CONTROL OF A TUBE FURNACE IN CONDITIONS OF RISK AND INCREASED EXPLOSION HAZARD

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Abstract

In the condition of rapid production intensification based on an increasingly complete and rational use of technical, material and labor resources, improvement of the production organization and labor, improvement of the system and management and planning methods, there is a need for an operational analysis of the current situation, improvement of methods for regulating, managing and reducing the anthropogenic, man-made and natural character risks. In the oil and gas sector, the distinctive features of which are the multi-connectedness and multidimensionality of their constituent technological apparatuses, industrial, environmental and economic risks are especially high. Considering that the technological processes basis is thermal processes occurring in apparatuses, in connection with this, the abstracts pay attention to topical automation issues, regulation and control of increased fire and explosion hazard processes occurring in a tube furnace, ensuring a reduction in the risk of the aforementioned emergencies.

Keywords: tube furnace, thermal processes, control object, gas-air ratio, production risk, explosive mixture, risk management

I. Introduction

Risk management is the most important element of successful activity for any production and industry associated with increased production and investment risks. All these factors are present in the oil and gas industry, and the successful operation of this industry is largely the result of proper and effective risk management, and above all, technological and industrial safety - a measures system designed to eliminate or minimize the accidents risk, environmental damage or damage to process equipment [1-4].

It is known that fires and explosions bring the greatest property damage to oil and gas enterprises, which account for almost half of all cases.

Industrial and technological safety, that is, the creation of such conditions at an enterprise or facility when the risk of accidents is minimal, and in the event of an emergency or an accident, an action plan is established to prevent it with minimal losses (damages) - an already established segment of the risk management system. Technologies for detecting and preventing the accidents development, fires and explosions are built into technological production systems [5, 6].

It should be noted that the increased danger processes of (fire and explosion hazard) also include thermal processes that play an important role in the chemical, petrochemical and oil and gas sectors.

As you know, the chemical reactions of substances, as well as their physical transformations, are accompanied by thermal phenomena. It is thermal effects that often form the basis of technological processes. In this regard, the automation issues, regulation and control of the heat exchangers functioning o, tube furnaces, evaporators and other chemical technology objects associated with heat transfer are relevant.

II. Methods

The main technological apparatuses of the refinery at the electric desalination plant-atmospheric-vacuum tube include tube various types furnaces (tube block furnaces, double tent-type furnaces, furnaces with radiant walls and vertical-torch type). Among them, tubular block furnaces are the most common, since the most perfect way to heat oil is to heat it in these furnaces [7].

In addition, when regulating the fuel gas-air ratio in similar tubular block furnaces, it is necessary to ensure safety measures, since with a lack of air in the furnace, an explosive mixture can form, which, under favorable conditions, can lead to accidents, explosions and fires [8, 9].

As is known, a tubular block furnace is a complex multidimensional and multiply connected automation and control object. When considering it as a control object, the analysis of the processes occurring in the furnace makes it possible to identify the main input and output parameters, as well as disturbing influences (Figure 1).

Disturbing influences: air temperature (controlled parameter), gas temperature (controlled parameter), rotational speed of electric motors (controlled parameter), oil consumption (controlled parameter), gas flow (controlled parameter) and oil quality (uncontrolled parameter).

The output parameter of the considered object is the oil temperature at the outlet.

The regulating purpose a tube furnace is to maintain the outlet product temperature in the presence of a large disturbances number, many of which are uncontrollable, which increases the risk of the aforementioned emergencies.

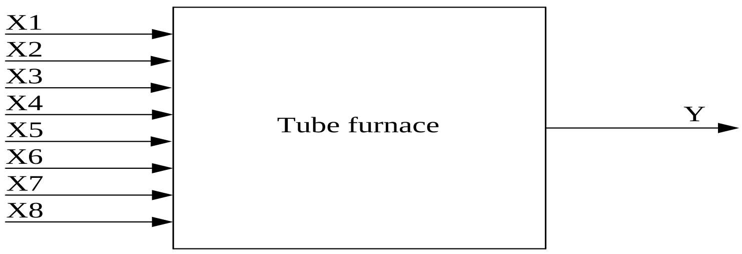

Figure 1: *Tube furnace as a control object*

X_1 - raw material consumption, X_2 - gas flow, X_3 - air flow, X_4 - temperature at the tube furnace inlet, X_5 - air temperature, X_6 - gas temperature, X_7 – rotational speed of electric motors, X_8 - oil density

In addition, a tube furnace is an inertial object with a delay in the main control channels, so the choosing task a control information parameter that quickly responds to changes in the furnace operation mode and developing an automatic control system that would compensate for the main disturbances is relevant.

The study of methods for constructing an automatic control system for the temperature at the outlet of a tube furnace is carried out on the heating an oil emulsion example that flows through the coil of a tube furnace and is heated by the heat generated during the combustion of fuel gas and air. From a large factors number affecting the exit temperature of the oil emulsion, the fuel gas supply and oil emulsion can be distinguished. The oil emulsion supply, as well as its temperature, are the main disturbances sources, and the fuel gas supply and air are control actions.

Namely, when regulating the fuel gas-air ratio, it is necessary to ensure safety measures, since an explosive mixture can form in the furnace if there is a lack of air. In this regard, it is necessary to provide for limiting the fuel flow so that this flow never exceeds the maximum allowable value corresponding to the current air flow value. When the air consumption decreases relative to a certain value, it is necessary to automatically reduce the fuel supply to the furnace. The solution to this problem can be found from the dependence of the temperature in the furnace on the ratio of fuel gas-air, which is extreme.

On Figure 2, the extreme controller finds the maximum flue gas temperatures above the pass wall by acting on the fuel gas-air ratio controller, which controls the primary air supply.

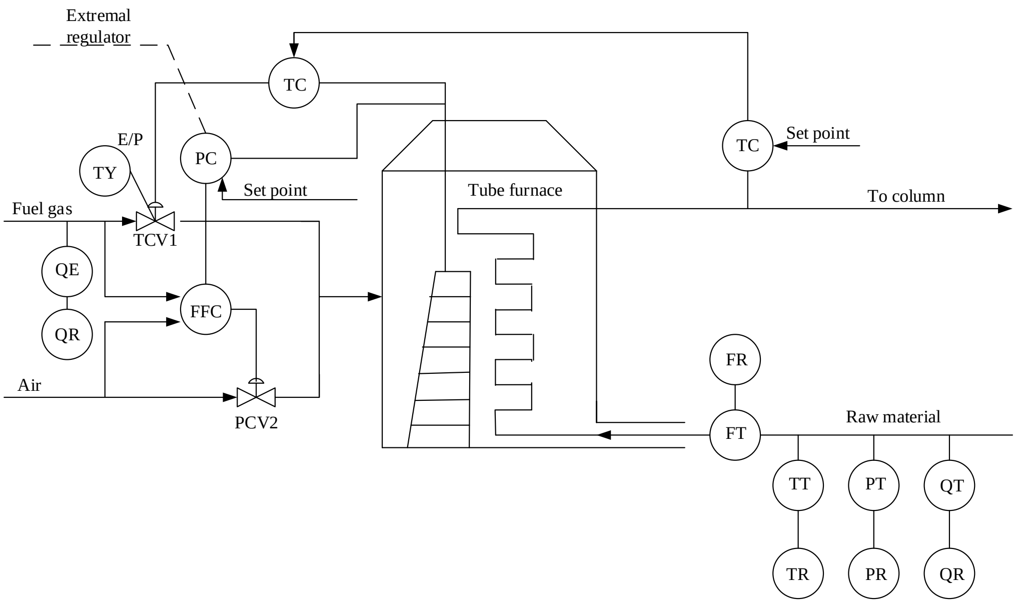

Figure 2: *Functional cascade scheme for controlling the product temperature in the furnace with an extreme controller that corrects the fuel gas-air ratio*

The circuit for stabilizing the fuel gas-air ratio is shown here. It regulates the fuel gas flow F_{fg} in a certain ratio with the air flow F_{air} (the so-called flow ratio regulator), so that the restriction on the fuel gas flow determines the temperature above the bridge wall T_{bw}:

$$F_{fg} = f(T_{bw}) \cdot F_{air}.$$

As a rule, the transfer functions for the channel fuel gas consumption - temperature above the bridge wall, as well as for the channel temperature above the bridge wall - temperature at the furnace outlet are the same type and can be described by first-order inertial dynamic links with delay:

$$W(p) = \frac{k}{T \cdot p + 1} e^{-\tau p}$$

According to the technology, the requirements with the indicator of the automatic temperature control system at the furnace outlet are as follows:

1) aperiodic nature of the transient process with an allowable overshoot of 0÷15%;

2) establishment (regulation) time no more than 3e4 s;

3) the temperature must be between 5°C and 90°C.

As a method for adjusting the controllers parameters, the method of automatic tuning for the PID-Control block using the MATLAB modeling package was chosen.

The automatic tuning results provided the specified requirements for the quality of the oil emulsion temperature transient process (Figure 3): aperiodic nature of the transient process with an 7% overshoot; regulation time T_{reg}= 2.5e4 s; the range of temperature change satisfies the technological regulations for the heating the oil emulsion process: from 5°C to no more than 90°C.

To maintain an appropriate temperature at the furnace outlet, it is also necessary to control such an important parameter of the considered technological process as the temperature in the preheater.

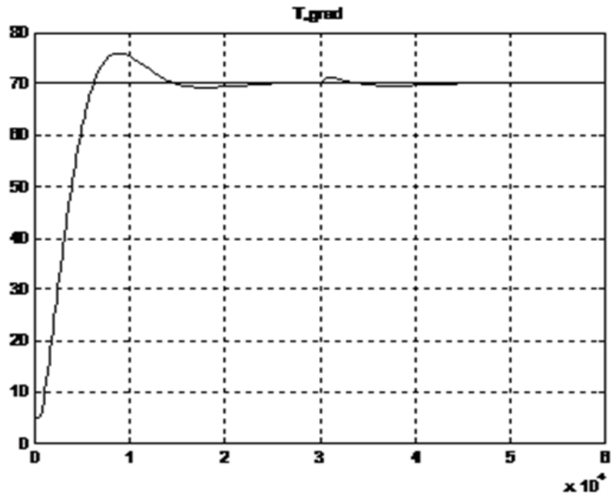

Figure 3: *Graph for the transient response of the oil emulsion temperature at the tube furnace outlet*

As a control algorithm, we will use the PID-control algorithm, which allows us to provide good control quality, a fairly short time to reach the regime and low sensitivity to external disturbing factors.

Below in Figure 4 shows a functional diagram of the oven temperature maintenance system.

The operator panel sets the temperature to be maintained in the preheater. This temperature is then fed to the PLC. The PLC also receives the value from the temperature sensor, compares the values, and finally generates a current output signal. This signal is sent to the electric drive, which opens or closes the gate valve. The electric drive converts electrical energy into the gate valve stem translational movement, resulting in a change in temperature in the tube furnace

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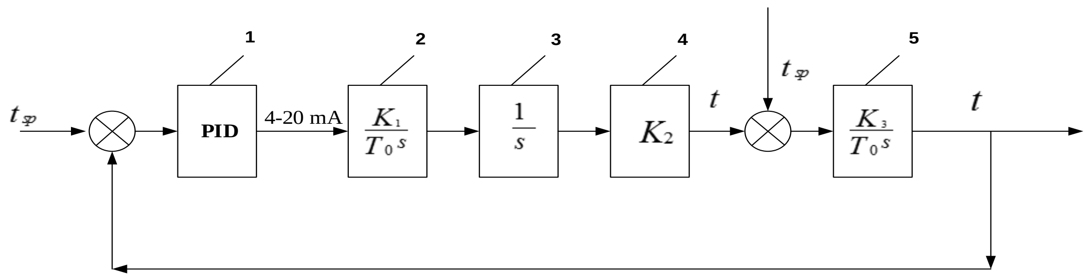

Figure 4: *Functional diagram of the temperature maintenance system in the furnace*
1 - PLC, 2 - Electric drive, 3 - Gate drive, 4 – Converting combustion gas into heat, 5 – Preheater

III. Results

The PLC also receives the value from the temperature sensor, compares the values, and finally generates a current output signal. This signal is sent to the electric drive, which opens or closes the gate valve. The electric drive converts electrical energy into the gate valve stem translational movement, resulting in a change in temperature in the tube furnace.

In this case, the linearized model of the control system is described by the following equations below set:

- discrepancy signal:

$$\theta = t_{sp} - t$$

- gate valve with electric drive:

$$T\frac{d\omega}{dt} + \omega = kI$$

$$\frac{d\varphi}{dt} = \omega$$

- preheater and gas conversion into heat:

$$v = k\varphi$$

$$T_{\text{под}}\frac{d\theta}{dt} + \theta = k_{\text{под}}v,$$

where I is the current control signal, ω is the engine angular speed, φ is the damper movement, v is the heat released when burning gas, θ is the temperature in the preheater.

In the controlling process the object under study, it is necessary to maintain the outlet temperature equal to 120 °C, therefore, a step action acts as the transfer function of the assignment, which changes its value from 0 to 120 °C at the time the program starts.

The model with selected blocks is shown in Figure 5.

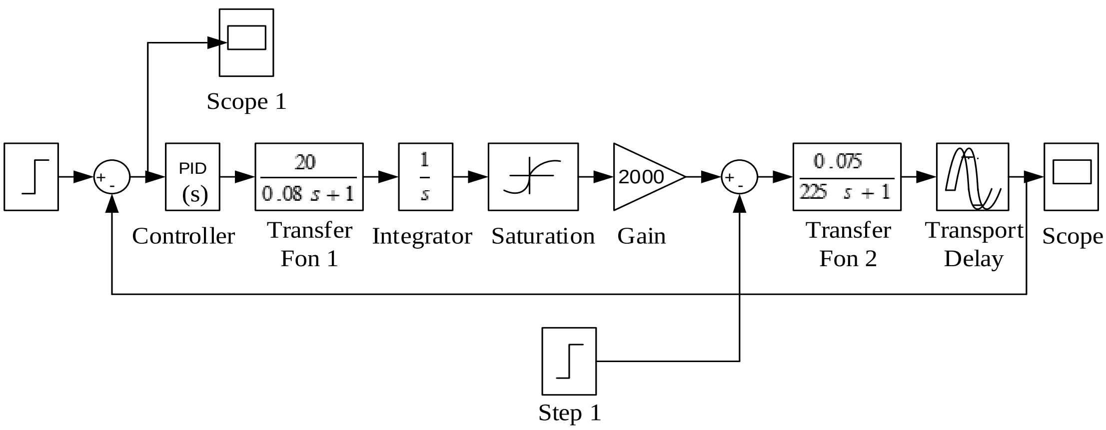

Figure 5: *Model in Simulink*

IV. Discussion

As a research result, a cascade-type control system is presented for the effective a tube furnace control, which is an object operating in risky and explosive conditions. This control system type provides more efficient and optimal control of the technological object under study, operating both under information deficiency conditions and under the various disturbances influence. In addition, in order to improve the quality of object under consideration control, the problem of synthesizing an automatic control system was solved, and the results obtained make it possible to improve the quality of the technological object under study transient process and ensure the stability of the automatic regulation system. This, in turn, minimizes the technological and technical risks that may arise at the facility, as well as the explosion likelihood of the technological apparatus.

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