The experimental researches of advanced systems for process management in thermo sensitive heat treatments

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This paper presents a modern electric heating for heat-sensitive thermal treatments (small parts, complicated configuration and high alloyed steels or medium, parts automotive, aerospace, marine and energy) which has implemented an electric furnace control system by thermo regulators with the PID control law. An important aspect is the development of a mathematical model for controlling electrical heating systems for heat-sensitive thermal treatments based on mathematical modeling to predict the mechanical properties and structure of the play resulting from heat treatment. Validation of the experimental research of heat treatment temperature sensitive, designed by the mathematical model for predicting mechanical properties and structure of the finished part and model for controlling electrical heating system based on PID adjustment algorithms consists in characterizing chemical, structural and physic mechanical a low power turbine blade made of heat treated steel C45-RO1.0503 electric heating system design (structural analysis to determine the chemical composition, structural analysis by light microscopy, electron microscopy SEM and EDX quantitative analysis, determination of hardness alloys).

1. Introduction

By using research methodologies and advanced design, we have created a modern electric heating system for heat-sensitive thermal treatments (small parts, complicated configuration and high alloyed steels or medium, parts automotive, aerospace, marine and energy) has equipment for automatic management processes in electric furnaces heat treatment.

The best solution economically viable is to use as raw materials of non alloy and low alloy structural mechanical properties to have been enhanced by special heat treatments performed through automated machines and an innovative, environmentally friendly and ordered expert systems.

The main objectives for achieving electrical heating system for heat-sensitive thermal treatments:

a) presentation of constructive solutions to improve the operation of electrical heating systems to heat treatments:

- making design changes to electric furnaces heat treatment furnace design a modulated heat treatment;

- implementation of an electric furnace control system through thermo regulators with PID control laws.

b) development of mathematical models for the design and control of electrical heating systems to heat treatments thermo sensitive by designing optimum heat treatment furnace by mathematical modeling with the initial data geometric dimensions of the piece, batch volume, material characteristics, the embodiment of industrial furnace and type of heat treatment performed and the results are optimal size of the parts of the furnace, heat balance and energy calculations furnace.

c) mechanical properties and structure prediction piece resulting from heat treatment:

- modeling and computer simulation using a specialized software diagram of heat treatment based on the structure and mechanical properties of the final product and the design according to initial data;

- mathematical modeling to determine the mechanical properties and structural piece obtained after heat treatment;

- experimental validation of the results obtained from modeling the mechanical properties and structural comparison with classical technologies piece heat treatment;

d) mathematical modeling of process control system for electric furnaces for heat treatment:

- shaping control heat treatment furnace, setting parameters for thermostatic agreement (classical tuning PID);

- process control simulation with Simulink software package (classical tuning PID) parameters for process management and optimization;

- implementation of the control system real classic furnace heat treatment diagrams and those based on PID adjustment algorithms and experimental validation of the results.

e) validation through experimental research of heat treatment temperature sensitive, designed by the mathematical model for predicting mechanical properties and structure of the finished part and model for controlling electrical heating system based on PID adjustment algorithms chemical characterization, structural and physic-mechanical heat treated parts.

2. Advanced management system for thermo sensitive heat treatment furnace

Electric furnace heat treatment used in the experiments is the type enclosure with dimensions 800 x 800 x 1400 mm, with two different temperature zones, maximum temperature of 1200 °C, supply 220 V, 50 Hz.

Led multivariable system consists of the following components:

- electric furnace with two identical modules powered by four electric resistance with total power of 1.6 kW/module and a module unpowered door.

- thermocouples - an adapter that has the purpose of measuring the temperature of the furnace;

- electrical resistance type actuators forced bar;

- annexes devices and equipments necessary for proper functioning of the furnace as measuring and control devices (voltmeters, ammeters, etc.)

- command and control system for the furnace with digital temperature control.

Fig.1. Electric furnace heat treatment thermo sensitive
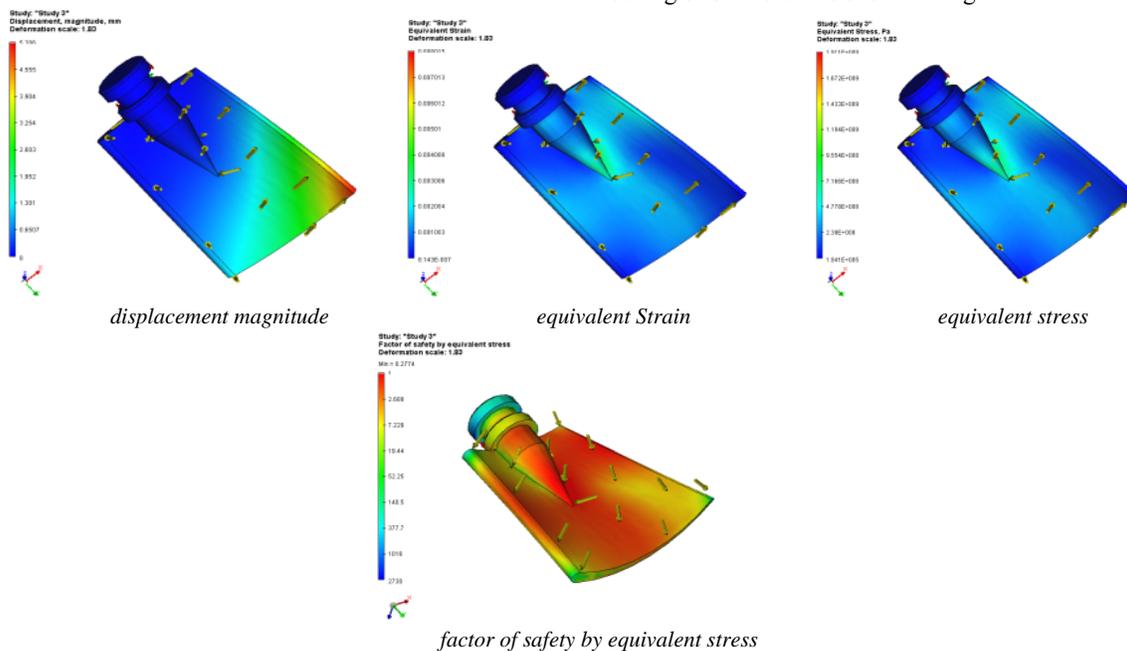
SHP turbine comprises a variable number of blades of different sizes and configurations designed according to the flow of the main adduction.

The materials used for the shaft and turbine blades must withstand various complex applications (bend and torsion), cavitations and corrosion complex mechanical, chemical and biological.

Common materials are bronze, brass, composite, cast iron and alloy steel.

Given the high cost of materials with high mechanical properties required in aggressive environment and working turbine blades and complex manufacturing technology we studied realization C45-steel blades RO1.0503, the heat treatment was applied to normalize order reduction state of tension and structural change in order to increase the toughness and wear resistance.

Finite element analysis of the state of stress and demands of SHP blade was performed using specialized software for finite element analysis using the preprocessor Autodesk Autocad.

The main steps of finite element analysis of the state of stress and displacement of the piece are:

- volume modeling, preprocessing and creating model structure finite element hydraulic turbine blade;

- determine the properties of the material of the piece;

- establishing the conditions for contour surfaces and surfaces exposed pressure with restrictions;

- solving the finite element method (FEM) and display the results for the amplitude movements, movements specific piece of tensions equivalent piece, determining the value of the coefficient of safety, the safety factor for the yield

Finite element analysis for tension and dynamic loading of SHP blade is shown in Fig. 2.

displacement magnitude   *equivalent Strain*   *equivalent stress*

factor of safety by equivalent stress

Fig.2. Finite element analysis for tension and dynamic loading
of SHP tempered blade system with PID controller.

Following analysis of the results shows that C45-RO1.0503 use of steel blades to produce SHP is only possible if the finished the piece is heat treated for stress reduction and structural changes state so that the the piece can take additional stresses that occur during operation and at the same time to increase the tenacity and abrasion resistance. Mechanical and technological characteristics of the material laid down in the program to predict the structure and mechanical properties are shown in table 1.

Table 1. Mechanical and technological characteristics

Characteristics of material (at t = 20 ^{0}C)			
density ρ_0			7753,6 [Kg/m3]
specific heat C_0			475,42 [Wh/Kg ^{0}C]
thermal conductivity λ_0			44,51 [W/m ^{0}C]
Mechanical characteristics			
hardness			22 [HRC]
internal stress			920 [Mpa]
elongation			14 [%]
reduction of section			60 [%]
charpy value			60 [J]
Technological characteristics			
critical temperatures	formula ASM [4]	formula Monge [4]	formulas from the program
Ac1 [^{0}C]	710,20	725,90	713,20
Ac3 [^{0}C]	787,26	775,72	787,24
Ms [^{0}C]	-	-	331,72
Normalizing heat treatment	heating temperature [^{0}C]		861
	heating time [second]		3660
	maintaining the temperature during the normalizing [second]		1380
	cooling conditions of the piece	cooling on air	

Considering the complexity of the piece, the existence of thin surfaces to achieve high precision temperature control enclosure with thermostatic furnace will be achieved with PID control algorithms that enable complex diagrams with high precision temperature control.

3. Multivariable control system of electric furnaces for heat treatment

The system for automatic heat treatment furnace involves the following steps:
- mathematical modeling to predict the microstructure and mechanical properties of steel depending on the brand, size and number of semi batch, mechanical properties and quality of the piece prior to heating for optimal heat treatment diagram setting;
- finite element analysis of the evolution in time of the temperature and heat flow of the piece subjected to heat treatment conducted in the furnace with thermostatic controlled PID;
- mathematical characterization of the behavior of the controlled heat treatment furnace and acting on its exterior sizes depending on operating mode;
- setting goals adjustment determined by the type of furnace process management, external signals and nature awareness of the mathematical model of the furnace;
- choice of method design involves optimizing parameter values agree, establish criteria for the selection and award regulators and determining optimal control algorithms;
- identification experimental model driven process, identification is performed online in safe working condition without play inside the furnace, as input data becomes available through measurement;
- simulating the control structure of the heat treatment furnace using the Simulink package;
- the usability of testing of algorithms design and implementation analysis, the optimal choice of equipment that ensures a precise implementation of the algorithm of management;
- implementing the heat treatment furnace control structures and tracking simulated time evolution of parameters followed;
- validation solution by analyzing the performance of the entire control system implemented allows the furnace if necessary redesign or adjustment parameters for the operating agreement.

3.1. Identifying experimental model of heat treatment processes thermo sensitive

Technological installation work is presented in a multivariable system with two inputs and two outputs, its mathematical model was obtained by parametric identification using Matlab-Simulink software platform.

Collection and processing of data necessary identification procedures were performed with a computer equipped with a card with A/D and D/A. Interfacing with computer technology installation was done using a plate LabPC + (National Instruments) containing A/D and D/A. The quantities measured in process (voltage signals in the range l - 5V) were scaled in the range 0 - 5V, so that the process input and output have the same type of signal, namely voltage in the range 0 - 5V.

The multivariable process with two inputs and two outputs, its mathematical model input and output can be put in the form of the transfer matrix of the form:

$$G_f\left(z^{-1}\right) = \begin{bmatrix} G_{f11}\left(z^{-1}\right) & G_{f21}\left(z^{-1}\right) \\ G_{f12}\left(z^{-1}\right) & G_{f22}\left(z^{-1}\right) \end{bmatrix} \quad (1)$$

Transfer functions from the main diagonal $G_{f11}(z^{-1})$ and $G_{f22}(z^{-1})$ models the main transfer channels of the process, the other two $G_{f12}(z^{-1})$ and $G_{f21}(z^{-1})$ highlighting the interaction between the two parts of the furnace.

Identification was done on-line in normal working conditions, heat treatment furnace being the piece inside, according to an algorithm of (Lazar C., 1999).

Identify the four transfer functions involves the following steps:

a) obtaining a set of input-output data.

Two experiments were needed to collect and process data necessary to identify the whereabouts transfer functions (f.d.t.) forming two columns of the transfer matrix (1) using Matlab function *arx*:

- the control signal is applied only on the first area of the furnace ($u_2 = 0$) and acquires both the outputs (y_1 and y_2), triplet (u_1, y_1, y_2) is used to identify the transfer functions $G_{f11}(z^{-1})$ and $G_{f12}(z^{-1})$ forming the first column of the transfer matrix (1).

- control signal is applied only on the second zone of the furnace ($u_1 = 0$) and acquiring both output sizes (y_1 and y_2), triplet (u_2, y_1, y_2) is used to identify transfer functions $G_{f21}(z^{-1})$ and $G_{f22}(z^{-1})$ that make up the second column of the matrix (1).

Both experiments were performed using real-time Simulink diagram of fig. 3.
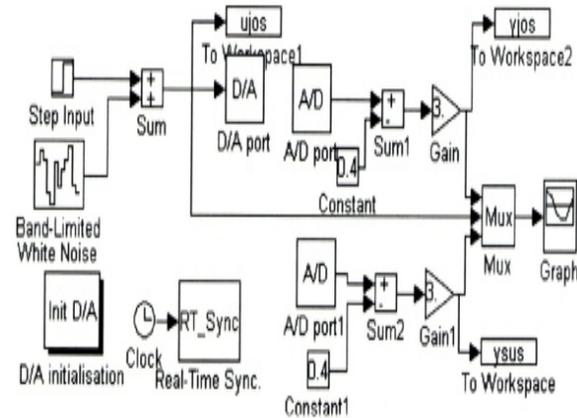
Fig.3. Real-time Simulink diagram for conducting experiments

Signal type curing step is generated using *Step Input* block overlapped block signal provided by *Band-Limited Noise* and apply 1 or 2 channel process through a D/A converter.

The output signals of the two channels are acquired with two A/D converters. The input u_i and output (y_1 and y_2) are stored in blocks of type *Workspace* for use in identification of ARX matlab function and displayed graphically using *Graph* block.

In both cases the applied input signal amplitude level 2V overlapping pseudo-random binary signal (parameter calculation algorithm used by MATLAB *arx* function may fail if a constant input signal).

Sampling period used was *Ts* = 40 sec. and to determine the block Simulink *Real-Time Sync* and operation which provides real-time Simulink diagram of fig. 3.

The data acquired are shown in fig. 4.a (first experiment) and fig. 4.b (second experiment).
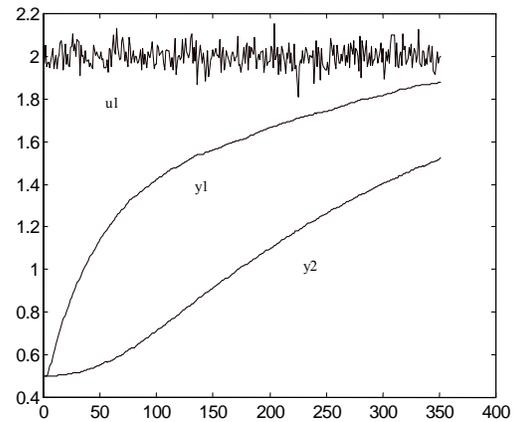
a) - experiment (i)
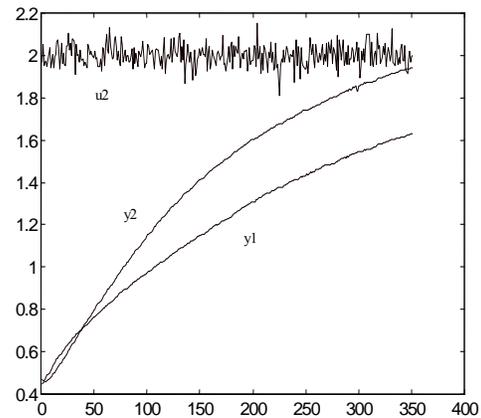
b) - experiment (ii)

Fig. 4. Data input/output obtained by experimental identification

In both figures the abscissa is the time variable in the sampling clock and the ordinate signals input/output in volts.

b) Examination, processing and filtering data.

As shown, the outputs taken from the process does not start from zero, but from an initial value (about 0.4V) corresponding to the initial furnace temperature of about 25 °C) in this step is done properly scaled outputs 0-5V range and translational *Constant* baseline blocks of fig. 4. for them to have originated as a starting point, also are removed samples are remarkably flawed due to acquisition errors.

c) Identification and validation of the model parameters obtained mathematical model.

Parameter estimation process was performed using the software package MATLAB function ARX models thus obtained in the "gamma". With the th2tf are then converted to discrete form transfer function (primary channels):

$$G_{fii}(z^{-1}) = \frac{B_{ii}(z^{-1})}{A_{ii}(z^{-1})} z^{-d_{ii}} \ , \ i = 1, 2 \qquad (2)$$

and the shape (for channels of interaction):

$$G_{fij}(z^{-1}) = \frac{B_{ij}(z^{-1})}{A_{ij}(z^{-1})} z^{-d_{ij}} \ , \ i = 1, 2; \ i \neq j \qquad (3)$$

Parameter estimation was done trying to obtain a mathematical model as small order, first tried to approximate the first order transfer function with $na = nb = 1$ and 0, and then to increase their order $na = 2$ and $nb = 0$ was considered that it was a good enough modeling (mathematical model validation was done by comparing the output of the process acquired mathematical model response to the same input signal).

The procedure for estimating the parameters of the transfer functions (2) of the main channels of the following results:

$$\begin{aligned}
B_{11}(z^{-1}) &= 0.0127 & d_{11} &= 2 \\
A_{11}(z^{-1}) &= 1 - 0.9941z^{-1} - 0.0064z^{-2} \\
B_{22}(z^{-1}) &= 0.0067 & d_{22} &= 4 \\
A_{22}(z^{-1}) &= 1 - 0.7613z^{-1} - 0.2329z^{-2}
\end{aligned} \qquad (4)$$

and the channels of interaction parameters to estimate the transfer function (3) produced the following results

$$\begin{aligned}
B_{12}(z^{-1}) &= 0.0019 & d_{12} &= 5 \\
A_{12}(z^{-1}) &= 1 - 0.6809z^{-1} - 0.3195z^{-2} \\
B_{21}(z^{-1}) &= 0.0058 & d_{21} &= 3 \\
A_{21}(z^{-1}) &= 1 - 0.6237z^{-1} - 0.3703z^{-2}
\end{aligned} \qquad (5)$$

It is noted that the transfer functions obtained are of second order, which simplifies the optimization problem (in terms of size) and leads to a numerical control laws with a small number of parameters and thus easier to implement.

At the same time, the approximation by the second order transfer function is sufficiently accurate, as can be seen in fig. 5 and fig. 6 comparing actual process responses obtained with experiments (i) and (ii) mathematical models answers to the same input signal using MATLAB function compare.

To determine the continuous model type f.d.t. (1), used to provide PID controllers were used the results shown in fig.5, a (measured output y_1) and in fig.5, b (measured output y_2).
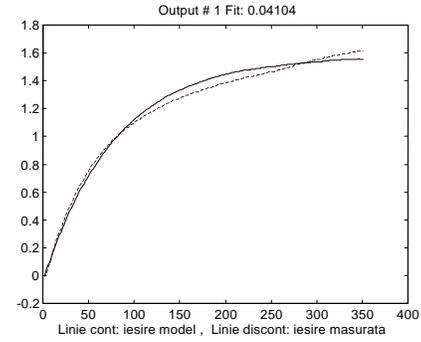
(a) output y_1 and response model $G_{f11}(z^{-1})$;
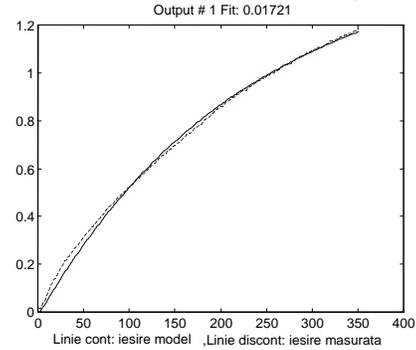
(b) output y_2 and response model $G_{f12}(z^{-1})$

Fig.5. Comparing the results obtained from the experiment u_1 (i)
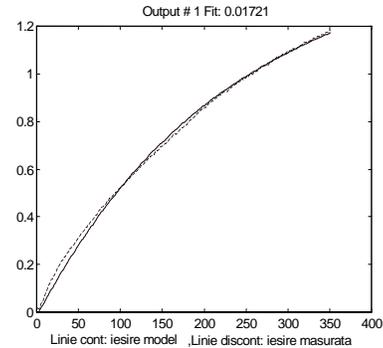
(a) output y_2 and response model $G_{f22}(z^{-1})$;
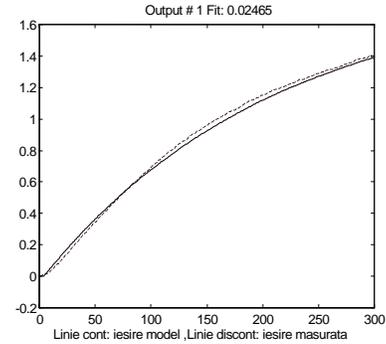
(b) output y_1 and response model $G_{f21}(z^{-1})$

Fig.6. Comparing the results obtained from the experiment u_2 (ii)

On the basis of the relationships (2 and 3) and the following parameters were obtained f.d.t. $G_{f11}(s)$

$$\left.\begin{array}{l} \tau_{11} = t_1 - t_0 = 3*40 - 0 = 120 \ \text{sec} \\ k_{f11} = \dfrac{y_{1\infty} - y_{10}}{u_{1\infty} - u_{10}} = \dfrac{1.9 - 0.4}{2 - 0} = 0.75 \\ T_{f11} = t_2 - t_1 = 73*40 - 120 = 2800 \ \text{sec} \end{array}\right\} \Rightarrow$$

$$G_{f11}(s) = \frac{0.75}{1 + 2800s} e^{-120s} \tag{6}$$

and respectively of f.d.t.$G_{f22}(s)$:

$$\left.\begin{array}{l} \tau_{22} = t_1 - t_0 = 4*40 - 0 = 160 \ \text{sec} \\ k_{f22} = \dfrac{y_{1\infty} - y_{10}}{u_{1\infty} - u_{10}} = \dfrac{2 - 0.4}{2 - 0} = 0.8 \\ T_{f22} = t_2 - t_1 = 123*40 - 120 = 4800 \ \text{sec} \end{array}\right\} \Rightarrow$$

$$G_{f22}(s) = \frac{0.8}{1 + 4800s} e^{-160s} \tag{7}$$

3.2. Simulation control structure using Simulink package

In order to obtain comparative results were simulated changeover control structure, with the PID and the predictive control algorithm on a step.

The canonical form P was simulated using the model in fig.4. f.d.t with the following notations:

main channels:

$$G_{fii}(z^{-1}) = \frac{B_{ii}(z^{-1})z^{-d_{ii}}}{A_{ii}(z^{-1})} = \frac{n_{ii}(z)}{d_{ii}(z)}, \ i = 1,2 \tag{8}$$

channels of interaction:

$$G_{fij}(z^{-1}) = \frac{B_{ij}(z^{-1})z^{-d_{ij}}}{A_{ij}(z^{-1})} = \frac{n_{ij}(z)}{d_{ij}(z)}, \ i = 1,2; \ i \neq j \tag{9}$$

In a similar manner the following notations have been used for the f.d.t decoupling controller

$$G_{Rij}(z^{-1}) = \frac{n_{rij}(z)}{d_{rij}(z)}, \ i = 1,2; \ i \neq j \tag{10}$$

one PID controller was designed to test the simulation using Simulink diagram of FIG. 8.

The controller for Haalman method has f.d.t. $G_{R1}(s)$ of equation (10) and was adequately implemented using Simulink block PID.
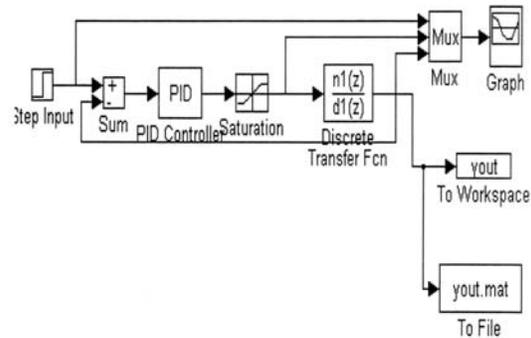
Fig. 7. Simulink for control structure diagram with PID algorithm.

The results of the simulation are shown in fig. 8. because the controller does not compensate for the dead time is an error observed stationary portions of the temperature profile ramp (reference).
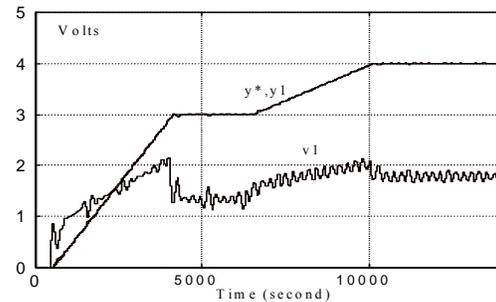
a). the simulation results of I area of the furnace
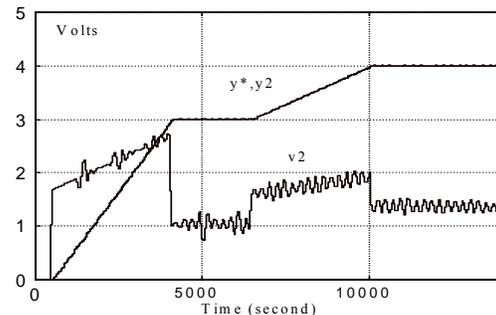
b). the simulation results of II area of the furnace

Fig. 8. Results of the simulation with PID

3.3. The design of the main regulators mono variables

A solution for temperature control of the two after decoupling process is the use of PI controllers designed Haalman method based on f.d.t. $G_{f11}(s)$ and $G_{f22}(s)$. Thus, using equations (8), (9) and (10) we obtain the following main regulators:

$$K_{R1} = \frac{2T_{f11}}{3\tau_{11}K_{f11}} = 20.74, \; T_{i1} = T_{f11} = 2800 \Rightarrow$$

$$G_{R1}(s) = 20.74\left(1 + \frac{1}{2800s}\right)$$

(11)

$$K_{R2} = \frac{2T_{f22}}{3\tau_{22}K_{f22}} = 25, \; T_{i1} = T_{f22} = 4800 \Rightarrow$$

$$G_{R1}(s) = 25\left(1 + \frac{1}{4800s}\right)$$

(12)

A high performance adjustable dead time compensation is achieved by using PID controller. Its design is developed using MATLAB routine ostep.m (C. Lazar, 1997), which allows the calculation of polynomials G_r, G_e and G_y defined by relations (11 and 12) based on ARX model of the process.

If the imposition of restrictions on the size of the control structure controller is modified to be included and restrictions.

It is usually limited due to the size of the control actuators and D/A converters. This leads to errors in calculating the size of the control as will be no difference between the control amount used for the determination of $u(k)$ and the actual command (limited) apply to the process.

To eliminate the error, enter the polynomial

$$R_e(z^{-1}) = z\left[G_e(z^{-1}) - 1\right]$$

(13)

and Simulink block for the implementation of the controller is shown in fig. 10.
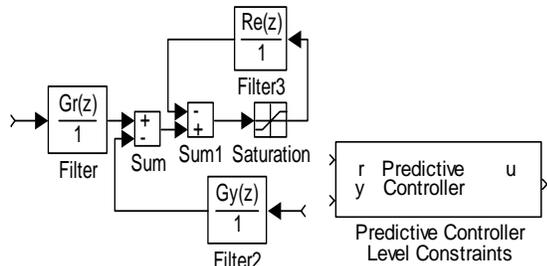
Fig.9. Simulink block for PID controller with limitation of control

The experimental results obtained with real-time control structures temperature heat treatment furnace are presented in the following subsections thermo sensitive dedicated to the establishment and implementation of the command structure and experimental validations.

3.4. The implementation of real-time temperature adjustment structure

The superior performance achieved with PID controllers for real-time implementation of structural adjustment renounced on-off control.

PID adjustment is implemented in a single control structure of a mono variable two-zone furnace temperature.

The controller for a channel was implemented with real-time Simulink diagram of fig. 10 and for the other channel was used identical scheme.
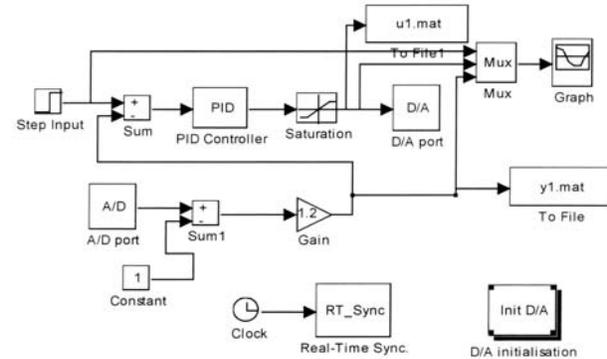
Fig.10. Real-time simulink diagram for implementing a PID regulator

Size control is provided on the grid control device with a static contactor D/A converter implemented in Simulink block *D/A port*. The initial size control can be set to block Simulink *D/A initialisation*.

Temperature measuring signal transducer and processed by the adapter was purchased by an A/D converter implemented with Simulink block *A/D port*. The functioning of real-time diagram in Fig. 11 is provided by the Simulink block *Real-Time Sync*, which fixes the sampling period.

Experimental validation of the results was made by applying a heat treatment to normalize a low power turbine blades made of steel C45-RO1.0503, normalizing heat treatment has the effect of changing their structure and tenacity.

In order to achieve a program of the corresponding experiments were carried out normalizing heat treatment and heat treatment with the conventional structure PID control algorithm based on turbine blades.

Parameters of heat treatment were designed with expert software that allows modeling and simulation of heat treatment and mechanical properties and structural determination of the piece and has as input the initial parameters of the process: the chemical composition of heat-treated steel, number and size blanks, the initial state of the structure of the piece, geometric and thermal conditions imposed piece, mechanical and structural properties obtained after heat treatment.

Heat treatment technology optimization is to reiterate calculation process parameters and compare the mechanical properties and structural characteristics of the piece obtained after heat treatment simulation with the original results, if a property is less than the calculated prescribed parameters of the process change data corresponding calculation, the simulation is repeated until the calculated properties are better than required.

PID control algorithm with of the furnace control system was implemented on a personal computer data acquisition system from the system.

Figure 11 shows the experimental results, taken from data acquisition board installed in the control system of electric furnace for heat-sensitive treatments, temperature charts - heating diagram calculated with classical algorithms, calculated temperature chart wizard and temperature PID algorithm actual furnace played by thermocouples placed in the furnace vault, corresponding module area I.
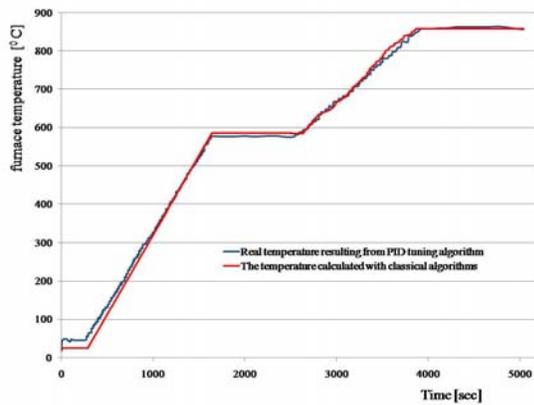
Fig.11. The result of PID temperature control (zone I of the furnace)

Fig. 12 shows diagrams of voltage control PID controller provided with static contact module I.
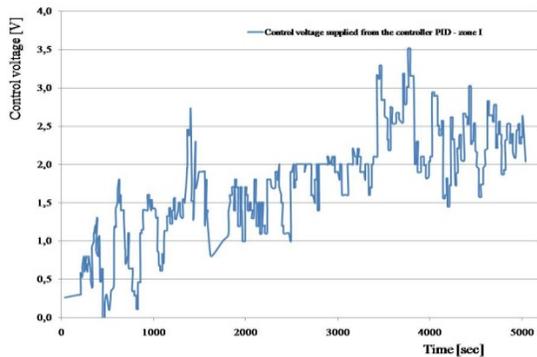
Fig.12. Control voltage PID controller provided with static contact (zone I of the furnace)

Fig. 13 shows the experimental results, taken from data acquisition board installed in the control system of electric furnace for heat-sensitive treatments, temperature charts - heating diagram calculated with classical algorithms, calculated temperature chart wizard and temperature PID algorithm actual furnace played by thermocouples placed in the furnace vault, corresponding module area II.
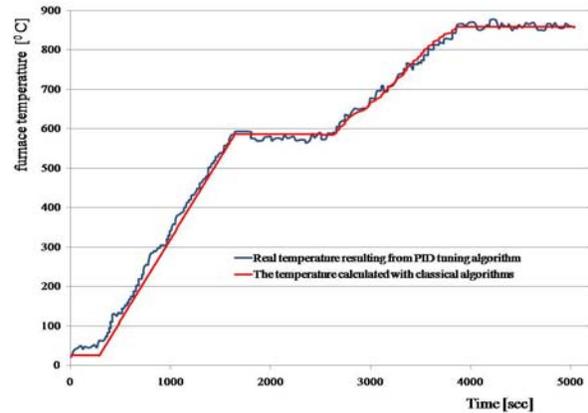
Fig.13. The result of PID temperature control (zone II of the furnace)

Fig. 14 shows diagrams of voltage control PID controller provided with static contact module II.
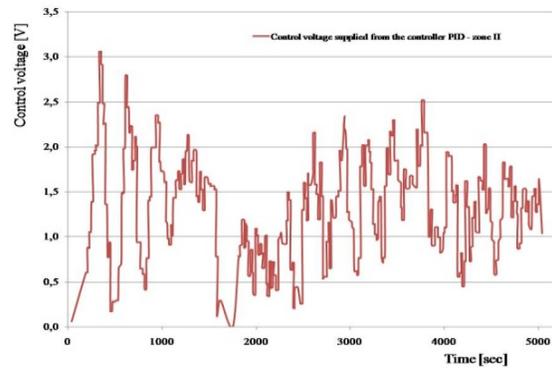
Fig 14. Control voltage PID controller provided with static contact (zone II of the furnace)

Finite element analysis of the evolution in time of the temperature and heat flux heat treatment temperature sensitive subject of the song was performed using specialized software for finite element analysis using the preprocessor Autodesk Autocad.

The studies presented in Fig. 16 refers to finite element analysis of the evolution in time of the temperature and heat flow for low power turbine blades subjected to heat treatment furnace temperature sensitive done with thermostatic controlled PID.

temperature

thermal flux magnitude
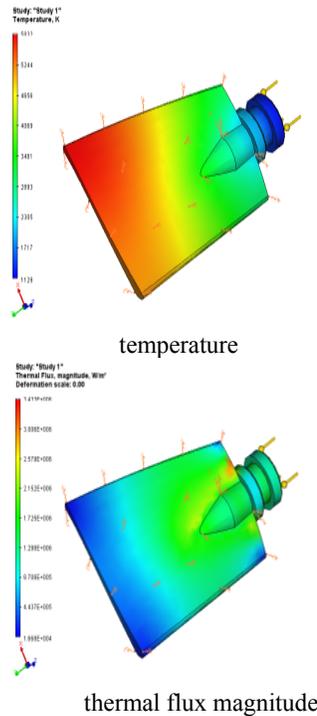
Fig.15. Finite element analysis for turbine blades in the furnace heat treated control structure in real time with PID

4. Test results and experimental measurements for temperature sensitive piece heat treated in the furnace

For the tests and experimental measurements were used samples of small hydro turbine blades for heat treated blades with conventional technology and heat treated in a furnace for heat treatment has implemented a management system structure PID control algorithm.

a) test specimens   b) hardness measurement points
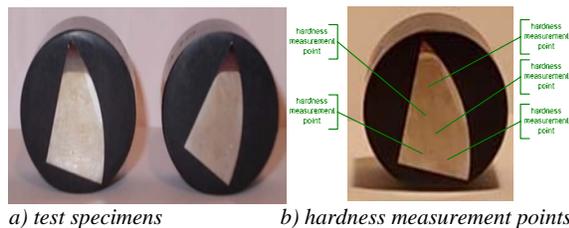
Fig.16. Specimens taken from the turbine blade heat treated with control system with PID algorithm

In Fig. 17 are shown images of secondary electrons obtained by electronic microscopy SEM VegaTescan LMH II, working - 46 High using detector type LFD (Large Field Detector), acceleration voltage electron beam used was 30 kV, and working distance was 15 mm.

EDAX analysis was performed on the sample surface layer to highlight its chemical composition is

observed the presence of chemical elements Fe, C, Mn, S, Si and O_2 in different proportions corresponding to the chemical composition of steel C45-RO1.0503.

If the heat treatment classical distribution of chemical elements in the sample material is uneven, pearlite is found in large islands scattered, surrounded by large areas consisting of ferrite.

In samples of heat treated blades in furnace control system based on PID algorithm shows that iron is observed following elemental analysis is found uniformly distributed in the base material as can be seen in the distribution map.

Carbon is present in the iron alloy, uniformly distributed, but is observed uniformly dispersed islands alloys thereof chemical compounds with Mn, S and Si.

The manganese is in the form of large islands uniformly dispersed in the mass of base material. Sulfur is a small scale and appears in different alloys with Fe, Mn, C, uniformly dispersed in the base material. Silicon is insignificant and appears only as an alloying element to the base material.

a) SEM image   b) EDAX elemental chemical analysis

all elements map   Fe map

C map   Si map

c) the distribution map of chemical elements
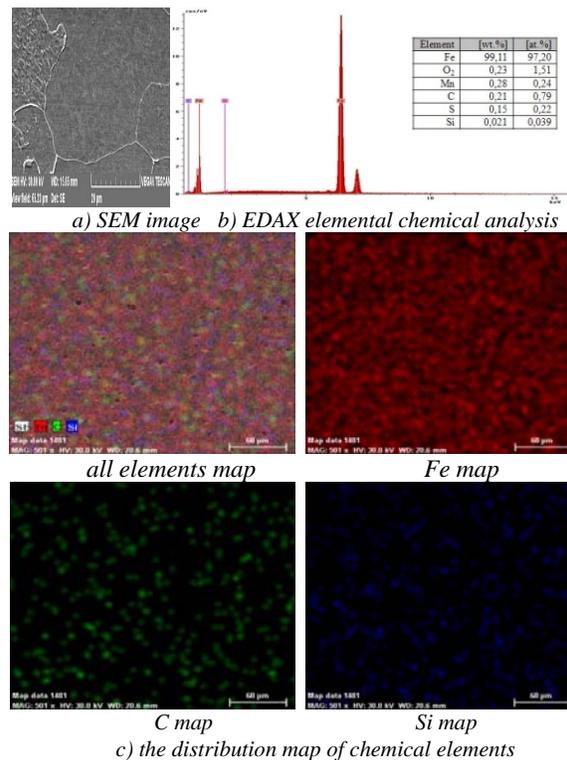
Fig.17. Heat treatment furnace with control system based on PID algorithm

Micro structural analysis of low power turbine blade, was performed on a scanning electron microscope SEM VegaTescan LMH II.

From the analysis of samples by electron microscopy SEM shows that if the heat treatment of pearlite grains are coarse classic uniformly distributed in the ferrite matrix therefore blade material's mechanical properties are reduced, the song has a good running low, low durability and low mechanical strength.

If the heat treatment temperature sensitive heat treatment furnace realized ordered thermostatic control systems with PID structure material consists of fine pearlite crystalline grains uniformly distributed in the ferrite matrix, the mechanical properties are superior parts have a high resistance to mechanical wear and high toughness.

Chemical composition: C = 0,49% ; Mn = 0,24% ; Si = 0,039% ; S = 0,22%

Description: carbon steel microstructure - ferrite and pearlite grains evenly distributed in the piece.

a) micrographs M1 *b) micrographs M2*
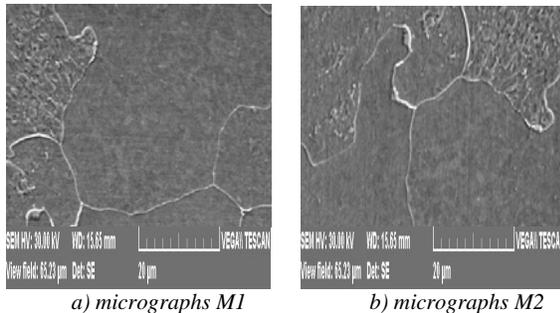
Fig.18. SEM image of pale material heat treated in heat treatment furnace temperature sensitive thermostatic controlled with a PID controller

Research hardness for specimens taken from low power turbine blades made of steel C45-RO1.0503 after heat treatment conducted in thermo sensitive heat treatment furnace system driven by a step predictive thermostatic type were made on a hardness tester Wilson Wolpert - 751N model.

Hardness testing device is provided with a shaped penetrator diameter steel ball Ø = 15.88 mm prints, under the initial load F0 = 9.8 [daN] the material, measuring device penetration depth is zeroed and applied to the penetrator overload F1 = 5 [daN].

After depletion of the material flow, visible penetration depth measuring device by stopping the movement of the indicator in essentially complete, remove the overload F1 and measures the depth of penetration of the indenter remaining in the material.

Hardness test was conducted on a group of four samples taken from two small hydro blades made of the same material and were individually heat treated heat treatment furnace was commissioned successively with classical system command and control system with a PID controller type.

The hardness HB to measure by 5 points to include the entire section blade load of 9.8 [daN], according to EN ISO 6507 and discussed values are the average of five determinations.

For placing the samples must be taken of the three main conditions: surface perpendicular to the direction of actuation of the indenter, immobility piece under the action pregnancy, avoid task deformation under the action of piece.

Table 2. Experimental data hardness HB values of piece

no. test	measuring point - hardness value [HB]					average hardness [HB]
	1	2	3	4	5	
test 1	221	237	241	221	223	228.6
test 2	221	247	239	234	231	234.4
medium	221.0	242.0	240.0	227.5	227.0	231.5
test 3	243	246	245	244	247	245.0
test 4	242	247	245	246	243	244.6
medium	242.5	246.5	245.0	245.0	245.0	244.8

Considering HB hardness values for the measurement of specimens can be done following chart for each specimen separately experimental time.

Fig. 19 presents diagrams of variation of hardness HB for specimens heat treated classic and sensitive heat treatment furnace.
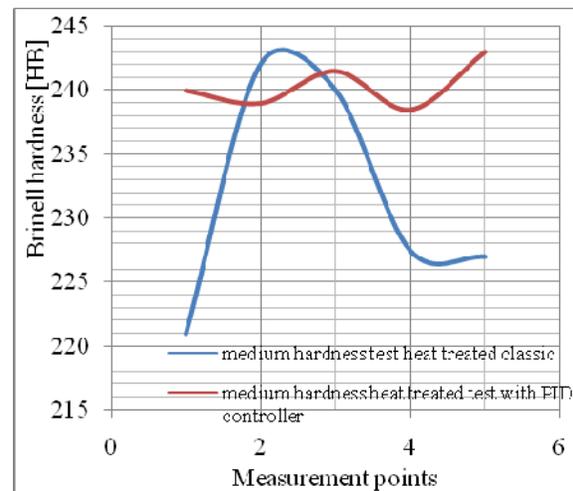
Fig.19 Cumulated hardness HB for specimens heat treated classic and thermo treatment with PID controller

According to the data presented in specialized standards-hardness steel C45 RO1.0503 they are made of low-power turbine blades for the treatment of normalization is 235 HB, comparing the results obtained shows that when treatment is classic the average hardness of 231.5 HB less than the requirements of the standard and if the heat treatment temperature sensitive 244.8 HB average values a step higher values of standard requirements.

5. Conclusions on the management of PID controller processes of electric

The central objective of the research is to design and implement a management system for electric ovens evolved based on a mathematical model for predicting original structural properties and mechanical properties of the workpiece obtained after heat treatment and modeling of the management system furnaces for heat-sensitive treatments on based algorithms evolve in order to increase the mechanical properties and structural parts and reduce the

percentage of treated Trmice reboot due to classical technologies.

Heat treatment processes can be modeled accurately with transfer functions for elements with stroke-order retarders, PID algorithms are implemented successfully in the control of such equipment but time is detrimental to the setting retarder.

Management systems for electric furnace analysis shows that if the tuning PID control accuracy is good for most classical charts thermal overload does not cause heating elements extending their operating results are influenced by the choice of the operating point and disturbances, but is observed to improve performance when using conventional control with dead time compensation.

From the results obtained by adjusting the electric furnace where it is found that traditional regulation is respected diagram heat treatment required with an accuracy of ± 10 0C acceptable for some types of heat treatment and grades of steel (alloy steel and low alloy) this type of control in turn has an adverse effect on the heating elements resulting in premature wear and a decrease in heating performance.

When adjusting the PID controller tuning accuracy is ± 3 0C good for most conventional heat treatment diagrams, this setting determines not strain heating elements extending their operating results are influenced by the choice of the operating point and disturbance but is observed to improve performance when using conventional control relay.

Experimental validation of the results was made by applying a heat treatment to normalize a low power turbine blades made of steel C45-RO1.0503, which has the effect of changing their structure and tenacity.

The experimental results are taken from data acquisition board installed in the control system of electric furnace for heat-sensitive treatments, temperature charts - heating diagram calculated with classical algorithms and the actual temperature of the oven resulting from PID control algorithm shown by thermocouples placed in the oven vault, related area (module) I and zone (module) II.

Additional information is shown in the diagrams with the appropriate supply voltage resistors PID control thermostatic oven.

Determination of chemical composition by EDAX spectrometry allowed a comparative analysis of the distribution of chemical elements in samples of material palettes microcell reveals the fact that if the heat-treatment furnace control system based on PID algorithm is more uniform dispersion of chemical elements relative to the treated samples heat in microwave classic control system that allows the conversion of a higher percentage of austenite perlite dispersed to obtain uniform fine structure that leads to an improvement of the mechanical properties of the part.

Microstructure blade material heat treated in heat treatment furnace is controlled with conventional systems composed of ferrite single phase crystalline grains which have flat and pearlite grains which are a mixture of two phases and presented in embossed steel microstructure is typical of overheating , identifies separation of the ferrite around the precipitates, the structure is unsuitable from the point of view of mechanical properties.

Material microstructure of heat treated blade heat treatment furnace with thermostatic controlled temperature sensitive PID consists of ferrite and pearlite evenly distributed, perlite transformation of austenite - made islands shaped ferrite embedded in the table, this determines superior mechanical properties .

From the analysis of samples by electron microscopy SEM shows that if the heat treatment of pearlite grains are coarse classic uniformly distributed in the ferrite matrix therefore blade material's mechanical properties are reduced, the song has a good running low, low durability and low mechanical strength.

If the heat treatment temperature sensitive heat treatment furnace realized ordered thermostatic control systems with PID structure material consists of fine pearlite crystalline grains uniformly distributed in the ferrite matrix, the mechanical properties are superior parts have a high resistance to mechanical wear and high toughness.

The analysis of the average values for each epruvetă durității partly HB can say că average hardness of heat-treated parts in ovens management system based on traditional technologies is HB 231.5 unlike the samples average hardness of heat-treated parts in ovens with thermostatic control system with PID where the average is 244.8 HB hardness.

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