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Structure and properties of laser alloyed surface layer

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ABSTRACT

Purpose: The purpose of the work was to create homogenous surface layer as a result of impulse laser alloying of TiO_2 and low-alloy steel.

Design/methodology/approach: The surfaces of samples, coated with ceramic coating, were then irradiated with CO_2 laser beam. During the work microstructure and phase investigations as well as measurement of microhardness have been carried out while the chemical composition of the surface layers has been determined.

Findings: The microstructure in all the paths created as a result of application of varied processing parameters was comparable. Chemical composition of individual zones which were a result of remelting proved creation of a surface layer rich in Ti.

Research limitations/implications: Further research is aimed to determine corrosion resistance of the alloyed samples.

Practical implications: TiO_2 layers are widely applied e.g. in medicine which makes them an object of unflagging interest by researchers.

Originality/value: Microstructure description of the alloyed surface layer cohesive-connected with base material, which eliminated fundamental problem involved with the created layers i.e. their poor adhesion, has been presented.

Keywords: Welding; Surface treatment

1. Introduction

Functional properties of many products and their elements depend not only on possibilities of transfer of mechanical load by the whole cross-section of the parts made of a material, usually heat-treated in case of metals and their alloys or on their physical and chemical properties, but also frequently, or even mainly, on the structure and properties of surface layers [1].

Surface layer can be divided into coatings (i.e. a layer of metal, alloy, ceramic or polymer material which are firmly created on the base surface in order to obtain the required properties) and surface layers (encompassing the area of materials with properties different than core properties) [1-15].

One of the most promising materials which finds application e.g. as protective anticorrosion coatings or coatings used for implants thanks to their good compatibility with blood or its bio-activeness is titanium dioxide.

Analysis of physical and chemical properties reveals that they are light, heat-proof, corrosion proof and wear resistant. Except for indisputable advantages of ceramic materials, there is also an unfavourable feature, which significantly limits its application.

Ceramic protection coatings, which are created on the surface of parts by means of plasma spray typically have low adhesion and low coherence.

Solution to this problem has been found in e.g. concentrated energy sources, which enable 'rebuilding' of the previously created coatings [2-15].

2. Experimental results

Samples made of 40Cr4 steel designed for surface treatment have been used; their surfaces have been covered with 100µm ceramic coating of TiO_2.

Metallographic tests before and after the process of laser irradiation have been carried out by means of JEOL JSM 5400 scanning microscope.

Coating microstructure after the process of spraying is presented in Fig. 1.

The obtained coating is not ideally coherent nor pore-free, which is connected with the spraying process itself, i.e. short time of heating of powder in plasma stream. This leads, in spite of high temperature of plasma, to only partial remelting of powder particles.

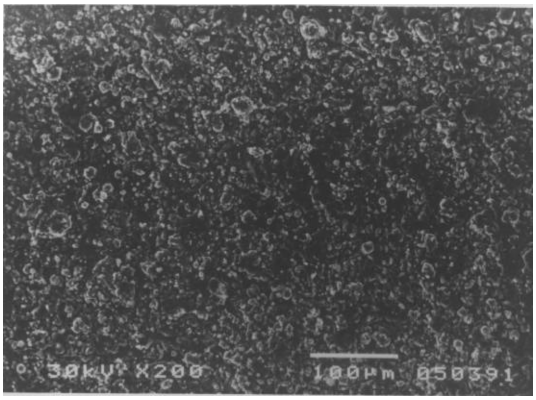

Fig. 1. Microstructure of plasma sprayed ceramic coating, magnification 200x

Next stage of investigations involved laser treatment of ceramic coatings in order to alloy the coating with base material.

Parameters of the process were initially determined in an experimental way according to the required homogeneity and coherence of the obtained layers. The following parameters of the laser treatment have been found optimal:

- impulse mode at 50% of filling in of irradiation time
- laser beam diameter = 18 mm
- radiation power Q = 1200 W
- focal distance for parabolic system of working beam shaping f = 250 mm
- protective blow of He gas,
- linear rate of irradiation: V_1=750, V_2=800, V_3=850 mm/min.

Scanning microscopy tests revealed characteristic deformation of the surface as a result of the surface treatment, Fig. 2.

Shape of the surface layer as a result of surface remelting depends directly on numerous parameters of the same process. As a result of an influence of the concentrated laser beam, the coating and base materials have been remelted. During the process of irradiation the created molten pool was conducive to intensive mixing of materials of coating and base material and caused creation of so called ‘outflow’ on the edge of the solidifying pool.

Fig. 2. presents an example of a remelted layer surface with the outflow on its side for all irradiation rates.

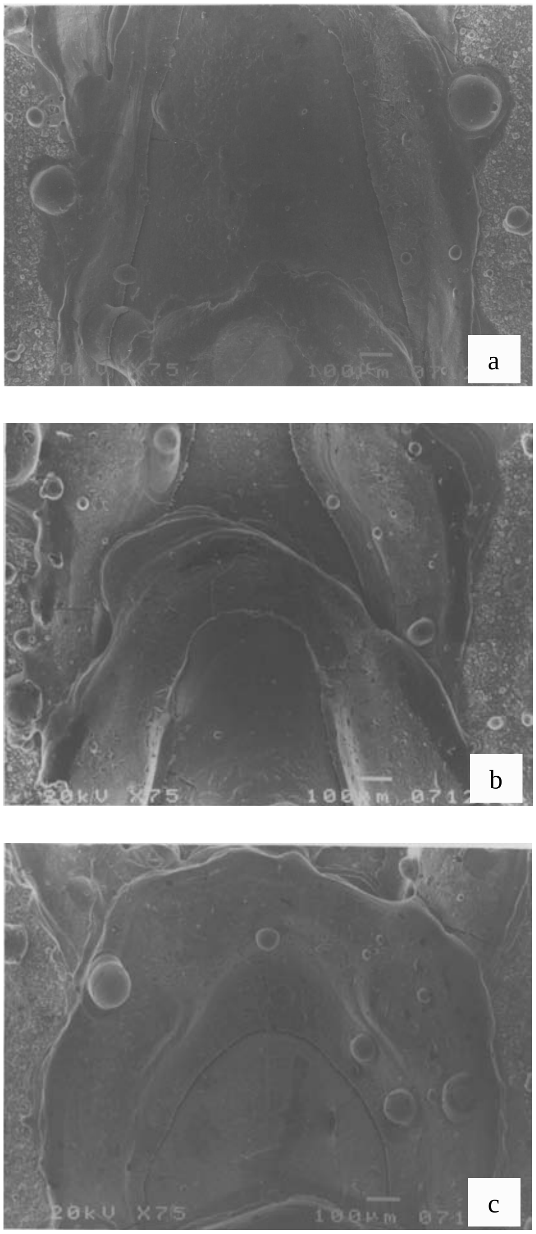

Fig. 2. Microstructure in remelting paths which occurred for the following rates of irradiation: a) V_1=750 mm/min, b) V_2=800 mm/min, c) V_3=850 mm/min

Characteristic waves on the surface affect such functional properties as wear resistance or fatigue strength.

Structural investigations of remelting path reveal significant refinement of structure and presence of cellular-dendritic structure (Fig. 3 ab).

Continuous outflow present at both sides of remelting path revealed acicular-dendritic structure (Fig. 3 b-d).

Presence of morphology of solidification front was directly connected with temperature gradient and rate of solidification throughout the mass of the material.

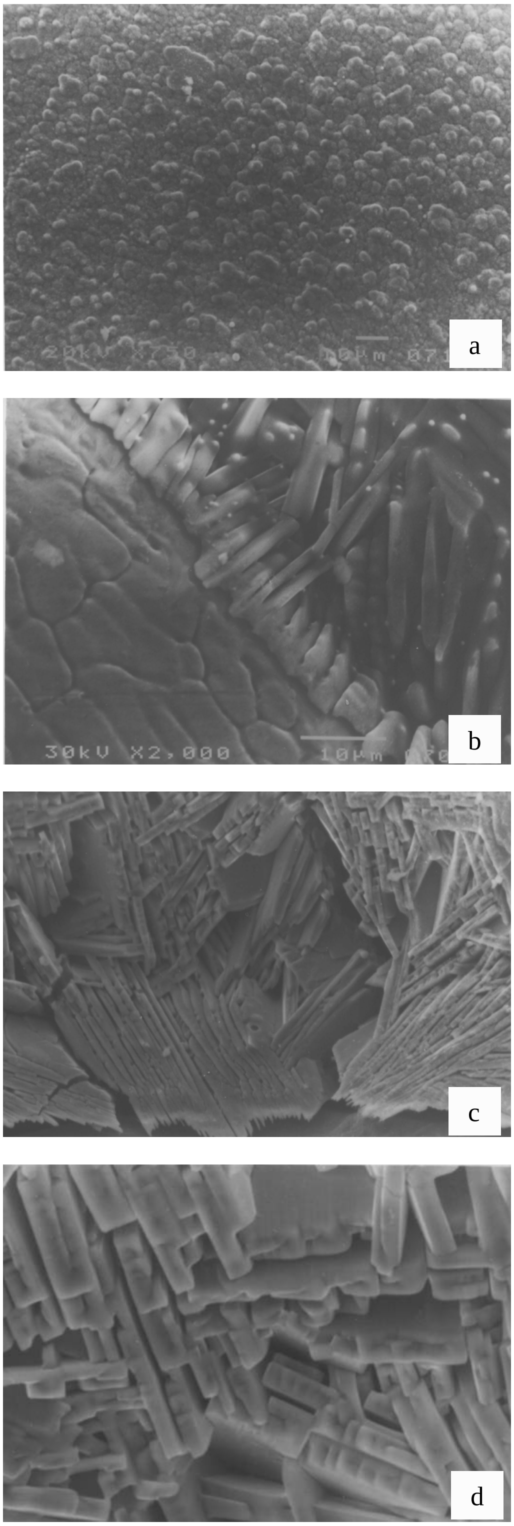

Fig. 3. Microstructure of the zones created as a result of the applied laser treatment, a) remelted path, b) borderline of the remelted zone and outflow zone, c,d) outflow

High speed of heating and cooling accompanying remelting processes considerably increase the risk of loss of coherence and appearance of cracks. The investigations have not revealed such defects, which could have influenced deterioration of functional properties.

The investigations involved determination of phase composition of the powder, sprayed coating and the alloyed surface layer. The investigations have been carried out by means of Seifert XRD-3003 X-ray diffractometer using radiation of $\lambda_{CoK\alpha1}$=0,17902 nm. The obtained diffraction patterns are presented in Fig. 4.

The investigations of phase composition of the powder revealed presence of three polymorphic modifications of titanium dioxide: brookite with orthorhombic cell, rutile and anatase with tetragonal cell.

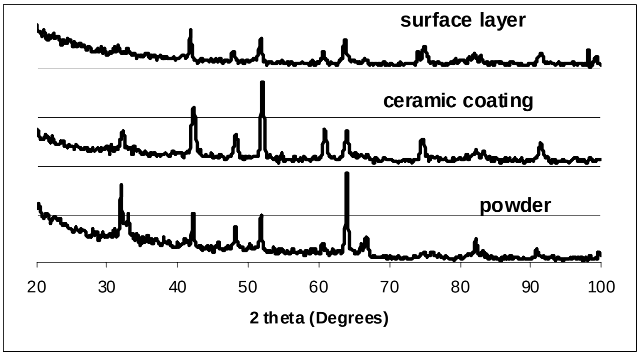

Fig. 4. Diffraction patterns obtained for ceramic powder, plasma sprayed coating and for alloyed surface layer

In both sprayed coating and the alloyed surface layer presence of only rutile has been revealed, which proves the fact of transformation of other two polymorphic modifications at over 700^0C into rutile.

Moreover, surface layer revealed presence of the phase coming from the base material, phase Feα.

Modification of chemical composition obtained for the alloyed surface layers has been proved by the scanning microscope with EDX device.

The results of point analysis of the sprayed and remelted coating are presented in Table. 1.

Measurements of microhardness on the cross microsections were performed by means of FTC FM-7 microhardness testing machine. On the basis of the test it can be assumed that remelting of the surface leads to occurrence of metastable structures which are characterized by higher strength properties. Microhardness of the alloyed zone amounted to 750HV0.1, while for the heat impact zone it amounted to 450HV0.1.

Table 1.
Chemical composition, (wt.%)

	Ti	O	Cr	Mn	Si	Fe
Layer	44.7	53.8	-	-	-	-
Alloyed surface layer	0.86	47.33	0.47	0.33	0.18	50.83
Outflow	42.28	49.8	0.53	1.26	0.13	5.85

3. Conclusions

- During the experiment laser treatment of TiO_2 was carried out in order to execute a process of alloying i.e. mixing of the coating and steel base material.
- Application of remelting of ceramic coating eliminates problem of its poor adhesion to steel surface, which results in the occurrence of cohesion forces
- Alloying of surface layer eliminates layer nature of the sprayed coatings and its porosity and impacts on its homogeneity. The layers do not reveal cracks and, despite higher speed of heating and cooling typical of laser surface treatment, were coherent.
- Investigations of phase and chemical composition in the alloyed surface layer revealed
- high concentration of the introduced elements, such as Ti. Presence of Fe in remelting path proves effectiveness of the applied laser treatment.
- Microhardness measured for the remelting path (750HV) definitely proves increase of strength parameters in the alloyed layer through introduction of alloying elements. As comparison, microhardness of heat impact zone amounted only to 450HV0.1 and 250HV0.1 for the core.

References

[1] L.A. Dobrzański, Fundamental of materials and metal science, WNT, Warsaw, 2002, (in Polish).

[2] A. Grabowski, B. Formanek, M. Sozańska, M. Nowak, Laser remelting of Al.-Fe-TiO_3 composite powder incorporated in a aluminium matrix, Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 95-98.

[3] W. Serbiński, B. Majkowska, Microstructure and corrosion properties of the laser treated superston alloy, Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 415-418.

[4] A. Zieliński, M. Jażdzewska, A. Narożniak, W. Serwiński, Surface structure and properties of Ti6Al4V alloy laser melted at cryogenic conditions, Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 423-426.

[5] L.A. Dobrzański, E. Jonda, A. Polok, Effect of laser treatment on changes of the surface layers properties of the hot work alloy tool steels, Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 42-46.

[6] A.M. Camacho, M. Marin, L. Sevilla, R. Domingo, Influence of strain hardening on forces and contact pressure distributions in forging processes, Journal of Achievements in Materials and Manufacturing Engineering 15 (2006) 166-174.

[7] R. Filip, Alloying of surface layer of the Ti-6al.-4V titanium alloy through the laser treatment, Journal of Achievements in Materials and Manufacturing Engineering 15 (2006) 174-180.

[8] M.H. Majzoobi, A. Ghomi, Optimisation of autofrettage in thick-walled cylinders, Journal of Achievements in Materials and Manufacturing Engineering 16 (2006) 132-144.

[9] Z. Nitkiewicz, Application of arc plasma source in surface science, Czestochowa University Press, Czestochowa, 2001, (in Polish).

[10] A. Dudek, Z. Nitkiewicz, H. Stokłosa, Analysis of the arc shape during remelting process, Materials Science 5 (2005) 34-37, (in Polish).

[11] T. Burakowski, T. Wierzchoń, Metals surface engineering. WNT, Warsaw, (1995) (in Polish).

[12] A. Dudek, Z. Nitkiewicz, The structure properties of surface layers which were obtained by alloying process, Acta Metallurgia Slovaca 8 (2002) 339-343.

[13] A. Dudek, Z. Nitkiewicz, Diagnostics of plasma arc during the process of remelting of surface layer in 40Cr4 steel, Archives of Materials Science and Engineering 28/6 (2007) 369-372.

[14] G. Moskal, L. Swadzba, T. Rzychoń, Measurement of residual stress in plasma-sprayed TBC with a gradient of porosity and chemical composition, Journal of Achievements in Materials and Manufacturing Engineering 23/2 (2007) 31-34.

[15] K. Naplocha, K. Granat, The structure and properties of hybrid performs for composites, Journal of Achievements in Materials and Manufacturing Engineering 22/2 (2007) 35-38.