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PLASMA NITRIDING OF POWDER VALVE SEAT INSERTS FOR DIESEL ENGINES

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Abstract

The effect of plasma conditions- gas mixture, nitriding time, pressure- on the surface layer microstructure and on the compound and diffusion layer properties at the surface of chromium alloyed powder valve seat inserts for diesel engines has been studied.

The glow discharge plasma nitriding was performed in gas mixture of 80% N_2 +20% H_2 at a pressure of 2.65 mbar and temperature of 520^0 C.

A high surface hardness of 710 HV5 and 890 HV 0.3 is achieved, as a consequence of the compound layer being formed very rapidly as a result of the content of alloying elements in the powder reaching metal steel matrix. The diffusion layer continues to grow steadily with time.

Key words: *plasma nitriding, powder metal, wear*

1. INTRODUCTION

In service many components and structures are subjected to varying loads which can lead to failure, as for example wear or fractures.

It is considered [1] that about 80% of all tribology problems within machine building industry is attributed to sliding and rolling elements, one fourth of which goes to wear.

One of the main tasks in the process of designing engine components is to determine their safety against stresses which cause unwanted failure.

Because the initiation and the development of surface microcracks are associated with localized surface regions, strengthening of surface may be increased by any of the available hardening processes.

There are various processes of harden the surface. One of them is nitriding, which has the advantage that it minimizes unavoidable distortions.

Several nitriding processes exit, among them ammonia gas nitriding, salt bath nitriding, plasma nitriding and powder nitriding [2, 3].

Plasma nitriding is one of relatively the suitable surface treatment processes. It is a glow discharge surface modification technique primarily used for case hardening of ferrous alloys as well as powder metal (P/M) to increase surface hardness and thus to provide improved wear resistance and fatigue.

During plasma nitriding, the specimen is the cathode of the direct current glow discharge. Impinging energetic particles (N_2, H_2, CH_4) deliver enough energy to the specimen to heat it to a pre-elected nitriding temperature. Unalloyed carbon steels, cast iron and sintered powder metal steel have a tendency to form an extremely brittle case that readily spalls during gas nitriding, but when their compound layer thickness is controlled, as is done in plasma nitriding, those surface exhibit good wear resistance and low friction [3-6].

2. EXPERIMENTAL

Valve seat insert (Fig.1) for diesel engines have been used as samples.

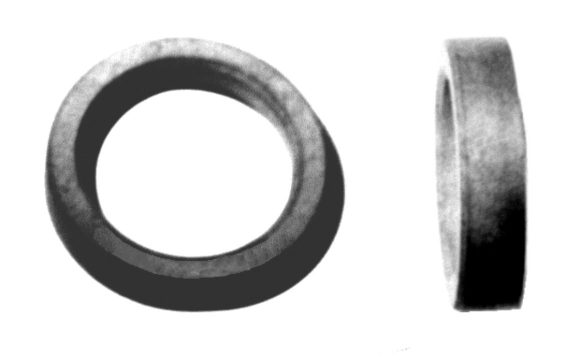

Figure 1: *Valve seat insert*

Seat inserts have been sintered using powder mixture (wt.%) of 1.4%C, 7.4%Cr, 4.3%Mo, 1.3%Cu and remaining being iron powder. Sintered seat insert hardness before nitriding was 287-310 HV5 and density 7.1 g/cm^3.

Figure 2 shows a P/M microstructure consisting of fine dispersed pearlite with small and uniformly dispersed carbides in a metal matrix.

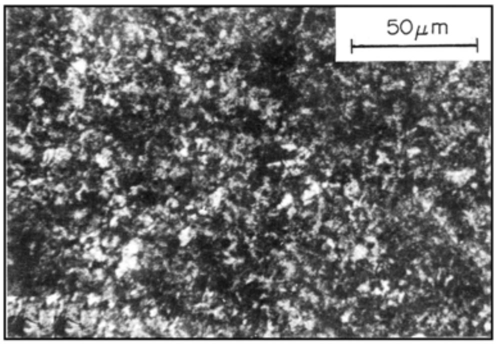

Figure 2: *Microstructure of P/M steel seat insert before nitriding*

Before nitriding the seat insert were washed and dried 3h at 150^{0}C, in order to remove oil and impurities from voids. Samples were nitrided in small laboratory plasma nitriding equipment. The glow discharge plasma nitriding was performed in an 80%N_2 +20%H_2 gas mixture, at a pressure of 2.7 mbar and a temperature of 520^{0}C for 3, 5, 7, 9 and 16h.

Microhardness measurements were carried out using a hardness tester with 0.3 and 5 kg load.

The nitrided zone microstructure was studied by optical microscopy methods.

3. RESULTS AND DISCUSSION

Surface hardness of plasma nitrided samples of P/M sintered steel as a function of nitriding time shows figure 3.

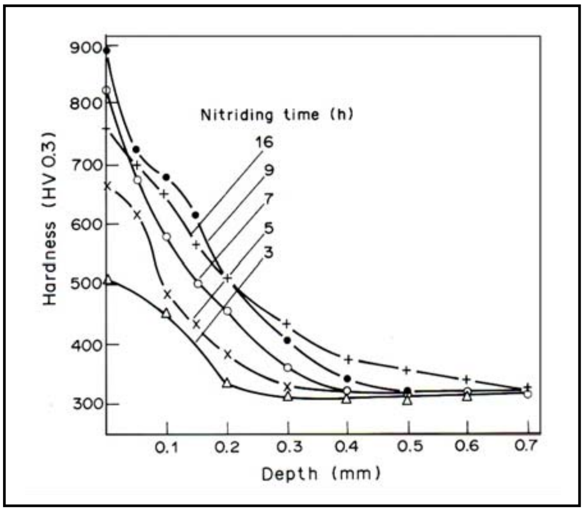

Figure 3: *Surface hardness of plasma nitrided samples of P/M sintered steel*

From figure 3 it can be observed that after plasma nitriding maximum value of the surface hardness 710 HV5 were achieved as a result of the content of chromium, molybdenum and carbon in the P/M steel matrix.

Changes of dimension are bigger on samples nitrided for longer times; they are in the range of 10- 15 μm, pointing to the necessity of introducing stabilization tempering of samples before nitriding.

Case depth was determined by microhardness testing an unetched cross section of the case using a hardness tester with 0,3 kg load. The microhardness depth profile of plasma nitrided samples of P/M sintered steel for various nitriding times is shown in figure 4.

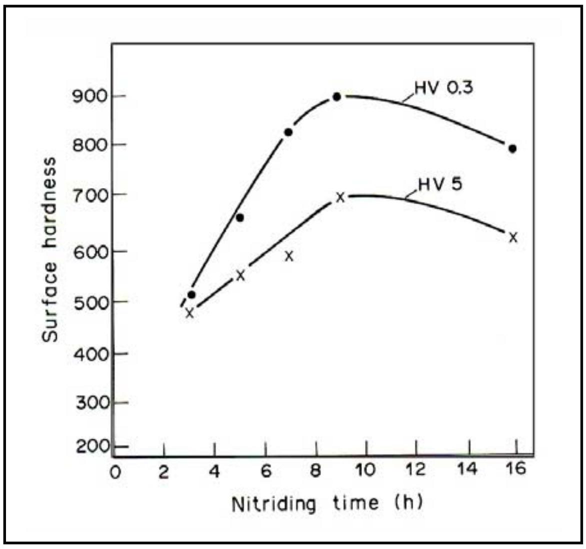

Figure 4: *Microhardnes depth profile of plasma nitrided samples of P/M sintered steel as a function of nitriding time*

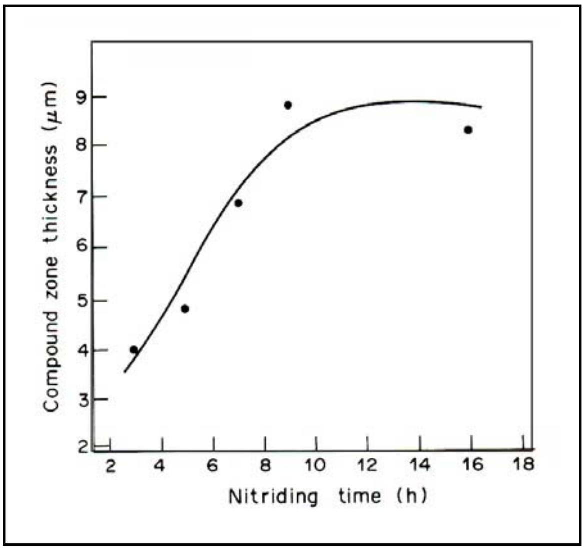

Figure 5: *Conpound layer thickness of plasma nitrided samples of P/M sintered steel as a function of nitriding time*

From figure 4 it can be seen that the diffusion zone depth steadily grows with the time of nitriding.

The compound layer develops when nitrogen species reach the workpiece surface at a rate faster than its diffusion rate into the matrix. The nitrogen content at the surface of the cathode P/M specimens is primarily a function of the gas composition and the nitrogen partial pressure. The diffusion rate depends principally on the treatment temperature. The compound layer comprises a monophased ε - Fe_{2-3} N, or γ' – Fe4 N, or polyphase of ε and γ'.

The specimens were etched in 5% nital and the compound layer thickness was measured by the optical system of the hardness tester that incorporates a direct reading vernier calibrated to 0.5 µm.

Figure 5 shows the compound layer thickness over the surface of P/M steel samples as a function of nitriding time.

From figure 5 it can be concluded that the compound layer grows differently, and that the growth of compound layer is not governed by the diffusion low.

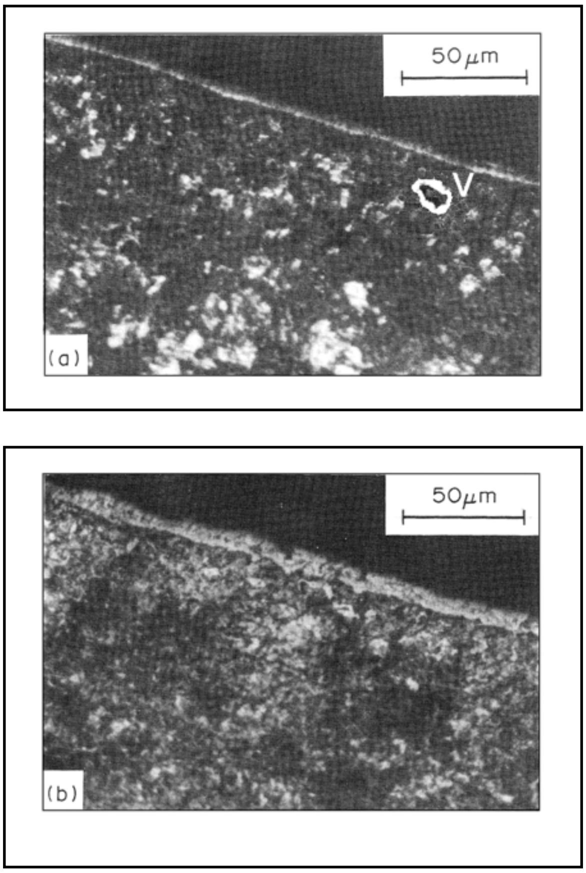

Figure 6: *Microstructure of cross – section of the surface layer of P/M steel seat insert after 3h (a) and 16h (b) plasma nitriding*

Microstructure of the cross-sections of the surface layers of P/M steel produced after 3 and 16h glow

discharge plasma nitriding in 80%N_2 +20%H_2 gas mixture, at a pressure of 2.7 mbar and a temperature of 520^{0}C are shown in Figure 6a,b.

It is observed that the compound layer is also formed around voids (V- magnified, fig.6a.), i.e. it follows the shape of voids present on the surface of the P/Mm steel samples. Formation of compound layers even around voids increases considerably the wear resistance of P/M steel samples.

Formation of the compound layer at the grain boundaries led to layer brittleness. From that reason it is the necessity of choosing carefully the temperature and duration of the plasma nitriding process.

4. CONCLUSION

On the basis test results it can be deduce:

Plasma nitriding of P/M steel parts is a very efficient process for increasing surface hardness.

The type microstructures of surface layers and noting the fact that a continuous and relatively thick compound layer following the voids has been realized, it point to a considerable improvement of wear properties.

The presence of the compound layer with maximum hardiness's of 715 HV5 and nitrided zone depth of 0.2 - 0.7 mm corresponding to 3-16h nitriding, is good basis for good anti-wear properties.

5. REFERENCES

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