INVESTIGATIONS REGARDING THE CAVITATION EROSION RESISTANCE OF THE $Al_2O_3$30(Ni 20Al) LASER DEPOSITIONS ON THE 17-4 PH STAINLESS STEELS

KATONA Ştefan-Eusebiu, OANCĂ Octavian, BORDEAŞU Ilare, MITELEA Ion, CRĂCIUNESCU Corneliu Marius

"Politehnica" University of Timisoara, Timisoara, Romania, EU
keusebiu@yahoo.com, octavian.oanca@yahoo.com, ilarica59@gmail.com, ion.mitelea@upt.ro, craciunescucm@yahoo.com

Abstract

On the surface of a 17-4 PH stainless steel, powders from the cermet group were submitted, using the plasma thermal spray technique on a METCO SULZER installation. Thereafter, a part of the sprayed samples were remelted at the surface withu the Nd:YAG laser beam, on a Trumpf HL 123 LCU installation. The cavitation behavior of the samples was tested using an ultrasonic vibratory cavitation erosion equipment. The examination at the optical microscope and scanning electronic microscope of the marginal layer and of the cavitated surface revealed the formation of a dense microstructure, finished by remelting, which explains the increase by 133 % of the erosion resistance compared with the structural state obtained through 1050 °C solution treatment with air cooling.

Key words: 17-4 PH stainless steel, cavitation erosion, thermal spraying, laser remelting

1. INTRODUCTION

For many applications, structural materials suffer from various types of surface degradation by corrosion and wear phenomena. In the case of hydraulic turbines, generating low pressure regimes should be avoided because it affects their lives. If these cavities, appeared in the low pressure zones, enter a high pressure zone, it produces their implosion, and as a result, microjets with sufficient high speed are formed [1-3]. The impact of these microjets with the solid adjacent surfaces generates tensions with a magnitude of several hundred megapascals [3]. Such tensions are source of important material losses in the surface zone of the solid, phenomenon called cavitation erosion [4 - 7]. In order to reduce or avoid losses through cavitation, high performance coatings of oxides, carbides and nitrides of Al, Ti, W and Cr are used, which may be applied to the substrate material. Research has shown that even though the TiN and Cr-N coatings are attractive due to the high hardness, they are not favorable to the phenomenom of cavitation due to the occurrence of delamination [8, 9].

In this paper we propose to improve the resistance to erosion by cavitation, using the plasma sputter deposition technique of cermet layers, which are then remelted with the laser beam in order to obtain a finishing of the microstructure and implicitly improved resistance to erosion by cavitation.

2. RESEARCH MATERIAL. WORKING METHODS

From a 17-4 PH stainless steel charge whose chemical composition is shown in **Table 1** were made cavitation samples that were subjected to the hardening treatment for release in solution from the temperature of 1050 °C with air cooling, and then some of them were covered at the surface with powders from the cermet group, type Al_2O_3 30(Ni 20Al), by thermal spraying using the METCO SULZER installation. At two sets of these samples, the spray coating was remelted with the Nd:YAG laser beam, on the Trumpf HL 124P LCU installation, with two regimes having identical power and frequency (800 W and 10 Hz) but different durations (of 8 ms and 10 ms, respectively). In **Table 2** chemical composition of this type of powders is given and in **Table 3** are its main features.

Table 1 The chemical composition of the examined steel

Additional and alloying elements (wt. %)											
C	Si	Mn	Ni	Cr	Mo	Al	Co	N	Cu	P	S
0.10	0.50	1.56	4.12	15.57	2.11	0.58	2.04	0.046	0.18	0.031	0.029

Table 2 The chemical composition of the ceramic powder type Al_2O_3 30(Ni 20Al) [10]

Chemical composition (wt. %)					
Al_2O_3	Ni 20Al	TiO_2	SiO_2	Fe_2O_3	Others
Balance	29 - 31	< 3	< 1.5	< 0.7	< 1

Table 3 Defining specifications of the powders [10]

Nominal particle size distribution	Color	Morphology		Manufacturing method	
		Ceramic	Metal	Ceramic	Metal
- 90 + 10 μm	Brownish Grey	Angular / Blocky	Spheroidal	Fused and Crushed	Chemically Clad Composition

The cavitation erosion tests were conducted in the Laboratory of Cavitation, on the vibratory machine with piezoceramic crystals T2, built after the regulatory requirements of ASTM G32-2010 [1,11,12], using drinking water from the local network as working fluid, whose temperature was maintained at the value of 22 ± 1 °C. The research procedure, looking at the stages, conducting mode and manipulation of samples, macro - and microscopic analyzes of the eroded surface, as well as the recording of the experimental results, are those specific to the laboratory and in accordance with the standards of ASTM G32-2010 [6,7,11,12].

3. EVALUATION AND INTERPRETATION OF EXPERIMENTAL RESULTS

The analysis of the behavior to cavitation erosion of the ceramic powders, submitted by the process mentioned above, is carried out on the basis of the specific curves which give the cumulative average penetration depth of erosion, MDE, and its speed, MDER, depending on the duration of the cavitation attack, **Figs. 1, 2**. For the evaluation of the resistance, these curves are compared to those recorded for the same steel, subjected to the heat treatment of quenching for release in solution at 1050 °C with air cooling. The comparison is performed by the evolutionary way of the curves in time and through the specific values of the MDE and MDER parameters at the end of the research (after the 165 minutes of attack).

The MDE(t) and MDER(t) curves, of approximation/mediation of the experimental results, are statistically built with the relations established by Bordeaşu et al. [13]. The experimental results, from **Figs. 1, 2**, represent the means of those obtained on a set of three samples from each type of treatment and ceramic powder coating.

The evolution of the curves and the dispersion of the experimental points towards the mediation curves highlight significant differences regarding the effect of processing conditions on the behavior of cavitation.

From the analysis of these data, the following observations can be drawn:

- the coatings produced by plasma spraying present a mean depth of erosion after 165 minutes of cavitational attack, decreased by 84 % (**Fig. 1**) compared with the structural state obtained by solution treatment and a mean depth erosion rate reduced by 95 % (**Fig. 2**);
- the laser remelting of the sprayed layer provides a significant increase to cavitation, the greater as the laser pulse duration was longer; thereby, the MDE values are reduced by 133 % compared to those specific to the heat treatment (**Fig. 1**) and with 27 % compared to those obtained by coating the surface by spraying (**Fig. 2**).

- as an order of magnitude, after the ratio between the values which tend to stabilize the depth penetration rates of erosion, the resistance to cavitation of the remelted layer with the laser radiation having a duration of 10 ms is greater then about 1.2 times compared to the remelted layer with the laser beam having a duration of 8 ms, by about 2.4 times compared to the surface of the annealed solution sample at 1050 °C.

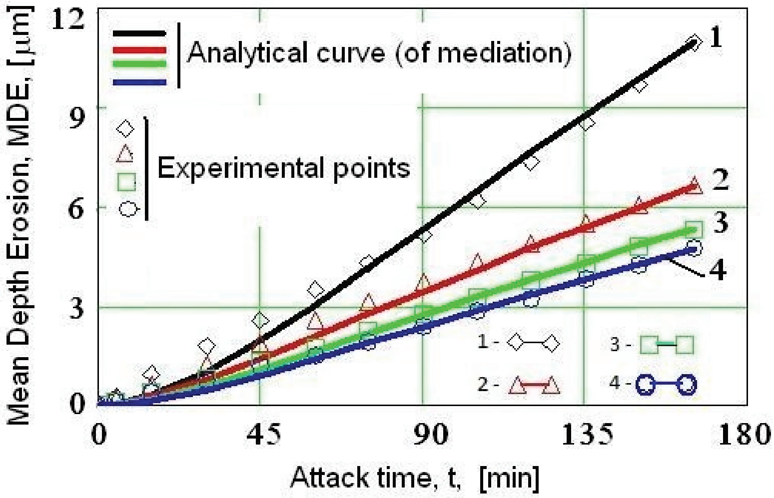


Fig. 1 Dependence of mean depth erosion against time exposure: 1 - Quenched 17-4 PH steel at 1050 °C with air cooling 2 - Thermal sprayed 17-4 PH steel without remelting 3 - Thermal sprayed 17-4 PH steel with remelting (P=800 W; f=10 Hz; pulse duration 8 ms) 4 - Thermal sprayed 17-4 PH steel with remelting (P=800 W; f=10 Hz; pulse duration 10 ms)

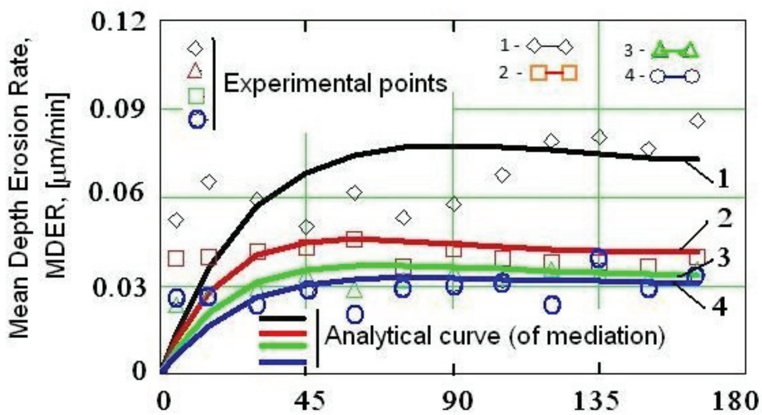
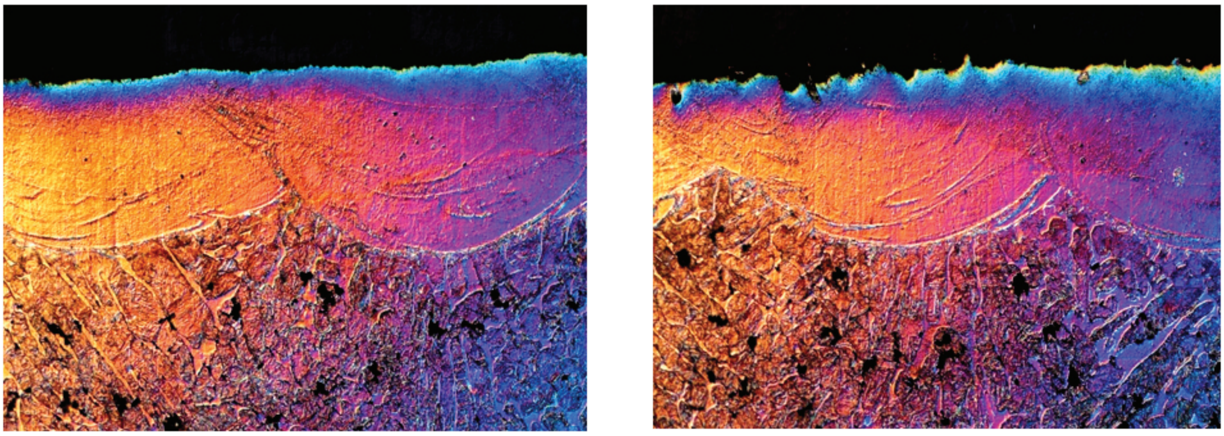


Fig. 2 Dependence of mean depth erosion rate against time exposure: 1 - Quenched 17-4 PH steel at 1050 °C with air cooling 2 - Thermal sprayed 17-4 PH steel without remelting 3 - Thermal sprayed 17-4 PH steel with remelting (P=800 W; f=10 Hz; pulse duration 8 ms) 4 - Thermal sprayed 17-4 PH steel with remelting (P=800 W; f=10 Hz; pulse duration 10 ms)

The explanation is related to the high hardness of the sprayed layer and remelted from the attacked surface (HV0.2 = 760...810 daN/mm^2), the main mechanical property, as evidenced by the research of Garcia and Hammitt [3], as being a large effect in the resistance to cavitation.

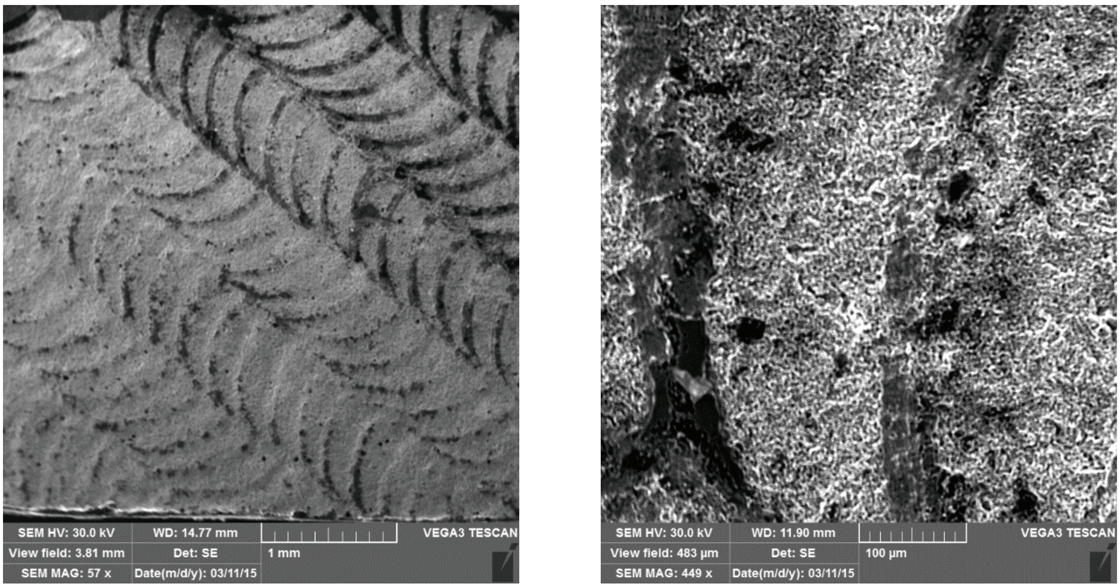
The image shown in **Fig. 3a** reveals the obtaining of a fine microstructure of the remelted layer, without porosites and other defects of continuity, with a good metallurgical bond at the substrate. After the cavitational attack, the same transversal section through the remelted layer with the laser beam (**Fig. 3b**) highlights an uniform degradation of its microstructure, with the pinchings produced mainly on the interface between the structural matrix and the particles of chemical combinations.

The examination by scanning electron microscopy of the surface topography tested by cavitation erosion (**Fig. 4a,b**) highlights the formation of crusts of similar forms, waves and uniformly distributed, at the processing with the laser beam. Also, as expected, an attack occurs preponderently, with pinching, which develops in microcraters, at the base of the waves created by the laser beam.



a b-

Fig. 3 Micrography of a transversal section through the sprayed and remelted layer with the laser beams, x 300: a - before cavitation ; b - after the cavitation test



a b

Fig. 4 SEM image of the laser remelted layer and tested to cavitation: a - lower magnification; b - detail

4. CONCLUSIONS

Covering the surface of parts which work in cavitation regime, with powders from the cermet group, type Al_2O_3 30(Ni 20Al), followed by power laser beam remelting, frequency and duration well defined, favors an increase in resistance to cavitation erosion by 133 %, compared to the structural state obtained by solution treatment at 1050 °C with air cooling.

The fine, dense, free of porosity microstructure, with high hardness, resulted by applying plasma spraying followed by laser beam remelting explains the pronounced improvement of the resistance at the wear by cavitation.

ACKNOWLEDGEMENTS

The support by a grant of the Romanian National Authority for Scientific Research, CNCS - UEFISCDI, project number PN-II-ID-PCE-2011-3-0837 is acknowledged.

REFERENCES

[1] BORDEASU I. Eroziunea cavitațională a materialelor, Editura Politehnica, Timișoara, 2006.

[2] FRANK J.P. MICHEL J.M. Fundamentals of cavitation, Kluwer Academic Publishers-Dordrecht/Boston/London, 2004.

[3] GARCIA R., HAMMITT F.G., NYSTROM R.E. Corelation of cavitation damage with other material and fluid properties, Erosion by Cavitation or Impingement, ASTM, STP 408 Atlantic City, 1960.

[4] MITELEA I. Știința materialelor, Vol. I, Editura Politehnica, Timișoara, 2006.

[5] MITELEA I., GHERA C., BORDEASU I., CRACIUNESCU C.M. Ultrasonic cavitation erosion of a duplex treated 16MnCr5 steel, International Journal of Materials Research, Vol. 106, No. 3, 2015, pp. 391-397.

[6] BORDEASU I., MITELEA I., KATONA S.E. Considerations regarding the behavior of some austenitic stainless steels to cavitation erosion, METAL 2012, 21th International Conference on Metallurgy and Materials, Ostrava: TANGER s.r.o., 2012, pp. 730-735.

[7] MITELEA I., BORDEASU I., KATONA E.S. Influence of the solution treatment temperature upon the cavitation erosion resistance for 17-4 PH stainless steels, 22nd International Conference on Metallurgy and Materials, Ostrava: TANGER s.r.o., 2013, pp. 208-213.

[8] MITELEA I. Materiale inginerești, Editura Politehnica, Timișoara, 2009.

[9] MITELEA I., DIMIAN E., BORDEASU I., CRACIUNESCU C.M. Ultrasonic cavitation erosion of gas nitrided Ti-6Al-4V alloys, Journal Ultrasonics Sonochemestry, Vol. 21, 2014, pp. 1544-1548.

[10] Cermet powder type Al_2O_3 30(Ni 20Al), http://www.oerlikon.com/metco/en/products-services/coating-materials/thermal-spray-maerials/cermets/.

[11] OANCĂ O. Tehnici de optimizare a rezistenței la eroziunea prin cavitație a unor aliaje CuAlNiFeMn destinate execuției elicelor navale, Teză de doctorat, Timișoara, 2014.

[12] Standard test method for cavitation erosion using vibratory apparatus ASTM G32-2010, http://www.astm.org/Standards/G32.htm.

[13] International Conference on Hydraulic Machinery and Equipments - HME 2008, http://aspc.cs.upt.ro/astr/index.php?page=revista&nr=15&articol=02.