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МЕХАНІКА ТА МАТЕРІАЛОЗНАВСТВО

UDC 629.7

THE INFLUENCE OF SURFACE PRETREATMENT ON THE QUALITY OF PLASMA COATINGS

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Summary. *The paper presents research in the field of ceramic coatings. In the experiment, 5 types of ceramic coatings were applied to the base material by means of water-stabilized plasma, which was non-alloy quality structural steel S 235J2+N EN 10250-2-2000. The properties of surface treatment of the substrate by blasting on Al2O3, Al2O3 with interlayer Ni, Al2O3+5% Ni, Al2O3+12 % Ni, Al2O3+20 % Ni were analysed. The quality of the surfaces was evaluated according to EN ISO 4287, where the values Ra and Rz were monitored. The quality of the ceramic coatings was analysed by light and electron microscopy.*

Key words: *plasma, coatings, surface, roughness, porosity.*

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Introduction. Plasma-sprayed coatings are used in a wide range of industrial applications, primarily for wear resistance, thermal barrier and corrosive environment [1, 2]. A thermal spray coating is built up and the microstructure is formed, when individual, fully or partially molten particles, traveling at a particular velocity, flatten, adhere and solidify on impact with the substrate [3, 4].

According to the stabilization medium, there are water-stabilized and gas-stabilized plasma torches. In the gas-stabilized torches, the influence of parameters is much more complex. Besides the current, the voltage and the rate of the plasma jet, also the quantity of the fed plasma, focusing and protective gas, the shape and design of the orifice, the nozzles and the diameter of the tungsten electrode play an important role. By increasing the current, the plasma temperature and electric conductivity increase. Gases have a great influence on the thermal relations of plasma.

For spraying powder materials and welding with powder filler materials, a wide range of various types of equipment is used all over the world. Plasma spraying equipment consists of a set of individual apparatuses and devices. A plasma torch is a powerful spraying unit. In dependence on the method of plasma formation in the torch, plasma torches can be divided into non-transferred arc torches, transferred-arc plasma torches and combined torches.

According to the sprayed material type, torches can be constructed for wire spraying or powder spraying. The advantage of wire spraying is a higher purity of wire and, as a result, a higher purity and quality of the sprayed layer. The advantages of powder spraying consist in a wider selection of powder, even among materials that cannot be produced in the form of wire, such as high-melting materials, oxides, carbides, etc.

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The major advantages of the plasma spraying process, which enable its relatively universal utilization, include:

- significantly wider range of sprayed materials (from high-melting metals, oxides, alloy combinations up to plastics),
- negligible heat effect on the basic material (200°C), which guarantees the dimensional and structural stability of the substrate and makes it possible to use its diversity, i.e. metals, alloys, ceramics, concrete, wood, graphite, etc.,
- possibility to form coatings at micron to millimetre thicknesses on small, as well as large areas,
- high spraying output, especially when water-stabilized plasma units are used,
- simple operation of plasma equipment [5 – 7].

Materials and methods. Experimental works were aimed on the material bola Non-alloy quality structural steel S 235J2+N EN 10250-2-2000. Chemical composition evaluated by spectral analysis on the device Belec compact port and mechanical properties of steel are shown in Table 1 and Table 2.

Table 1

Chemical composition of S 235J2+N EN 10250-2-2000 (in wt. %)

C	Mn	Si	Cr	Ni	Mo	P	S	Al	Cu	Nb	Fe
0.038	0.152	0.023	0.10	0.033	0.028	< 0.002	< 0.002	0.029	0.057	0.018	rest.

Table 2

Mechanical properties of S 235J2+N EN 10250-2-2000

Yield strength [MPa]	Tensile strength [MPa]	Elongation [%]	Notch impact energy (-20) [J]	Hardness HV 30
289	498	25	27	134

The test plates were 200 mm wide, 250 mm long and 8 mm thick.

In the experiment were made the following types of coatings:

- coating Al_2O_3 granularity of 40-90 μm, the properties of which are in Table 3.
- coating Al_2O_3 with interlayer NiCr / Chemical composition of NiCr material in Table 4.
- coating Al_2O_3 + 5% Ni /Ni granularity 50-90 μm
- coating Al_2O_3 + 12% Ni /Ni granularity 50-90 μm
- coating Al_2O_3 + 20% Ni /Ni granularity 50-90 μm.

Table 3

Properties of Al_2O_3

specific weight [g/cm^3]	3,66
melting point [^{o}C]	2050
Hardness HV 50	1800-2000
tensile strength [MPa]	150
compressive strength limit [MPa]	3000

Table 4

Chemical composition of interlayer coating material NiCr (in wt. %)

C	Mn	Si	Cr	Fe	Ni
0.18	1.66	1.23	19.43	0.65	rest.

Surface pre-treatment of test samples was realized by abrasive blasting using used steel granulate dG=0.6 mm of an auteutectoid heat treated steel, the chemical composition are given by the manufacturer of which is in Table 5. Blasting medium has homogeneous structure of martensite and bainite (hardness 460-600 HV 30), which fulfills the condition of optimum reflective elasticity and resistance to material fatigue. Blasting medium was accelerated by compressed air and the air pressure was 0.4 MPa.

Table 5

Chemical composition of blasting material (auteutectoid heat treated steel) (in wt. %)

C	Mn	Si	P	S	Fe
≥ 0.75	≥ 0.4	≥ 0.7	< 0.04	< 0.04	rest.

Plasma spraying of the coatings was realised using a water-stabilized Pal-160 plasma torch. The spray parameters used are in Table 6. The spacing of the samples from the mouth of the plasma torch was 350 mm. Plasma gas composed of dissociated molecules and ionized hydrogen and oxygen atoms was used in a 2:1 ratio.

Table 6

Used parameters of plasma spraying

electric power input	160 kW
spraying power	30 – 50 $kg.hod^{-1}$
coolant	H_2O
stabilizing medium	H_2O
cooling water consumption	10 – 12 $l.hod^{-1}$
plasma beam temperature	30 000 °C
water pressure	min. 0,25 – max. 1 Mpa
Cathode wear	2 – 4 $mm.min^{-1}$
the number of revolutions of the anode	3000 min^{-1}
electrical current intensity	380 400 A

The microgeometry of the coatings was evaluated using stylus profilometer Surftest SJ-301, Mitutoyo, Japan, with a diamond tip (radius of curvature 5 μm) located on the spring arm. The surface quality was assessed on the basis of the international standard ISO 4287 – Profile method by arithmetical mean deviation of the assessed profile Ra and maximum height of profile Rz.

The measurement parameters were chosen as follows:

1) base length l=2.5 mm,
2) the number of basic lengths N=5,
3) measured profile: R (middle line system),
4) filter: Gauss,
5) evaluated length ln=12.5 mm.

Structure analysis of the coating structure was observed using REM JEOL JSM-7000 F with a micro analyser. At the metallographic cut-outs, the areas at the substrate-coating interface were evaluated. The look of the coating, its relationship and porosity as well as its connection to the substrate were analysed.

Results and discussion. The results of the microgeometry measurements are presented in the graph in Fig. 1. The results of surface evaluation of the blasted base material confirmed the correct use of the blasting materials in terms of proper roughening of the surface before subsequent application of the coating and the blasted surface in terms of recommended roughness values (Ra=8-12 μm) matched the required interval. The surface at the end of the blasting was markedly segmentated. The segmentation allows for a good mechanical anchoring of the coating to the surface of the base material.

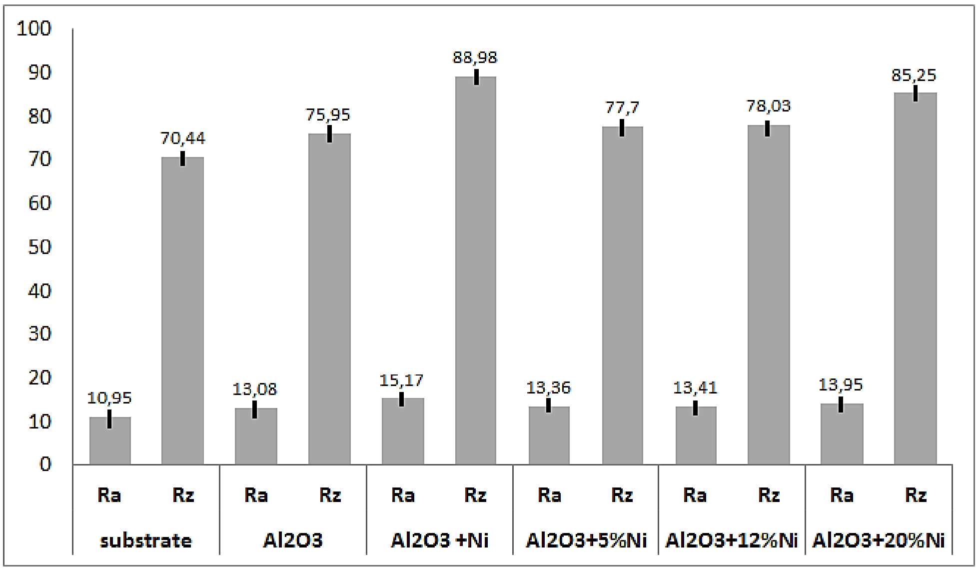

Figure 1. Average values of Ra a Rz in [μm] for rated surfaces

From the comparison of the measured values of the individual values of the micro geometry of the coatings, it can be stated that the values of the Ra were increased from the coating Al_2O_3 with ØRa=13.08 μm, Al_2O_3+5 % Ni with ØRα=13.36 μm, Al_2O_3+12 % Ni ØRa=13,41 μm, Al_2O_3+20 % Ni with ØRa=13,95 μm, followed by the coating Al_2O_3+ between the layer with the highest average value ØRa=15,17 μm. A similar growing trend is also followed by the values of Rz.

The metallographic analysis results are documented in Fig. 2 to 7. Since all coatings were classified as satisfactory according to the metallographic evaluation, only some surfaces have been documented. The average thickness of the interlayer NiCr is 103 μm. The applied interlayer was compact without interruption between the substrate and the Al_2O_3 coating.

In Fig. 2 is the morphology of the Al_2O_3 coating surface. There are no visible violations in the surface layer. The coating covers the entire surface. The coating was applied uniformly in layers as illustrated in Fig. 4. At the fracture area, the presence of inclusion or not was observed cavities. In Fig. 5 is the coating surface of Al_2O_3 doped with 12 % Ni. Similar to Fig. 2 no discontinuities observed in surface coverage. Optionally, the irradiation parameters can be labelled as satisfactory. The fracture area of the laminated coating is recorded in Fig. 6, where the light Ni particles in the Al_2O_3 matrix were identified by EDX analysis.

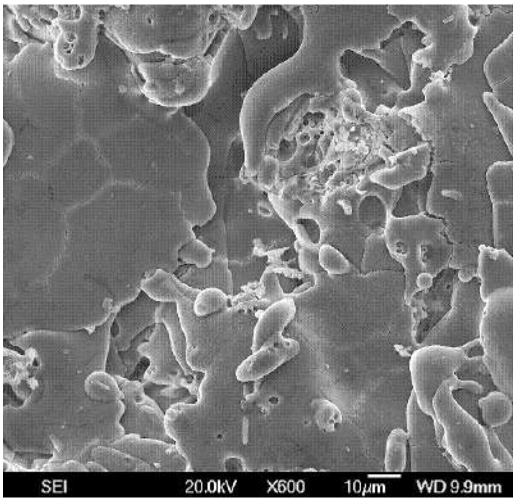

Figure 2. The surface of Al_2O_3 coating

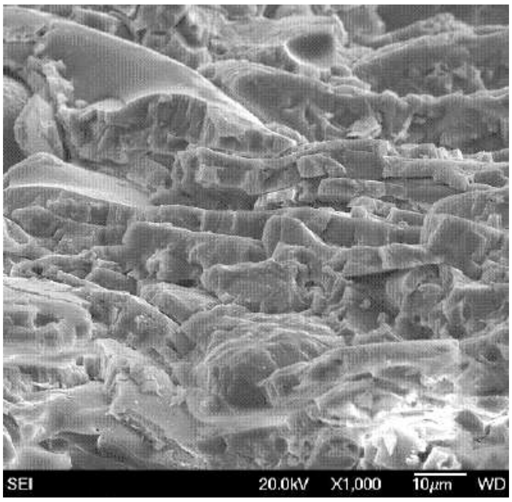

Figure 3. Lamellar structure of Al_2O_3 coating

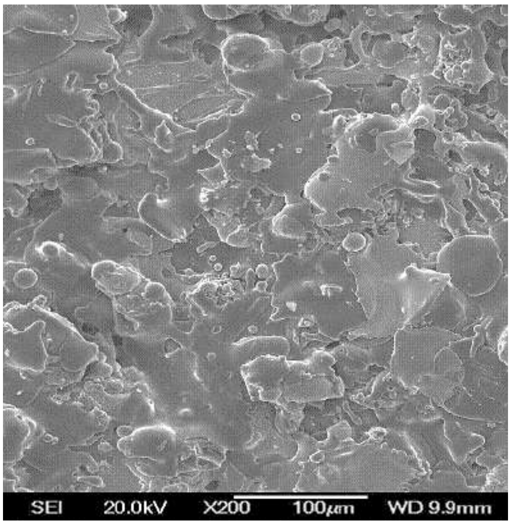

Figure 4. Surface of Al_2O_3+12 % Ni coating

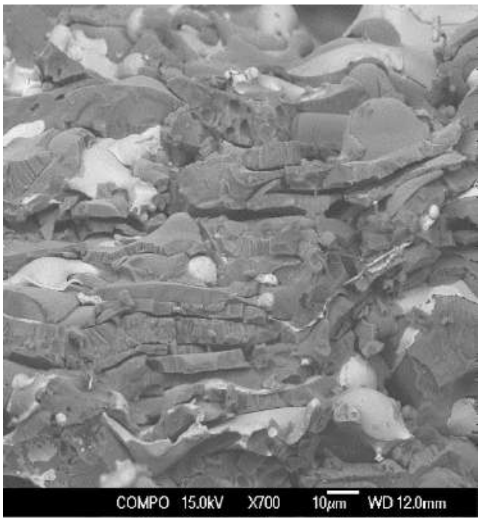

Figure 5. Structure of Al_2O_3+12 % Ni coating

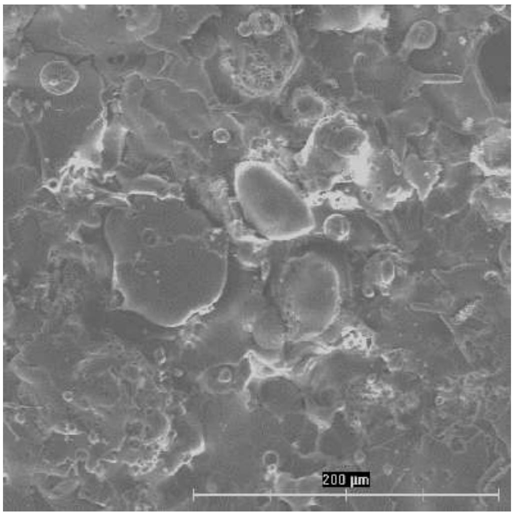

Figure 6. Surface of Al_2O_3+20 % Ni coating

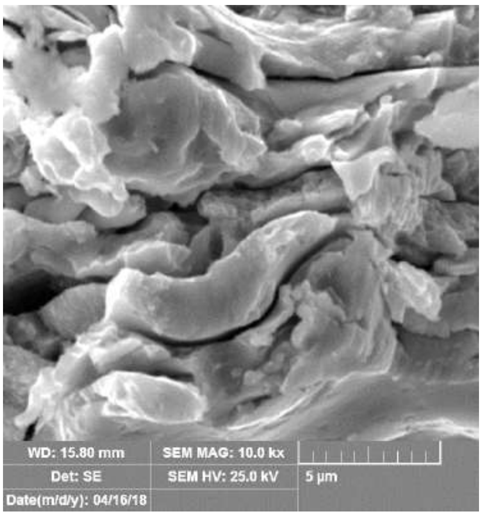

Figure 7. Structure of Al_2O_3+20 % Ni coating

In Fig. 6 is the coating surface Al_2O_3+20 % Ni. The surface of the coating is compact without surface defects. The fracture area of the coating is shown in Fig. 7. In detail, it is possible to observe the melted particles and the significant segmentation of the individual layers. The presence of impurities in the meantime was not recorded.

The average thickness of the Al_2O_3 coating was 284 μm, the coating Al_2O_3+5 % Ni was 270 μm, the Al_2O_3 coating +12 % Ni was 311 μm and the Al_2O_3 coating +20 % Ni 265 μm.

Conclusion. The evaluation of the coatings Al_2O_3, Al_2O_3+5 % Ni, Al_2O_3+12 % Ni, Al_2O_3+20 % Ni are found only minor differences. The highest coating thickness was coated with Al_2O_3+ interlayer NiCr. It is a bilayer coating of 387 μm.

The average roughness values of Ra, Rz did not show large differences. Highest roughness values showed an Al_2O_3 + interlayer with an average value of ØRa=15.17 μm and ØRz=88.98 μm.

All tested coatings have a clear interface between the base material and the layer as evidenced by the microscopic analysis. This fact is a sign of the good adhesion of the particles of the sprayed material to the unevenness of the pad.

The investigated coatings were classified as satisfactory in terms of the compactness of surface coverage of the samples examined, the morphology of surfaces, the low level of defects on the surface or in the individual layers. Among occurring defects can include pores or inadequately remelted particles. Their share in the samples examined was minimal.

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УДК 629.7

ВПЛИВ ПОПЕРЕДНЬОГО ПІДГОТОВЛЕННЯ ПОВЕРХНІ НА ЯКІСТЬ ПЛАЗМОВИХ ПОКРИТТІВ

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Резюме. *Вдосконалено технологію термічного напилення покриттів з метою оптимізації їх мікроструктури. Розглянуто серію керамічних покриттів. Під час експерименту на основу наносили 5 типів керамічних покриттів за допомогою стабілізованої у воді плазми, яка являла собою конструкційну сталь S 235J2+N, за EN 10250-2-2000. Проаналізовано властивості обробки поверхні підшару попереднім обдуванням дисперсними частинками та нанесенням Al_2O_3, $A_{l2}O_3$ з проміжним шаром Ni, Al_2O_3+5 % Ni, Al_2O_3+12 % Ni, Al_2O_3+20 % Ni. Найбільшу товщину мало покриття Al_2O_3+ міжшаровий прошарок NiCr. Це двошарове покриття товщиною 387 мкм. Усі отримані покриття мали чіткий інтерфейс між основним і нанесеним матеріалом, що підтверджено мікроскопічним аналізом. Це є ознакою доброї адгезії частинок напиленого матеріалу до основи. Якість поверхонь оцінювали згідно з EN ISO 4287, контролювали значення Ra та Rz. Додатково поверхню керамічних покриттів проаналізовано методами оптичної та електронної мікроскопії. Значення шорсткості Ra, Rz були подібними за величиною. Найвищі значення шорсткості мало покриття Al_2O_3+ проміжний шар із середнім значенням ØRa=15,17 мкм і ØRz=88,98 мкм. Дефектів та тріщин на поверхні пропонованих покриттів не виявлено, що свідчить про можливість їх застосування в промисловості. В перерізі покриттів не спостерігали розшарувань та мікротріщин, що є підтвердженням їх високої адгезійної стійкості, міцності та тріщиностійкості. Пропоновані покриття можуть бути використані для подовження ресурсу металургійного та гірничого обладнання.*

Ключові слова: *плазма, покриття, поверхня, шорсткість, пористість.*

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