Automatization of agglomerative production on the base of application of Neuro-Fuzzy controlling systems of the bottom level

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Abstract
The results of development of concept of automatization of agglomerative production on the base of application of adaptive Neuro-Fuzzy systems on the bottom level of automatic-control system of technological process (ACSTP) with the aim of adaptation of control system to parametrical and signal uncertainties are given. It is proved that adaptation of complex ACSTP to the functional uncertainties may be fulfilled on the base of calculation of vector of general control strategy of the upper hierarchy level of ACSTP.
The given results allow to realize complex program of automatization of agglomerative production, which is connected with solution of tasks of synthesis of adaptive systems of multilevel control, which allow to increase the productivity with support of specified quality of ready product determined by Technical regulation TR 228-AP-56-2003 and to reduce its energy usage.
Key words: AGGLOMERTAION, AUTOMATIZATION, NEURO-FUZZY SYSTEMS

One of the main factors sharply reducing the competition capacity of domestic product of mining and smelting enterprise in native and foreign markets is its high prime cost and low quality, which is, as compared with foreign manufacturers of agglomerative stock, 1-3 % less. In conditions when wear of fixed assets at the most iron reduction plants is 70-80 %, the factors of cost supplement are conditioned by significant energy density (in agglomerative complex of OJSC “YUGOK”, energy density is 21% from the total cost), disturbance of current regimes of equipment working and conditions for carring out of technological processes. The problem grows when working regimes of agglomerative equipment are close to technologically determined restrictions and the control objects are nonlinear, unsteady and are characterized by the presence of intensive uncontrolled disturbances [6].

Researches of leading foreign and native scientists prove that one of the most effective, low-cost and giving rapid economical effect ways for solution of above mentioned task for increase in efficiency of agglomerative production and metallurgical quality of agglomerate with simultaneous decrease of its prime cost is the guarantee of proper operation of in-line equipment due to development and implementation of complex automatization of technological process of agglomerate production.

The main task of functioning of complex adaptive system of automatic control of technological process (ACSTP) (with the only computer information complex) is the control of main process flow parameters, their mathematical treatment and operative management of technological subsystems. Development and implementation of such adaptive ACSTP allows to increase productivity, reliability, rhythm and competition capacity of manufacturing of native products of mining and smelting enterprise.

Fulfilled analysis of agglomerative technology allowed to conclude that this manufacture is the typical non-linear multilevel process of mining and smelting industry, for which realization of complex program of automatization is connected with solution of tasks of synthesis of adoptive multilevel controlling systems, which allow to increase the effectiveness of production and cut its energy consumption.

As the dynamics of agglomerative process depends on the range of non-controlled factors $c_i \in \Omega_{ci}, i = 1, 2, 3$ (i=1 – vector of unknown quasi-stationary coefficients of objects equation; i=2 - functions of time, which cannot be measured; i=3 – unknown functions of state variables of objects or measured variables input-output), adaptation of control system to parametrical and signal uncertainties may be realized during application of connectionist technologies at the bottom level of ACSTP, and to functional uncertainties – on the base of calculation of general strategy vector of control of upper hierarchy level of ACSTP of agglomerative production.

To realize integrated programme of automation of production processes, as upper level of adaptive ACSTP one should include the subsystems, which allow to determine the following: technological and technical and economic features of production; conception of day-to-day management of local systems of stabilization with realization of robustness principle to perturbation actions; main operating conditions of processing equipment; conditions and principals of load matching between parallel stages of multistage manufacturing complex; effective, from the point of view of technical-economic values, channels of control in the systems of secondary regulation of multiconnected dynamic objects of technological processes with adaptation of localized outlines on the lower hierarchy levels of ACSTP; preventive-maintenance schedule of processing equipment.

As it is mentioned in the works [1-3] there achieved certain positive results, but such tasks were solved not in an integrated manner and they mainly present separate systems in the development and industrial realization of ACSTP by agglomerative complex in Ukraine and CIS countries. Problems of operative management connected with production and also automatization of cooperation of various system levels almost were not investigated and haven’t become implemented [3].

Analytical review of works connected with problems of automatic control of agglomerative process has showed that in conditions when the characteristics of agglomerative stock and conditions of processing equipment change, final performance of agglomerative shop significantly depends on the effectiveness of automatic control of subsystems of lower level, which is primary determined by adaptive and robust properties of localized ACSTP.

Automated control system of agglomeration operating process should include the following: chemical identification system of raw materials, which comes into burden; automatic-control system of loading and unloading modes for raw materials from hoppers of charge preparation plant; automatic system for charge preparation; automatic-control system of loading process of the charge on sintering belt; automatic-control system of the sintering process of charge on the sintering belt.

System of complex automatization of agglomerative technological process should solve the tasks of batching of burden material components, control and regulation of moisture content, control of course and end of agglomerate sintering process. Herein the information about the course of technological process should be available to all local subsystems. So it is necessary to create single information field connected with data measurement system of certain processing lines.

According to the developed functional scheme of adaptive ACSTP by agglomerative complex [4], the task of increase in efficiency, reliability, rhythm and competition capacity of production of agglomerate is solved by means of optimization of agglomerate sintering process, which requires determination of basic model of agglomerate production, which reflects the connection of main parameters of agglomerative process.

The developed concept of automatization of agglomerative production is based on the usage of integral assessment of indirect measures of vertical velocity of agglomerate sintering as the index of sintering process [4]. This index allows to provide formation of cautioning for local systems of automatic control, which during fulfillment of imposed restriction provide dynamic characteristics of control object on the base of Neuro-Fuzzy systems application. Technological variation of complex index of sintering process may be the result of change both physic-chemical properties of burden and technological conditions of process guide. To fulfill expert determination of effective actuating path of the process, there may be put in neuro-fuzzy subsystem of determination of active ACS to the functional scheme of adaptive ACSTP. On the base of productive rules it determines proration factor of the preset value of local or group of local ACS, outcome parameter of which is the reason for change of process complex index.

Considering fulfilled investigations, working draft of simplified functional scheme of agglomerative machine for ACS of burden surface temperature under incendiary hearth looks as follows (fig.1).

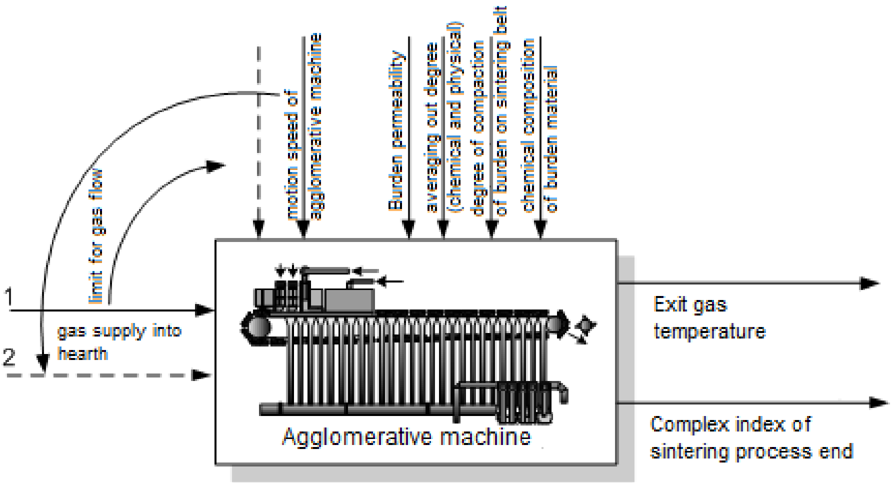

Figure 1. Working draft of simplified functional scheme of agglomerative machine.

To the functional peculiarities of developed adaptive ACSTP by agglomerative production enters the algorithm of automatic change of managing values of local systems of automated regulation (ACS) depending on technical-economic conditions of manufacture. In the figure 1 there mentioned two possible variants of ACS work of surface temperature of the burden under incendiary hearth, which has technological limits (400-1500 °C) and is measured by devices Tera -50, DISK-250, group RK15 with accuracy class 0.5: at the absence of limits for gas flow as control parameter there accepted the mixture of natural and blast furnace gas supply with thermal property Q = 2800…3000 kcal / nm^3 into the hearth, which is measured with the help of devices DM, BPL -1K BIK, DISK-250 (0-2000 nm^3/hour, accuracy class – 2.0) and has the following limits: excess air coefficient 1.2 – 1.4; pressure of gas mixture not lower than 1.0 kPa (100 kgs / cm^2), during pressure reduction the upper level of ACSTP let the control signal for sintering machine braking action; under the condition of achievement of gas up limit, control goes to ACS of batch sintering, which uses as control parameter pallets motion speed with the limit <5.0 m / min.

In ACS correlation “gas-air” in nodulising drum and mine as control parameter there suggested using the flow of ventilator air to provide full gas combustion. Optimum temperature according to hearth length is 1150…13000C.

Technologically determined air pressure boundary on the burners of ignition furnace 0-630 kgs / m^2 (control means DM KSD-3, TNMP -52 with strength class 2.0-2.5) and air flow 0 - 8000 nm^3/year (control means DM 3583M, KSDZ accuracy class 2.0).

ACS correlation “burden-water” in the nodulising drum provides optimum moisture of the burden within 7-10%. As control action in the system there suggested to use the amount of water, which is supplied on the nozzles, and as being controlled one – rarefication according to vacuum chambers and complex index of vertical velocity of sintering.

ACS height of burden layer on sintering belt provides setting of burden layer height on the sintering belt and control of later height - return quantity and complex index of vertical velocity of sintering.

Typical functional scheme of adaptive Neuro-Fuzzy systems of automatic control.

Fulfilled statistical examination of control object with the channel “ignition temperature of burden – temperature in 24 vacuum chamber” allowed to develop functional scheme of adopted Neuro-Fuzzy system of automatic temperature control of burden surface under incendiary hearth (fig.2).

As far as consumption of mixture of nature and blast furnace gas with thermal property Q = 2800…3000 kkal / nm^3 at excess air coefficient 1,2…1,4 Qg = 700 m^3 / h provides burden ignition temperature 1100^{o}C, that when the conditions of manufacturing process Technological Regulation (TR) 228-AP-56-2003 are observed, it allows to finish sintering process above the 24 vacuum chamber (maximum temperature 220^{o}C in 24 vacuum chamber is indirect measure) as the task signal we will use the value 220 ° C. Q_g heath.

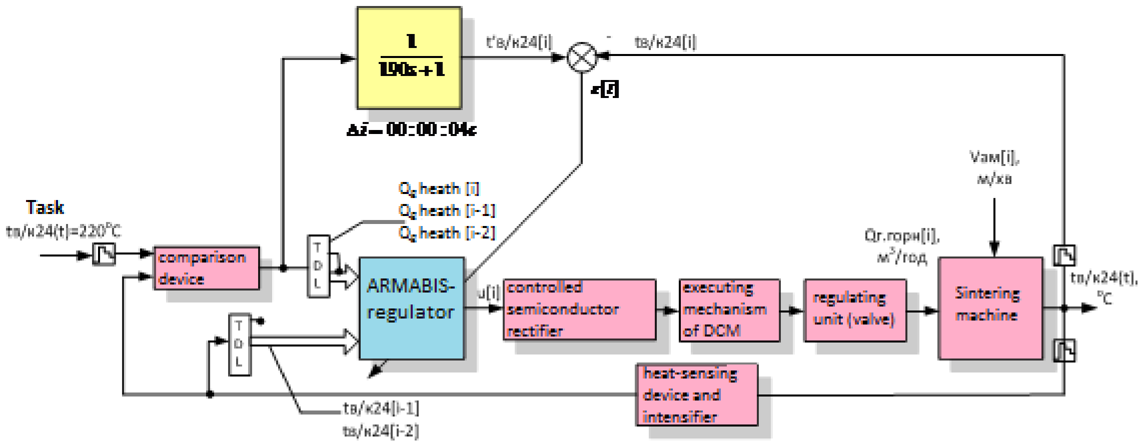

Figure 2. Structural scheme of adoptive Neuro-Fuzzy system of automatic control of burden surface temperature under ignition hearth

Direct current motor (DCM) with end switches and reducing gear installed in agglomerative shop of OJSC “AMKR” is chosen as executing mechanism. During usage of DCM with independent excitation and maximum stress at anchor 200 V during moving of damper valve from 0 to 90° makes 25 sec. Thereafter executing mechanism may be designed as integrating stage, as the roll angular deflection of DCM equals the integral from shaft speed. Integrator amplification factor may be find on the basis of the following: damper valve turn from 0^o to 90^o makes 25 s. during connection of an anchor of DCM to the nominal stress 220 V.

$$K_{int} = \frac{9}{25 \cdot 200} = 0{,}0182 \text{ angle degree/s V} \quad (1)$$

As gas flow into hearth is proportional to opening angle of damper valve from 0^o to 90^o, according to supply Qg=700 m^3/hour, there conforms maximum angle of opening 90^o, which corresponds to the model of reinforcing member:

$$K_{valve} = \frac{700}{90} = 7{,}8 \, m^3 \text{ hours degr.air} \quad (2)$$

As in conditions of sintering plants there used controlled semiconductor rectifier (CSR) with nominal stress at the output 200 V and voltage controlled, which changes within the limits from 0 to 10 V, proportional part of the model CSR may be determined as following:

$$K_{CSR} = \frac{200}{10} = 20 \quad (3)$$

As temperature sensor and intensifier of output feedback there used installed equipment TERA – 50, DISK – 250, gr. – RK15 with measurement range 400 – 1500° C at corresponding range of output current 4 -20 mA. According to these conditions model of sensor and intensifier may be realized on the base of intensifier, coefficient of which is determined after inclination of working unit of sensor statical characteristic:

$$K_S = \frac{20-4}{1500} = 0.01 \ mA/^{\circ}C \qquad (4)$$

To fulfill simulation researches there developed a model (fig. 3) in the program Matlab of adaptive Neuro-Fuzzy system of automatic regulation of burden surface temperature under incendiary hearth according to structural scheme (fig. 2). Nonlinear dynamic model of control object with channel "burden ignition temperature – air temperature in 24 vacuum chamber" was used as control object.

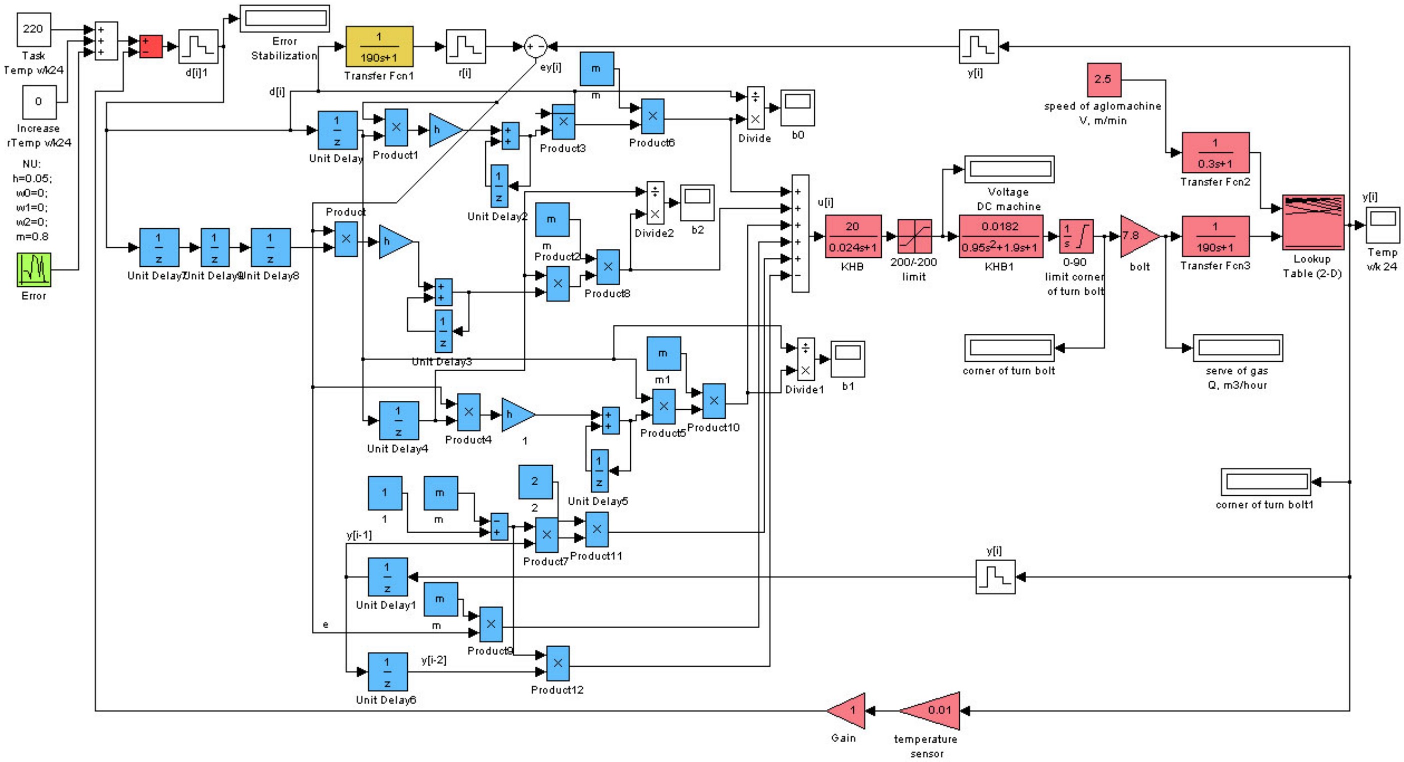

Figure 3. Full nonlinear dynamic model of adaptive control of the sintering process on the base of adoptive Neuro-Fuzzy system ARMABIS ADL(2.2)-CAP of burden surface temperature under incendiary hearth.

Modeling results of adaptive Neuro-Fuzzy system ADL(2.2)-CAP of burden surface temperature under incendiary hearth are presented in the figure 4.

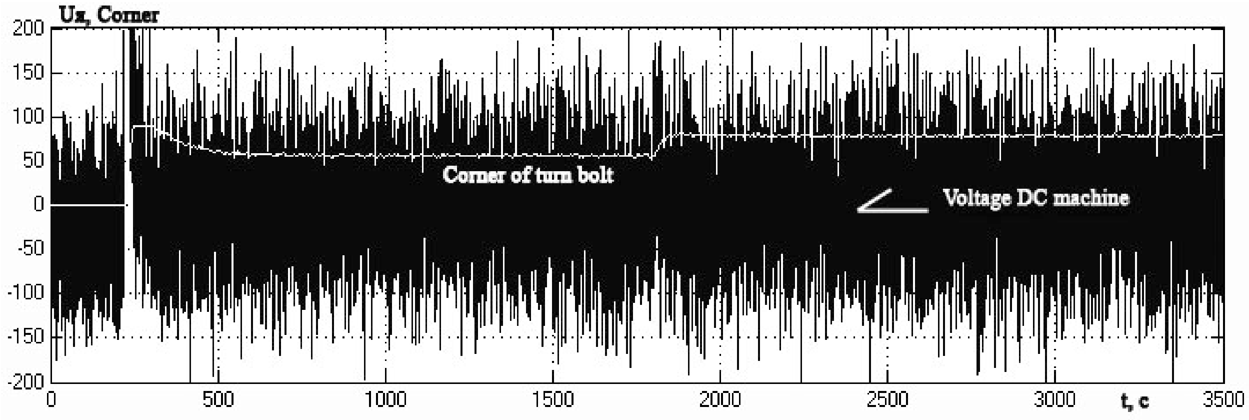

Figure 4. Time history of armature voltage (drive motor) of DCM and angular deflection of damper valve during action of wide-range gauss noise with deviation 1%.

Modeling results speak for satisfactory quality of regulation of adaptive Neuro-Fuzzy system ARMABIS ADL (2.2) – CAP of burden surface temperature under incendiary hearth during variations of perturbation action (sintering belt speed) and presence of wide-range gauss noise with 1% deviation in the channel of temperature measurement in 24 vacuum chamber.

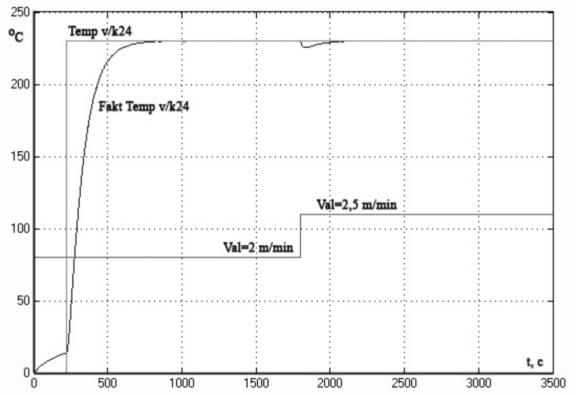

Figure 5. Transition processes according to temperature in 24 vacuum chamber during noise influence in ACS channel and change of sintering belt velocity from 2 to 2.5 m/min.

Typical structural scheme of Neuro-Fuzzy system of automatic control. In the base of Neuro-Fuzzy ACS temperature of burden surface under incendiary hearth there is a method of control of gas consumption, which is supplied into hearth. This ACS (fig. 6) should provide good burn-up and full automatization of hearth work.

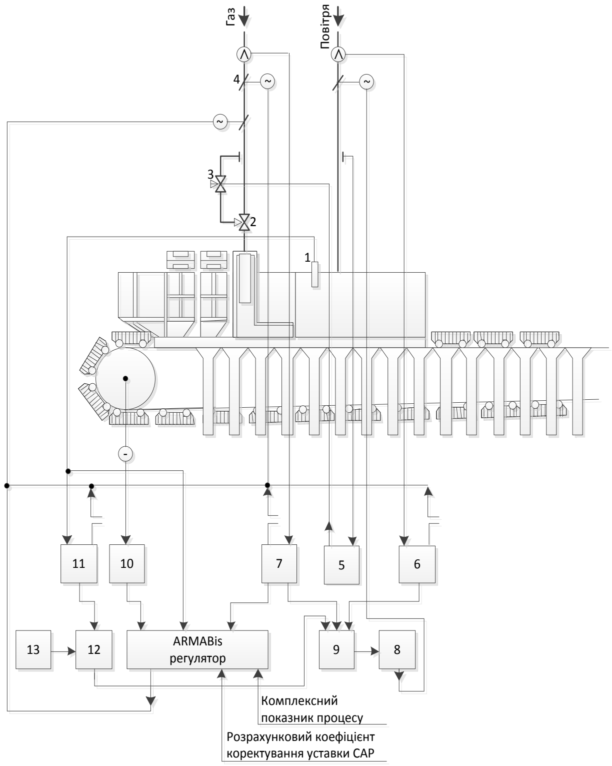

Figure 6. Structural scheme of adaptive Neuro-Fuzzy-ACS of temperature of burden surface under incendiary hearth

According to the developed method, the main loop of automatic control is built on the typical equipment of agglomerative production and includes speed sensor of sintering belt 10, gas flow sensor 7, control instrument, executing mechanism and ARMABiS-regulator is additionally added, it changes gas flow during variations of entering perturbation actions: batch moisture, carbon content in it, etc.

ACS correlation “gas-air” in the hearth is included to the secondary circuit of Neuro-Fuzzy-ACS temperature of burden surface under incendiary hearth, which keeps set coefficient of air loss to provide full combustion of gas.

ACS correlation “gas-air” consists of gas and air flow sensors 7,6, control instrument 8, set-point adjuster 13 and air or restriction ventilators. For temperature restrictions, which are determined by hearth lining reliability and necessary degree of burning-up of upper layer of the burden, there extra added into system temperature correction outline, which consists of pyrometer1, temperature sensor 11, set-point adjuster 9 and corrector 12. Temperature correction outline is the external one and influences the signal of outline of correlation “gas-air”, and sum signal changes air flow, which leads to the correction of the temperature in the hearth.

Developed adaptive Neuro-Fuzzy-ACS temperature of burden surface under incendiary hearth optionally tests short braking action and run-up, gas and air unpacking. According to prototype [5] during short braking action of sintering machine for keeping of pallet side surfaces from superheat and surface flash there provided regime of “idling”. Idling restriction 4 upon the signal, which speaks for braking action of sintering machine, automatically reduces gas flow for the hearth in the amount determined by the installation of gas flow measurement 7 and provides flare holdup. At the same time there reduces the temperature in hearth due to change of air flow coefficient, which is provided by introduction into command circle of ARMABiS-regulator of contact of air flow measurement 6, which is broken while flow, which provides necessary air excess.

To control specified productivity of sintering machine during the initial period after start-up, gas flow is determined automatically with the aim to provide technologically defined heating-up temperature of the hearth. At the following stage when achieving working temperature in the hearth 11, there is given a command to start the sintering machine.

In the system there is provided gas automatic shutdown and automatic brake of sintering machine while gas and air expansion. Shutdown, as in prototype [5], is fulfilled by safety valve of direct action 2, which is installed on the gas pipe line and interlocked with attention device of air pressure drop 5 with the help of three-throw electro-pneumatic valve 3, which covers the impulse line of safety valve under the signal of device 5 about decompression, which is lower than allowed.

Conclusions

Fulfilled analysis of sintering production from the point of view controlling processes automatization allows to conclude that this manufacturing is typical nonlinear multilevel object of mining and smelting industry, for which realization of complex program of automatization is connected with solution of tasks connected with synthesis of adaptive systems of multilevel control, which allows to increase manufacturing productivity during holdup of specified quality of finished stock determined by Technical Regulation TR 228-AP-56-2003 and cut its energy usage.

There developed a concept of sintering production automatization, which is based on the application of adaptive Neuro-Fuzzy systems at the lower level of ACSTP with the aim to adopt control system to the parametrical and signal uncertainties, and adaptation to the functional uncertainties is fulfilled on the base of vector of general strategy control of upper hierarchy level of ACSTP.

References

1. Fedorovskiy N. V. , Danshin V. V., Gubanov V. I., Sigua R. I.. Avtomatizatsiya fabrik okuskovaniya zheleznykh rud i kontsentratov [Automatization of factories of lumping of iron ore and concentrate]. Moscow, Metallurgiya, 1986, 339 p.
2. Fedorovskiy N. V., Dementeva E. M., Pleskach V. I., Taravskiy M. F. Nekotorye voprosy optimizatsii aglomeratsionnogo proizvodstva [Some questions of optimization of agglomerative production]. *Automatization of agglomerative and blast furnace production.* Kiev, Tekhnika, 1969, p. 94–101.
3. Fedorovskiy N. V., Matov A. L., Kucher V. G. Issledovanie osnovnykh parametrov regulirovaniya protsessa spekaniya aglomerata [Investigation of main parameters of sintering process control]. *Automatization of agglomerative and blast furnace production.* Kiev, Tekhnika, 1969. P. 126–133.
4. Shchokin V. P., Misko S. M., Mishchenko P. D. (2005) integrated control and information management system of agglomerate production. *Vostochno-Evropeyskiy zhurnal peredovykh tekhnologiy*. No 4/2. p. 16.
5. Shurkhal V. A., Sigov A. A., Nevmerzhitskiy E. V. Avtomaticheskoe regulirovanie zazhiganiya pri aglomeratsii [Automatic regulation of ignition during

agglomeration]. *Automatization of agglomerative and blast furnace production.* Kiev, Tekhnika, 1969. p. 25–35.
6. Sidorenko V. D., Morkun V. S, Shchokin V. P. Analysis of energetic working regimes of main shops of OJSC "YuGOK". Scientific technical report is provided by technical requirements, time schedule, terms and conditions NDR No 1392/20-938-12 dated Septebber,1 2012 between OJSC "YuGOK" and State Higher Educational Institution "Kryvyi Rih National University", 97 p.