



T.A.G. S.r.l. Sede Legale ed Amministrativa: 23843 Dolzago (LC) Via Marconi, 9
Telefono 0341 45.12.22 - Telefax 0341 45.12.00
E-mail: info@tag.it - http://www.tag.it
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Electrochemical Stripping of Gas Turbine Coating. An Industrial Alternative for the Traditional Stripping Chemical Process (?)

J. HENRIQUEZ⁽¹⁾, A. TROMBETTA⁽¹⁾, C. GIOLLI⁽²⁾

(1) TAG - Dolzago / Italy, (2) BHGE - Firenze / Italy

Abstract

Nowadays, the global industry presents different and effective ways to clean turbine components, that are for example: mechanical processing (sanding, grinding) and/or chemical acid reactions in water solutions or gases, that are in general called stripping methods.

Using electrochemical techniques such as open circuit potential, polarization curves, chronoamperometry and more, several couples of metal base (MB) / coating (C) were investigated and, in this way, it was possible to better understand the MB/C system and to propose a new stripping methodology, that could be cheaper and faster than the traditional ones.

In this sense, the aim was to demonstrate that in some cases it is possible to improve the cleaning results using a controlled electrolysis process. The main goal was to select the optimal values for a series of parameters such as: pH, temperature, electrolyte concentration, Electrochemical Potential, Density Current, stirring speed, etc. Experimental results show that the electrolytic process is faster and more selective than traditional ones.

Frame

TAG was established in 1998, aiming to become soon a forerunner in the heat treatment sector and its applications as well as in Ion Nitriding, Nitrocarburizing and T-oxi Oxidation. Additionally, TAG have processes and plants for: sub-zero treatment, Aluminizing, Vacuum



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brazing and from 2019 a HIP system. Besides that, the company has also a division fully dedicated to chemical stripping.

Components in hot sections of gas turbines are usually made of Ni or Co based alloys. Such materials have high mechanical characteristics but poor resistance to high temperature corrosion. To improve these negative aspects, coating formed of a layer called bond coat (BC) and more external ceramic coat, called thermal barrier coating (TBC), are applied to the surface.

In general, the stripping process is an essential step in repairing and reconditioning worn parts and consists in removing the coating from surfaces. The main feature in the process used by TAG is to guarantee the full removal of the coating without damaging the base material and without altering the component geometry.

During the last fifteen years of experience, hundreds of thousands of turbine component have been stripped with "traditional" methods such as: acid solution, basics solutions and HFIC process.

As a part of such process (basic and acid stripping) some in-between steps are necessary for the activation of the surface: sanding, grinding, masking (in some cases) and others. These activities need time and imply an increment of the cost. On the other hand, some nickel/cobalt alloys cannot be treated in the traditional solutions without compromising the geometrical specification (i.e. required tolerances).

Traditional Stripping Process

The cleaning process of an electrodeposited and flame-sprayed coating is a necessary part of the surface finishing. The main chemical reaction conducted correspond to an oxidation: the metal is converted from the zero-oxidation state value toward a higher value.

The term "traditional" used in this article refers to all processes that do not combine the use of the electric power (use of overpotential) to provoke the dissolution reaction of the metal coating. For example: the immersion reactions in acid baths, high temperature gas reactions, molten salts baths, etc.



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TAG'S innovation

An electrochemical reaction can be understood as a normal chemical reaction plus an electrical potential (overpotential) through to which an electroactive specie will dissolve. Thus, a controlled oxidation will be produced in the anode. Electrochemical stripping should be employed when the immersion solutions (traditional process) are ineffective, unavailable or too difficult to be used due to their aggressivity to the metal base.

The main goal of this study was to setup a series of parameters such as: pH, temperature, concentration of electrolytes, overpotential, current density, distance between anode and cathode, among others, in order to obtain a controlled oxidation of the coating without causing corrosion in the base metal. If the chemical composition of a coating type MCrAlY (M = Ni, Co) and the chemical composition of a super alloy as for example INCONEL®, HASTELLOY®, etc, are considered, it is possible to verify that they are very similar in terms of the elements that compose them (mainly Ni, Co, Cr, Al, etc), however, the main difference are related to their amount and microstructure. Such similarities imply that the electrochemical parameters that characterise the two materials are very similar. In the case of a Pt/Al type of coating, the difference is observable, and the values mentioned above differ appreciably. So, in order to extract the coating without damaging the base metal, the electrochemical solution must be able to oxidize the first (C) while passivating the second (MB).

This type of investigation can be carried out by means of the polarization curve technique. A polarization curve can be constructed doing small variations in the overpotential value and measuring the response of the system in terms of current density. The sweep speed must be the slowest possible, in this way the stationary conditions are maintained. The starting point of the cathodic and anodic curves corresponds to the open circuit potential (OCP).



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Experimental Procedures and Results

All the measurements presented in this article were carried out with a potentiostat-galvanostat AUTOLAB PGSTAT302N. The working electrodes were manufactured isolating an area of surface of 1 cm². The reference electrode used was Ag/AgCl mounted in a Luggin capillary. The counter electrode was selected from various materials, such as: graphite, nickel-based superalloy, stainless steel, etc. All reagents and solutions were prepared from commercial products Merck® and distilled water. The distance between anode and cathode was kept constant distance lower than 5 mm. The three-electrode cell was connected to a water circulating thermostatic bath allowing the control of the solution temperature to within 1°C, the experiments were conducted in temperature selected between the 40°C and 70°C. The pH of the solution used was recorded before and after each experiment. The OCP potential was recorded for 8 or 12 hrs before each polarization experiment. Potentiostatic scans were performed from 370 mV below OCP to 1000 mV above at a scan rate of 0.1 mV/s. Figure 1 shows four polarization curves (two anodic and two cathodic) for a couple Ni base alloy (MB) / NiCrAlY (C). They were all performed in a basic solution named TAG5. From these results it is possible to appreciate that in a potential window comprised between: [+0.8; +1.0] V vs. reference electrode, the oxidation of the coating with a current density (A/cm²) of about 3 decades higher than the one verified for the base metal surface. Figure 2 shows a chrono amperometry curve, Current (A) vs. time (s), performed for 5 hours at constant potential of + 0.8V vs ref. with small intervals at 0.0V vs. ref. In this way many of the species formed on the surface of the electrode can migrate more easily to the bulk solution. The system evolves towards lower Current(A) values. The photography in Figure 2, corresponds to the work area in the Ni base alloy (MB) / CoNiCrAlY (C) (200 nm) electrode. Nor sanding nor grinding was applied before and after the electrolysis process for both: the working electrode and the counter electrode.

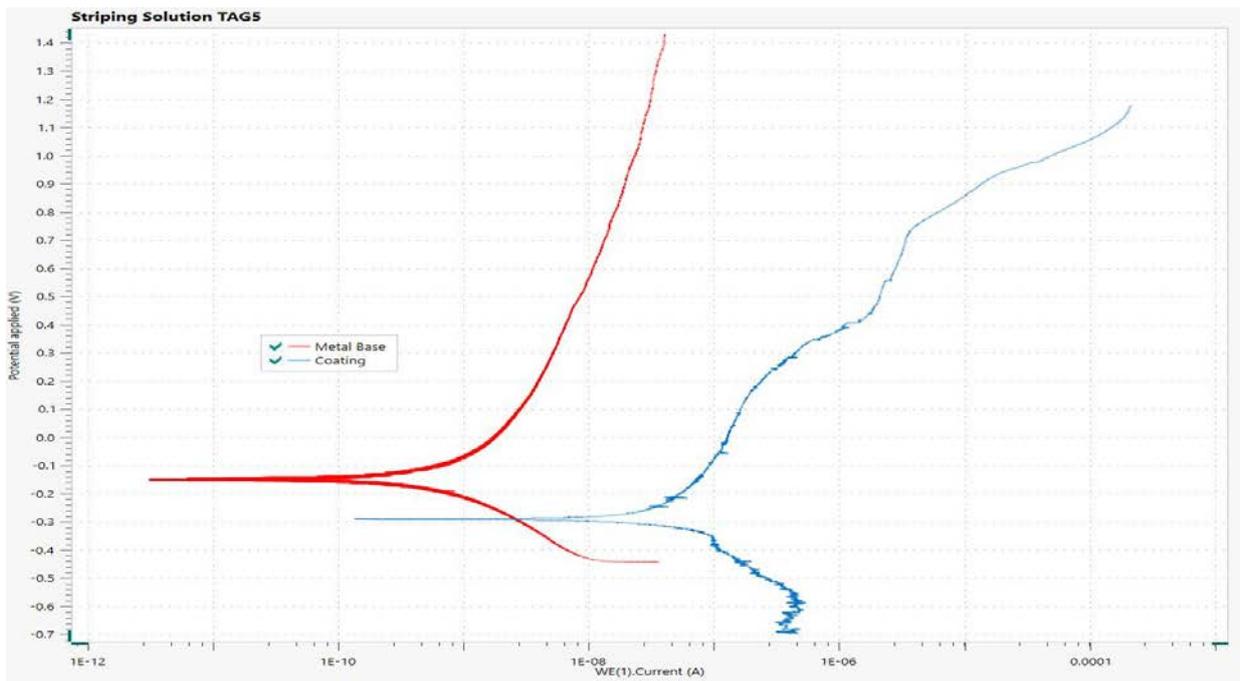


Figure 1. Potentiostatic curves in TAG5 solution. In **RED** the Metal Base (Ni-based) and in **BLUE** the Coating (CoNiCrAlY). E vs Ag/AgCl

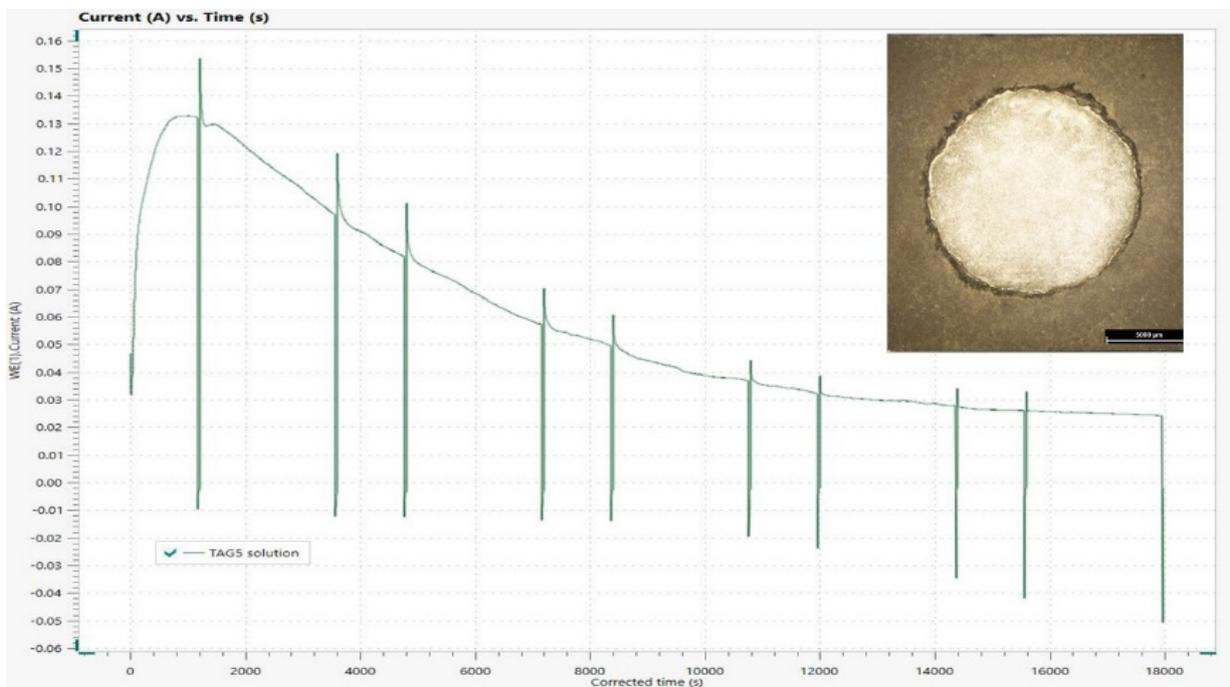


Figure 2. Chrono amperometry curve - Current (A) vs. time (s). 5 hrs. +0.8V combined with 0.0 V. On the Right, the sample with the isolated work area (CoNiCrAlY/Ni-based alloy).

Conclusions

- The present study shows that it is possible to perform a faster and more selective stripping process avoiding also several preparation steps in between characteristic of traditional stripping processes.
- The overpotential, current density, temperature, pH and stirring values must be accurately tailored, basing on the difference of electrical potential between the working and the reference electrode. Considering these aspects, an electrochemical process shows to be more selective than the traditional one, but it is necessary to consider the energetical costs (rectifiers, bus bars, racking/rack design, and the cost of electrical current).
- The cathode must follow the anode shape. This, in almost all the turbine component cases, is a great engineering challenge.

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