INFLUENCE OF STRUCTURAL STATE ON CAVITATIONAL EROSION OF MARTENSITIC STAINLESS STEEL QUENCHING AND LASER HARDENED

IOAN PĂDUREAN[1],
MARIN TRUŞCULESCU[1], I. GABRIELA DEMIAN[2]

The paper continues the previous researches of the author, on the same topic- cavitation erosion- researches which ended with a Ph.D. thesis and through other works Samples of the martensitic stainless steel have been thermally treated and tested under cavitation erosion. There have been obtained modifications of the cavitational resistance dependent on the thermal treatment by use of structural analyses and micro hardness tests the influence of microstructure on the steel cavitation resistance had been stressed out. The thermal treatment of quenching + high tempering ($Q + T_H$), followed by quenching + high tempering + laser hardened ($Q + T_H + LQ$) or by quenching + high tempering + superficial laser quenching + low tempering ($Q + T_H + LQ + T_L$) give a high cavitational erosion resistance to martensitic stainless steel.

1. INTRODUCTION

The erosion intensity depends on a great variety of factors, such as: structural state, the blade material, the suction height, the duration of the phenomenon and the local conditions [1, 2, 3, 4, 5].

Papers [1, 2, 3] for the GX4CrNi13-4 stainless steel showed:

- composition characteristic,
- variant of thermal treatment($Q+T_H$; $Q + T_H + LQ$; $Q + T_H + LQ + T_L$),
- the eroded masses and the erosion velocity for each variant of thermal treatment determined by cavitational attack in a vibratory magnetostrictive test facility with nickel tube.

A detailed analysis of the cavitational erosion parameters of the thermally treated samples under different technological variants had offered the values of Table 1.

[1] "Politehnica" University of Timişoara
[2] University of Craiova

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Table 1

Values of eroded mass and erosion velocity

Thermal treatment	Eroded mass $\times 10^3$ [g]			Erosion velocity $\times 10^5$ [g/min]		
	Time [min]			Time [min]		
	50	100	165	50	100	165
Quenching – 1058°C/1h/water **(Q)** **High Tempering –** 650°C/3h/air **(T_H)**	3.30	9.43	17.63	10.00	12.50	12.50
(Q + T_H), (Laser Quenching)(LQ) in bands **I.** – 500W/3min/7,5 mm/s	1.90	8.00	17.00	8.00	8.00	8.00
(Q + T_H), (Laser Quenching)(LQ) in bands **II. –** 500W/3min/7,5 mm/s +**Low Tempering (T_L)**- 300^0 C/1h/air	1.00	5.90	16.00	7.50	7.50	7.50

2. MICRO STRUCTURAL ANALYSES

The samples from the GX4CrNi13–4 stainless steel, after the cavitation tests were sectioned on the generatrix, prepared and analysed metallographic.

The metallographic attack was made with the reactive CR 12361 / 1999 [1].

Areas A and B (Fig. 2.1) had been metallographic studies; the corresponding microstructures are on Plate I.

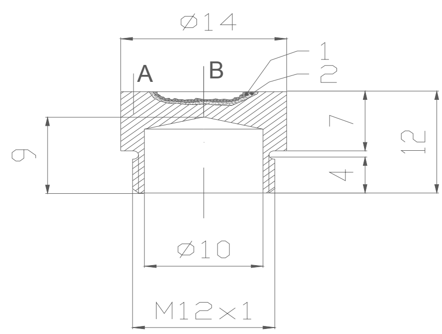


Fig. 2.1

The structure of the specimens is presented in the Figs. 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 2.10, 2.11, 2.12, 2.13.

The metallographic analysis of the samples subjected to cavitation erosion tests put into evidence the following aspects:

– after the quenching and high tempering there appears tempered martensite with fine carbide precipitation in the martensite needles (Figs. 2.2, 2.3).

– breaking up of the crystalline grains, formation the micro fissures and the intensification of the separations of complex carbides at the boundaries of the grains (Figs. 2.4, 2.5).

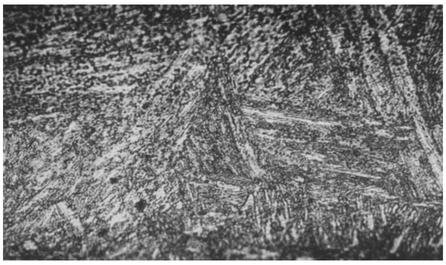


Fig. 2.2 – Zone A OM 500 ×

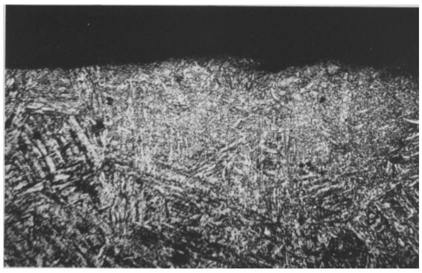


Fig. 2.3 – Zone B OM 100 ×

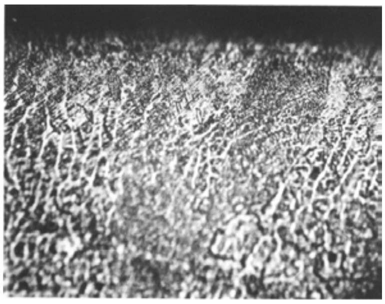


Fig. 2.4 – Zone B OM 500 ×

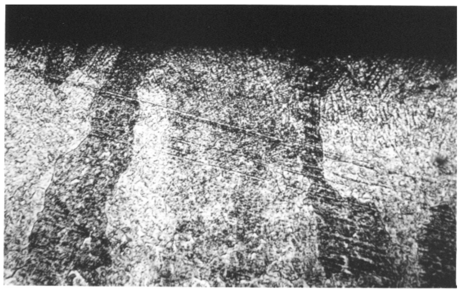


Fig. 2.5 – Zone B OM 500 ×

Note: Figs. 2.2, 2.3, 4,5 – STATE: Quenching + High Tempering

Fig. 2.6 – Zone A OM 100 ×

Fig. 2.7 – Zone A OM 500 ×

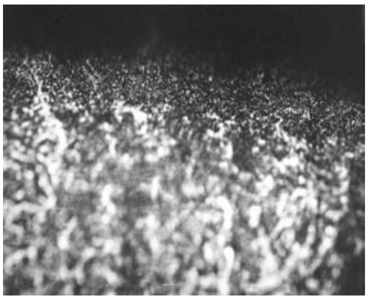


Fig. 2.8 – Zone B OM 100 ×

Fig. 2.9 – Zone B OM 500 ×

STATE: Quenching + High Tempering + Laser Quenching

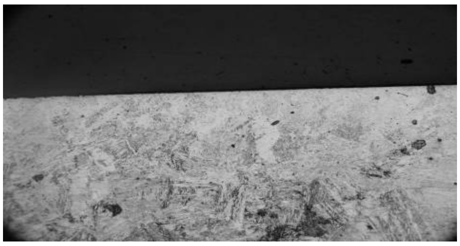


Fig. 2.10 – Zone A OM 100 ×

Fig. 2.11 – Zone A OM 500 ×

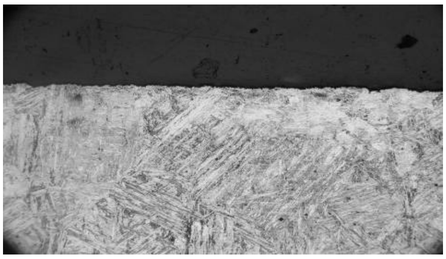


Fig. 2.12 – Zone B OM 100 ×

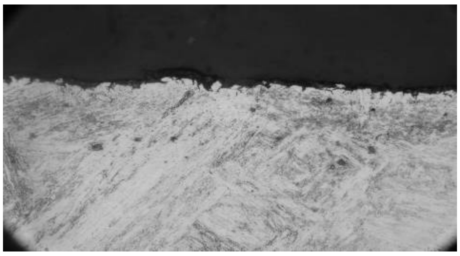


Fig. 2.13 – Zone B OM 500 ×

Note: Figs. 2.10, 2.11, 2.12. STATE: Quenching + High Tempering + Laser Quenching + Low Tempering

OM – optical microscope with 100 × or 500 × increase factor

The followings are observed in the superficial layers made by the laser radiation quenching:

– the finishing of the granulation, formation of fine needles martensite (Figs. 2.6, 2.7).

– taking off and the expulsion of some material particles. (Figs. 2.8, 2.9); In the cavitation eroded area there appear fine microcrackes, detachments and expulsions of very small grains.

The samples under a low tempering after laser quenching present:
– finishing of martensite needles and carbide precipitates (Figs. 2.10, 2.11).
– multiple microcrackes in the cavitated area, detachments of micro grains and a greater dispersion of the carbides precipitates (Figs. 2.12, 2.13).

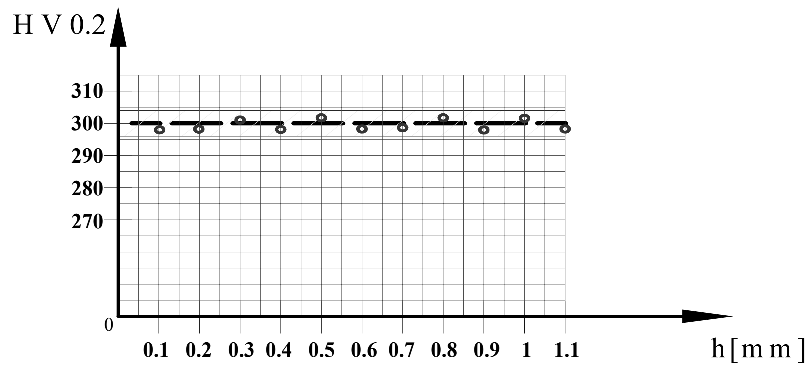
3. MICRO HARDNESS TESTS

There were made micro hardness measurements (HV 0.2) in A and B (Fig. 2.1) of cavitational eroded samples.

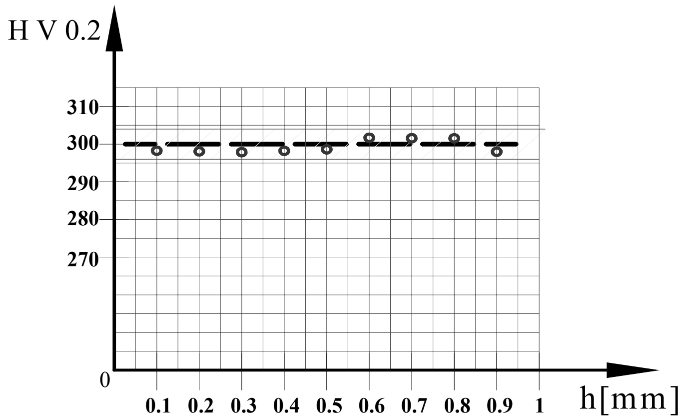
The step of indentation hardness was constant and there was observed the evolution of hardness on the height of samples (Fig. 2.1).

Figure 3.1 shows the evolution of microhardness of quenched and tempered samples.

Quenching + High Tempering GX4CrNi13-4



a)



b)

Fig. 3.1

Figures 3.2, 3.3 show the evolution of laser superficial quenching treated samples

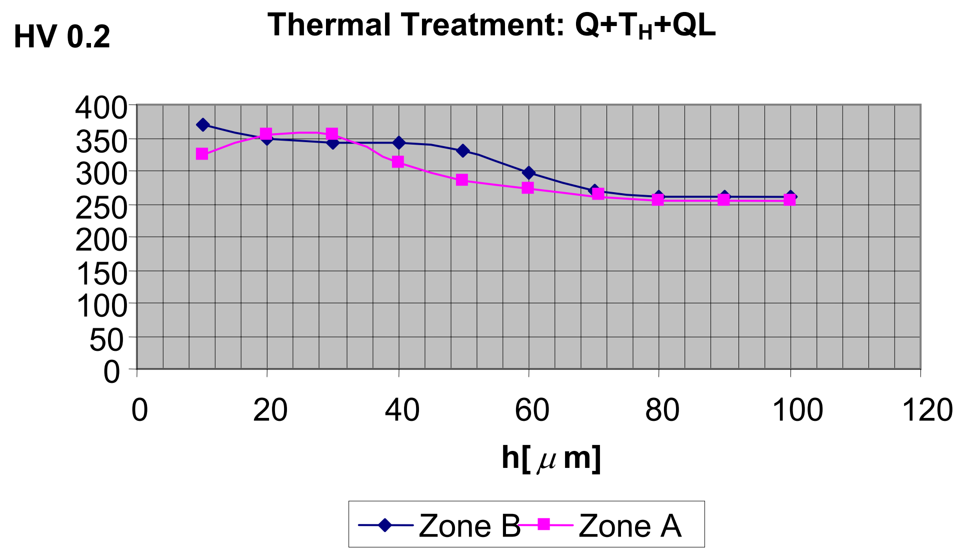


Fig. 3.2

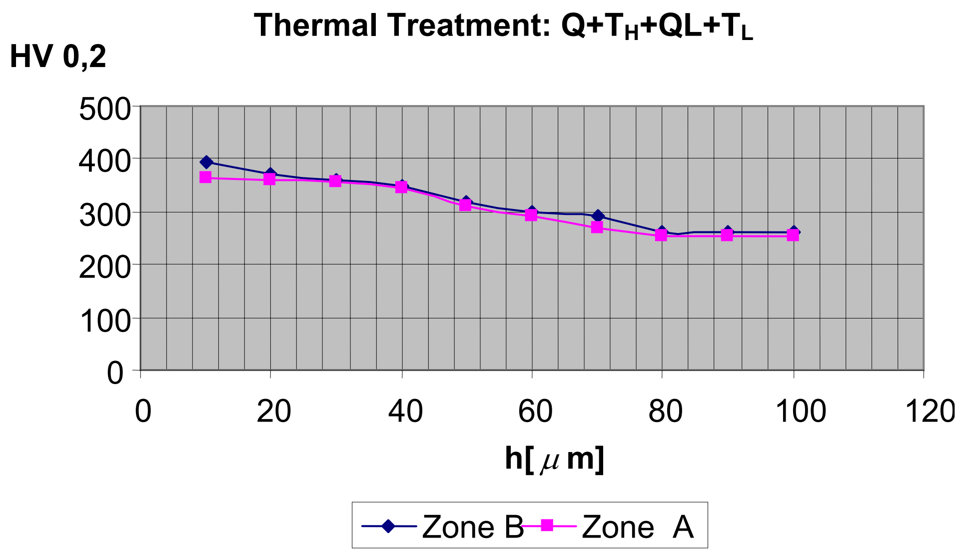


Fig. 3.3

The micro hardness tests show the following aspects according to the variant of thermal treatment:

Increase hardness in a superficial structure obtained by quenching and laser radiation quenching,

Though by quenching obtaining the highest hardness values of superficial layers, the cavitational erosion resistance is not one of the best,

In the superficial layers obtained by laser quenching there appear tensional states of compression which add to the increase of the cavitatonal erosion resistance.

4. CONCLUSION

All these structural aspects show that the cavitation phenomenon produces tensions, great local temperatures that determine the expulsion of material particles and favors diffusion phenomenon which modify the separations of the zonal carbides.

The metallographic analyses and the hardness tests have revealed the great role of structural state on the erosion resistance of martensitic stainless steel GX4CrNi13-4.

The damages through cavitation were achieved through the attack at the boundaries of the crystalline grains, the formation of micro-fissures and by breaking into pieces of some grains;

The material in the cavitation zone presents also structural modifications on small depths. It appears also a finishing of the granulation and an agglomeration of complex carbides at the limit of the grains;

Through the structure fines, the homogeneity of the granulation and the uniform dispersion of carbides, the steel that we talk about presents a good cavitation resistance.

The technological variants of thermal treatment through which superficial layers of fine grains are obtained with fine and hard structural constituents and compression tension states, are in favour of increasing of the resistance cavitational erosion of martensitic stainless steel.

The metallographic analyses put into evidence the great resistance of the tempered Martensite and complex carbides in the the GX4CrNi13–4 stainless steel.

It is recommended to put into industrial practice this thermal treatment or the blades made from the stainless steel GX4CrNi13–4.

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