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Structure of detonation sprayed coatings of composite aluminium-oxide powders Al-Me_xO_y

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The material and technological conception of the production of composite coatings with aluminium strengthened by oxide particles as well as the production of intermetallic phases from the Al-Me systems is presented. The composite powders of aluminium with oxides: Fe_2O_3, Ni_2O_3, Cr_2O_3 were formed by mechanical alloying in a vibratory mill. The coatings were detonation sprayed with a mixture of propane and oxygen at different technological parameters. To form composite coatings, SHS synthesis in a stream of reactive gases was used. The structure of coatings was analysed by means of light and scanning microscopy methods and by X-ray diffraction. Under high pressure of gases, the occurrence of dispersive intermetallic phases and aluminium oxide was found. The investigations have confirmed that the composite coatings Al-Me_xO_y-(Al-Me)-Al_2O_3 and Al-(Al-Me)-Al_2O_3 can be manufactured from reactive aluminium powders with selected oxides by means of the detonation method.

1. INTRODUCTION

The main purpose of the conducted research was to determine the influence of the detonation spraying parameters on the structure and phase composition of coatings (Table 1). It was assumed that for properly chosen process parameters, a self-propagating high-temperature synthesis (SHS) of the aluminium matrix of powders with dispersive oxides would be possible. It was also assumed that the composite Al-Me_xO_y powders would be manufactured by means of mechanical alloying. The exothermic effect of Al-Me_xO_y reduction was shown in a thermogravimetric analysis. The scope of the research covered:

- manufacturing of Al-Me_xO_y powders in a vibration mill
- determination of powders' structure and phase composition,
- detonation spraying of coatings,
- determination of the structure and phase composition of the formed coatings of aluminium matrix composite type (AlMCs)

The target of the structural analysis was also to determine the changes of the phase composition of coatings formed from reactive powders. It was assumed that the selected aluminium coatings would be hybrid dispersion strengthened with intermetallic phases and aluminium oxides.

Table. 1. The parameters of De-gun sprayed processes.

	PARAMETR 1	PARAMETR 2
OXYGEN [MPa]	0.10	0.15
PROPANE [MPa]	0.08	0.018
FREQUENCY [Hz]	5	4

2. RESEARCH MATERIALS AND METHODS

For the production of composite powders, aluminium powder was used with granulation of up to 70µm as well as powders of the following oxides: Fe_2O_3, Cr_2O_3, Ni_2O_3 and TiO_2, of chemically pure grades and granulation of up to 20 µm. The powders were manufactured in a rotary vibration mill, using steel chambers of 2 dcm^3 capacity and steel grinding media of 8 diameter. The 40% chamber fill was assumed as well as the ratio of grinding media against powder weight of 10:1. The amplitude of 8 mm and frequency of 14 Hz of chambers' vibration were applied. The chosen parameters of mechanical alloying had been determined in previous investigations [1-3]. The thermal analysis of the synthesized powders was carried out on a SETARAM thermobalance equipped with a program for heating and cooling the samples. After grain separation, the selected powders were detonation sprayed, at different oxygen and propane pressure for a constant powder feeding rate (Fig. 1). The structure of the powders and coatings was determined on metallographic specimens using a Reichert 2 microscope. The powders' morphology and structure were examined by means of a Hitachi scanning microscope. The phase composition of the coatings was determined by an X-ray diffraction method, by analysing the diffraction patterns taken by means of Philips diffractometer.

3. RESEARCH RESULTS

The structure of composite powders with aluminium and Cr_2O_3 , Ni_2O_3 , Fe_2O_3 is presented in Fig. 1. Having analysed the mechanical alloying parameters and the powders' structure, as well as having taken into account the formation of the detonation sprayed coatings' structure, it was assumed that the MA process time of 6 hours is sufficient to form powders with dispersive oxides in the matrix. The curves of thermal analysis of the powders with oxides are characterized by an endothermic effect of aluminium melting and an exothermic effect of the intermetallic phases synthesis (Fig. 4). Examples of the coatings' structure after spraying are shown in Fig. 3. The X-ray analysis has confirmed the occurrence of intermetallic Ni_3Al and $FeAl_3$ phases in the coatings sprayed under higher gas pressure. The assumed material and technological conception corroborates the assumption that after detonation spraying of composite Al-Me_xO_y powders, Al-Me_xAl_y-Al_2O_3 coatings with hybrid strengthening of the aluminium matrix can be obtained.

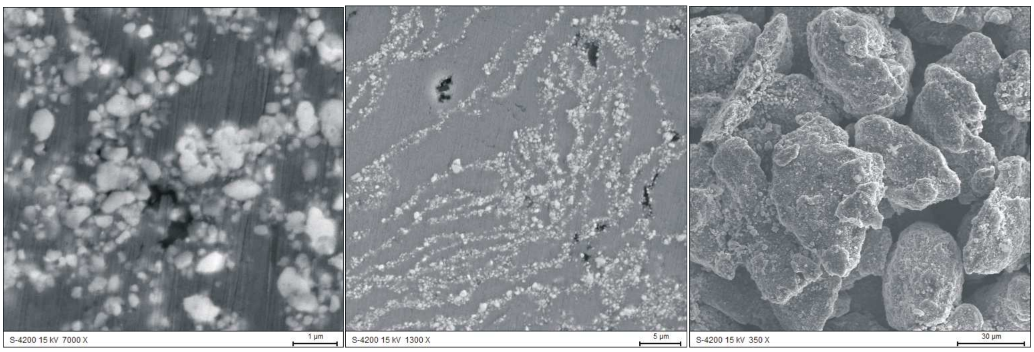

Fig. 1. The morphology and microstructure of Al-Fe_2O_3 powder.

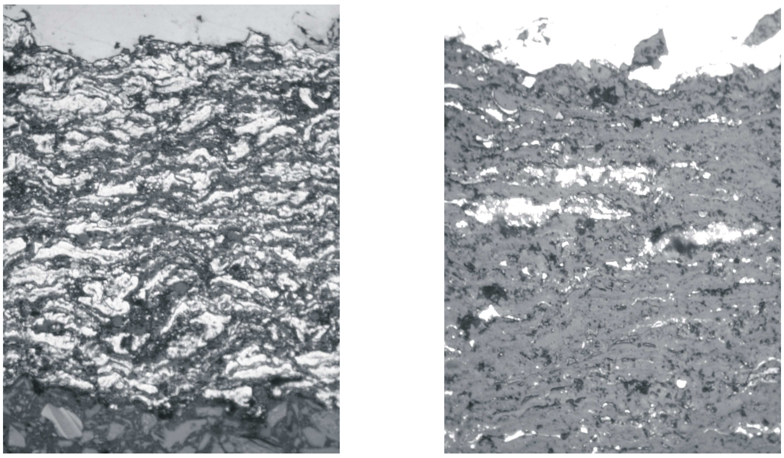

Fig. 2. The microstructure of composite Al.+Ni_2O_3 coatings
a) sprayed at parameters 1
b) sprayed at parameters 2

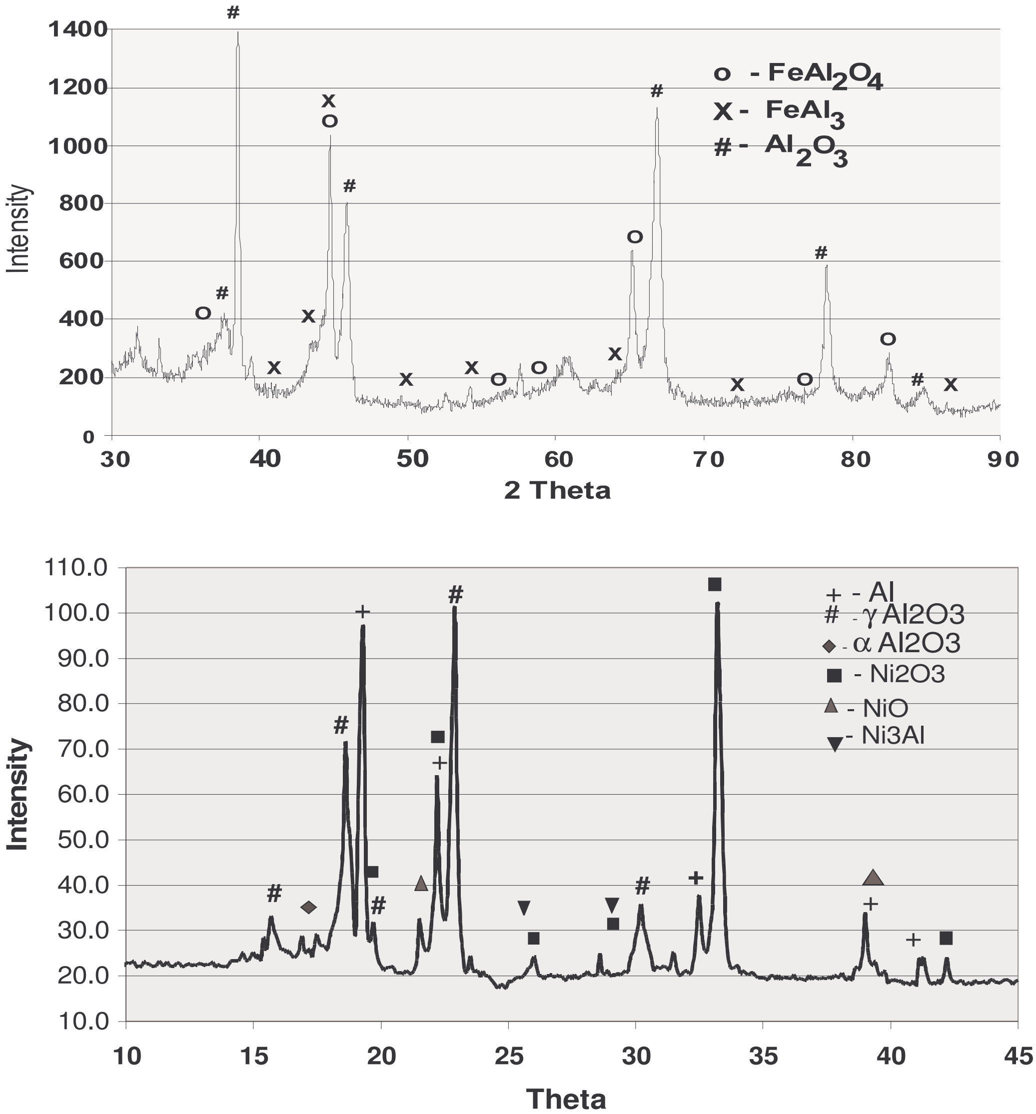

Fig. 3. X-ray diffraction patterns of D-Gun sprayed coatings.

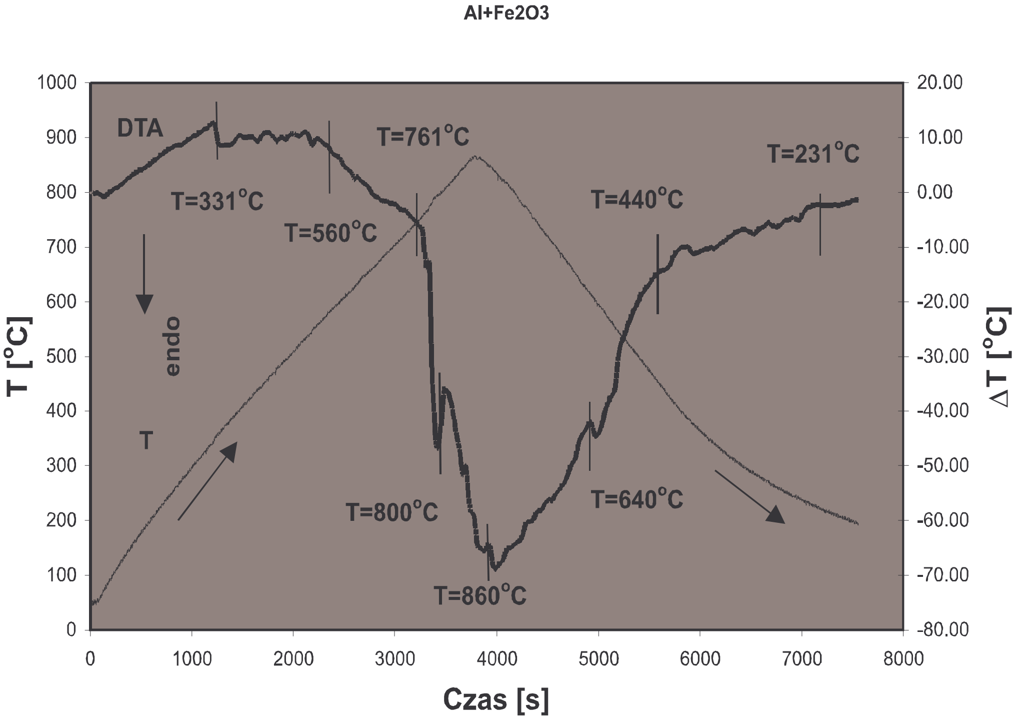

Fig. 4. DTA analysis of MA Al-Fe_2O_3 powder.

4. CONCLUSIONS

The research has confirmed that during detonation spraying of composite Al-Me_xO_y powders, a dispersion structure of the composite coating is formed which contains an aluminium composite coatings with aluminium matrix and oxides depending on the type and percentage content of oxides.

The exothermic effect of aluminothermal reduction and the amount of aluminium in coating is in accordance with following reaction:

$$\mathbf{(2y+3m+z)Al + 3Me_xO_y \longrightarrow zAl + 3Me_xAl_m + yAl_2O_3}$$

Due to high velocity of the gases stream, in the detonation spraying of coatings, composite powders should be used when produced from mixtures of high reactivity. Thermally sprayed aluminium in coating matrix coatings with iron oxide have very advantageous tribological properties.

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