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# SIMULATION OF STATE OF HIGH-TEMPERATURE OBJECTS UNDER CONDITIONS OF INCREASED RISK

*Simulation of high temperature objects state under the conditions of increased risk. The given paper suggests to use the combination of classic and neuron fuzzy models to increase the efficiency of decision – making during the appearance of highly explosive situations. Unlike the existing models it enables to consider the conditions and characteristic of risk situations on the base of the developed fuzzy rules.*

***Key words***: *thermal objects, simulation of the condition of high temperature objects, risk conditions of high temperature objects, neuron model of high temperature object.*

## Introduction

Today much attention is being paid to energy efficient technologies in appliances, in constructions of city economy and on enterprises [1]. Considerable part of such objects are connected with high-temperature, the availability of gas under high pressure, which stipulates for ensuring their explosion hazard and risk prediction. One of such tasks is the development of models of the under consideration objects for determination of conditions and characteristics of risk situations. Both, the technical devices (constructions, apparatuses, machines and their elements) as well as thermo physical processes, which take place in thermodynamic systems of such systems will be understood as the high-temperature objects in this paper [4]. The main characteristics of high-temperature objects is temperature curve, which is achieved by the specific aggregate of requirements among which there may be the set level of temperature and pressure of specific zones of the objects. Simulation of state of the high-temperature objects requires prediction and forestall the system conditions transfer to the sphere of risk. The state of an object, when its specific parameters, such as temperature, gas volume, pressure, are close to maximum permissible values shall be considered as the situation with the increased risk.

## Problem analysis

Let us consider the classical approach to the simulation of high-temperature objects. Functioning of high-temperature objects is usually described by the system of differential equations in quotient derivative, which may be obtained on the basis of equations of thermal balance or on the basis of simulation of temperature and time modes of objects heating. But with such description of specific high-temperature object and determination of initial and boundary conditions for its functioning, the system of differential equations in quotient derivatives may be of big dimensions, which is explained by large number of parameters of the process.

Let us consider the known model of industrial boiler which is used today in the city economy [4]:

$$P_{\tau i} = P_{т.ном.i}(k_{1i}\mu_{1i}p_{1i} + k_{2i}\mu_{2i}p_{2i}), \qquad (1)$$

where $P_{\tau i}$ – pressure in the boiler; $P_{т.ном.i}$ – value of the nominal pressure; $p_{1i}$, $p_{2i}$, $\mu_{1i}$, $\mu_{2i}$ – pressure of the steam and opening of regulating valves of cylinders of high and average pressure ($\mu_{2i}$=const); $k_{1i}$, $k_{2i}$ – fractions of capacity of cylinder of high pressure.

With the total determination of initial and boundary conditions of its functioning we get the system of differential equations in quotient derivatives of the following kind:

$$\begin{aligned}
&\frac{\partial\mu_{1i}}{\partial t}=\frac{1}{T_{apci}}(\frac{1-\omega_{\tau i}}{\sigma_{apxi}}+\mu_{moi}+\Delta\mu_{mi}-\mu_{1i});\\
&\frac{d\Delta\mu_i}{dt}=\frac{k_{qki}}{T_{mncbi}}(1-\omega_{\Gamma i});\\
&\frac{dp_{1i}}{dt}=\frac{1}{T_{tpi}}(\sqrt{\frac{p_{ki}-p_{1i}}{k_{tpi}}}-\mu_{1i}p_{1i});\\
&\frac{dp_{2i}}{dt}=\frac{1}{T_{pli}}(\mu_{1i}p_{1i}-\mu_{2i}p_{2i});\\
&\frac{dp_{ki}}{dt}=\frac{1}{T_{ki}}(D_i-\sqrt{\frac{p_{ki}-p_{1i}}{k_{Tpi}}});\\
&\frac{dD_i}{dt}=\frac{1}{T_{vi}}(\nu_i-D_i);\\
&\frac{d\nu_i}{dt}=\frac{1}{T_{pi}}(\frac{1-\omega_{\tau i}}{\sigma_{apci}}-\frac{P_{1i}-1}{\sigma_{Tpi}}-\nu_i+\nu_{0i}-k_{pi1}\frac{dP_{1i}}{dt})
\end{aligned}\qquad(2)$$

where $p_{1i}$, $p_{2i}$, $\mu_{1i}$, $\mu_{2i}$ – steam pressure and opening of regulating valves of cylinders of high and average pressure ($\mu_{2i}$=const); $p_{ki}$ – pressure of the steam on the boiler outlet; $D_i$ – amount of steam, generated by the boiler; $\nu_i$ – generalized index, which characterizes fuel, water and air supply to the boiler; $\sigma_{apxi}$, $\sigma_{Tpi}$ – constant of fuel supply speed regulation; $k_{pi1}$ – gain factor of boiler loading regulator on the first derivative of pressure of "fresh" steam; $k_{Tpi}$ – factor, which characterizes pressure losses in the pipeline of "fresh" steam; $T_{tpi}$, $T_{pli}$, $T_{apci}$, $T_{mncbi}$ – the constant of time of pipeline of "fresh" steam; $\mu_{moi}$, $\Delta\mu_{mi}$ – controlling signals of the system of the secondary regulation of capacity frequency; $k_{qki}$ – factor of frequency correction of the system ARFP; $k_{1i}$, $k_{2i}$ – capacity fraction of high pressure cylinder.

The analytical, statistic and variation methods are used for the simulation of high-temperature objects. Analytical methods represent decision in the kind of analytical functions, allowing to research the influence of the model parameters and input data on the decision results. Numerical and analytical methods have own advantages and disadvantages. Numerical methods allow to solve complicated boundary problems, the decisions to which are impossible or difficult to find analytically, and allow to get approximate values of the under research functions in the set points of the sphere under research. Numerical methods for solving differential equations in quotient derivatives substantially depend on requirements to methods convergence, which are determined during choosing of difference schema, as well as on speed of their solution by computer, which drops together with the increase of the object's parameters. Variation methods are widely used and allow to obtain the value of the under research function, however it is rather difficult to obtain the target function which describes the object under research.

If is necessary to note that immediate parameters of risk commonly are not part of such models and are determined during the computer simulation. Apart from that, in practice the analysis of highly explosive situations for specific objects is usually represented in the instruction manual in the kind of the set of factors, influencing their appearance. In case the situation with the increased risk appears (for instance, sharp increase in steam pressure), it requires the operator interference, faulty actions of whose increase the risk of explosion. The conditions of appearance of such situation in the kind of factors:

change of temperature of feeding water (with the decrease of feeding water temperature, the overheating of steam increases);

change of fuel humidity (with the decrease in humidity of solid fuel, the temperature of overheated steam decreases; with the increase in humidity – increases);

temperature of overheated steam depends not only on humidity, but on other fuel properties, including the level of blackness (limpidity) of flame in fire chamber.

Expert evaluation are used for the simulation of such states [4], which allow to determine conditions and parameters, which characterize the availability of risk situations. The main advantage of such an approach is the complex solution of the task in the comprehensive form. But the disadvantages are the possible ambiguity and non-sufficient backgrounding of separate decisions, which depend on the experience of the operator [3].

In our opinion, during the simulation of high-temperature objects it is necessary to note that the models of such objects have to consider explosion hazard as the aggregate of risk factors in the kind of parameters and conditions for appearance of risk situations, which allow to formalize the algorithm of decision making during the object controlling.

**Approach to simulation of the state of high-temperature objects**

Intellectual technologies, allowing to obtain the simplified models and algorithms for decision making, are widely used in different spheres of science and manufacturing. The objective of the present work is the development of generalized model of high-temperature object with the usage of both, traditional numerical methods, and intellectual technologies, which will enable to consider characteristics of the appearance of explosion hazard situations.

Simulations of state of high-temperature objects will be considered as the aggregate of classical model (2) in the kind of system of differential equations in quotient derivative (SDE in QD) and neuro-fuzzy model on the basis of intellectual technologies. If is necessary to note, that building of neuro-fuzzy model requires additional information, as the results of simulation of classical model, which allows to formulate the set of rules, which describe the process of object's functioning.

For further teaching of neuro-fuzzy network and determination of parameters and factor of risk situation we will use the expert evaluations. The additional part of rules to the data base is formulated on the basis of expert evaluations, with will ensure knowledge in case of possible risk situations, which take place in high temperature object. The stage of correction is aimed at adjusting parameters of high temperature object.

Let us consider in details the stages of model building on the example of model of steam boiler. As is noted in [2] the most influential parameters are the following four variables, which are represented according to equations (1) and (2): $P_E=P_n-P_m$ – pressure deviation in the steam boiler, which is determined as the difference between the current value and the determined standard value, corresponding to the norm; $S_E$ – speed of change $P_E$; $C_{PE}=P_{\tau(i-1)}-P_{m.nom.(i-1)}$ – pressure deviation, which is determined as the difference between the current value $P_e$ and the value, obtained in the previous measurement; $C_e$ – speed of deviation; $C_m$. The state of the boiler we will research during the steam-heating degree change, that is the pressure change (HC=$\Delta$m – heating change).

For the descriptions of values of variables there were used the following linguistic values (abbreviated names correspond to the first word letters in English for further comprehension by experts):

PB – positive big, PM – positive middle, PS – positive small, NO – nought, NB – negative big. For pressure change $H_c$ under the condition of increased risk, there was taken the big prolonged jump of PB.

Following the results of simulations by classical methods, there had been created neuro-fuzzy net of the ANFIS type, which realizes the system of fuzzy Sugeno output in the kind of double-double neuronic net of direct signal distribution. There were used the values $P_\varepsilon$ and $C_{PE}$ for input, and the $H_C$ for output. The assignments of layers are the following: the first layer – therms of input variables; the second layer- antecedent (references) of fuzzy rules; the third level – normalization of the level of rules execution; the fourth level – rules conclusion; the fifth layer – result aggregation, obtained on different rules. Network inputs are not singled out into the separate value. Fig.1. presents the general view of ANFIS net with three input variables ($x_1, x_2, x_3$) and five fuzzy variables $x_1$, $x_2$, $x_3$ , there will be used therms in 5.

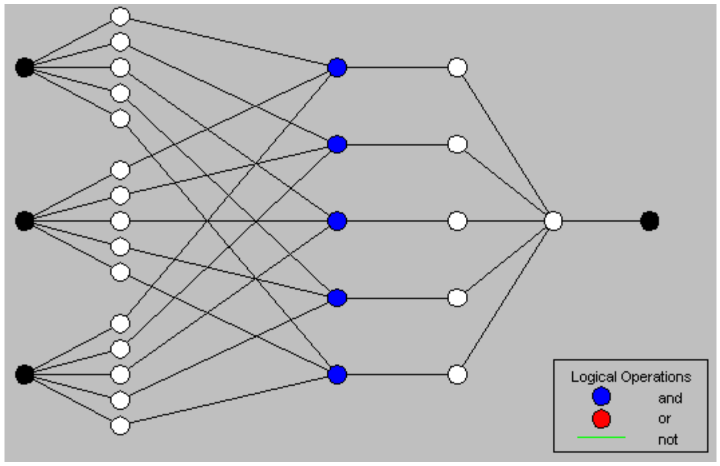


Fig 1. Architecture of neuro-fuzzy net of stream boiler states.

In the result there was obtained the set of rules for evaluating the state of the high temperature object, that is of the first boiler which is show in table 1.

Table 1

**Set of fuzzy rules of boiler states.**

| $P_E$ | $C_{PE}$ | $H_C$ | $P_E$ | $C_{PE}$ | $H_C$ |
|---|---|---|---|---|---|
| *NB* | *HE* | *PB* | *PO* | *NB* | *PM* |
| *NB* | *NS* | *PM* | *PO* | *NM* | *PM* |
| *NM* | *NS* | *PM* | *PO* | *PB* | *NM* |
| *NS* | *PS* | *PM* | *PO* | *PM* | *NM* |
| *NS* | *NO* | *PM* | *PS* | *PS* | *NM* |
| *NO* | *PB* | *PM* | *PS* | *NO* | *NM* |
| *NO* | *PM* | *PM* | *PB* | *NS* | *NM* |
| *NO* | *NB* | *NM* | *PM* | *NS* | *NM* |
| *NO* | *NM* | *NM* | *NO* | *PS* | *PS* |
| *PO* | *NO* | *NO* | *NO* | *NS* | *NS* |
| *NO* | *NO* | *NO* | *PO* | *NS* | *PS* |
| *PO* | *NO* | *NO* | *PO* | *PS* | *NS* |
| *PO* | *NO* | *NO* | | | |

As it is seen from the above set of rules, the big prolonged jump of pressure, which characterizes the risk situation, is described by one rule only. This testifies to the fact, that the sphere of risk in this model is weakly formalized, after the expert's rules processing, the following two rules were added to the above aggregate, which led to the additions to the knowledge base from the positions of risk situations:

If $P_E$ =NB, then (if $C_{PE}$=NB, то $H_C$=PB);

If $P_E$ =NB, then (if $C_{PE}$= NM, то $H_C$=PB).

Correction of the object state under risky situation, if the pressure suddenly increases, was carried out by the parameters, which do not satisfy the corresponding rules. Results of simulation relatively to the speed comparison of the considered model and suggested model are given in table 2.

Table 2

**Speeds of boilers state models**

| *Model* / *Factor* | *Thermal balance* | *Temperature distribution* | *Classical with neuron fuzzy* |
|---|---|---|---|
| *Speed of result obtaining* | *8 s* | *6 s* | *1,5 s* |

Simulation results allowed to determine the exactness of the suggested model, the value of which 0.92, which supports its adequacy. Apart from that, it allows to take into account the risky situations. Thus, the suggested approach may be applied to the high-temperature objects, which are subject to situations with increased risk.

## Conclusions

The paper suggests to consider the model of high-temperature objects as the aggregate of classical and neuro-fuzzy models. Such an approach allows to consider the conditions and characteristics of risky situations on the basis of fuzzy rules.

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