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PLASMA NITRIDING AND PLASMA NITROCARBURIZING OF A LOW ALLOY STEEL SELECTED TO PRODUCE CAMSHAFTS FOR DIESEL ENGINES

A. Cabo[1]*, S. P. Brühl[2], G. Prieto[3,4], W. R. Tuckart[3,4]
[1]IONAR S.A. / [2]Universidad Tecnológica Nacional, Concepción del Uruguay/ Universidad Nacional del Sur / [4] CONICET

INTRODUCTION

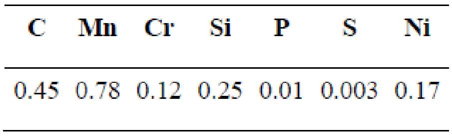
Camshafts are a relevant part of diesel engines of extended use today. These components work under torsion and are also prone to fatigue and wear damage. Usually they are manufactured by casting, forging or machining from forged bars of low alloy steels. In most cases, the machined surfaces are quenched and tempered by induction heating. To withstand the efforts imposed on the active surfaces and improve tribological and fatigue properties, the industry used for decades thermochemical technologies such as: salt bath or gaseous nitriding and nitrocarburizing processes.

This work studied the effects of plasma nitriding and plasma nitrocarburizing, on the tribological behavior of the steel SAE 1045HM3 proposed to produce camshafts.

Results show that plasma nitrided samples present the best tribological behavior compared to the nitrocarburized and quenched and tempered ones. The influence of the roughness produced by the thermochemical processes also appears to be important.

MATERIALS AND METHOD

The steel used was a SAE 1045HM3 in the form of annealed bar stock 57.10 mm in diameter. Its composition is presented in Table 1

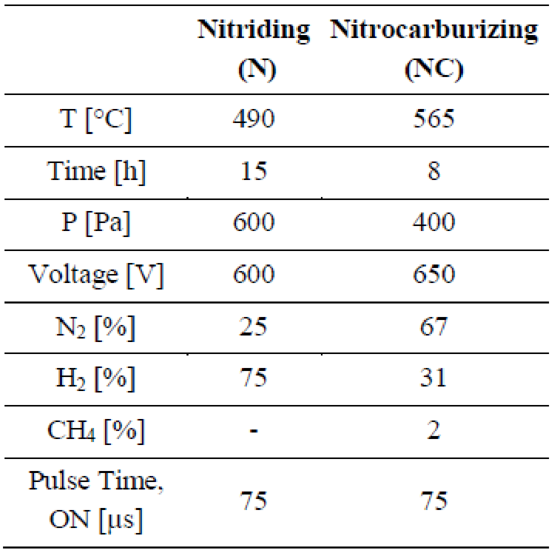


C	Mn	Cr	Si	P	S	Ni
0.45	0.78	0.12	0.25	0.01	0.003	0.17

Table 1: Chemical composition (%wt) of steel specimen

Disc samples 50 mm outside diameter, 12.6 mm inside diameter and 5 mm in thickness were machined. The samples were quenched and tempered to obtain a martensitic structure of 620 HV (56.2 HRC), similar to the case hardness obtained by induction hardening in the actual camshaft production.

Two groups of samples were selected, one for plasma nitriding (N) and the other for nitrocarburizing (NC). A third group, named “QT” is composed of blank samples, only conventionally heat treated. The parameters used in the plasma treatments are shown in Table 2



	Nitriding (N)	Nitrocarburizing (NC)
T [°C]	490	565
Time [h]	15	8
P [Pa]	600	400
Voltage [V]	600	650
N_2 [%]	25	67
H_2 [%]	75	31
CH_4 [%]	-	2
Pulse Time, ON [µs]	75	75

Table 2: Parameters of superficial plasma treatments.

Pin-on-disc tests were used for wear behavior characterization of the samples. Specimens were tested under two sets of conditions, namely, *as-received* and *polished*. The *as-received* specimens were kept with the same roughness parameters that were obtained after the thermochemical treatments, while the second batch of specimens was polished using abrasive SiC papers up to 320 grit. All specimens were ultrasonically cleaned with toluene for 5 min before and after each test. A 5 mm diameter tungsten carbide ball was used as the counter-body. Roughness parameters were determined using an optical 3D roughness measurement system based on focus-variation. The sliding speed in all cases was 0.06 m/s, while the sliding distance was set at 500 m for the *as-received* stage and 28500 m for the polished stage. The applied normal load was 10 and 40 N respectively.

Tests were performed using a low-viscosity, additive-free paraffinic Vaseline bath, with a cinematic viscosity of 17 cSt at 40 °C. All the experiments were performed under ambient laboratory conditions (25 °C, 65% relative humidity). Wear surfaces were analyzed by means of optical microscope while wear scar depth was determined in at least at 10 different positions using the aformentioned optical 3D measurement system.

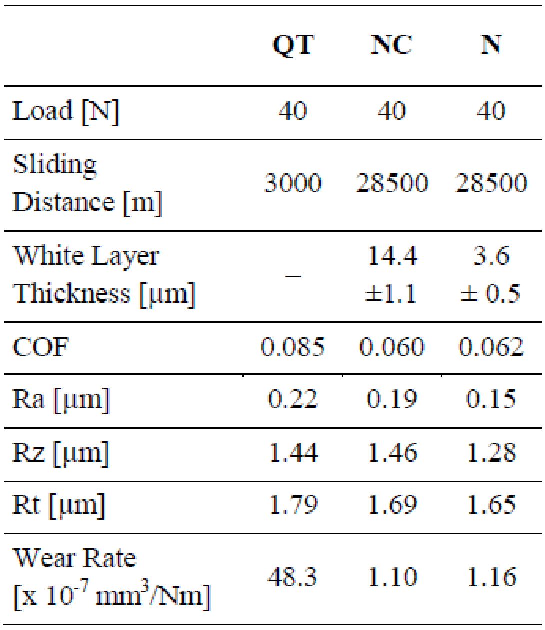
RESULTS AND DISCUSSION

Microhardness measurements shown that NC samples had an average white layer thickness of 15.6 μm and a diffusion layer thickness of 430 μm, while for the N samples the average white layer thickness was of 3.5 μm and the diffusion layer thickness of 330 μm.

QT specimens had an as-received roughness of 0.1 μm (Ra) and 1.40 μm (Rt), while in N and NC specimens it was of 0.2 μm (Ra) and 2.07 μm (Rt). Wear rate of QT specimens was so low that it could not be determined, while for N and NC specimens it was in the range of 1.0 x 10-5 mm3/Nm. The roughness parameters equated after polishing, thus results could be considered as independent of surface topography. Optical microscopy evaluation of polished specimens shown that the white layer of both N and NC specimens was not significantly diminished by polishing.

Roughness variations after thermochemical treatments had been reported by several authors, although in the majority of the cases, the analysis has been restricted to Ra values, such as the work of Çetin, et al. [2], who measured a Ra increase from 0.02 to 0.18 μm while studying plasma nitrided AISI 420 steel.

In our case, the higher value of Rt before polishing of N and NC specimens means that they had more prominent and singular peaks, which are prone to severe plastic deformation and subsequent break-off due to elevated contact stresses [3, 4]. Table 3 shows the results of the wear tests of the polished specimens



	QT	**NC**	**N**
Load [N]	40	40	40
Sliding Distance [m]	3000	28500	28500
White Layer Thickness [μm]	–	14.4 ±1.1	3.6 ± 0.5
COF	0.085	0.060	0.062
Ra [μm]	0.22	0.19	0.15
Rz [μm]	1.44	1.46	1.28
Rt [μm]	1.79	1.69	1.65
Wear Rate [x 10^{-7} mm^3/Nm]	48.3	1.10	1.16

Table 3: Quantitative results of wear tests of polished specimens.

CONCLUSIONS

From the present study the following can be concluded:

- The nitriding process produces less reduction of the hardness underneath the white layer; this is important from the stand point of the load bearing capacity of the case.
- Greater roughness after thermochemical treatments promotes a higher wear rate. However the friction coefficients are similar for all materials, ranging from 0.06 to 0.08.
- A low roughness level is more important than the thickness of the white layer. The nitrided samples, even though they had a thinner compound layer, had the same tribological perfomance than nitrocarburized specimens.
- Thermochemically treated materials showed wear rates one order of magnitude lower than quenched and tempered material.

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