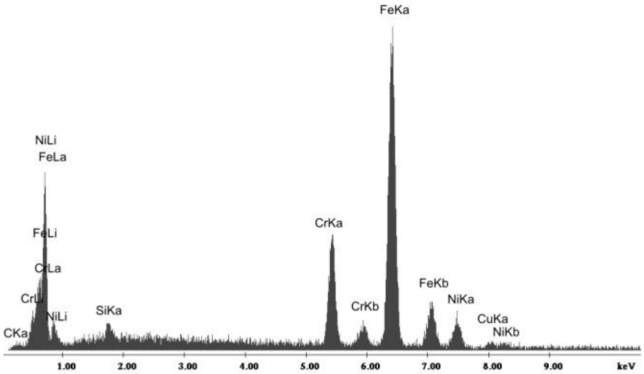



Fig. 6. Example of energy dispersive X-ray spectra (EDS) of the precipitates shown in Fig.4b

Examples of scale formed on the surface of the cast GX25CrNiSi18-9 steel after holding at 900 and 950°C for 48 hours and oxidation for the next 24 hours are shown in Fig. 7÷8. It was found that with increasing temperature of oxidation the scale formed on the tested material was characterised by stronger tendency to detachment from the metallic core [4, 7, 8].

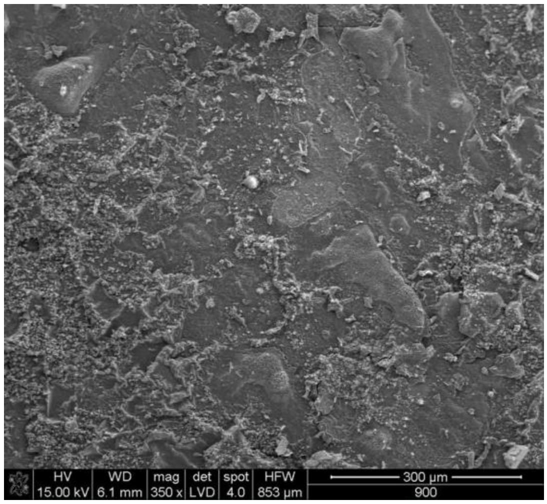
The scale formed on the sample oxidised at 900°C is heterogeneous. In its structure one can distinguish areas with well-developed crystalline forms (Fig. 7b) and areas of less-developed surface, which are covered with crystals in the form of pyramids visible at a magnification of about 10000x (Fig. 7d). Analysis of the areas with crystalline forms shows their enrichment in Cr, Mn and O (Fig. 7c), while other areas are rich in Fe (Fig. 7e).

The scale formed on the sample surface oxidised at 950°C suffered almost complete degradation and numerous cracks were observed (Fig. 8a, d, f).

On the surface of the examined sample, the characteristic zones can be distinguished:

- with the remaining scale of different morphology (Fig. 8a, b),
- free from the products of high-temperature corrosion (Fig. 8d).

The scale remaining on the metallic core had a relatively compact structure with numerous crystalline forms on the surface. The conducted chemical analysis revealed the presence of elements such as Cr, Fe and O (Fig. 8f, g). Moreover, in some of these precipitates, the presence of Mn was also detected (Fig. 8b, c). Analysis of the areas free from the precipitates allowed stating that, like the crystalline forms, they were rich in Cr, Fe, Mn and O, and additionally also in Ni and Si (Fig. 8d, e).

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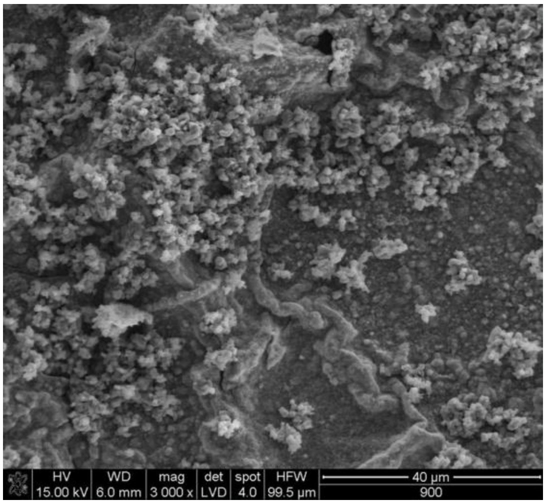


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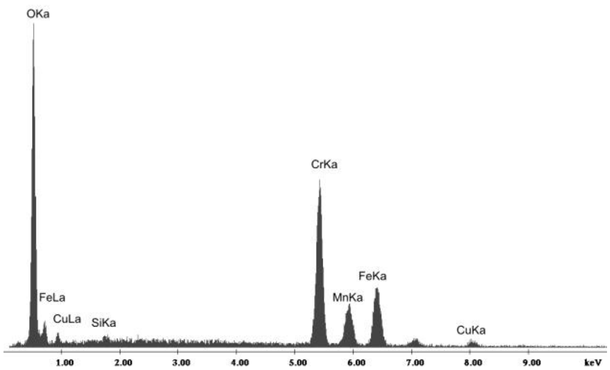


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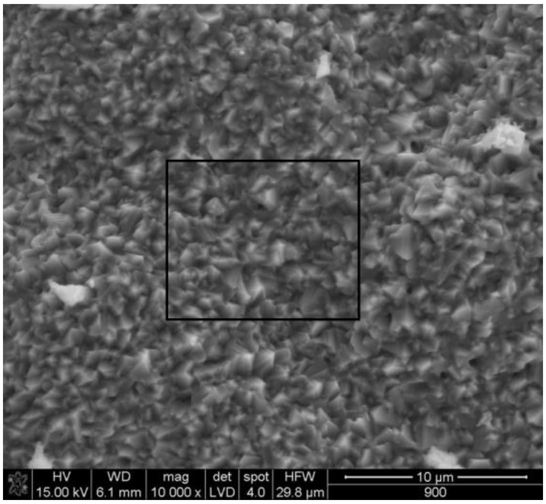


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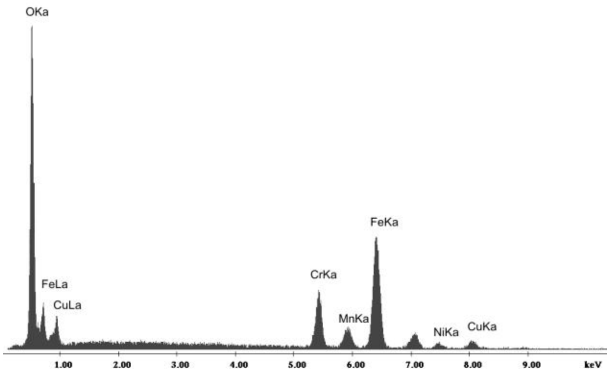
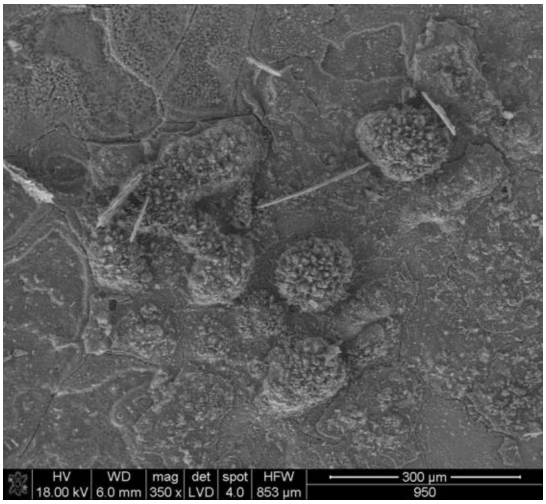



e)

Fig. 7. Surface condition of the examined steel after oxidation at 900°C for 24 hours with the energy dispersive X-ray spectra (EDS) of the examined areas

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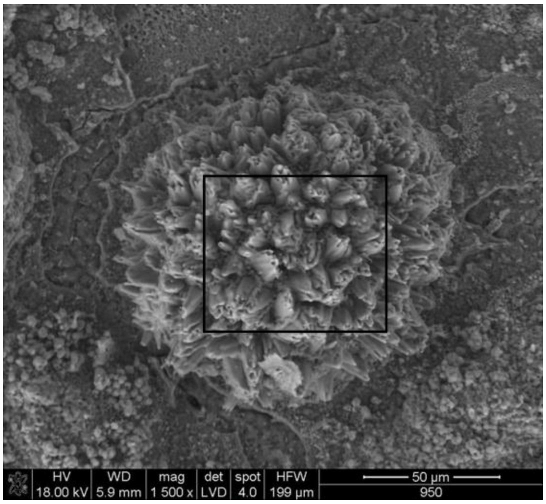


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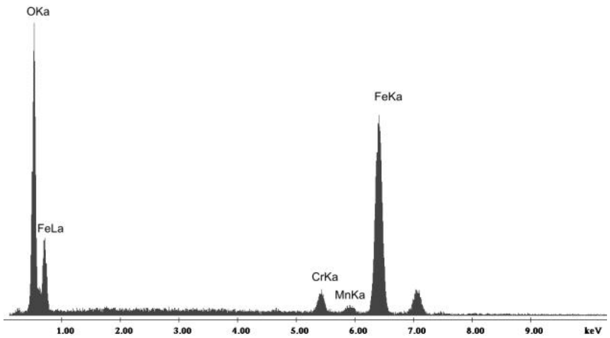


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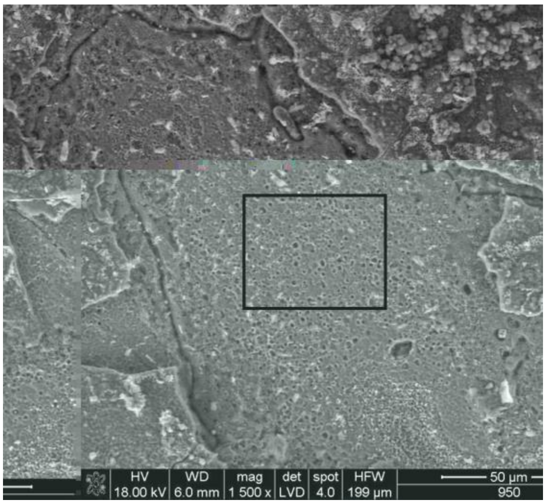


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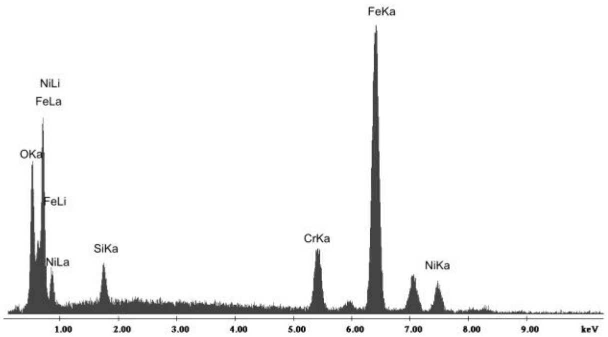


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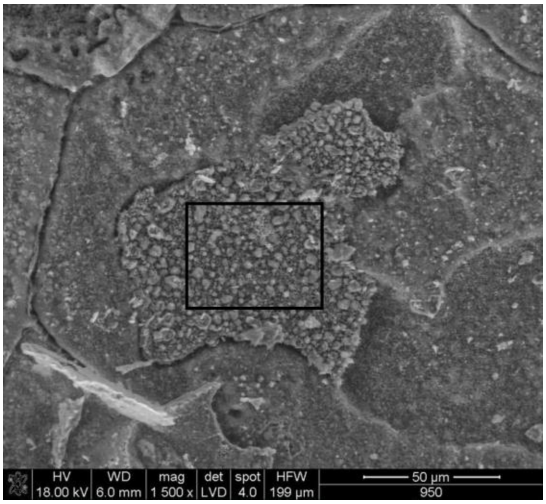
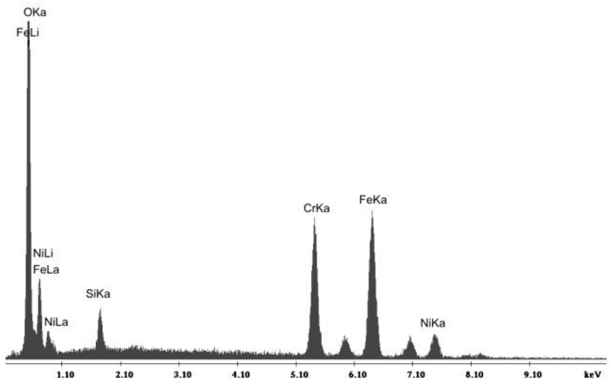



f)




g)

Fig. 8. Surface condition of the examined steel after oxidation at 950°C for 24 hours with the energy dispersive X-ray spectra (EDS) of the examined areas

# 4. Conclusions

- In starting condition, the examined cast GX25CrNiSi18-9 steel is characterised by austenitic matrix with microhardness of 219÷226 $\mu HV_{20}$.
- Holding of the examined cast steel at 900 and 950°C for 48 hours promotes the precipitation of fine-grained phases enriched in respect of the matrix in Cr, Mo and C. They mainly occur at the grain boundaries and in their neighbourhood.
- The scale formed on the examined cast steel held at 950°C shows numerous cracks and voids compared to the scale formed at 900°C.

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