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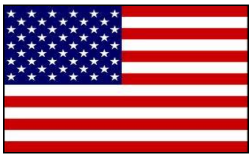
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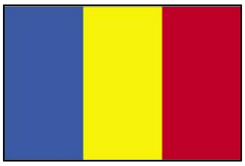
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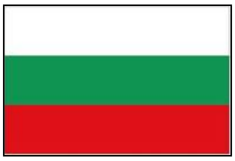
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Session 2. Energetics and Process Technique

DETERMINING ADHESION / COHESION STRENGTH OF PLASMA SPRAY COATINGS USING THE ROCKWELL - C METHOD

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Abstract: The plasma spray coatings are subject to high influence of surface loads, corrosion, and temperatures which cause damage in the form of separation of the coating from the substrate or flacking of the coating from the substrate edges. Adhesion is the main factor that opposes the influence of the external loads, and defines the quality of the bond of the coating with the substrate. Each type of coating has a determined quality of adhesion as per appropriate standard in order to meet functional properties during operation.
There is no universal coating test for all types of the coatings, the test is chosen depending on the technology used for the production of the coating, the type of material from which it was made and its thickness. One of the many tests that are used for assessment of adhesion / cohesion strength of plasma spray coatings is the scratch test. The aim of this paper was to evaluate the cohesive / adhesive strength of the plasma spray Ni22Cr10Al1Yalloycoating. The testing was conducted using the Rockwell C diamond indenter with a tip radius of 200 µm. The results showed that the scratch test is an efficient method for assessment of adhesion and cohesion of plasma spray coatings.
Keywords: plasma spray coatings, Ni22Cr10Al1Y, scratch test, adhesion strength, cohesion strength

INTRODUCTION

For testing adhesion / cohesion strength of thin and thick coatings a large number of laboratory tests are standardized [1], [2], [3]. The scratch test is a reliable and simple method for determining the coating adhesion bond strength with the substrate. In order for the inorganic oxide ceramics and the organic HA - hydroxyapatite ceramics to be used as functional biomedical coatings on a substrate, the deposited layers of the ceramic coatings must be without defects and detailed adhesion / cohesion strength tests must be performed. For testing the adhesion of coatings using the scratch method used is a micro scratch tester and a nano scratch tester. The micro scratch device uses a Rockwell C diamond with a radius of: 10, 20, 50, 100, 200, 400, 800 µm and the nano scratch device uses a spherical diamond with a radius of: 1, 2, 5, 10, 20 µm (a = 90 ° or 60 °). Most commercial devices use the Rockwell C diamond indenter with a tip radius of 200 µm. This indenter has been used for years for examining the adhesion of coatings a thickness of 0.1 - 30 µm by scratching the surface of the coating. The same indenter can be used for testing thicker plasma spray coatings by scratching the coating surface on the cross section. Depending on the type of the coating material and its thickness other types of indenters may be used, [1]. Adhesion testing of thicker plasma spray coatings is carried out on the polished cross-sectional surface of the sample. Due to the availability of the diamond Rockwell C device with a radius of 200 µm and the simplicity of the test it is frequently used to determine the adhesion of plasma spray coatings. In addition to the normal Fn force in the course of testing the depth of penetration of the indenter and the force of friction can also be determined. The acoustic signal detector is placed above the diamond indenter (needle) and registers the vibrations which occur on the emergence of damage. In addition to the acoustic sensor, the device has sensors that register friction force. The movement of the indenter along the sample leads to the formation of different damages depending on: the stress at the interface, the cohesion strength between the lamellae, the share and size of the micro pores, the presence of unmelted particles, micro-cracks, oxides, micro-hardness and the value of the applied Fn force. Due to the simplicity of the test, the scratch test is very suitable for

optimization of the plasma spray powder deposition parameters in order to produce a coating with optimal mechanical and structural properties, [1].
This paper analyzes the assessment of the adhesion / cohesion strength of plasma spray VPS - Ni22Cr10Al1Y coating using the scratch test on the cross section of the coating, using bulletins describing the screening procedure [4]. For scratch testing used was the plasma spray Ni22Cr10Al1Ycoating deposited on an INCONEL X-750 alloy substrate 20x10x5 mm in size. The results showed that the method is effective and the values were discussed.

MATERIALS AND EXPERIMENTAL DETAILS

For the production of the coating,the powder AMDRY mark 9624 wasused,which is an alloy of nickel with a content of 22 wt% Cr, 10 wt% Al and 1 wt% Y. The powder had a range of granulation from 11 to 37µm, [5]. The deposition of the powder was carried out at low pressure with the vacuum plasma spray system of the company Plasma Technik AG using the control board A-2000 and the F4 plasma gun. As the plasma gas a mixture of Ar / H2 gases was used. Prior to deposition of the powder, cleaning and preheating of the surface of the substrate made of INCONEL X-750 alloy was carried out by transferred arc at a temperature of 850°C [6]. To assess the adhesion / cohesion coating strength using the scratch test, the coating layers were deposited on a sample of the alloy INCONEL X-750 dimensions of 20x10x5 mm. The test specimen was prepared by cutting, grinding and polishing, as in the hardness test, and the scratch load was conducted on the cross section of the sample that was mounted in bakelite. Scratching was conducted using the Rockwell Cmethod with a diamond indenter with a radius of 200 µm with a normal Fnforce, [4]. During the trials, the diamond indenter was moving at a constant speed over the surface of the sample in the direction from the substrate to the interface with the coating and the surface of the coating, as shown schematically in Fig.1.

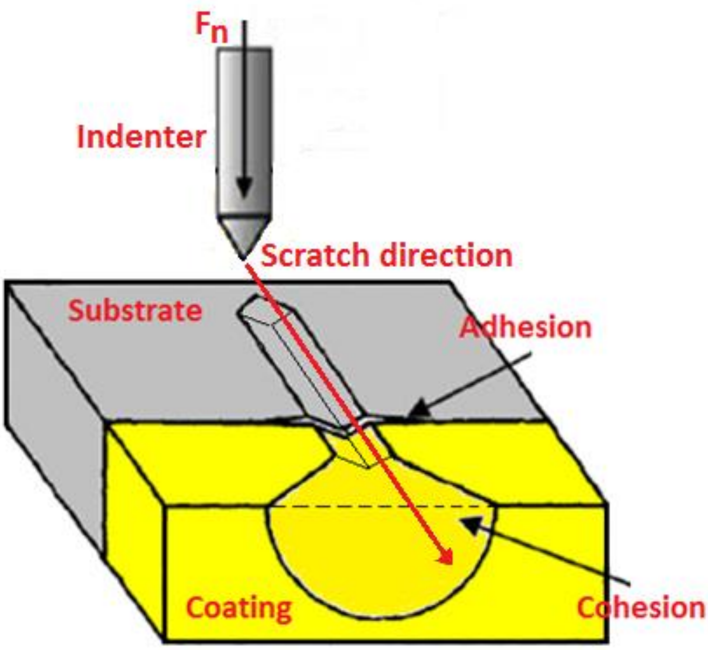

Figure 1. A schematic representation of the scratch test

For the tests used were three different normal Fnforces (10, 25, and 39 N) at a constant speed of the indenter of 1 mm / min. For all the loads applied thelength of scratches was 0.7 mm. The geometry of the indented coating was different and under the influence of the applied normal Fnload.

RESULTS AND DISCUSSION

The microstructure of the Ni22Cr10Al1Y coating deposited in a vacuum was quite homogeneous with a good bond to the substrate. The results obtained by scratch testing show good adhesion and cohesion of the coating for the applied load, as shown in Fig. 2. For the indent made with 10N observed was that the stresses entered with normal Fn force together with residual stresses in the coating did not cause any changes on the interface, such as micro-cracks or plastic deformation of the substrate or coating, as can be seen in Fig. 2b). With increasing the load to 25N changes occur on the interface and coating layers. The channel made with the indenter is wider than the width of the channel made with a load of 10N. Increased stress together with the residual stresses in the interface area cause plastic deformation of the substrate and coating.

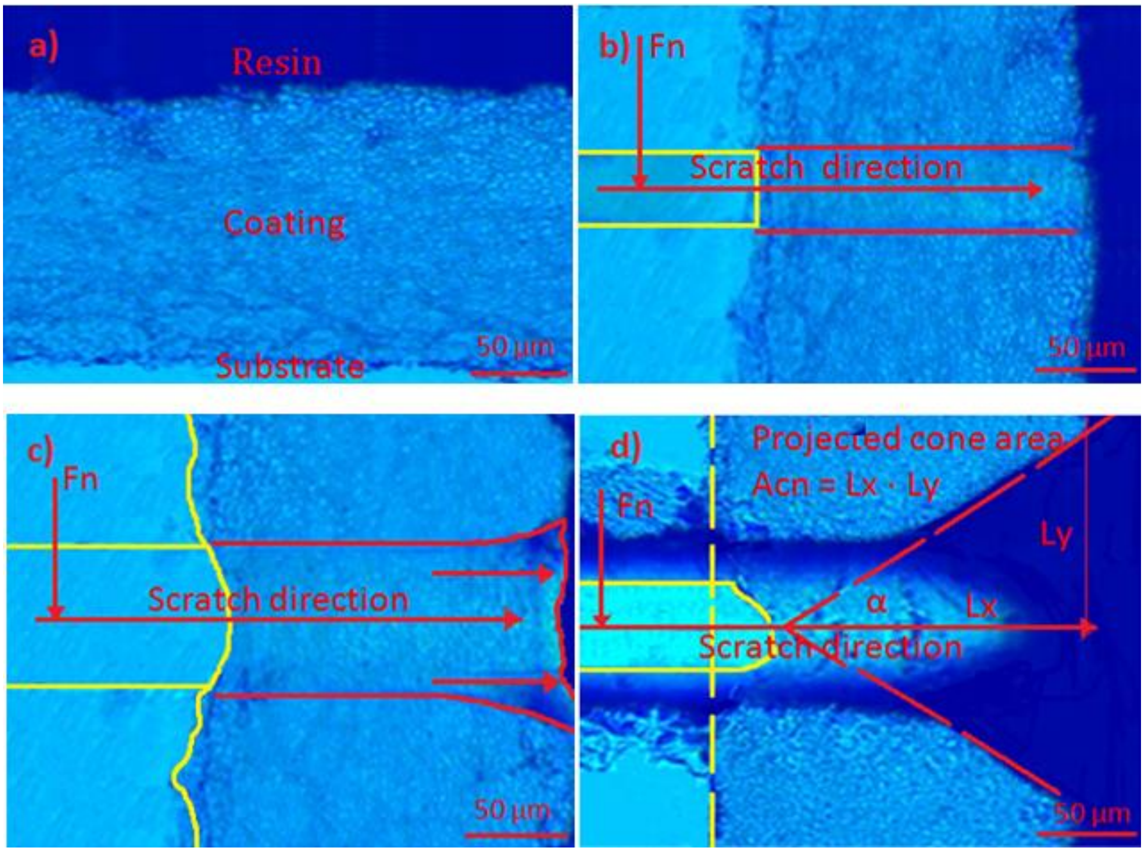

Figure 2. BM microstructure: a) NiCrAlY coating; b) the surface scratch with a load force of 10N; c) the surface scratch with a load force of 25N and d) the surface scratch with a load force of 39N.

The material of the substrate with the primary γ-phase due to plasticity penetrates into the coating in the direction of the normal Fn force, which also plastically deforms the coating which has the same basic structure with the γ-phase. Due to the plastic deformation in the area of the interface and the coating micro or macro cracks do not appear. On the surface of the coating, as a result of the highest stress condition a highest degree of plastic deformation is observed, cone shaped, as shown in Fig. 2c).As the normal Fn force increases to 39N in the interface area the degree of plastic deformation of the substrate and coating increases. On the interface no crack appears indicating very good adhesion strength caused by good adhesion of coating to the substrate. The surface of the formed cone is a function of the load, and its value depends on: the residual stress in the coating layers, coating toughness, hardness and microstructure of the coating. To a certain degree of normal load Fn for materials that are plastic, such as the NiCrAlY alloy characteristic is a linear increase of the longitudinal parts of the cones indicating a good inter-lamellar bond and a good bond of the layers, which are deposited layer by layer to the formation of the final coating thickness. At one point, with an increase of the normal load Fn the stress in the coating exceeds the plastic deformation, and causes the appearance of a cone shaped crack in the coating which extends in the direction of movement of the indenter from the deeper layers of the coating to the surface of the coating. The formed cone surface is calculated as the product of the lengths derived by the equation $A_{cn} = L_x \cdot L_y$, as shown in the Figure 2d). The formed crack in the shape of a cone with a surface of A_{cn} is the main factor for assessing the adhesion / cohesion strength of the coating. The surfaces of the cones or plastic deformation of the material of the substrate and the coating which occur during the test at the substrate / coating interface characterize the coating adhesion and the cone shaped fractures in the coating characterize the coating cohesion. The larger the cone shaped fracture surface, the lower the bond strength of the coating. This is a basic factor for optimizing powder deposition parameters. In the tested coating the cone shaped fracture occurred within the coatings, but not at the interface, which indicates good adhesion and a cohesion fracture caused by the stress state of the layers in the deposited coating.

CONCLUSION

Based on the performed scratch test characterization of plasma spray VPS-Ni22Cr10Al1Ycoatingthe following conclusion can be made:
The scratch test as a mechanical method of testing coatings confirmed that it can be successfully applied for this type of material for the assessment of adhesion / cohesion strength, as expected based on set procedures and standards.
The test analysis shows good adhesion of the coating because at the substrate / coating interface plastic deformation of the substrate and the coating occurred instead of the creation of micro cracks.
The results showed that the scratch test can be successfully used as an effective method for assessing the cohesion of plasma spray coatings.

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