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The change of NiCrBSi alloys' phase composition after plasma spraying

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Abstract

Material for investigations was NiCrBSi powder for components' coatings which improve their corrosion resistance as well as resistance to friction wear and erosion. Plasma spraying method was used to produce a coating with thickness of 300 μm on low-alloy steel which was then remelted with the base material. Using X-ray quality analysis, phase composition was determined for: NiCrBSi powder, obtained coating and the alloyed surface layer. Crystallinity degree was also calculated for NiCrBSi layer sprayed on the base material.

Keywords: Theory of crystallization, Solidification process, Crystallinity degree

1. Introduction

Advances in investigations and preparation of materials with improved properties are mainly stimulated by their further applications [1-5]. More modern and more complex materials are still being constituted [6-9].

Materials, whose application is more and more popular through combination of exceptional properties, include coatings used e.g. in conditions of intensive wear or interaction of corrosion agents [10-17].

Heat spraying (natryskiwanie cieplne) is one of the methods which is gaining on interest; it consists in producing, on the surface of a component, a layer with properties different than the coated material. Process of applying of various types of coatings is performed by means of a special torch which is used to melt and spray materials in the form of a powder [7]. During plasma spraying the particles of material are ejected from the torch with high speed and settle on the surface of the element and on each other while creating the layer. Process of creation of the coating is composed of three stages: collision of the sprayed particles with base material, binding of the sprayed particles and creation of a coating structure [1].

Sprayed coatings are characterized by lower adhesion to base material, high level of porosity and low cohesion. One of the options for improvement of these properties is application of modern tools, such as concentrated sources of energy (laser, plasma). Produced coatings are then remelted, where, as a result of their renewed crystallization, the constitution of the whole surface layer occurs in the processed material.

Bearing in mind all applications connected with chemical, petrochemical industries, civil engineering and automotive industry, many metallic material compositions on the basis of Ni have been of interest to many domestic and foreign research centres [10-17].

The purpose of the investigations was to determine phase composition of: NiCrBSi powder, the coating produced by means of plasma spraying and the alloyed surface layer which was created as a result of remelting of the coating with metal base.

2. Materials and methodology

Material used for investigations was NiCrBSi powder obtained by mechanical method of spraying from liquid phase. This material is used for coating of components while ensuring their resistance to corrosion, friction wear and erosion. Chemical composition of the powder used for investigations is presented in Tab. 1.

Table 1.
Chemical composition in wt. % NiCrBSi

Fe	Cr	B	Si	Ni
3.43	14.13	3.26	3.91	rest

On the surface of the samples made of 40Cr4 low-alloy steel with dimensions of 70x20x5 mm by means of plasma spraying, CrNiBSi coating with thickness of 300 μm was produced.

Next stage of the investigations was remelting of CrNiBSi coating with base materials – alloying. The process of alloying consists in remelting-based saturation of surface layer with alloy components which were partly or entirely soluble in base material as a result of impact of concentrated source of energy (laser, plasma) [7]. The alloying was performed by means of plasma arc with the following parameters: current intensity: 90-120A, torch movement: 460 mm/min.

Microstructure investigations were performed by means of Neophot 23 optical microscope and JEOL JSM 5400 scanning microscope.

X-ray quality analysis was performed in order to reveal phase changes of: NiCrBSi powder, coating after spraying and the layer after remelting. Investigations of phase composition were performed by means of Seifert XRD 3003 X-ray diffractometer using radiation of $\lambda_{CoK\alpha}$=0,17902 nm. Parameters of diffractometer operation were as following:

- power supply 40 kV
- current 30 mA.

Measuring step of 0.2^{o} and impulse count time of 10s.

3. Results

The investigations performed by means of optical microscope enabled determination of the size and shape of powder particles. The grains of the investigated powder were of spheroid shape and average particle diameter of about 50μm (Fig.1).

Microstructure of the sprayed NiCrBSi coating and the alloyed surface layer was presented in Fig. 2 and 3, respectively. The results of X-ray phase analysis were presented in the form of diffractograms in Fig. 4-6.

Diffraction of initial powder showed presence of peaks coming from nickel and chromium. Moreover, the presence of CrB, Ni_3B, Cr_3Si, NiSi phases (Fig. 4) was revealed.

Shape of the diffractogram presented in Fig. 5 proves presence, in the sprayed coating, of two phases: crystalline (Ni) and amorphous. Creation of amorphous phase should be explained by the fact of fast cooling of the remelted mass of powder, i.e. rapid reduction in temperature, which prevented occurrence of the process of total crystallization. The metallic glass appears in such cases; it is the frozen liquid and is characterized by lack of further order of atoms.

In order to determine crystallinity degree in the coating, the obtained diffractogram of the coating was then subject to numerical processing, which consisted in:

- background trimming,
- smoothing,
- separation of peaks from crystalline phase and wide-angle peak from amorphous phase,
- determination of the crystallinity degree.

To separate each peak, the Pearsons VII mathematical function was employed.

Assuming that X-ray radiation intensity in the crystalline areas is proportional to crystalline phase mass share, and diffusion scattered radiation intensity is proportional to amorphous phase mass share, crystallinity degree can be determined using dependence proposed by Wunderlich (1) [5]:

$$S_K = \frac{\sum I_{kryst}}{k * I_{amorf} + \sum I_{kryst}} \quad (1)$$

where:

$\sum I_{kryst}$ - total of integral intensities of the radiation in crystalline areas,

I_{amorf} - integral intensity of diffusion scattered radiation in amorphous areas,

k - proportionality coefficient

X- ray quantitative analysis revealed 38% participation of cristalline phase in the coating obtained as a result of plasma spraying.

X ray qualitative analysis of surface layer (Fig. 6) obtained by remelting (alloying) of the coating with steel base revealed presence of CrFeNi phase with regular cell and the following parameters: a=b=c=0.3591 nm, $\alpha=\beta=\gamma=90^{0}$.

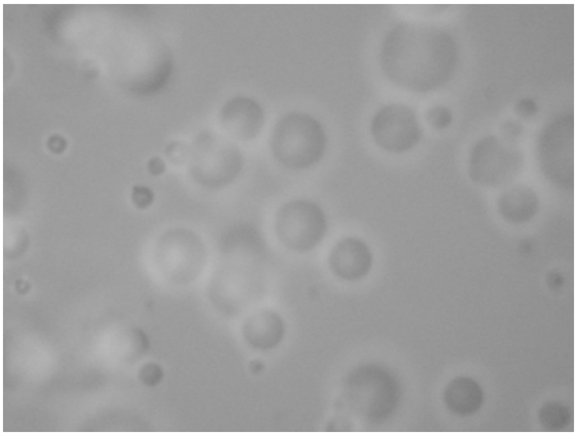

Fig. 1. Shape of particles of NiCrBSi powder, optical microscope, magn. 500x

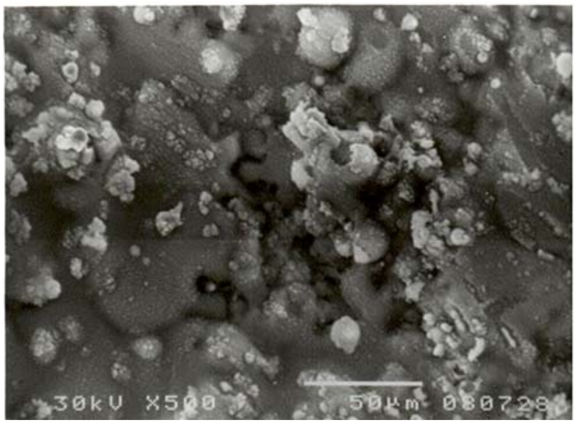

Fig. 2. Microstructure of the sprayed coating

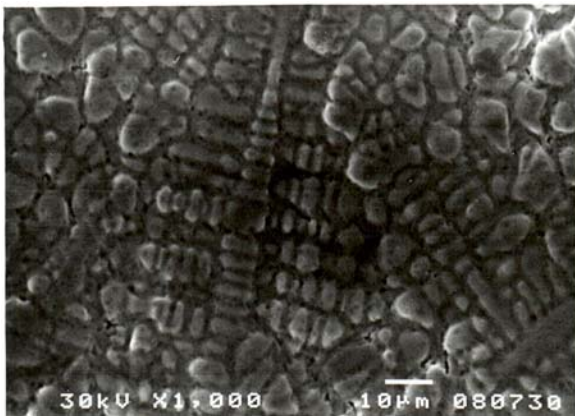

Fig. 3. Microstructure of the remelted surface layer

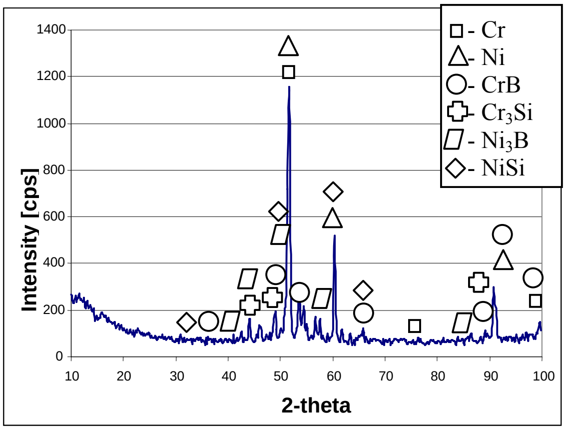

Fig. 4. X-ray diffractogram of NiCrBSi powder

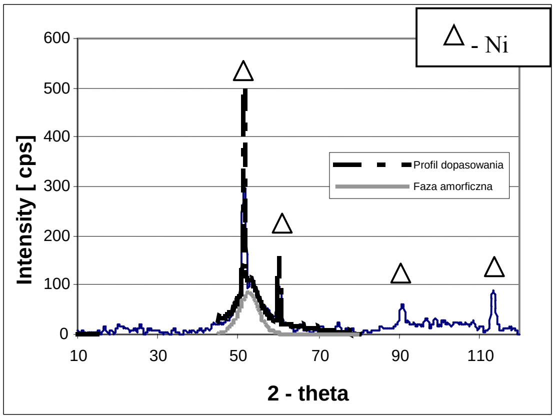

Fig. 5. X-ray diffractogram, sprayed coatings

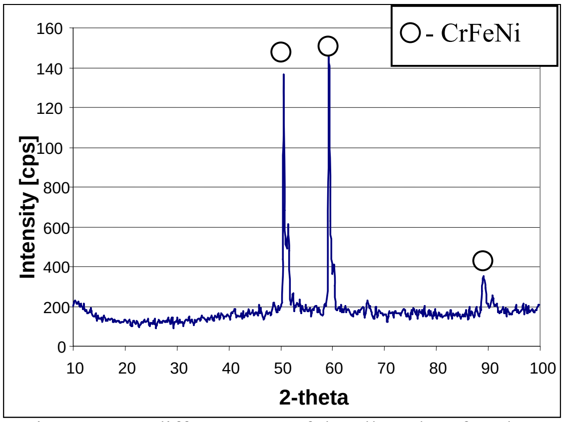

Fig. 6. X-ray diffractogram of the alloyed surface layer

4. Conclusions

The purpose of the performed investigations was analysis of phase composition:

- NiCrBSi powder,
- coating obtained by the method of plasma spraying,

– the alloyed surface layer obtained as a result of coating remelted with base material.

X-ray qualitative analysis has revealed the presence of the following phases in the investigated powder: CrB, Cr_3Si, Ni_3B, NiSi and Cr and Ni.

In the coating obtained through plasma spraying of NiCrBSi powder, the presence of amorphous phase has been observed; it was created as a result of high cooling rate for the remelted particles. X-ray quantitative analysis has revealed 38% level of crystallinity in the sprayed coating.

Analysis of the alloyed surface layer has revealed presence of CrFeNi phase.

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