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► To cite this version:

J. Jules, D. Grevey, Jean Pelletier, M. Pilloz, P. Kirat, et al.. SURFACE TREATMENTS BY Cw YAG LASER. Journal de Physique IV Proceedings, 1991, 01 (C7), pp.C7-61-C7-64. 10.1051/jp4:1991713 . jpa-00250780

HAL Id: jpa-00250780

<https://hal.science/jpa-00250780>

Submitted on 1 Jan 1991

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SURFACE TREATMENTS BY Cw YAG LASER

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Abstract : The feasibility of surface treatments by cw YAG laser has been established. Concerning solid phase treatment, we explored superficial quenching of grey cast iron. It brings out that it's no necessary to precoat the sample before treatment, the natural absorptivity is sufficient.

Concerning liquid phase transformation two examples are presented : surface alloying and cladding. For the first one, the power required for a given melted depth is 2 times lower than for a CO₂ beam. Concerning the second example, it appears that the use of a step index fiber could ameliorate obtained results. Finally from a metallurgical point of view, obtained structures are the same than with a CO₂ beam.

I INTRODUCTION

Because of required power level the only use of CO₂ laser was considered in material's surface treatments. Now Cw high power YAG laser (upper than 1kW) are marketed and the possibility of beam carrying through an optical fiber allows us to use it for new industrial applications.

In this paper, we illustrate the surface treatments possibilities both in solid phase and in liquid phase owing to a Cw beam coming from a 600 μ m diameter's gradient index's optical fiber coupled with a 1200W's Nec cw YAG laser [1].

II EXPERIMENTAL RESULTS

II.1 Solid phase treatment

Here we present surface quenching of a lamellar grey cast iron. The material contains about 3% of carbon and has a pearlitic matrix.

In view to determine the treatment's parameters we use Fouquet's chart [2] and we modify the results because of the variation in absorptivity due to :

- the different surface coatings (paint, graphite spray, Salt baths) [3]
- the difference in wavelength (CO₂/YAG) [4]

The figure (1) shows obtained results for a treatment with a power of 600W, a focal spot of 2mm and a scanning speed of 55cm/min. The microstructure is similar than those observed after a CO₂ treatment. We have an incomplete dissolution of Carbon due to the kinetics and the result is that we can see graphite lamellar and pearlitic zone in treated area. Hardness measurements confirm results with value of 200H_{VO,1} in non transformed zone and about 800H_{VO,1} in the treated parts.

It is important to note that this treatment has been made on a sample free of coating. Indeed it doesn't exist significant difference in the result of the treatment if the sample is coated or not. In the meantime one exception appears when the surface coating is white paint (Titanium oxide). In this case the reflectivity is maximal and the treatment no possible.

II. 2 Liquid phasis treatments - Surface alloying

The substrate is an aluminum alloyed with 5% of Silicon and 3% of Copper and coated owing to the plasma technic with Nickel (4% Al). The depth of the coating varies from 80 to 125 μm . These materials are choose in view to compare surface alloying to those obtained by S. BONNET - JOBEZ [5] with a CO_2 laser. The figure (2) illustrate a typical obtained alloy. In this case, the treatment's parameters are a power of 760W, a laser spot of 1mm, a scanning speed of 1m/min and a gaseous cover with nitrogen.

The realized alloy is about 300 μm thick, value obtained only with a power of 1600W in the case of CO_2 laser. These results are confirmed by an EPFL's study [4].

The structure is a very fine dendritic stucture with a high hardness (650 $\text{H}_{\text{V}0,2}$). An X Ray diffraction 's analysis allows us to connect this hardness to the presence of intermetallic compounds like Al_3Ni , Al_3Ni_2 and Al_2Cu .

Finally, from this study it brings out that the decrease of the power and the increase of interaction time enables to ameliorate the quality of the alloy (homogeneity, disappearance of cracks and porosity).

II. 3 Liquid phasis treatment - cladding

We realize stellite cladding (63% Co, 28% Cr, W, 1,25%C) on a 304 stainless steel (18% Cr, 8% Ni). Our choice was advised by the fact that these materials are largely studied both in classic technology [6] and in CO_2 laser technology [7].

The figure (3) presents a cladding made owing to a power of 1100 W, a laser spot of 1,1mm and a scanning speed of 90cm/min. An hardness of 350 $\text{H}_{\text{V}0,1}$ shows that the dilution's rate is important ($\approx 20\%$). In the case of a quasi null dilution's rate, PILLOZ [7] measured hardness of about 600 $\text{H}_{\text{V}0,1}$. So this parameter must be controlled in order to insure the wanted treatment.

When the scaning speed decreases, we have a key hole and an higher dilution. To insure a correct geometry for the cladding we must prefer a step index fiber which gives a "flat hat" spatial repartition of the energy[8] and limits the apparition of a key hole.

The obtained microstrusture at the interface melted area/non melted area becomes visible on figure(4). Dendrits are perpendicular to the solidification front and we can see a zone with a planar solidification front, due to the low conductivity of the steel.

It's the same metallurgy than with CO_2 laser. An X Ray diffraction of the cladding, of the substrate and of the powder shows that we have always a c.f.c. structure, with a coating's crystalline parameter equal to the inox one ($\approx 3,57 \text{ \AA}$).

If we made reference to Hernandez's [6] and Pilloz's (7) works we can think that we have a solid solution enriched in cobalt, result that we'll verify in an ulterior study.

III CONCLUSION

The aim of this study wasn't the research of optimal conditions for the treatments, but the demonstration of the YAG's surface treatment's feasibility. Numerous points must be cleared.

Concerning solid phasis treatments, the rigorous measurments of interaction's efficiency will be implemented owing to microcalorimetric technic. After we'll quantify possible performances.

Concerning liquid phasis treatments, it appears that a winning exists if we use a YAG laser. For the same treated depth, the usefull power is 2 times lower.

Now we must characterize very strongly the microstructure in order to see if significant differences exist; We think of hypereutectic aluminum alloy for which Marchione [4] has shown an evolution due to the cooling speed.

Concerning the cladding, absoption phenomena versus powder's granulometry and spatial repartition of the energy must be take into account.

That's what we propose to do later.

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Fig. 1 : cross-section of a YAG laser treated grey cast iron;

$P = 600 \text{ W}$; $\Phi = 2 \text{ mm}$; $V = 55 \text{ cm/mn}$; $G = 125$.

Fig. 2 : micrograph of the laser surface alloy obtained by melting of a Ni predeposited layer on an Al-Si substrate;

$P = 760 \text{ W}$; $\Phi = 1 \text{ mm}$; $V = 1 \text{ m/mn}$; $G = 125$.

Fig. 3 : micrograph of a Co-base coating on a stainless steel;

$P = 1100 \text{ W}$; $\Phi = 1 \text{ mm}$; $v = 90 \text{ cm/mn}$; $G = 125$.

Fig. 4 : optical micrograph exhibiting the plane front growth between the substrate and the coating;

$P = 1100 \text{ W}$; $\Phi = 1 \text{ mm}$; $v = 90 \text{ cm/mn}$; $G = 500$.