



# INITIAL APPROACH FOR OPTIMAL GAS MIXTURE COMPOSITION IN PLASMA NITRIDING PROCESSES OF STEELS

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## SUMMARY

Nowadays many industries apply the plasma nitriding treatment in steels that are under intense working conditions, like hydraulic pumps and turbines. The main purpose of the plasma nitriding process is to enhance tribological properties of the material, such as hardness, wear and corrosion resistance. The treatment of plasma nitriding, by introducing interstitial nitrogen into the bulk of the material, generate complex microstructures, such as iron nitrides ( $\gamma'$ -Fe<sub>4</sub>N and/or  $\epsilon$ -Fe<sub>2-3</sub>N), chromium nitrides, expanded martensite and/or expanded austenite. In steels, a white layer, known as “compound layer”, is formed on the top of the treated surface after the nitriding process.

The microstructure composition and nitrided layer thickness can be changed by manipulating the configuration of gas mixture and other parameters, for instance, temperature, internal pressure, treatment time and even the geometry of the treated samples. To investigate the ideal gas mixture for the plasma nitriding treatment, several studies on different mixtures have been performed, but many authors keep differing on the applied gas mixture composition. From the author's knowledge, there is not a single paper pointing the ideal gas composition for a desired nitrided layer. This study gathers the scattered data about the influence of different gas mixtures in stainless steel plasma nitriding processes and presents an initial approach for the best theoretical plasma nitriding mixture compositions, taking into consideration the many characteristics the compound layer can acquire depending on the gas mixture.

It is remarkable that most researchers do not employ argon in their gas mixture when plasma nitriding a steel. The results for the best theoretical gas mixture for different layer characteristics can be summarized as follow, focusing in thickness, crack formation and number of phases presented in the layer: 1) Thicker layer (40%N<sub>2</sub> + 40%H<sub>2</sub> + 20%Ar): crack formation and bi-phased( $\gamma'$  +  $\epsilon$ ); 2) Thick layer (65%N<sub>2</sub> + 15%H<sub>2</sub> + 20%Ar): no crack formation and bi-phased( $\gamma'$  +  $\epsilon$ ); 3) Thin layer (10%N<sub>2</sub> + 40% H<sub>2</sub> + 50%Ar): crack formation and mono-phased ( $\gamma'$ ); 4) Thinner layer (10%N<sub>2</sub> + 15%H<sub>2</sub> + 75%Ar): no crack formation and mono-phased( $\gamma'$ )

It's vital to emphasize that the “thinner layer” described previously is actually the thickest mono-phased  $\gamma$ -Fe<sub>4</sub>N layer that can be obtained without crack formation, as well as “the thin layer” is the thickest mono-phased layer ( $\gamma'$ -Fe<sub>4</sub>N) with some crack formation. These nomenclatures

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were applied to carefully avoid misunderstandings with the thickest bi-phased layer ( $\gamma'$ -Fe<sub>4</sub>N +  $\epsilon$ -Fe<sub>2-3</sub>N) – named as “thicker layer” – with crack formation and the thickest bi-phased layer – named as “thick layer” – without crack formation. When compared among themselves, the thickness, in ascending order, is: thinner layer, thin layer, thick layer and thicker layer.

The results summarized in this paper are just an initial approach. More studies must be conducted with the proposed gas mixtures to evaluate the simultaneous effect of nitrogen, hydrogen and argon with the specified percent amount and state if a destructive interference among the gases does not occur, that is, confirm if the best results are indeed obtained for the specified gas mixtures in this paper.

**Keywords:** optimal gas mixture; plasma nitriding; steels