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AUTOMATIC DUST MEASUREMENT SYSTEM USING A MAGNETIC SUSPENSION

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Abstract- The article discusses an automatic dust measuring system operating on the principle of magnetic levitation. The description of the proposed scheme of an automatic system for measuring dust concentration is given. A block diagram of an automatic dust concentration measuring system and an algorithm for the operation of a system including three sequentially performed steps, each of which consists of incomplete simultaneously performed operations, have been compiled. Formulas are obtained that describe the condition of dynamic equilibrium for each flowmeter float and the condition of dynamic equilibrium for a unit for measuring the increment of the filter weight, and a formula is obtained for determining the dust concentration by dividing a signal proportional to the weight of the dust by a signal proportional.

Keywords: Measuring Instrument, Magnetic Suspension, Filter, Inductive Transducer, Solenoid, Magnetic Core, Regeneration, Levitation.

1. INTRODUCTION

The article discusses an automatic dust concentration measurement system operating on the principle of magnetic levitation. The principle of magnetic levitation has many advantages. One of them is that the levitating body, which acts as a sensitive element, can be placed in various measuring chambers, which make it possible to localize the influence of the factor of interest to the researcher on the levitating body and exclude the influence of all the others. This allows measurements to be made under a wide variety of environmental conditions, for example, in a liquid or gaseous medium, at various temperatures and pressures, in vacuum, at various angular positions of the levitation axis on board aircraft and ships, on tankers for level measurement and density of transported liquids, for measuring the flow and density of marine fuel in tanks, etc. [6].

The convenience and accuracy of converting the effects of many parameters of substances, materials and products into a vertically acting force makes it possible to use MLS to measure these parameters.

At present, a large number of MLS magnetic levitation systems have been created and implemented in measuring technology, which are implemented according to a single design scheme. They have an invariable part of the design - this is a traction unit, including a solenoid and a magnetic rod core, and a variable part - an electronic circuit that includes a core displacement sensor, an electronic amplifier and a solenoid current regulator. A cardinal influence on the electronic circuit of the MLS is exerted by the type of sensor, depending on which the circuit of the electronic amplifier is built. Moreover, the type and name of the MLS is determined by the type of sensor used.

When developing and designing MLS to control the parameters of substances, materials and products, the problem arises of determining and evaluating the dynamic indicators of the quality of the system [1]. Due to the fact that MLS in its structure is a closed system of automatic control of the solenoid current, it is characterized by a state of instability, which is characterized by the appearance of self-oscillations of the levitating body - the magnetic core. To exclude self-oscillations of the levitating core, a dynamic corrective link is introduced into the system's impact circuit, which significantly improves the dynamic quality of the system and expands the boundary of its stability area. This makes it important to carry out theoretical and experimental studies of the properties of a dynamically adjusted system in order to determine the necessary and sufficient conditions for ensuring the state of stable levitation of the magnetic core and, using them, determine the boundary of the stability region by the transfer coefficient of the section of the open circuit of influences and by the gain of the electronic amplifier.

The paper describes the proposed scheme of an automatic system for measuring dust concentration. A block diagram of an automatic system for measuring the concentration of dust and an algorithm for the operation of the system, which includes three sequentially performed stages, each of which consists of incomplete simultaneously performed operations, are compiled. Formulas are obtained that describe the dynamic equilibrium condition for each flow meter float and the dynamic equilibrium condition for the block for measuring the filter weight increment, and a formula is obtained for determining the dust concentration by dividing the signal proportional to the weight of the dust by the signal proportional to the volume of the controlled medium.

The relevance of this topic is that the elimination of shortcomings and the improvement of previously created devices, as well as the use of new methods and the latest achievements in electronics make it possible to complete the processes quickly and accurately. On the other hand, high reliability is required. Particularly stringent requirements are placed on devices. The paper considers the development of a device for automatic measurement of dust concentration in various industries.

2. RESULTS AND DISCUSSION

At present, the creation of new devices in the field of control and measuring technology is of great importance. The purpose of the work is to create a block diagram of an automatic dust concentration measurement system, to draw up an algorithm for the operation of the system, which includes three sequentially performed stages, each of which consists of incomplete simultaneously performed operations. The stage of purge through the system of a certain portion of the controlled medium in the direction from left to right and from right to left for simultaneously performed operations: filtration of the medium with one filter and regeneration of another filter, measurement of the medium flow rate during the purge process, determination of the volume of the medium being purged. Thus, the blocks for measuring the weight increment change roles [6].

One of the sources of pollution of the air basin of industrial facilities and the air of industrial premises (workshops, warehouses, etc.) is dust. Dust concentration measurement is a difficult task. This is due to the fact that dust is a complex system, which, in contrast to gas in air, cannot be adequately described by one or two parameters [4, 5]. There are several basic methods for measuring the mass concentration of aerosols in air.

The most common method is gravimetry, in which air samples are pumped through a filter, and the difference in the mass of the filter before and after sampling measures the concentration of dust in the air. The method has both advantages and disadvantages. It requires long-term sampling for the analysis of atmospheric air, in which dust particles are usually contained in low concentrations, but at the same time it has high accuracy in determining high concentrations of dust in the air of the working area. To determine the content of dust of various fractions in the air, special auxiliary devices are used, impactors, which make it possible to separate particles of different aerodynamic sizes. The proposed automatic system for measuring the concentration of dust can be used in various industries, allowing you to improve the accuracy of measurements and automate the operation of cleaning the filter from dust [8].

Figure 1 shows a schematic diagram of an automatic system for measuring the concentration of dust [1, 2]. The system operation algorithm includes three sequentially performed stages, each of which consists of incomplete simultaneously performed operations [3]. The stage of blowing a certain portion of the controlled medium through the system in the direction from left to right (according to the drawing) consists of the following simultaneously performed operations: filtering the medium with filter 5, regenerating filter 6, measuring the flow rate of the medium during the blowing process (Q), determining the volume of the medium being blown (V).

When the medium is filtered by filter 5, the bottle 3 with filter 5 is pressed against the sealing ring 17 by the magnetic force of the solenoid 5 connected by the switch 38 of the time relay 42 to the power source 53, the flow stimulator 41 (compressor) is turned on by the switch 40 belonging to the relay 42, and the controlled environment through the open valves 49 and 50, switched on by switch 47 belonging to relay 52, are "driven" through the filter layer 5 through the system from left to right. At the same time, valves 48 and 51 are in the closed state. When filter 6 is regenerated, filter 6 enters the auto-oscillation mode by filter 6. In this case, the switch 39 of the relay 42 connects the solenoid 16 to the current control system with a large gain. To do this, in series with the current regulator 20, by opening the switch 24 of the relay 52, an additional amplifier 22 is connected, which increases the overall gain of the control system to a value sufficient to excite self-oscillations magnet of the interacting system magnetic rod 10 - inductive transducer - solenoid 16. At the same time, relay 52 is in the closed state, preparing the system for the next stage of work.

When measuring the flow rate of the medium during the purge, the switches 45 and 46 of the relay 52 are in the position (left in the diagram), in which the current signal I2 of the solenoid 32 is connected to the 5 direct input of the differential block 54, and the current signal i2 of the solenoid 33 is connected to the inverse input flow meter 25. The solenoid 32 holds in the magnetic field the float 26 of the downward flow of the medium, and the solenoid 33, the float 27 of upward flow of the medium.

The device can be used for automatic control of air dustiness in various industries, as well as in solving environmental problems related to the control of environmental pollution. The condition of dynamic equilibrium for each float of flowmeter 25 has the form:

- For float 26 downstream;

$$G_2 + k_2 Q = k_0 i_2 \tag{1}$$

- For float 27 upstream;

$$G_3 - k_3 Q = k_0 i_3 \tag{2}$$

where, G_2, G_3 are weight respectively floats 26 and 27; k_2, k_3 are float drag coefficient 26 and 27; i_2, i_3 are solenoid currents 32 and 33; k_0 is coefficient of electromagnetic force of interaction of solenoids 32 and 33c magnetic rods 36 and 37; Q is volumetric flow of the medium to be cleaned from, Assuming, G_2=G_3=G; k_2=k_3=k from Equations (1) and (2) get:

$$Q = \frac{k_0}{2k}\left(i_2 - i_3\right) \tag{3}$$

To determine the volume of the purged medium, a signal proportional to the flow rate Q is fed from the output of the differential block 54 to the input of the integrator 56, where the volume of the medium V passing through the filter layer 5 in time τ is determined by the method of continuous integration of the flow signal Q over time t, settable time relay 42

$$V=\int_0^\tau Qdt=Q\tau=\frac{k_0}{2k}\left(i_2-i_3\right)\cdot\tau \tag{4}$$

The purge time τ is selected experimentally depending on the filter parameters. A signal proportional to the volume V is fed to the input of the divider block 55 divisions. The stage of determining the dust concentration includes the following operations: measuring the weight of the dust settled in the pores of the filter 5 and determining the dust content in the volume of the medium passed through the filter 5 (the dust concentration in this volume is judged on the dust concentration in a controlled environment).

After the set time τ, relay 42 switches the system to the measurement mode. To perform the first operation, the solenoid 15 is connected by the switch 38 to the current regulator 19 through the closed switch 23 (bypassing the amplifier 21). In this case, the bottle 3 with the filter 5 goes into a state of free soaring under the influence of the magnetic field of the solenoid 15.

At the same time, the switch 39 connects the power source 53 to the solenoid 16, the magnetic force of which presses the bottle 4 to the sealed ring 18. The switch 40 turns off The flow stimulator 41 is activated and the supply of the controlled medium to the system is stopped. In this case, the dynamic equilibrium condition for block 1 for measuring the weight increment of filter 5 has the form:

$$G_1+G_n=k_0i_1 \tag{5}$$

where, G_1 is initial weight of bottle 3 with filter 5; G_n is the weight of dust deposited on filter 5; k_0 - is the coefficient of the electromagnetic force of the interaction of the solenoid 15 with the magnetic rod 9; and i_1 is the current of solenoid 15, where

$$K_0=\frac{\pi}{8}\times\frac{d_м^2}{d_n^2}\times B_m(b)\times h\times K(\overline{z}) \tag{6}$$

where, d_n is the diameter of the solenoid winding wire, m; d_m is the diameter of the magnetic core, m; $B_m(b)$ axial magnetic induction of the core material, depending on its length, T; h is the height of the solenoid winding, m; $K(\overline{z})$ is relative coefficient of force interaction of the solenoid with the magnetic core in the state of levitation. because it is a function of relative arguments $\overline{z}$; and $\overline{b}$; $\overline{R}$; $\overline{r}$, characterizing the structural dimensions of the system.

$$\begin{aligned}K(\overline{z})&=\overline{z}\times\ln\frac{\overline{R}+\sqrt{\overline{R}^2+\overline{z}^2}}{\overline{r}+\sqrt{\overline{r}^2+\overline{z}^2}}-(\overline{z}-1)\times\\&\times\ln\frac{\overline{R}+\sqrt{\overline{R}^2+(\overline{z}^2-1)^2}}{\overline{r}+\sqrt{\overline{r}^2+(\overline{z}^2-1)^2}}--(\overline{z}+\overline{b})\ln\times\\&\times\frac{\overline{R}+\sqrt{\overline{R}^2+(\overline{z}+\overline{b})^2}}{\overline{r}+\sqrt{\overline{r}^2+(\overline{z}+\overline{b})^2}}+(\overline{z}-1+\overline{b})\times\\&\times\ln\frac{\overline{R}+\sqrt{\overline{R}^2+(\overline{z}^2-1+\overline{b})^2}}{\overline{r}+\sqrt{\overline{r}^2+(\overline{z}^2-1+b)^2}}\end{aligned} \tag{7}$$

where, $\overline{z}=\frac{z}{h}$; $\overline{b}=\frac{b}{h}$; $\overline{R}=\frac{R}{h}$; $\overline{r}=\frac{r}{h}$; I_s is solenoid current, A; h is winding height, m; z is the distance from the upper end of the core to the upper edge of the solenoid winding, m; and R and z are the outer and inner radii of the solenoid winding.

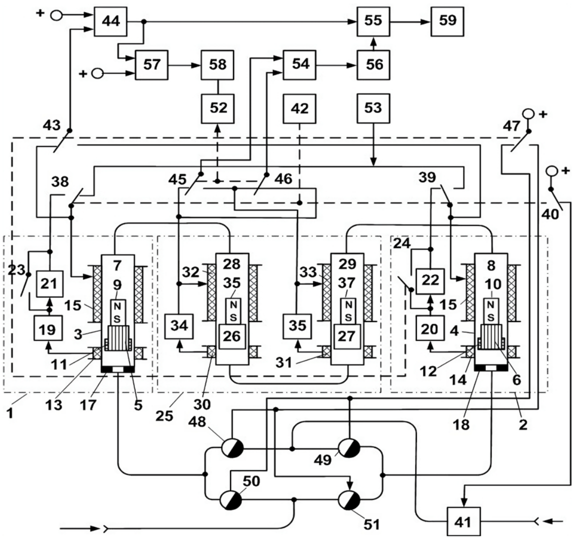

Figure 1. Schematic diagram of an automatic dust measurement system

The signal proportional to the weight of the bottle 3 with dust G_1+G_n is fed through the switch 43 of the relay 52 to the first input of the differential block 44, the second input of which is fed with a reference signal proportional to the weight of the bottle G_1=k_0i_1 (without dust). As a result, at the output of block 44, a signal is generated that is proportional to the weight of the dust deposited on filter 5:

$$G_n=k_0\left(i_1-i_0\right) \tag{8}$$

This signal is fed to the first input of the differential block 57, the second input of which is supplied with a signal proportional to the maximum value of the gain of filter 5. The signal at the output of block 57 characterizes the margin for a possible increase in the weight of dust on filter 5. To perform the second operation, the signal from the output of the differential block 44 is also fed to the input of the dividing block 55 division. Block 55 determines the dust concentration P (mg/l) by dividing the signal proportional to the weight Gn of the dust by the signal proportional to volume V of controlled medium:

$$\dot{I} = \frac{G_n}{V} = \frac{2k}{\tau}\frac{i_1 - i_0}{i_2 - i_3} \tag{9}$$

After performing the division operation, the signal from the output of block 55, proportional to the dust concentration, is fixed on indicator 59. The purpose of the stage of analysis of the weight gain of dust on the filter is to organize the cycles of the system. The system has two cycles: a small one, in which the operations of blowing the medium and measuring the weight gain of dust on the filter alternate before the start of regeneration, i.e. without changing the direction of the medium flow and a large one, in which the operations of changing the direction of blowing the medium through the system alternate according to the signal of the exhaustion of the dust weight gain reserve and the start of regeneration of the used filter. A small cycle is organized with the help of a time relay 42, a large cycle with the help of a relay 52 for changing the direction of the flow of the controlled medium. If the weight gain of the dust during its measurement does not exceed the maximum allowable value, then the gain margin signal keeps the relay 52 off and the small cycle is repeated: purge, measurement.

If the dust weight gain signal exceeds the maximum allowable value, then a signal appears at the output of block 57, which puts the electronic key 58 into the state of a logical unit, turning on the relay winding 52, which switches all its switches to the opposite position switch 23 opens, switch 24 closes, switches 45 and 46 switch the inputs of block 54, switch 47 switches valve 49 and 50 to the closed state, and valves 48 and 51 to open state.

Thus blocks 1 and 2 for measuring the weight increment change roles: block 1 is switched to the filter regeneration mode, and block 2 is switched to the dust extraction mode and proceeds to repeat the large cycle. The device provides an increase in the accuracy of dust concentration measurement due to the full pressing of the bottle with the filter to the sealing ring during the filter purge.

3. CONCLUSIONS

A block diagram of an automatic system for measuring the concentration of dust and an algorithm for the operation of the system, which includes three sequentially performed stages, each of which consists of incomplete simultaneously performed operations, are compiled. The stage of blowing through the system of a certain portion of the controlled medium in the direction from left to right, the filtration mode of the controlled medium and the regeneration of the filter with dust. Thus, the blocks for measuring the weight increment change roles. Formulas are obtained that describe the dynamic equilibrium condition for each flowmeter float and the dynamic equilibrium condition for the block for measuring the filter weight increment, and a formula is obtained for determining the dust concentration (mg/l) by dividing the signal proportional to the dust weight by the signal proportional to the volume-controlled environment.

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