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H. Grammont, T. Puig. SURFACE HARDENING OF TA6V BY FORMATION OF CHROMIUM CARBIDES COMPOSITE STRUCTURES. Journal de Physique IV Proceedings, 1991, 01 (C7), pp.C7-77-C7-80. 10.1051/jp4:1991717 . jpa-00250847

HAL Id: jpa-00250847

<https://hal.science/jpa-00250847>

Submitted on 1 Jan 1991

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SURFACE HARDENING OF TA6V BY FORMATION OF CHROMIUM CARBIDES COMPOSITE STRUCTURES

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ABSTRACT

In order to improve erosion resistance and tribological properties of TA6V turbine blades new protective coatings are under study. In this work we investigated the composite structures obtained by laser remelted ternary Cr-C-Ni coatings. Indeed the $[\text{Cr}_3\text{C}_2 - \text{Ni } \gamma]$ fine structure presents satisfying tribological [1].

INTRODUCTION

The blade geometric integrity and stages airtightness are among the main compressor efficiency parameters. The former is degraded by the erosion due to ingested foreign object sand particles, the latter by the wear of blade tips against the casing airtight rings. The aim of this study is to investigate the composite structures obtained by laser remelted ternary Cr-C-Ni coatings liable to provide titanium blades with adequate protection [2,3].

fig. 1: ternary diagram Ni-Cr-C, projected view of liquidus sections */1/*. Temperature in Kelvin, concentration in weight percent.

fig.2: sample of type A, electrophoretic deposit.

EXPERIMENTAL PROCEDURE

Two types of deposits were tested: electrophoretic and electrolytic deposits.

Electrophoretic deposits present pores and poor adherence. Furthermore, precise chemical composition can be obtained. Three types of eutectic structure ($\text{Cr}_3\text{C}_2 - \gamma$, $\text{M}_7\text{C}_3 - \gamma$, $\text{M}_{23}\text{C}_6 - \gamma$) appear on the equilibrium Cr-C and Ni-Cr-C diagrams [3]/[4]/[5].

In order to obtain these eutectic structures, the melting of Ni - Cr - C coatings with the chemical compositions related to the following isothermal eutectic reactions was achieved (fig.1):

- liquid $\rightarrow \text{Cr}_{23}\text{C}_6 + \alpha + \gamma$ 1832 K
(point 1) [44 wt% Ni, 55 wt% Cr, 1 wt% C]
- liquid $\rightarrow \text{Cr}_3\text{C}_2 + \text{C} + \gamma$ 1827 K
(point 4) [81 wt% Ni, 17 wt% Cr, 2 wt% C]
- a [80 wt% Ni, 20 wt% Cr_3C_2] was tested as well.

Electrolytic deposits possess better adherence and homogeneity but carbides concentrations are limited to 10 wt% Cr_3C_2 . A [90wt% Ni, 10wt% Cr_3C_2] one was also performed.

In order to prevent the titanium diffusion from the substrate to the coating, an undercoating was interspaced. Two types of the latter were used: an electrolytic nickel layer and an electrolytic chromium layer [6]. Because of adherence consideration, a fine nickel P.V.D. coating was added prior to the chromium layer. The thickness of the different coatings is indicated in figures 2 and 3.

fig.3: sample of type B, electrolytic deposit.

fig.4: experimental device.

A spectra-physic CO_2 continuous laser, beam shaped by an homogeneizer (kaleidoscope: $5 \times 15 \text{ mm}^2$), was used to melt deposits on samples (fig.4).

The laser parameters are:

Power density: $P = 3 \text{ w/mm}^2$.
Interaction time: $T_i = 1 \text{ s}$.
Speed rate: $v = 2,5 \text{ mm/s}$.

The samples are analysed by Scanning Electronic Microscopy (S.E.M.) and Electron Probe Micro Analysis (E.P.M.A.). Structures are revealed by aqua regia reagent (Nitric acid (1.33) 25 ml, hydrochloric acid (1.19) 75 ml).

RESULTS

A- MELTING OF ELECTROPHORETIC DEPOSITS

The laser melting of chrome-carbone and chrome-carbone-nickel deposits gave disappointing results because of many defects such as irregular distributions of carbides and high number of cracks and pores. Melting of nickel-carbide Cr_3C_2 samples of type A gave a 50 μm carburized layer on the surface of the sample. However E.P.M.A. reveals the presence of titanium carbides with no interesting properties instead of chromium carbides (fig.5,6,7,8). During the laser treatment solid diffusion occurred at the nickel-titanium interface, leading to the formation of low melting temperature alloys. So the TA6V substrate and the nickel layer melted and titanium diffused up to surface (fig.8).

fig.5: S.E.M. micrograph of a [80% atomic Ni, 20% atomic Cr_3C_2 carbides] deposit after laser remelting. Sample of type A.

fig.6: Optical micrograph of a [80% atomic, 20% atomic Cr_3C_2 carbides] deposit after laser remelting. Sample of type A.

fig.7: S.E.M. micrograph of a [80% atomic Ni, 20% atomic Cr_3C_2 carbides] deposit after laser remelting. Sample of type A.

fig.8: E.P.M.A. of a [80% atomic, 20% atomic Cr_3C_2 carbides] deposit after laser remelting. Sample of type A.

B- MELTING OF ELECTROLYTIC DEPOSITS

After remelting fewer defects occurred than in the electrophoretic coatings (fig.9). At the surface, eutectic structure was observed among cells of chromium and nickel but the typical hardness of the carburized zone after remelting is about 500 Hv0.15, (fig.10).

An E.P.M.A. should be necessary to precise the nature of the eutectics. At the interface titanium-nickel, a melted zone was still observed. However the unmelted chromium coating prevented the diffusion of titanium up to surface.

fig.9: micrograph of a [93% atomic, 8% atomic Cr_3C_2 carbides] deposit after laser remelting. Sample of type B.

fig.10: micrograph of a [93% atomic, 8% atomic Cr_3C_2 carbides] deposit after laser remelting. Sample of type B.

CONCLUSION

Remelting of electrophoretic coatings of nickel Cr_3C_2 carbides seems not to give positive results. Many defects appeared in deposits and because of the fusion of the nickel underneath coating, the TA6V substrate and the nickel- Cr_3C_2 deposit were mixed.

Remelted electrolytic coating gave better result. Nevertheless the surface state is still too rough and the hardness of deposit too low. So the coating might not be rich enough in carbides.

In order to increase carbon concentration, next test will be done with a spray carbon layer on the surface.

Indeed the superficial melting by laser of an initially graphitized $\text{Ni}_{70}\text{Cr}_{30}$ substrate gives submicronic eutectic cellular structure /1/.

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