

Effect of plasma nitriding on the impact wear resistance of AISI 8620 steel

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Abstract: The present study investigated the effect of plasma nitriding on the impact wear resistance of AISI 8620 steel. Nitriding was performed at 500 °C for 12 h in a 20% N₂–80% H₂ atmosphere. Microstructural characterization and microhardness measurements revealed the formation of a ~4 µm thick compound layer and an effective case depth of ~260 µm, with surface hardness increasing from 220 HV_{0.05} (untreated) to 572 HV_{0.05} (nitrided). Impact wear tests using a reciprocating hammer-type rig (5 Hz, 8000 impacts) demonstrated that plasma nitriding enhanced wear resistance, reducing the wear rate by 63% under a contact pressure of 2.89 GPa.

Keywords: AISI 8620, Impact wear, Plasma nitriding.

1. Introduction

AISI 8620 is a low-alloy steel widely used in high-stress and impact-loading applications due to its balanced hardness and toughness (Laguna-Camacho et al., 2025). Impact wear, arising from repeated surface contact, is a major failure mechanism in components such as steam generators, spline couplings, turbine blades, and gears, leading to surface degradation, crack initiation, and reduced service life (Ren et al., 2022; Shabana et al., 2025).

Enhancing surface properties of existing materials is an effective approach to mitigate such failures (Kovacı et al., 2022). Among surface modification techniques, nitriding is extensively employed to improve the mechanical and tribological performance of steels under impact and sliding conditions (Kaba et al., 2022). Plasma-assisted nitriding forms a hard compound layer, mainly composed of ϵ -Fe-₂₋₃N and γ' Fe₄N phases, and a diffusion zone beneath, through nitrogen diffusion from N₂-H₂-Ar gas mixtures. This process offers lower operating temperatures (~540 °C), minimal distortion, shorter treatment times, and enhanced wear, fatigue, and corrosion resistance (Binder et al., 2015).

Despite these advantages, the impact wear behavior of plasma-nitrided steels remains insufficiently explored. The present study investigates the dynamic response and damage mechanisms of plasma-nitrided AISI 8620 under cyclic percussive impact loading, comparing the performance of the modified surface layer with that of the untreated substrate using a reciprocating hammer-type test rig.

2. Materials and Methods

AISI 8620 low-alloy steel, selected for its combination of hardness, wear resistance, and toughness (Sánchez-López et al., 2025), was machined into discs of 28 mm diameter and 5 mm thickness. Surfaces were wet-ground and polished to an average roughness of $R_a = 0.04 \mu\text{m}$.

Plasma nitriding (PN) was performed in a vacuum chamber at a base pressure of 2×10^{-2} mbar. Hydrogen gas (2.5 mbar) was initially introduced for surface cleaning,

followed by preheating at 250 °C for 30 min. Nitriding was conducted at 500 °C for 12 h using a 20% N₂-80% H₂ gas mixture, with controlled cooling under vacuum. The cross-sectional morphology, nitride layer thickness, and hardness distribution were evaluated using a light optical microscope (LOM), surface roughness measured by contact profilometry, and microhardness tester with a 50 g load.

Impact wear tests employed a reciprocating hammer rig, where a 10 mm AISI 52100 steel ball impacted the steels at 5 Hz for 8000 cycles under dry conditions (25 ± 4 °C, 40 ± 5% RH). A 240 N load generated a maximum Hertzian contact stress of ~2.89 GPa. After impact tests, crater volumes were measured with a 2D profilometer, and wear rates were expressed as mm³ per cycle. Wear tracks on the steels and counter-body were analyzed using LOM with NIS-Elements software.

3. Results and Discussion

The conventionally manufactured AISI 8620 steel exhibited a ferritic-pearlitic microstructure (Fig. 1 a). PN induced notable changes, forming a ~4 µm thick compound layer over a diffusion zone. Cross-sectional hardness profiles (Fig. 1 b) showed a gradual decrease toward the core, with an effective case depth of ~260 µm, defined as the depth where hardness equals substrate hardness plus 50 HV (ISO 2639, 2002). The nitrided layer was resistant to etching, indicating a higher electrochemical potential than the substrate (Yan and Liu, 2010; Ren et al., 2022), and exhibited a surface hardness of ~572 HV_{0.05}.

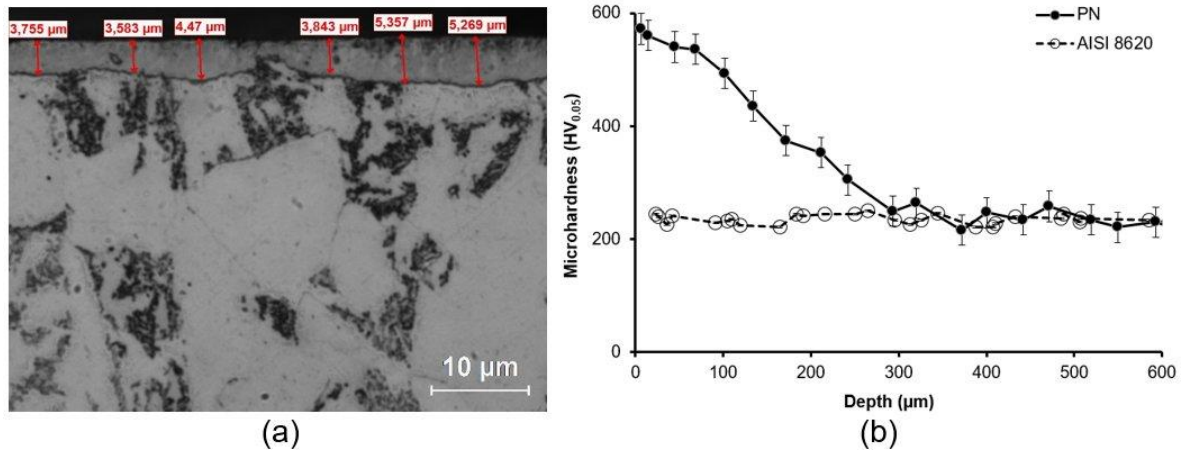


Figure 1. Cross-sectional characterization of nitrided steel. (a) LOM cross-sectional view and (b) microhardness profile for plasma nitrided steel.

Figure 2 shows the 2D surface profiles of the steels before and after PN. The treatment increased surface roughness due to the formation of microscopic pores in the compound layer, consistent with observations by Hassani-Gangaraj et al. (2014).

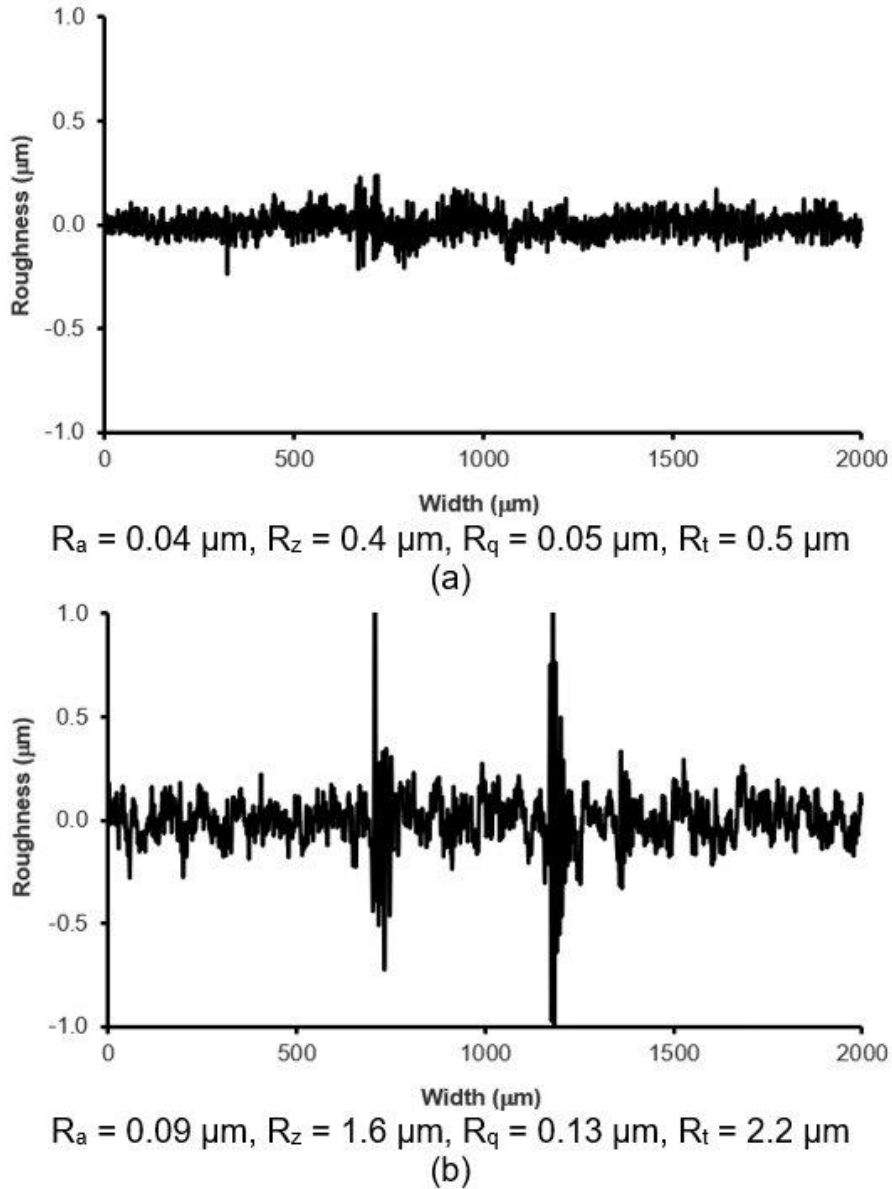


Figure 2. Surface roughness profiles with 2D parameters: (a) untreated and (b) nitrided steels.

Figure 3 shows the 2D and 3D cross-sectional profiles of wear scars after repeated impacts. The untreated steel exhibited poor wear resistance, with a wear scar width of 1.354 ± 0.18 mm and depth of 37.48 ± 8.6 μm, accompanied by pronounced plastic flow at the scar edges. In contrast, the nitrided steel showed limited plastic flow and markedly improved wear resistance, with a maximum wear depth of 17.87 ± 1.0 μm slightly exceeding the ~4 μm compound layer but only affecting ~7% of the ~260 μm case depth. This indicates enhanced resistance to plastic deformation and material removal, consistent with previous findings on deep plasma-nitrided steels (Ren et al., 2022). Additionally, surface roughness within the wear zone was reduced for the nitrided steel. Overall, the nitriding treatment markedly mitigated impact-induced damage and reduced pile-up formation.

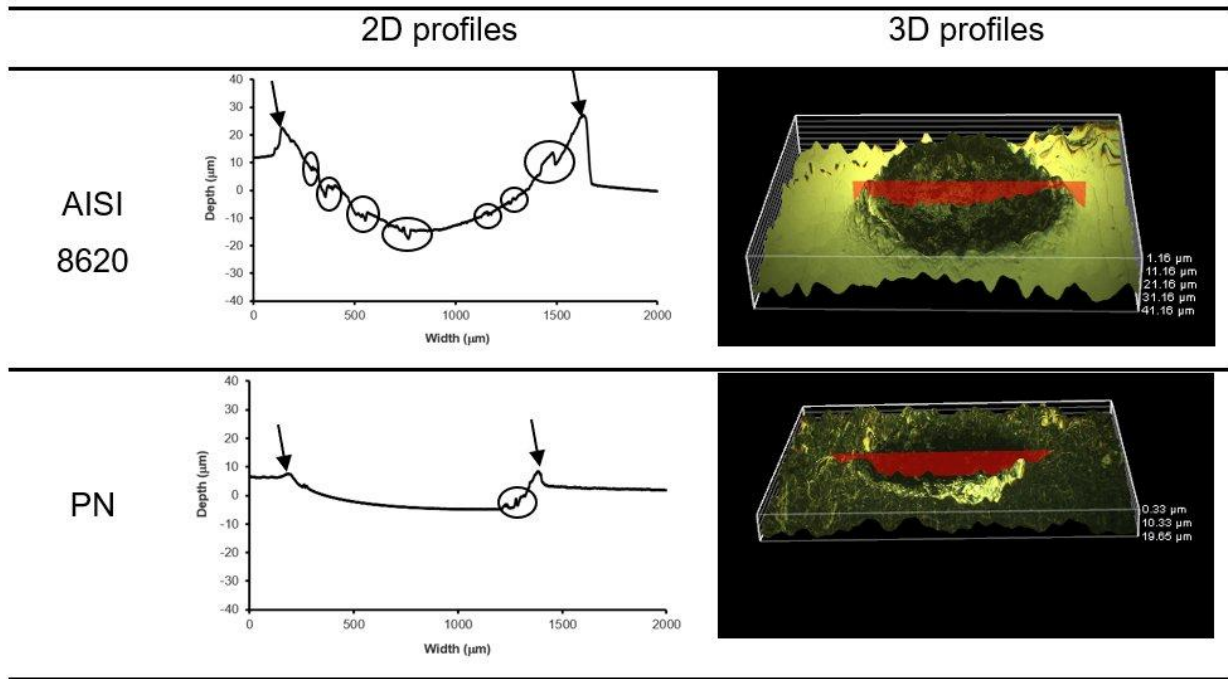


Figure 3. 2D and 3D cross-sectional wear profiles.

Figure 4 compares the average wear rates of the tested steels. The nitrided steel exhibited the lowest wear rate ($0.87 \times 10^{-6} \text{ mm}^3/\text{cycle}$), representing a 63% reduction compared to the untreated steel ($2.38 \times 10^{-6} \text{ mm}^3/\text{cycle}$) under identical impact conditions at a Hertzian contact pressure of 2.89 GPa.

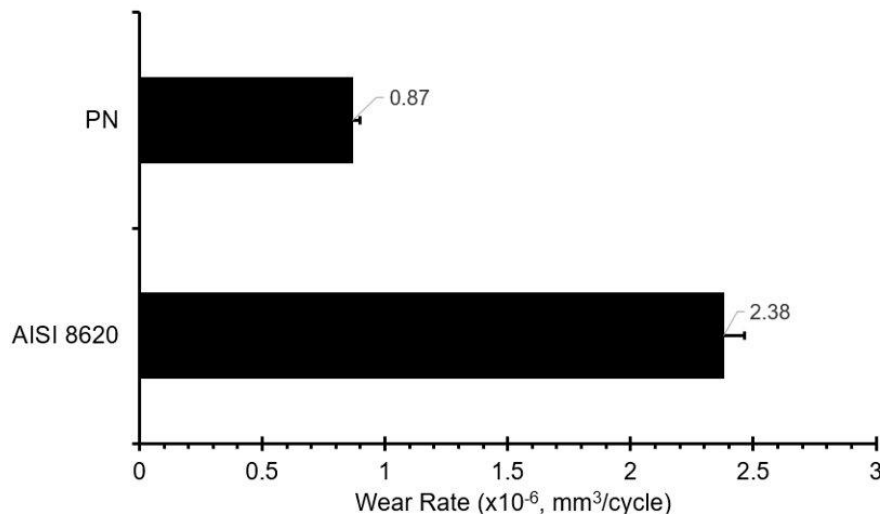


Figure 4. Wear rates of untreated and surface treated steels.

Figure 5 shows the LOM images used to examine the impact wear mechanisms of untreated and nitrided steels. The nitrided steel exhibited a shallower wear scar (Fig. 3), indicating that its hardened layer largely retained structural integrity under impact loading. The untreated steel showed severe pitting and delamination, whereas the nitrided steel displayed oxide patches with minor cracking at the scar center. The higher oxide fraction on the nitrided surface likely acted as a solid lubricant, reducing wear. Similar findings by Duan et al. (2019) suggest that a hard nitrided layer supports the oxide film, enhancing wear resistance.

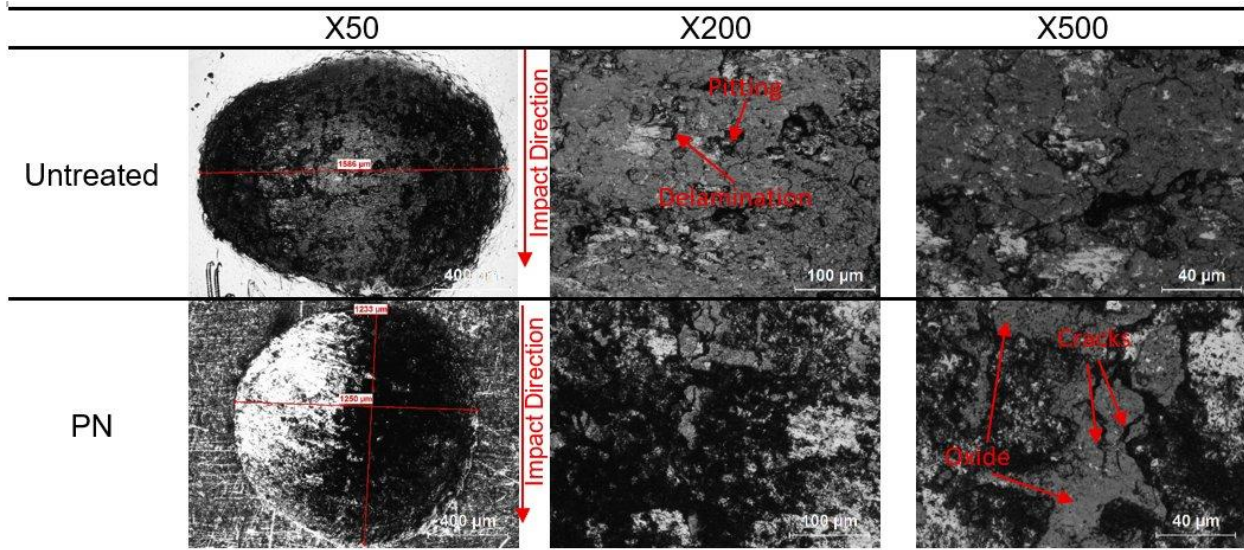


Figure 5. General and detailed LOM views of the wear scars of the untreated and nitrided steels.

4. Results

The impact wear behavior of untreated and plasma-nitrided AISI 8620 steels was evaluated. The main findings are as follows:

-Plasma nitriding produced a $\sim 4 \mu\text{m}$ compound layer and an effective case depth of $\sim 260 \mu\text{m}$, increasing surface hardness nearly threefold compared to the untreated steel.

-Under identical impact conditions (2.89 GPa), the nitrided steel showed a 63% reduction in wear rate relative to the untreated steel.

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