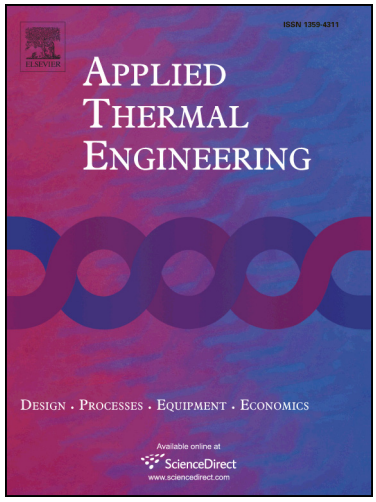

Research Paper

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LOWCOST AUTOMATED CONTROL FOR STEEL HEAT TREATMENTS

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Abstract

The aim of this paper is to propose a low cost, automated furnace control system for the heat treatment of steel. We used an open source electronic prototyping platform to control the furnace temperature, thus reducing human interaction during the heat process. The platform can be adapted to non-controlled commercial furnaces, which are often used by small businesses. A Proportional-Integral-Derivative (PID) controller was implemented to regulate the furnace temperature based on a defined heat treatment cycle. The embedded system activates the furnace resistors through Pulse Width Modulation (PWM), allowing for control of electrical power supplied to the furnace. Hardening and tempering were performed on standard steel samples using a traditional method (visual inspection without temperature control) as well the embedded system with PID feedback control. The results show that the proposed system can reproduce an arbitrary heat treatment curve with accuracy and provide the desired final hardness as inferred through metallographic analysis. In addition, we observed a 6% saving in energy consumption using the proposed control system. Furthermore, the estimated cost to implement the system is 42% lower than a commercial controller model implemented in commercial furnaces.

Key words: Temperature control, PID control, Automation, Applications, Performance analysis, Steel industry.

1. Introduction

Metal processing techniques have increased with the improvement of production processes and treatments to materials and mechanical parts, driven by technological developments in process control. Advancements in the accuracy of measuring instruments, sensors, actuators, and control techniques, have not only increased knowledge of material properties and their alloys, including the sintering of new composites, but also contributed to new developments. However, steel continues to be the most frequently used material in the industry due to its low cost, availability, recyclability, strength, and versatility. The uses of iron and carbon alloys have expanded by adding new alloying elements and, in particular, different kinds of heat treatments that can provide new and diverse mechanical properties. This process is of fundamental importance for industry because the materials are sufficiently soft to have their geometric forms modified before heat treatment. After heat treatment (hardening followed by tempering) the workpiece obtains a certain hardness and assumes the final mechanical properties. Usually this is the last step in the process for building a workpiece. Therefore, any non-conformity during this process corresponds to a loss of time, material and energy, resulting in significant financial loss.

Effective structural transformation of a material depends on the correct heating cycle. There is an optimal heating curve for each steel alloy and material application which are recommended by material suppliers. Structural and dimensional problems [1] are reflected in decreased workpiece life time, unexpected cracks when subjected to stresses, and greater number of stops for maintenance as result of cutting, bending, and forming tools.

However, most furnaces used in small businesses do not have proper heat treatment controls, and the process is performed by an experienced professional. In such cases, the target temperature is inferred by visual inspection of the workpiece's color which changes as the temperature increases. As such, the temperature control system (traditional method) depends on human interaction, is often empirical and subjective, and may result in limited operation efficiency, high consumption of energy [2], and fault of the components.

To control the process temperature without extensive operator involvement, feedback control system is necessary. This system depends on a controller that acquires the