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AUTOMATED SYSTEM OF TEMPERATURE HEATING AND COOLING CONTROL OF RESISTIVE FURNACE

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Abstract: The paper is devoted to the design and the implementation of an automated system for experiment control of metallic parts heat treatment using resistive furnace with additional nitrogen cooling. The way we have identified and designed the control loop of heating and cooling is described. The designed control system software and hardware are described too. Finally we specify some possible directions of the next development.

Key words: resistive furnace, heating, nitrogen cooling, control loop.

INTRODUCTION

Presented system come into existence as reaction to demand for controlling experiments of metallic parts heat treatment using the electric resistive furnace LM 112.10 with shielding nitrogen atmosphere.

DESCRIPTION OF CONTROLLED HEAT TREATMENT TECHNOLOGY

The heat treatment of metallic parts is a process, which main aim is to improve required properties like for example hardness, toughness etc. There are many good known technologies for achieving mentioned properties (hardening, annealing, tempering, etc.). That's why we described only two of them, which have been relevant for developing the control algorithm.

For designing of every heat treatment is necessary heating to the assessed temperature (for example austenitic temperature by hardening), holding time, time and course of cooling. For comparison of the conventional and unconventional heat treatment two examples of time – temperature curves are presented. The conventional heat treatment which shape is shown in Fig. 1, and the unconventional heat treatment by Lašček which is shown in Fig. 2.

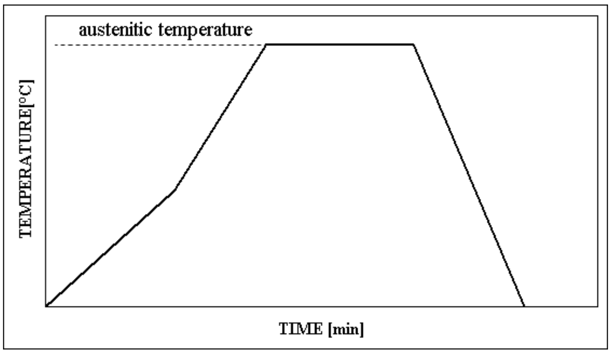

Fig. 1 Chart of the conventional heat treatment

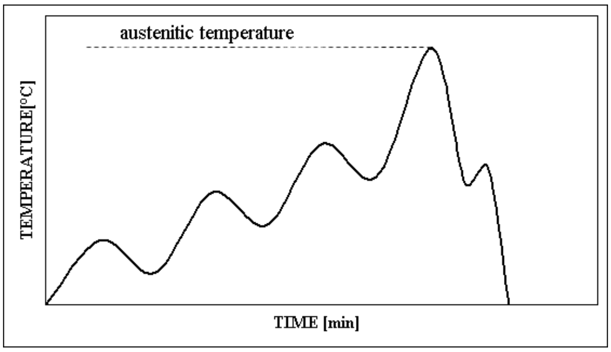

Fig. 2 Chart of the unconventional heat treatment chart by Lašček

The main aim of using the unconventional heat treatment method is to increase the toughness of metallic parts maintaining its hardness. In principle it is heat treatment of parts using theirs temperature difference between the core and surface, that correspond to the by numeric simulation predefined state of solid stress. To be able to use this method there is necessary to know both the core and the surface temperatures of the part.

SYSTEM HEFAISTOS

After analysis of mentioned technologies and equipment the affordable hardware for temperature measuring has been chosen (NI DAQ USB 9211) and the hardware part of system has been constructed (see Fig. 3). According to a construction of the furnace, which has only one winding and is controlled by PC, we have used the PID algorithm with pulse width modulation of control action (electric power switching). For the cooling control we decided to use incremental PID algorithm for the control of servo-drive of the nitrogen valve with constant speed because of increasing the lifetime of the valve.

Heating of the metallic part in the resistive furnace and its cooling with flowage of gaseous nitrogen are two different processes; that is why we solved them separately.

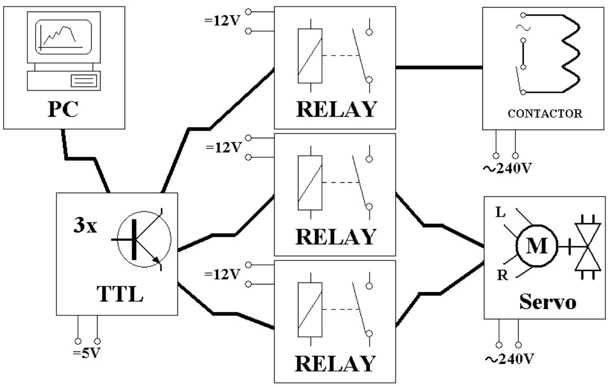

Fig. 3 Block scheme of system hardware

We measured dynamic characteristics (temperature change dependence on time as a reaction to the step wise input signal) of heating in resistive furnace and its cooling by gaseous nitrogen. According to the shape of measured transient characteristic the dynamic model of the furnace has been approximated as the first order system with variable time constant. As a result we chosen PI regulator for the heating control and for the cooling control too. To eliminate the interaction between the two control loops of heating and cooling, we have used the alternative box, which counts the values of control actions for the electric power switch control and for the nitrogen valve servo-drive control. If the value of control action brought on input of the alternative box from PI regulator is greater than 50%, the control action for heating will be used. But if the value of control action brought on input of the alternative box from PI regulator is less than 50%, the control action for cooling will be used. The interaction between heating and cooling control loops by itself is eliminated with suitable hysteresis band. Structure of the whole program is shown in Figure 4.

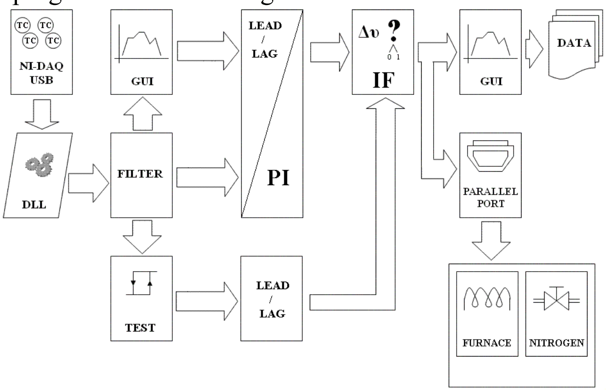

Fig. 4 Routine of the furnace heating and cooling

The alternative box also takes into account the difference between the temperatures of the parts core and surface.

There are three modes of heating control of processed part by itself. Fully automatic mode, which uses the user defined time temperature curve, than it is the automatic cutoff of user defined temperature and finally the manual mode, in which user directly controls the electric power switching of the furnace winding and operating the gaseous nitrogen valve.

During the whole experiment the archiving of measured temperatures is done for the reason of later elaboration. The system settings of individual experiments and the user defined time temperature curves are stored in the same way. All of this data are stored in *.CSV format, which enables their import to other applications (e.g. MS Excel) for theirs later analysis. Therewithal we have the ability to make experiments with various combinations of system settings and user defined time temperature curves.

The main application window of Hefaistos software (see Fig. 5) is divided into three parts:

The largest part, which consists of common chart for displaying the user defined time temperature curve and curves which are proportional to the temperature of the part core and surface, in the bottom of the screen is common chart for displaying curves which are proportional to percentage rate of furnace performance and of the outlet of the gaseous nitrogen valve, in the right part of the screen is situated the operator control panel.

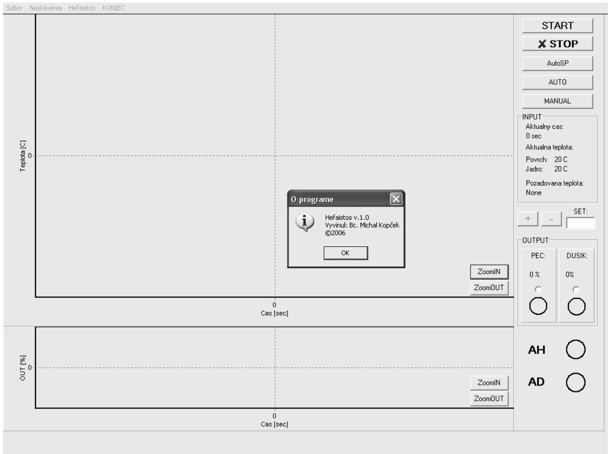

Fig. 5: Main application window

CONCLUSION

The presented system come into existence as a reaction to demand for controlling experiments of metallic parts heat treatment. Except the software control of heating process, the problem of parallel cooling was solved too, for the reason of slowly cooling of the part.

Presented solution take into account basic requirements on software systems of planned experiments, including archiving of experiment trends, which are necessitated by European guidance for assurance of quality of manufactured products.

The main contributions of this solution are:

- Collateral heating and cooling control;
- Software control of the temperature time profile;
- Elimination of the mutual interactions between two control loops;
- Archiving of the adjustment data of experiments for next application;
- Temperature trends generating and archiving;
- Temperature measuring of the core and the surface of the part.

Next direction of development will be oriented to design of software support for user interface, increasing of control quality of both modes and design of experiments documentation generator.

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