Control by technological mode parameters with an intellectual automated system

2016 IOP Conf. Ser.: Mater. Sci. Eng. 155 012025

(http://iopscience.iop.org/1757-899X/155/1/012025)

IOP Conf. Series: Materials Science and Engineering **155** (2016) 012025 doi:10.1088/1757-899X/155/1/012025

Control by technological mode parameters with an intellectual automated system

A A Stupina[1,2], A A Shigina[1,2], A O Shigin[3], M V Karaseva[1,2], L N Korpacheva[2]
[1] Siberian State Aerospace University 31 “Krasnoyarskiy Rabochiy” av., Krasnoyarsk, 660037, Russia
[2] Department of Economics and Information Technology of Management, Siberian Federal University, 3 Vuzovskii Lane, Krasnoyarsk, 660025, Russia
[3] Department of Mining machines and complexes, Siberian Federal University, 95 “Krasnoyarskiy Rabochiy” av., Krasnoyarsk, Russia

E-mail: saa55@rambler.ru

Abstract
The scheme of functional correlation of input and output parameters of the "drilling rig – rolling cutter bit – rock" system is proposed. The necessity to apply drilling rigs of the automated intellectual system with the adaptive element for a quick time response of the investigated system on the change of physical and mechanical rock properties and the maintenance of the adjusted operating parameters of the technical system in an optimal ratio.

Introduction

The control systems play an important role in the automation and control by technological processes in the mining industry. Nowadays the problem of such systems development is quite relevant since the increased efficiency of control is impossible without the automated control systems (ACS) based on the information technologies and advanced mathematical models [1, 2].

But modern automation control systems of the drilling process do not react to the changes of the interrelation properties of the object (rocks), do not adjust the operation modes and do not compensate the disturbances of the complex technical systems "drilling rig – rolling cutter bit – rock" functioning (hereinafter refers as the object of control or R-B-R) that reduces its efficiency [3]. The insuring the efficiency requirements (timeliness) and accuracy of the information transferring is a fundamental requirement for the control quality improving by the object and process.

Intelligent automated control systems

The urgency of the investigation in the field of intelligent ACS is that in the conditions of increase of requirements to the characteristics of the information exchange in ACS significantly increasing the demands on the quality of the transmission systems functioning [4]. A structure that interacts with the external environment and in the process of obtaining necessary information from it generates the purpose of the action and analyses the impact on the system (physical and information) is applied for the generalized intellectual systems. The main elements of the control system in this case are an intellectual converter and basic control system.

In the case of using the control system of artificial intelligence as intellectual converter of the implemented expert systems, situational management, management of structural dynamics of complex technological [5] and other intellectual systems and their elements. A mathematical model of intellectual control system includes three parts: intellectual converter of the control object and control systems (computing, transforming and performing units). The intellectual converter alters the information about the external environment and the object of control and transforms it into the signals of impact on the controllable devices of the system. The converter uses a unit of decision-making for the generation impact on the controllable system by the object.

In general the ability for adaptive changes of the state is the most important quality of the elements and environment. To achieve the adaptive state one should keep in mind that in the cases of the system motion under the direct influence of the external driving forces (the signal impact), the direction of adaptive motion of the system is predicted, and when the system moves under the indirect influence of external forces it is required to interrupt the periodic adaptive movement to determine the direction of the correcting action. An adaptive element as a unit of the electromagnetic type (an adaptive rotationally-feeding mechanism) designed for the simultaneous smoothing of random shock loads of the drilling process and getting rapid feedback on the time and magnitude of impact must be included in the hardware system for its implementation on the basis of the drilling rig intelligent automated control [6].

The control by the parameters of the drilling mode is characterized by a large number of input and output variables. A system R–B–R as an object of control can be represented in the form of relations (Figure 1). The specifies parameters for the adaptive element of the system R–B–R is information about the changes of physical and mechanical characteristics of the rock expressed by the values of drilling speed V_d, axial forces P_{af}, rotation frequency n_r at the current moment and the change of drilling speed ΔV_d for a discrete period of time. The output parameters of the adaptive element are the current I and its changes ΔI at the given discrete period of time that indirectly reflects the index of drill ability and its changes. The input parameters of the automated intellectual control systems (AIS) are the output parameters of the adaptive element, the drilling speed and its changes, axial force and rotation frequency at the given moment of time. At the output of the AIS applying the calculation algorithms the correction of the axial force and rotation speed as well as the information about the strength and structural properties of the rock are worked out. The output parameters of the regulator are correction values of the axial forces ΔP_{af}, rotation frequency Δn_r, calculated values of the drill ability index of I_d and its changes ΔI_d in this discrete period of time.

The adjusted operating parameters axial force $P_{af}+\Delta P_{af}$, rotation frequency $n_r + \Delta n_r$ are the input control impact for the system R–B–R. To generate a control impact for the control object corresponding to the algorithm of its operation it is necessary to have a control unit (a controller) that performs functions without the direct human activity. A controller in the system R–B–R is an intellectual system with an adaptive element.

The input parameters that characterize technical capabilities of the drilling rig and drilling conditions are divided into:

- controllable ones that are quickly adjustable (P_{af}, n_r);
- controlled ones that don not depend on the drilling process (design parameters K_r of the drilling rig: weight, dimensions, types of drivers of the basic mechanisms) and dependent on the drilling modes (diameter and depth of the hole P_d, vibration parameters of the rig: amplitude, frequency B_r);

- uncontrolled random: parameters of the destructible environment P_{en}.

A complex of indicators characterizing physical and mechanical properties of the rock as an object of destruction while drilling in the form of random functions (strength threshold of the rocks under uniaxial compression, fracture, abrasion, cut, etc.) belongs to the parameters of the destructible environment P_{en}.

The output parameters characterize physical results of the destruction process of the rock and they are divided into:

- observable (V_d, n_r, P_{af}, resource of a bit T);
- unobservable: quickly computed (the performance of the rig for a change P_{ch}; the energy intensity of the drilling process E_d, power of the rotationally-feeding mechanism N and not calculated quickly (cost for drilling one meter of the hole C_d).

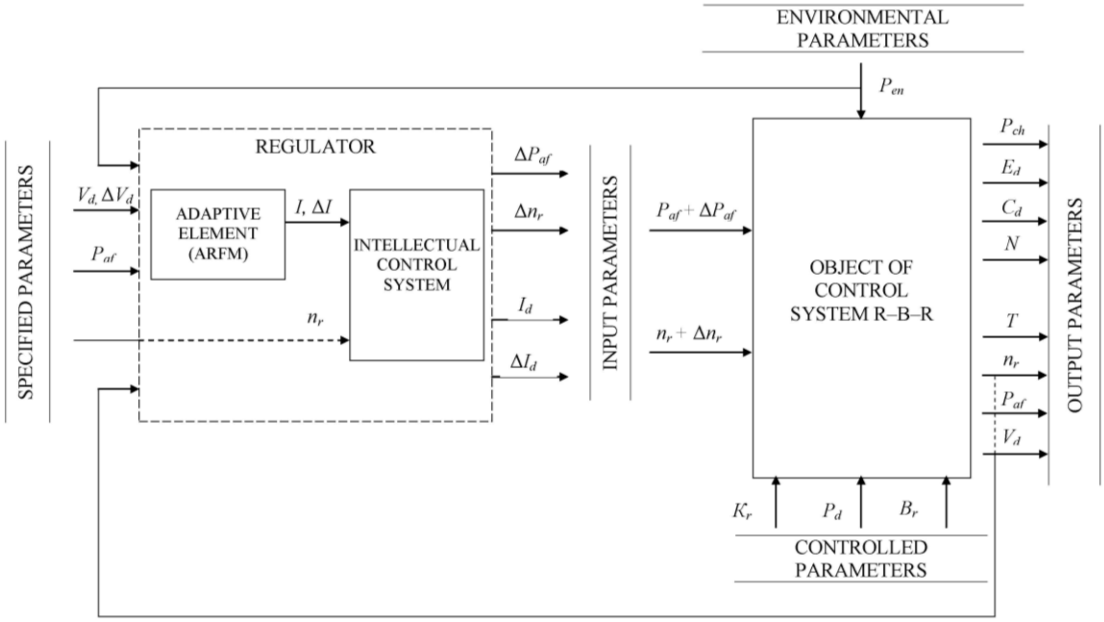

Figure 1. The proposed scheme of functional relations of input and output parameters of the system R–B–R

It should be noted that the energy intensity of drilling E_d can be regarded as a function of input parameters (P_{af}, n_r) and uncontrolled random disturbances (P_{en}) and they should have their actual values for the feed and rotation mechanisms of the drilling rig.

For optimal system output parameters R–B–R it is necessary to apply adaptive rotationally-feeding mechanism [7] when there is no significant time delays to adjust short-term random disturbances. The system R–B–R continuously receives the input control impacts in the form of adjusted values as the axial force and rotational speed resulting in the correspondingly changing output parameters. As the output parameters the controlled parameters (V_d, P_{af}, n_r, T, E_d, N, P_{ch}, $C_{d)}$ can be taken. The desire to optimize the drilling process led to attempts to design models of this process based on theoretical calculations and empirical regularities characterizing the performance of bits and the efficiency of destruction of the rock [8]. For the mathematical formulation of the problem of the optimizing the studied technological process it is proposed to apply mixed criteria as a function of primary parameters. To improve the optimal control of the drilling process in non-steady modes of operation the problem of multi-criteria parametric optimization with the mixed criteria is stated [9] since the studied object of control in operation mode is continuously influenced by stochastic external influence, in particular, unpredictable changes of the rock properties causing critical impact shock loads and affects negatively the operation of the whole technical system.

The most valuable functionals of the possible relations among the parameters of the selected groups are:

$$Z_i = \varphi_i(U, P_{en}, P_d, N, K_r, V_d, B_r), \quad (1)$$

$$U_i = \varphi_i(P_{en}, P_d, N, K_r, V_d, B_r). \quad (2)$$

Functionals of the form (1) give a general solution. Functionals of the form (2) express the conformity control by the process of rolling cutter drilling. If the input parameters U_i correspond to the extreme values of the optimization criterion Z_i for each set of parameters the equation (2) describes an optimal control by the drilling process.

The intellectual automated control system by the technological process of drilling rock operates according to the following algorithm. The external environment influences the functioning process of the object. This system involves an auxiliary adaptive component [4], sensor, computer, and controller. The object is also affected by disturbances that are independent from the control system: random load disturbance (vibration, dust levels, temperature, error devices, failure in the control system). The adaptive element helps to smooth out these unpredictable disturbances.

For the analysis of input information about changing of the object properties the impact sensors (specified unit) in the computer send the information signals about the speed changes of the technological process and the current in the stator of the adaptive mechanism (specified impact). In the computer these information signals are converted to the control ones (the information about the actual characteristics of the object) with a controller (controllers, control units) intended to smooth short-term variations and to implement the process of control and software unit containing the developed computational technique (implementation of the control algorithm). Then control signals are sent to the operating unit realizing the decision made and of helping the appropriate operating parameters changing (automated adjustment). These techniques determine the predicted resource of tool, unit costs for the technological process corresponding to the actual values of the operating parameters and properties of the object. This information determines the optimum speed of the process and operating parameters (output parameters). To improve the quality characteristics of the system the actual values are compared with the optimal ones and automatically changed with the corrective units. The feedback realizes fast transmission of the information (one-hundredth of a second) about the current operating conditions of the control object from the control object to the control part. After the corrective action the adaptive element works in the newly defined modes. The calculated values are displayed on the dashboard using the visualization module intended to demonstrate the simulation results and the subsequent control of the operator.

Conclusion

To make a conclusion we can note the necessity to use AIS adaptive element for quick timely response of the system in drilling machines with to modify the properties of the object of influence and the subsequent adjustments and maintaining the operating parameters of the control object in the optimal ratio. The proposed algorithm of the optimal control system "drilling rig – rolling cutter bit – rock" is based on the use of correctitude values of axial force and rotation speed derived in the controller using computational techniques that assess the resource, productivity and economic efficiency of the process that allows to control current values of the operating parameters, properties of the rock mass, as well as changes in its strength, structural characteristics and to optimize the process of the system operation using the optimal values of the input characterized by the permissible value of thrust and the optimum value of rotation frequency of the operating unit. Further the application of such a AIS will reduce the operating costs for the drilling process in conditions of uncertainty and to improve the functioning of the technical system.

References

[1] Zaitsev K S 2003 Using group technology to plan data processing in computer-aided control system *Automatic and Remote Control*. Vol. **9** № **64** pp. 1507-1512.
[2] Shigina A A, Stupina A A and Shigin A O 2014 Functioning analysis of automated intellectual system with adaptive element *Modern problems of science and education*. Vol. 2, № 52. URL: http://www.science-education.ru/116-12783.
[3] Stupina A A, Shigina A A and Shigin A O 2013 The analysis of efficiency of the multi-parameter system. *Vestnik SibGAU* Vol. **2** № **48**. pp. 94-100.
[4] Stupina A A, Shigina A A, Shigin A O, Karaseva M V and Ezhemanskaja S N 2014 Automated intellectual system with the short-duration nature of feedback. *Life Sci J*. Vol. **11**, № **8s**. pp. 302-306.
[5] Ohtilev M Ju, Sokolov B V and Jusupov R M 2006 Monitoring and control intellectual technologies of difficult technical objects structural dynamics. Moscow: Nauka. 410 p.
[6] Shigin A O, Shigina A A, Gilev A V, Vokhmin S A and Kurchin G S 2015 Development of automated closed-loop drive upon designing of roller bit drilling rig for open pits. *Journal of Theoretical and Applied Information Technology*. Vol. **80** No.**1** pp. 95-104.
[7] Shigin A O 2013 Adaptable rotary-feed mechanism of rock drilling machine for reduction of unpredictable loads in complicated-structure rock drilling. *Gornyi Zhurnal*. № **7** pp. 79-83.
[8] Stupina A A, Shigin A O, Shigina A A, Karaseva M V and Korpacheva L N 2014 Control and Management by Resource of Rolling Cutter Bits in Drilling Rock Massif. *Middle-East J. Sci. Res*. Vol. **21** № **1** pp. 84-90.
[9] Stupina A A, Shigina A A and Shigin A O 2015 Mathematical formulation of technological processes optimization problem. *IOP Conf. Series: Materials Science and Engineering*. TIAA. IOP Publishing Ltd., Bristol, UK. Vol. **94** conf 1. doi:10.1088/1757-899X/94/1/012001.