

ELECTROCHEMICAL REMOVAL OF CARBIDE COATINGS PREPARED USING THE HP/HVOF TECHNOLOGY

SCHUBERT Jan¹, ČESÁNEK Zdeněk²

¹ *Výzkumný a zkušební ústav Plzeň, Czech Republic, EU, schubert@vzuplzen.cz*

² *Research and Testing Institute Pilsen, Czech Republic, EU*

Abstract

Carbide coatings prepared using the HP/HVOF technology are widespread and commonly used surface treatment. These coatings provide various advantages compared with the substrate material and are able to supply top mechanical and corrosion properties at a low cost. On the other hand, the removing of carbide coating is a big problem. It is not important if the removal is necessary for the renovation of the part or if there was a production error and there is no other way of repair than a complete removal of the coating from the substrate. The problem is that these coatings have the highest hardness (around 90 HRC), which reduces the number of possible ways of removal. More precisely, there is only one method suitable for this operation and it is grinding (time consuming, expensive and with limited geometry of use...). This paper is focused on the use of electrochemical removal of carbide coatings, which can fully replace the grinding. The benefits are a low cost and the possibility of removing the coating from a shaped surface. Results in this paper show the removal of the CrC-NiCr coating prepared by means of HP/HVOF (JP-5000). The main aim was to evaluate the efficiency of this process, which is assessed as a weight loss of the coating after predetermined time. The final surface was evaluated using the optical microscopy with the focus on the mechanism of removal and the quality of the substrate material.

Keywords: HVOF, coating, CrC-NiCr, carbide coating, electrochemical coating removal

1. INTRODUCTION

Nowadays, thermal spraying of ceramic and other coatings is widely used in highly stressed structural elements including equipment components designed for aerospace industry, energy industry and space applications in which it is necessary to ensure a high degree of abrasive, erosive, corrosive and thermal resistance. Thermally sprayed coatings are widely used in many industrial applications as replacement of hard chrome plating. Proper application and selection of the coating can increase component life and reduce risks of failure, which also leads to reduction of maintenance expenses in the long term [1].

The problem comes when it is necessary to remove the coating from the surface of the coated part. There are plenty of reasons for doing that. The most obvious reasons are the repair of previously coated part or the removing of the coating because of its wrong composition.

The aim of this study was to find solution for a quick and an effective way of removing the HVOF (High Velocity Oxygen Fueled) sprayed coating based on CrC-NiCr. Removal of such kind of coating is time consuming and very expensive. The problem is that currently used methods are based mainly on grinding because machining is not able to manage coatings like CrC-NiCr with hardness around 60 HRC or more. It is commonly known that grinding is one of the most expensive and time consuming technologies. Therefore there was demand to find a process suitable for the CrC-NiCr coating removal for a lower cost.

The way how to provide such results for a low cost was found in using an electrochemical process (electrolytic bath) of an adequate composition that could be effectively used under certain conditions. The process of searching the proper bath composition and voltage and current setting was long and this paper presents only final results of this effort. There are several patents in this area dealing with this problem but none of them is

focused directly on CrC-NiCr. The patents also present really complex and expensive solutions and the goal of this study was to find a simple and an easy way of coating removal without unnecessary coolers, oxygen supplies and other devices [2, 3, 4]. The preliminary solution was found in using electrolytic bath of the composition mentioned further in this paper. It was also necessary to optimize the current input into the bath and compare different settings. Stripping effectiveness was not tested by this time from the view of anode/cathode distance. It is the subject of further research together with the possibility of using this technology for curved surfaces.

2. EXPERIMENT

Experimental samples were prepared using the HVOF technology. Preparation of samples and subsequent tests were performed in the laboratories of Research and Testing Institute Plzen (VZU). Steel 1.4923 (X22CrMoV12-1) was selected as a substrate material because it is commonly used for final parts in the energy industry. One material was selected as the material for coating (Cr₃C₂-NiCr 75 / 25). The powder of designation K-854.22 was agglomerated and sintered powder with particle distribution -45 + 10 μm.

The selection of the coating was based on previous research and its good mechanical and corrosion characteristics [5]. Standard optimized parameters were used for preparing the samples using the HVOF technology [6]. The substrate surface was degreased and grit blasted before spraying (brown corundum F22 grit 0.8 to 1.0 mm was used as an abrasive medium). Dimensions of samples were 50 x 50 x 5 mm and they were coated only from one side.

Equipment used for the electrolytic coating removal was based on the Hull tray with higher power output. Type of the device was CDG545 with automatic stirring and aeration. The equipment design can be seen in **Figure 1**. The composition of bath was 20 % of sodium carbonate, 5 % of tartaric acid and 75 % H₂O. The bath temperature was not controlled because the reaction is highly exothermic and thus the temperature naturally climbed approximately to 100 °C. The current was set at 20 and 30 A.

2.1. Measurement conditions

The measurement was conducted under two different conditions based on previous internal research. The conditions are presented in **Table 1**. Three samples were used for each setting and resulting values are average of 5 measurements for each sample. Length of the sample exposure to electrolytic bath was 40 minutes and both kinds of measurements were conducted each 10 minutes.

The measurement was focused on the weight loss and decreases of coating thickness both dependent on time. Dimension measurements were conducted using micrometer and weight measurement using the Sartorius TE 214S-0CE precise weight scales with accuracy of 0.1 mg.

Table 1 Experiment conditions

Current (A)	Bath composition	Anode / Cathode distance (cm)
20 A	20 % sodium carbonate, 5 % tartaric acid and 75 % H ₂ O	3
30 A	20 % sodium carbonate, 5 % tartaric acid and 75 % H ₂ O	3

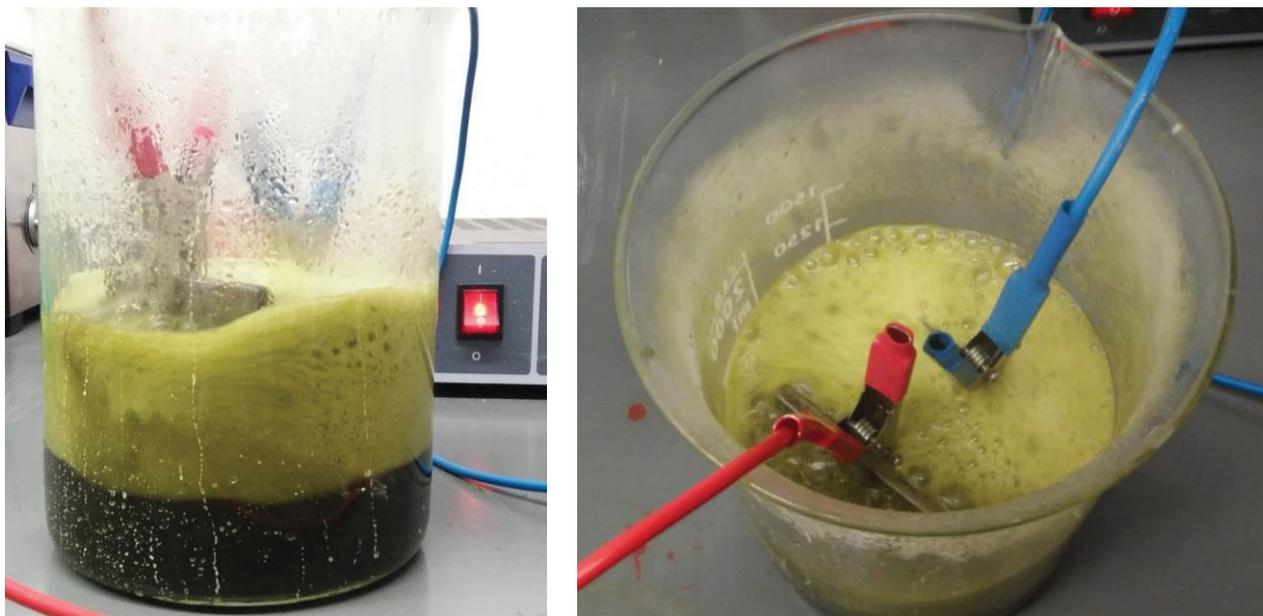


Figure 1 Experiment procedure and design of equipment

3. RESULTS AND DISCUSSION

The achieved results are clearly visible in presented graphs. The first two graphs (**Figure 2** and **Figure 3**), which deal with the cumulative mass loss and the square cumulative mass loss, show that the effectiveness of the process can be increased by increasing the electrical current supply into the bath. The results were surprisingly linear, which is positive, because this fact allows the calculation of time necessary for removing the layer of the known thickness. This fact is important, because in further research the influence of distance between anode / cathode is evaluated. Further results will help to optimize both the distance and current input into the bath. Results of distance effectiveness will also help during the phase of designing the device for removing coating from the curved surfaces, because there will always be problem with not precisely fitting counterparts.

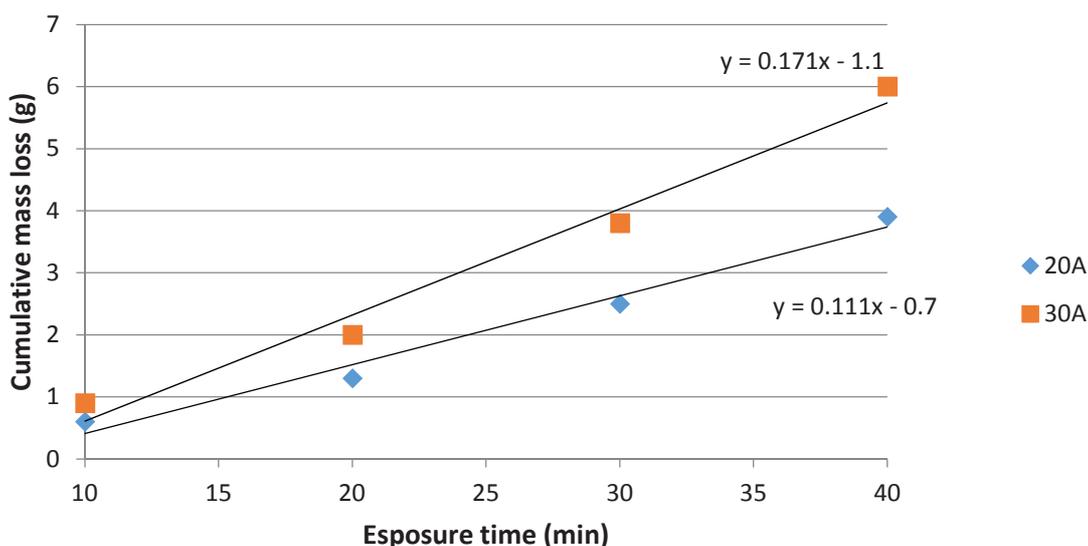


Figure 2 Cumulative mass loss depending on time

The third graph (**Figure 7**) represents the coating thickness reduction depending on time. It is evident that there is linear decrease in the coating thickness reduction in time. This fact correlates perfectly with our preliminary assumption. The reduction can be explained by the following processes. At the beginning (approximately from 0 - 10 minutes) the reduction of thickness is upmost. It is given by the fact that the surface of the coating is rough (approximately 8 - 13 Ra). Therefore the area of contact with electrolyte is much bigger than at the polished sample. From this reason the first stage of removing the coating is going by much quicker rate than the following ones. The roughness is given by the technology of applying the coating on the top of the sample and for HVOF it is characteristic in the range from 8 to 13 Ra. This process is connected with the influence of flattening effect caused by the electrolytic material removal. The closer the singular peak of anode to the cathode is the faster the rate of thickness reduction is. It will be necessary to study deeper this first stage of the process for further optimizing and refinement of this phase.

After the flattening of the surface and reduction of contact surface with electrolyte the steady phase follows. During this phase the coating is equally removed from the surface (also possible to see in **Figure 7**). During this phase the coating material is equally removed from the surface and is transported up to cathode or remains excluded in the bath solution.

The final phase is also visible in the last graph (**Figure 7**) under the exposition of 40 minutes. During this phase the remnants of coating are dissolved and removed and the process gradually slows down. Surprising result of this test was that the surface of coated substrate was also electrochemically cleaned and ready for machining or re-coating. The following figures (**Figure 4**, **Figure 5** and **Figure 6**) of step by step process follow and represent each stage of measurements (10, 30, 40 minutes). It is also possible to see the gradual removing of the coating together with the final stage of electrochemically cleared surface of samples disposed of the previously coated layer. It is also possible to observe that the initial roughness of the substrate material (given by preliminary blasting) was reduced by this process.

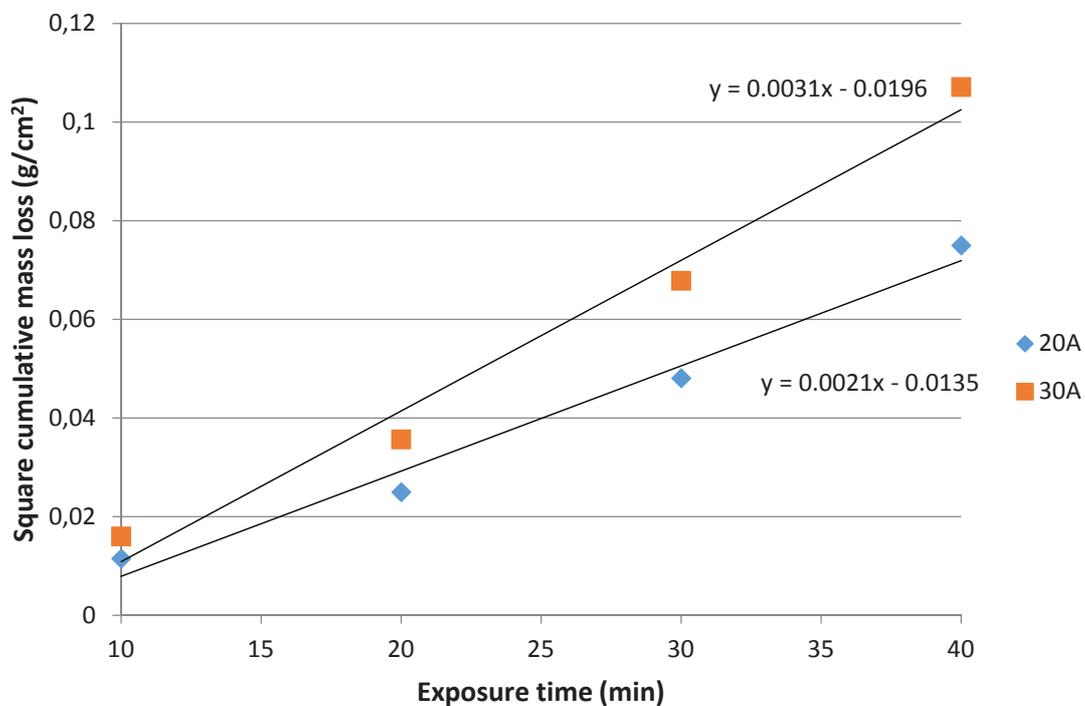


Figure 3 Square cumulative mass loss depending on time

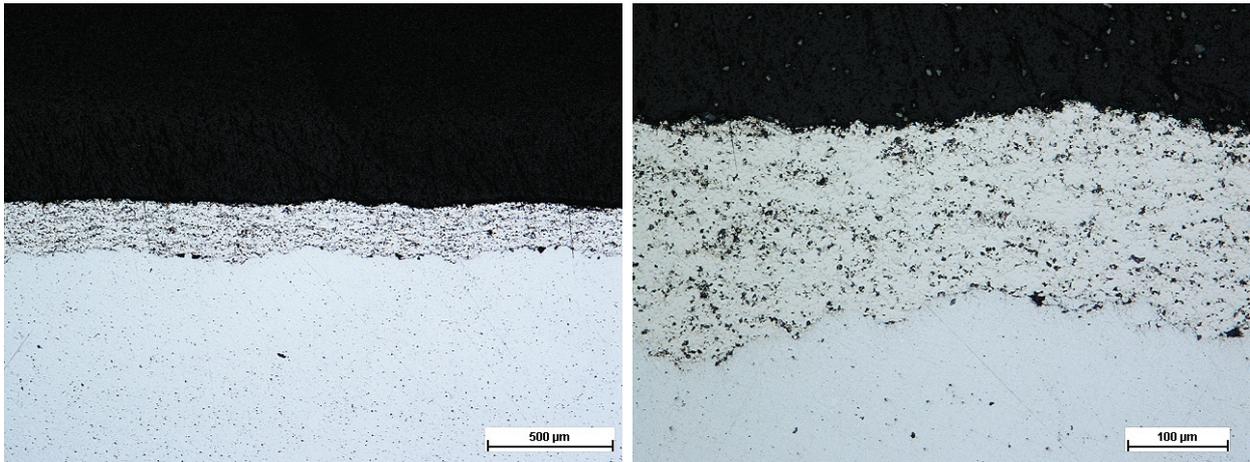


Figure 4 Cross-section of the sample exposed to electrolyte under the condition of 30 A current for 10 minutes (left 50x magnification, right 200x magnification)

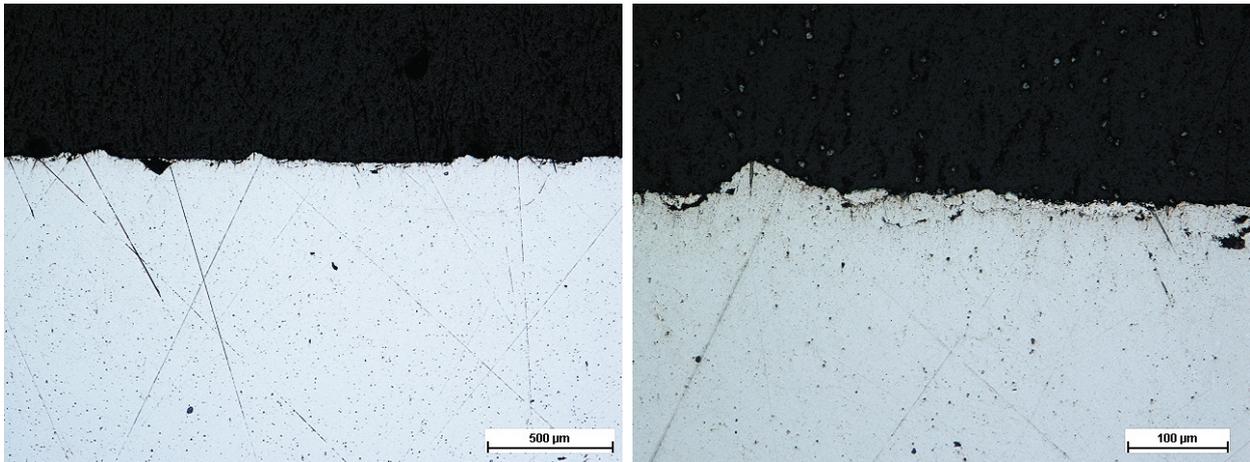


Figure 5 Cross-section of the sample exposed to electrolyte under the condition of 30 A current for 30 minutes (left 50x magnification, right 200x magnification)

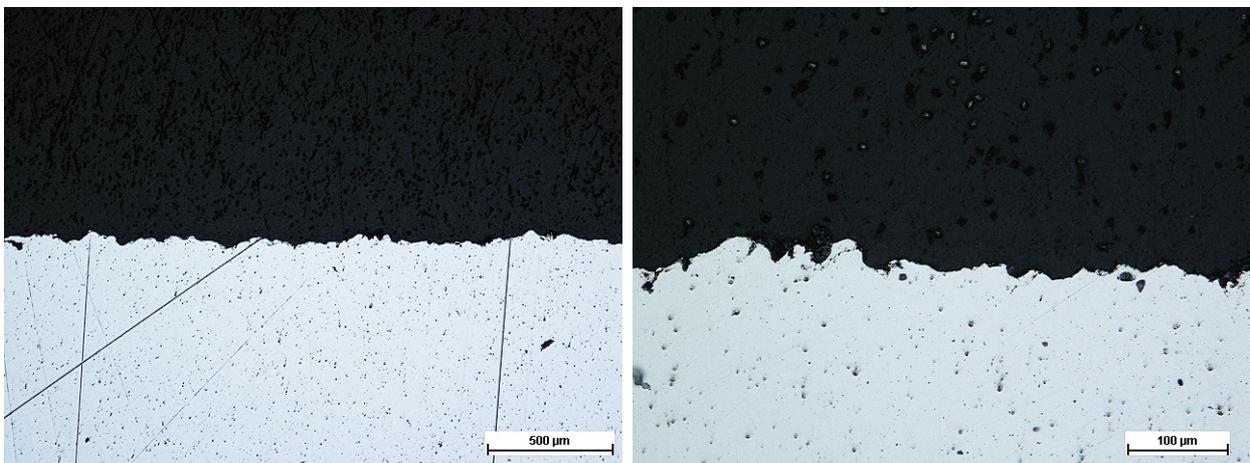


Figure 6 Cross-section of the sample exposed to electrolyte under the condition of 30 A current for 40 minutes (left 50x magnifications, right 200x magnification)

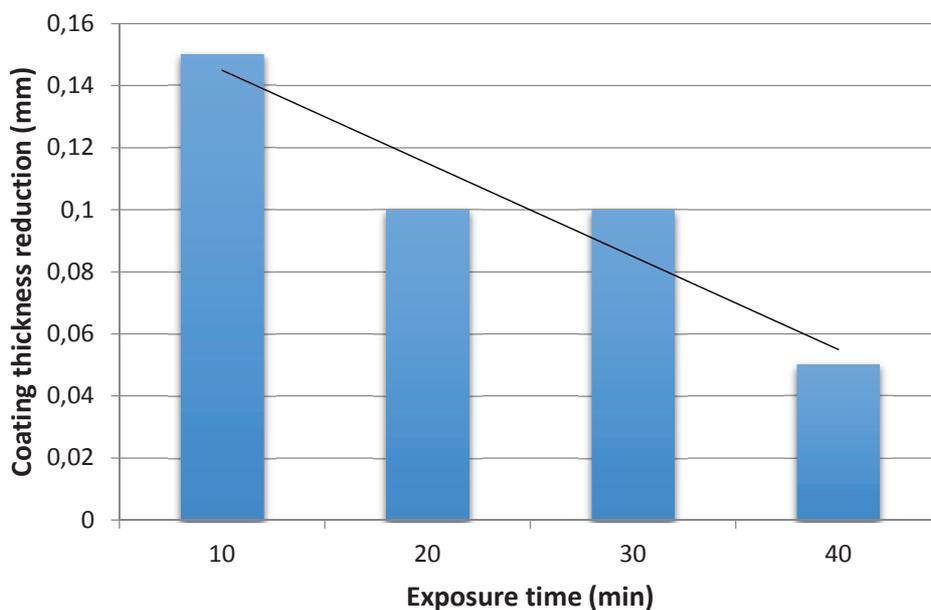


Figure 7 Square cumulative mass loss depending on time

4. CONCLUSION

The paper deals with the current need for finding solution for easy, quick and cost effective way of removing a thermal sprayed coating from the surfaces of parts. The reason is given by expensiveness and time consumption of other possible ways of performing it. This research has made first steps by initial tests of the above mentioned bath composition, current input and other variables. The results obtained during this research will be used as background data for further research focused on finding solution for larger scale parts and on applying this procedure in production.

ACKNOWLEDGEMENTS

The paper has originated in the framework of institutional support for the long-time conception development of the research institution provided by Ministry of Industry and Trade of the Czech Republic.

REFERENCES

- [1] MCGRANN, R.T.R., GREVING, D.J., SHADLEY, J.R., RYBICKI, E.F., KRUECKE, T.I.T., BODGER, B.E. *Surface coating technolog.*, vol. 59, 1998, pp. 108-109.
- [2] KAWAGISHI, S., ARISATO, Y. Electrolytic stripping bath for removing metal coatings from stainless steel base materials, *patent*, US4111767 A, 5.9.1978.
- [3] FAIRBOURN, D. C. Methods for removing coatings from a metal component, *patent*, US8377324 B2, 19. 2. 2013.
- [4] LORIG, E. T. Method and apparatus for the electrolytic coating of metal strip, *patent*, US2461556 A, 15. 2. 1949.
- [5] TEKMEK, C., OZDEMIR, I., SOYKAN, H.S., CELIK, E. NiCr coatings on stainless steel by HVOF technique, *Surf Coat Technol.*, 2003, pp. 1070-1073.
- [6] ČESÁNEK, Z. Thermally sprayed coatings used in corrosion agresive environment, *disertation work*: West Bohemian Universityin Pilsen, 2015.