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Application Of Neural Network and Fuzzy Logic System, Optimal Control Combination To Design Vibration Damping Drill Press Force Controller For СВШ-250Т Rotary Drilling Machine

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Abstract – The paper introduces fuzzy compensation control algorithm based on fuzzy logic tool to adjust the opening voltage of elector-hydraulic throttle to control the drilling force of СБШ-250Т rotary drilling machine.The proposed solution is to use an artificial neural network to replace the vibration sensor to recognize the amplitude and frequency of axial vibration on the rotary drilling machine. Vibration amplitude, vibration frequency, and drill bit pressure setting are input variables for fuzzy logic system. This system has the function of inferring and deciding the parameters that need to be properly compensated with the goal of reducing vibration for the drill, and at the same time, in order to take advantage of the maximum power of the drill rotary motor, the drilling force of the system is required.The evaluation results are verified through modeling using the Simulink mat-lab tool, which can be applied to the current control system to improve and improve the quality of the existing control in order to reduce vibration for the СБШ-250Т rotary drilling machine, which are now being used most in open mines in Quang Ninh, Viet Nam.

Keywords – Drilling machine СВШ-250Т; neural network ; fuzzy logic.

I. Introduction

Rotary drilling machine (RDM) is a device widely used in open-pit mining. During the drilling process, when encountering soil and rock with different hardness, operator has to actively adjust the parameters of the drilling mode such as rotational speed, shaft pressure, etc. base on their experience. The purpose of that is to reduce vibration, reduce damage to mechanical structures, and ensure drilling productivity. At the same time, the regulations on the level of vibration safety in work, also place additional requirements for a solution to limit vibration for the RDMs during the drilling process.

Some previous studies have also mentioned the problem of optimal control of drilling parameters based on rock hardness. However, due to limitations in technology as well as instruments, the direct measurement of rock hardness faces many technical difficulties [6], [7].Therefore, the idea of using an indirect method as applying artificial neural networks to identify rock hardness by measuring important parameters of the drilling process such as rotational speed, pressing force is expected to bring about new results.

Based on the information predicted from the neural network, it is possible to build a fuzzy compensation algorithm (δu) to automatically intervene in the opening voltage of the current elector-hydraulic throttle for the purpose of adjusting the drill force to suit the actual rock properties.The proposed solution is evaluated through modeling the control system on simulation software. The results confirm that the control system is fully adapted and responds well to the current mining environment, reducing machine vibration, improving the quality of the control system while still ensuring the working productivity of the drilling machine.

II. PROPOSAL OF A PRESSURE CONTROL SYSTEM FOR ROTARY DRILLING MACHINE.

2.1. The proposed principle diagram for the control system of the drill force

Schematic diagram of the control system of the drill force on СБШ-250T drilling machine [2],[3],[5] (figure 1)

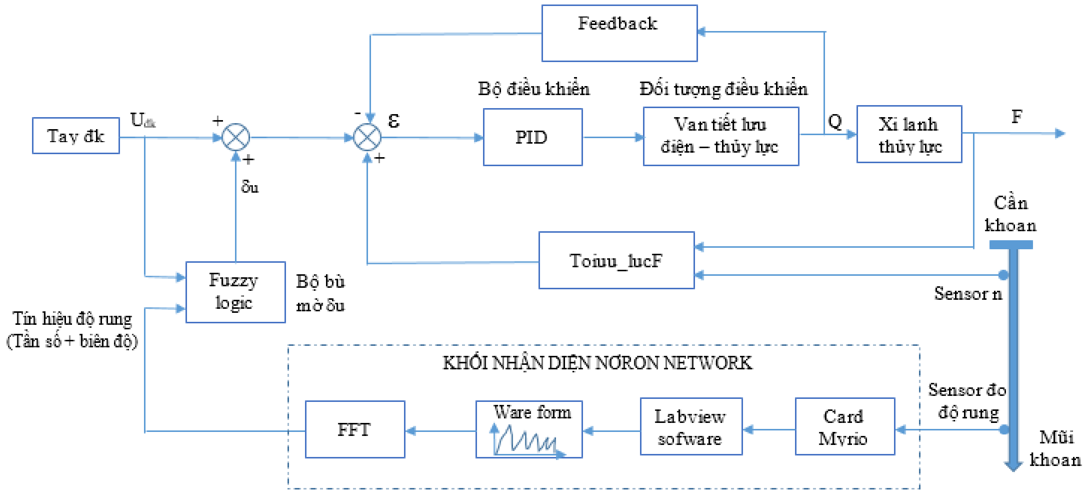


Figure 1. The proposed principle diagram for the control system of the drill force on СБШ-250T machine

In the current control system, the set point signal U_{dk} is set manually by the operator sitting in the driver's cabin, through the PID controller to change the voltage to control the elector-hydraulic throttle. In the proposed system, the control voltage will be compensated by an amount of δu through 2 blocks, including:

+ The sensor measures vibration and converts the vibration signal by FFT: in the proposed model, it is equivalently replaced by the Neural Network Recognition Block (with the function of recognizing the amplitude and frequency of the vibration after training the network). success).

+ Fuzzy logic: has the function of collecting vibration amplitude and frequency signals from the Neural Network Identification Block to make a decision to compensate the appropriate voltage level (δu) to reduce machine vibration.

2.2 Building neural network to recognize vibration frequency and amplitude [1], [6]

Neural network is a very effective tool for the identification and control of nonlinear and invariant objects and systems. The ability to self-learn and self-update its knowledge and data information is one of its strengths, making the network increasingly rich in knowledge and becoming smarter.

The success in developing a neural network depends heavily on the quality and quantity of samples during training. The variables of the drilling process such as rotational speed, drilling force are important variables and are selected as inputs for the neural network. The output quantity is the frequency and amplitude of the vibration acceleration.

+ Data table for network training process, Table 1:

Table 1: Input and output database for neural network training

STT	Input		Output	
	Rotary speed n	Drill force F	Frequency f	Vibration acceleration amplitude A
	(rpm)	(tan)	(Hz)	(m/s^2)
1	50	30	0.16	0.3
2	63	27.5	0.48	0.65
3	70	25	0.8	0.35
4	75	24	1.6	0.15
5	78	23	2.4	0.23
6	84	20	2.88	0.2
7	90	17	4,16	0.75
8	96	15	4.96	0.25
9	102	13	5.6	0.2
10	107	12	6.4	0.15
11	110	10	8.8	0.1
12	123	9	9.6	0.02
13	132	8	13.12	0.05
14	138	7	16	0.03
15	145	6	19.2	0.05
16	150	5	22.4	0.03

+ *Network design and training:*

The network is programmed in Matlab's m_file. After declaring the requirements of the network structure, the number of layers of neurons, the number of neurons in the layers, the transfer function is shown in Figure 2 and Figure 3. The training results for the bias graph image are shown in Figure 4 and Figure 5.

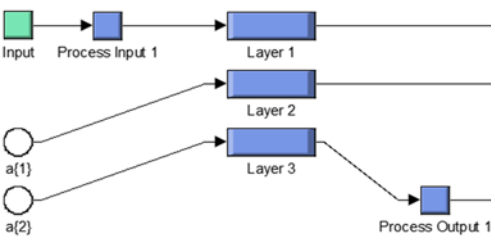


Figure 2. 3-layer reduced structure of the network

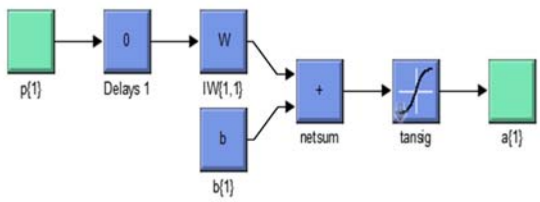


Figure 3. Input layer reduction structure of the network

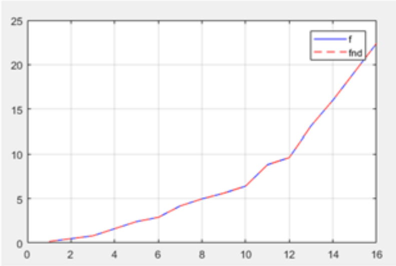


Figure 4. Error in network training - vibration frequency f

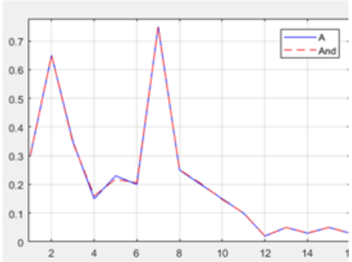


Figure 5. Error in network training - vibration acceleration amplitude A

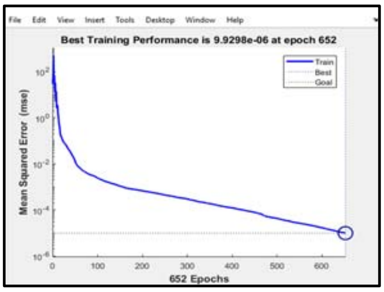


Figure 6. Error in network training

The test results on the input and output data sets of the 3-layer network model [16 x 36 x 2] show that the identity dataset follows the sample data set. It is concluded that the newly established feedforward neural network has learned the input and output signal samples. The difference between the actual value and the target value achieved after 652 times (Epochs) of training as shown in Figure 6.

2.3. Fuzzy_logic application to design fuzzy compensation controller (δu).

+ Define input and output language variables:

Variable in:

1. Frequency f of the vibration signal, using 5 fuzzy sets: from (0.08 – 22.4) Hz.

2. Vibration amplitude, using 5 fuzzy sets: from (0.003 – 1.14) m/s2.

3. Control voltage Udk, using 5 fuzzy sets: from [0 - 24]V.

Turn out: offset angle δu , using 5 fuzzy sets from [-24 ÷ 24]V.

The structure diagram for the fuzzy infers in mat-lab is given as Figure 7

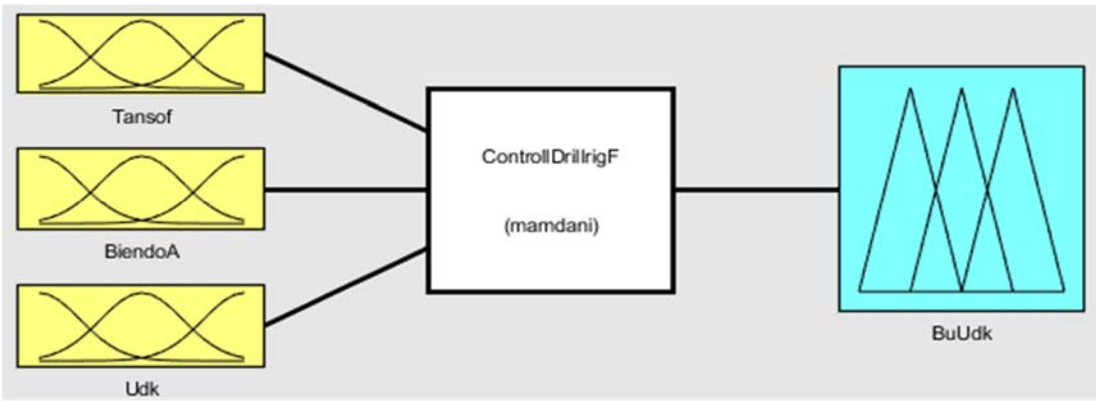


Figure 7. The structure diagram for the fuzzy inferr

+ Building composition rules and defuzzification methods:

The nonlinear communication relationship of the fuzzy inferr with 3 input variables and 1 output variable according to the data table has a total of 125 rule-combining propositions:

If Tansof = Tansofi and BiendoA = BiendoAi and Udk = Udki then BuUdk = BuUdkj

The fuzzy inferr is installed with the Max-Min composition device, the inference is done with Min's law and the fuzzy union is done by Max's law. Univalued fuzzy and defuzzed by center-average method.

+ *Results of simulation running in matlab as shown in Figure 8.*

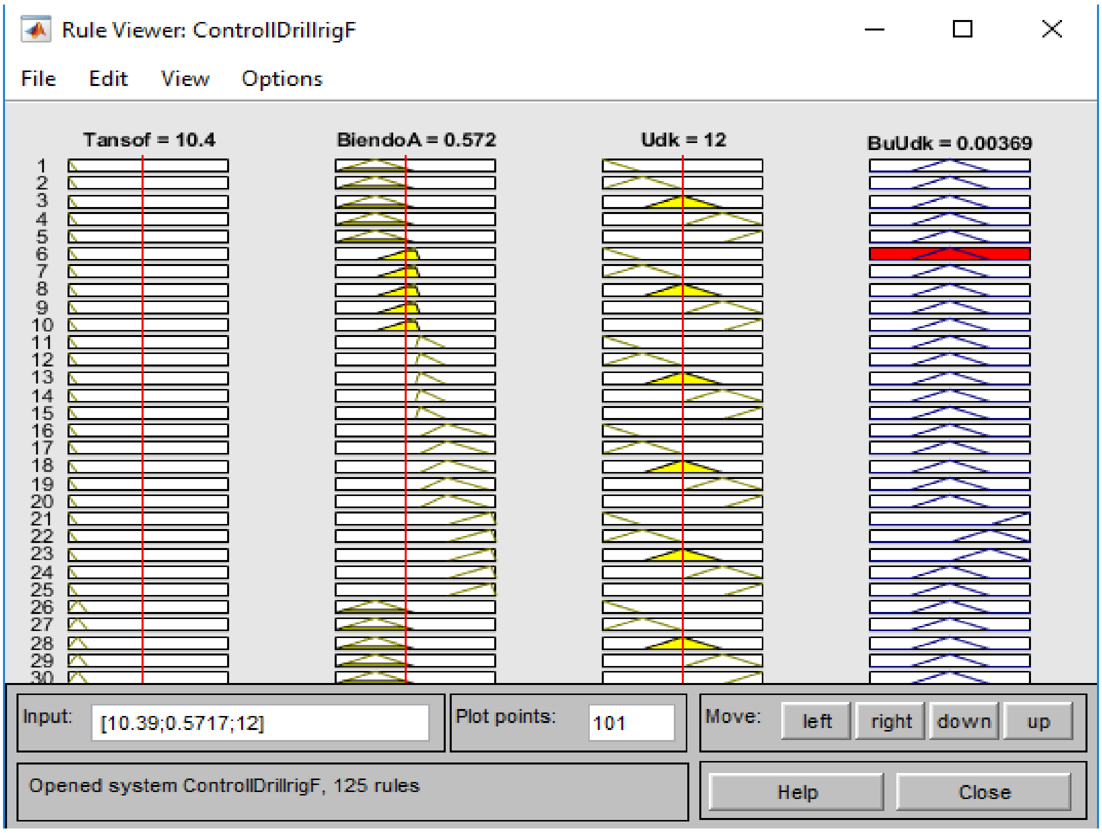


Figure 8. Output fuzzy offset inferr test results δu

2.4. Building to optimize the drilling force

In order to ensure that the vibration is within the allowable threshold for the corresponding octave frequency bands, the rotary and force control channel controllers have adjusted to reasonable values of rotational speed and pressure of axis. The problem is that when the vibration of the system is satisfactory, it is necessary to make the most of the power of the rotary engine for the best drilling productivity. The author proposes to keep the same rotational speed and to optimize the pressure adjustment to take advantage of the drill motor's power, because when increasing the pressure of the drill force, the vibration of the current system will not increase.

The torque of the motor is determined [5]:

M = F*r

F: the unit shaft pressure (Newtons), r: drill radius (r = 123mm)

The torque converted to the motor shaft will be:

Mqđ = M*K = M*11.05

K: is the gear ratio of the reducer connecting the motor shaft to the drill bit, K=11.05

The power of the rotary engine of the drill will be:

Pđc = M*ω = (0.123*F*ω)*11.05 = 0.00237*F*n

Rated power of rotary motor of the system Pdm = 60KW with an efficiency of 0.89, we have the working capacity of the motor:

P = Pđm x 0.89 = 60000 * 0.89 = 53400W

To optimize the power of the drill motor, we use the least squared error as the objective function to adjust the drilling force:

MSE = (P - Pđc)2 < G

G: the desired error value

The algorithm flowchart is shown in Figure 9.

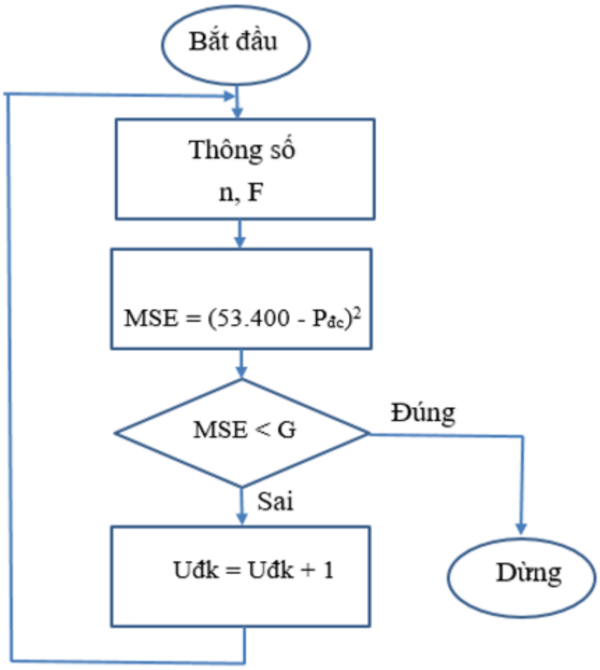


Figure 9. Flowchart of optimal adjustment of drill press force

The simulation diagram of the optimal control block for drill press is shown in Figure 10.

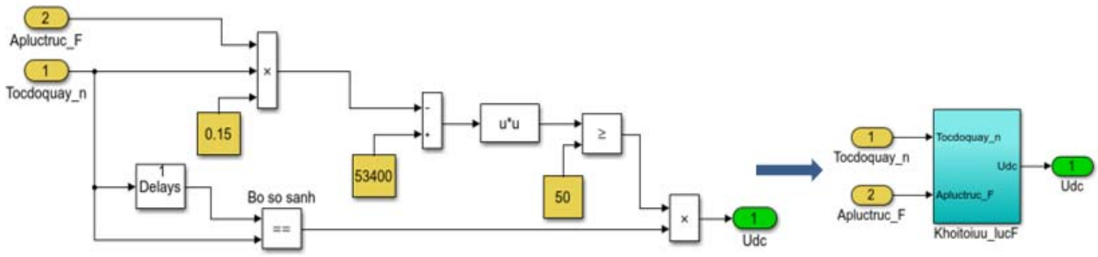


Figure 10. Diagram of optimal control of drill force

III. Application of Neural network and Fuzzy logic combined with optimal control of drill press force to model the drilling pressure control system on СБШ-250Т rotary drilling machine

After successfully developing 2 sets of tools Neural network and Fuzzy logic combined with the construction of the Optimal Control Block for drilling force, they will be saved in the library of simulink matlab to serve the research and development modeling process. From the proposed schematic diagram (Figure 1), connecting blocks together and running the simulation is shown in Figure 11.

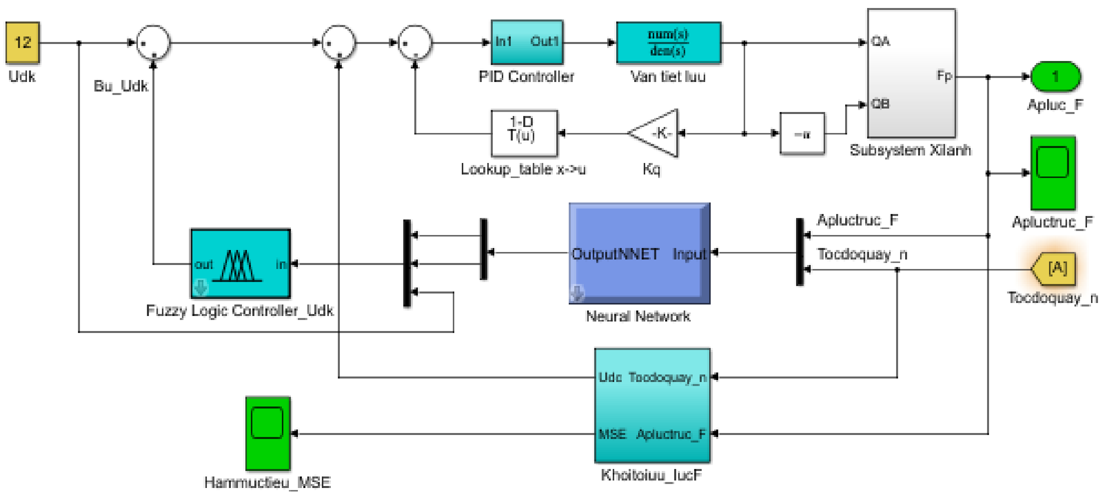
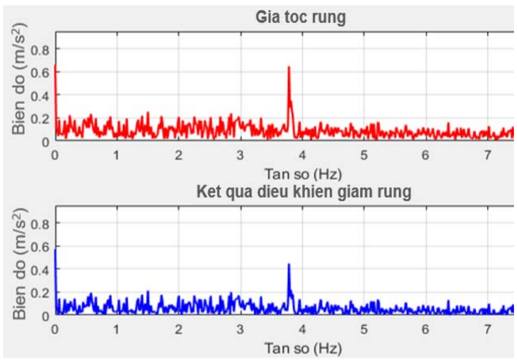
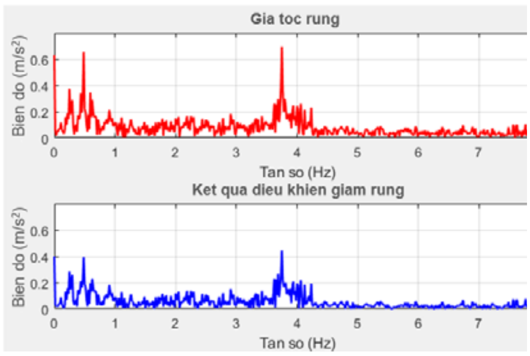


Figure 11. Block diagram of the pressure control of the drill bit on the C-250T RDM

Test run results in operating conditions with soil and rock of different hardness, the system without blur compensator and the system with blur compensator combined with the control block that optimizes the pressure of the drill bit to give satisfactory results. For the requirements set on the quality of control and the target of vibration reduction for the device, see Figures 12 and 13. Where red is the amplitude and frequency of vibration with the current controller, blue is the boundary. vibration intensity and frequency with the proposed controller. Thereby, the peak amplitude decreased by 40%.



Hình 12. Kết quả test thử nghiệm trên mô hình ở độ sâu 1m



Hình 13. Kết quả test thử nghiệm trên mô hình ở độ sâu 13m

IV. Conclusion

The paper refers to the contents of research and development of two tool kits such as neural network and fuzzy logic, combined with an optimal control block for drill press force with the aim of building a fuzzy compensating controller that affects The current control system to control the optimal drilling force and reduce vibration for the machine includes:

+ Successfully training a neural network to recognize the amplitude and frequency of the vibration acceleration caused by the drilling rock hardness.

+ Developing fuzzy logic to determine the offset voltage combined with the optimal control block and acting on the controller to optimally adjust the pressure of the drill bit.

+ Synthesizing and modeling the proposed drill press pressure control system, compare the evaluation with the current controller in use.

+ The research results are checked on the simulation model, evaluated by the quality criteria of the control system, the vibration reduction criteria on the machine allowing the applicability of the controller in practice. operate the drill.

+ The research results confirm that the application of two sets of neural network and fuzzy logic tools combined with an optimal control block for drilling force to improve and improve control quality and reduce vibration for drills is a solution. suitable method for controlling nonlinear electric drive systems taking into account complex geological conditions.

+ It is proposed to continue to evaluate the stability and sustainability of the control system with fuzzy compensation through the combination of controlling the pressure channel and the rotary channel at the same time. The desired solution to be applied in practice in the operation, adjustment and control of the drilling machine will contribute to improving the quality of the control system and the working performance of the rotary drilling machines in actual production today. .

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