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# Design and simulation of fuzzy logic based temperature control for a plasma nitriding process

Stelian-Emilian Oltean[a,]*, Mircea Dulău[a]

[a]*Department of Electrical and Computer Engineering, "Petru Maior" University of Tîrgu-Mureş, 1 N.Iorga st., 540088, Romania*

**Abstract**

The plasma ion nitriding is a multivariable process used for surface treatment. An important process parameter is the workpiece temperature in glow discharge. Due to the nature of the process containing nonlinearities and uncertainties, conventional control can be replaced with an advanced control based on intelligent systems. The paper contains the design of a fuzzy logic control of the workpiece temperature in a plasma ion nitriding process. The simulation diagram of the overall system was implemented and tested in Matlab/Simulink environment and uses a neural network model for the heating effect. The neural network model has been previously determined by using the practical knowledge and experimental data from different nitriding processes.



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*Keywords:* fuzzy logic control; plasma ion nitriding process; plasma nitriding control; plasma nitriding parameters.

## 1. Introduction

Plasma nitriding is a surface treatment technique which uses the direct current (DC) glow discharge phenomena to introduce elemental nitrogen in the crystalline lattice of the material [1]. The mechanical properties of the treated workpiece are increased by forming the nitrides in the surface layer. So, the advantages of using this thermo-chemical method, also known as plasma ion nitriding (PIN) process, are: obtaining high surface hardness and resistant surface, increasing the tensile strength, yield point and wear resistance, improving the fatigue life of alloy steels, tool steels and stainless steels. The nitriding process is accomplished in a workchamber where the plasma is generated in a gas mixture, usually at rough vacuum (0.75-10 torr) [2].

* Corresponding author. Tel.: +40-265-233212; fax: +40-265-233212
*E-mail address:* stelian.oltean@ing.upm.ro


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The nitriding process is complex and the diffusion of nitrogen depends on various parameters of the equipment as temperature of the workpiece, quality of the glow discharge, time of the treatment, gas flow and concentration. The workpiece material, quantity and geometry are important too. In [3-7] the properties of the treated material were investigated under different process parameters. For advancing the surface treatment in [6] refining microstructure and micro-alloying processes were proposed to activate the formation of aluminum nitride (AlN) by plasma nitriding.

So, there are a multitude of nitride treatment options and different type of equipments that make difficult to define global models and controls of the process. Although mathematical models can be defined as in [7], more and more often artificial intelligence methods are applied, first to predict the surface properties [8-11] (e.g. hardness change, nitriding layer thickness) and then to develop dedicated software applications that help to improve and to optimize the nitride treatment process. These applications often use soft computing solutions for modeling and control. For example techniques based on artificial neural networks ANN, evolutionary algorithms EA, fuzzy logic FL, expert systems ES and case-based reasoning CBR were developed and implemented in [7, 12-18] to compute different values of the process parameters (i.e. temperature, time, gas flow) and assist the entire process.

The paper presents the design stage and simulations of fuzzy logic control of the workpiece temperature in plasma nitriding process. The idea of such control system was given by the fact that the current control system of the actual nitriding equipment requires constant human supervision and is used only for maintaining the working temperature of the installation. The modern structure of the controller was chosen due the nature of the complex equipment (presence of nonlinearities and uncertainties, also lack of knowledge regarding some parameters) and it was designed by using the practical experience in nitriding processes. The fuzzy logic control was implemented in the Matlab/Simulink environment and tested in a simulation diagram which contains also the neural network model of the workpiece heating effect, constructed in [19]. The results will show that, in future, a practical implementation of the control system could not only maintain the temperature but also to heat up the treated parts.

The remaining part of the paper is organized as follows. In section 2 is presented the plasma ion nitriding equipment and some of the actual PID control system characteristics. The fuzzy controller for the workpiece temperature is described in section 3. The section 4 contains the simulation diagram of the workpiece temperature control system in plasma nitriding process and some results obtained using the Matlab/Simulink environment. Conclusions are made in the final part of the paper.

## 2. Plasma nitriding equipment. Actual PID control system

Plasma nitriding equipments are designed to achieve a thermo chemical nitriding treatment. As was also stated in the introduction the plasma ion nitriding is made in a vacuum chamber using a direct current (DC) glow discharge phenomena. A schematic diagram of PIN system and the experimental equipment are presented in Fig. 1. Some technical details of this were presented in [19].

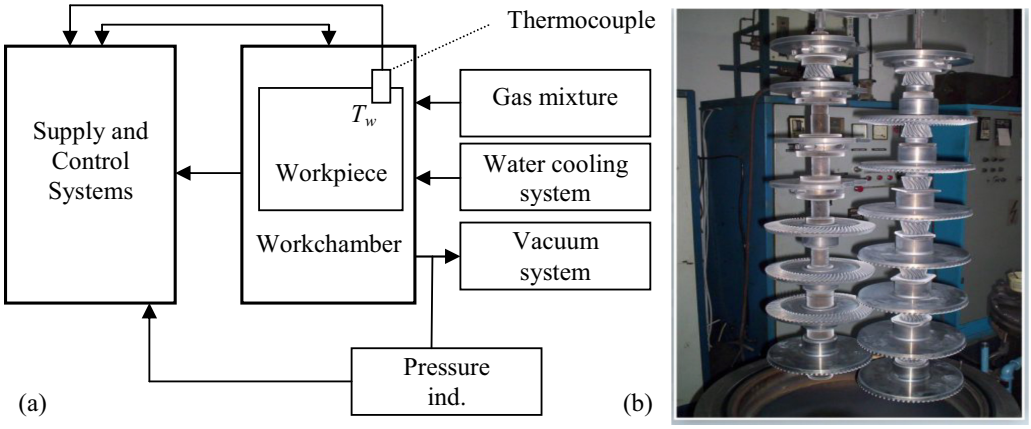


Fig. 1. (a) Schematic diagram of PIN system; (b) PIN experimental equipment.