Improving safety of the operation of pipe heaters oil and gas production

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Abstract. In technological processes of modern enterprises of oil and gas production flammable and explosive substances turn, which, combined with a wide range of changes and extreme values of technological parameters - temperature, pressure, flow rate, corrosivity, causes high rates of accidents risk. Pipe heating furnaces are among the most dangerous objects of oil and gas production, more than 10% of all accidents occur on them. Cause most of these accidents is leakage of pipe coil and the ingress of the process medium into the combustion space of the pipe heater. During operation, irreversible damage accumulates in the pipe coil metal, there is an uneven stress-strain state due to thermal force loading, there is a carbon deposition on the inner surface. This article discusses the process of carbon-producing in the pipe heaters on the example of a pipe heater box type using a computer predictive model of the production process. According to the results of the study, a new evaluation criterion for the level of coking of the pipe coil – the rate of carbon-producing is proposed and its value corresponding to the maximum permissible level of coking is determined. Calculation of the rate of carbon-producing is carried out by virtual quality analyzers using the process parameters of the carbon-producing.

1. Introduction
Pipe heating furnaces of oil and gas production are among the most dangerous production facilities, have high accidents risk [1]. Statistical data on accidents in the oil and gas industry from 2007 to 2017 show that they account for 11.6 % of all accidents, of which 85 % are fires and explosions (figure 1; table 1).

Cause most of these accidents is leakage of pipe coil and the ingress of the process medium into the combustion space of the pipe heater. In the metal pipe coil accumulate irreversible damage, there is a nonuniform stress-strain state due to thermal and force loading is the carbon deposition on the inner surface. In the process of operation, deformation and destruction of pipe coils occur due to the steel creep, brittleness and cracking of metal, change in strength characteristics due to the effects of nitrogen, carbonation, corrosion.
2. Accidents prevention

For timely detection of pipe coil zones with increased damage to the metal structure and unacceptable stress-strain state, new methods and technical means of control are intensively developed, in particular, methods and tools for assessing the technical condition and predicting the safe operation resource of equipment based on the use of electromagnetic-acoustic (EMA) effect are promising [2, 3]. The coking of the inner surface of the pipe coil has several negative consequences – the open flow area of the pipe coil decreases, the heat transfer to the technological environment decreases, which leads to a significant change in the technological parameters and a violation of the optimal operating mode of the furnace, overheating of the pipe coil in the area of internal deposits leads to its burnout. For elimination of these negative phenomena, timely cleaning of a pipe coil of internal deposits is made.

Currently, to prevent accidents associated with the burnout of the pipe coil, methods are used that do not make it possible to assess the damage to the metal of the coil, control the thickness of its wall and the level of coking during the operation of the furnace. Existing AWA systems of pipe heaters indicate dangerous coking of the pipe coils according to the following criteria: according to the temperature difference between the concurrent flows of the process medium at the outlet of the radiant coils of the furnace; to increase the pressure of the process medium at the inlet to the furnace at a constant flow rate; by the temperature of the flue gases at the furnace pass [4, 5]. The ESS systems react and stop the operation of the furnaces in case of burnout of the pipe coil according to the following indicators: a sharp increase in temperature at the pass of the furnace and flue gases at the outlet of the furnace, accompanied by a drop in the concentration of oxygen in the flue gases; reducing the pressure of the process medium at the outlet of the furnace.
3. Furnace production process control

The formation of coke in the furnace coils is a complex process, depending on a large number of factors. One of the parameters characterizing this process is the rate of carbon-producing. Ideally, the equation for the rate of carbon-producing should be based on the physical and chemical theory of coking, taking into account the specifics of the specific furnace (based on the analysis of the furnace for a long time, on expert data). The use of this parameter in the automatic process control systems (APCS), automatic warning alarm (AWA) and emergency shutdown system (ESS) allows to prevent burnout of pipe coils due to their coking, to maintain the optimal operation of the furnace. This research used empirical formulas for rate calculation of carbon-producing, based on the use of APCS technology (improved control and safety protection systems) and virtual quality analyzers (VA) to presentation the basic idea of improving the safety of operation of the pipe heaters by improving the APCS, AWA, and ESS. To calculate the level of coking of the pipe coil was empirically determined the pattern of changes in the level of sediments:

\[ U = Y \left( \frac{T_{\text{cur}}}{F} \right) - 1 \]  

where \( U \) – sediment level in % of the maximum value; \( Y \) – the basis of the exponential function, which is calculated based on the standard time of use of the pipe coil; \( F \) – fitness function; \( T_{\text{cur}} \) – the current time of use of the coil.

APCS-system is a multi-dimensional predictive optimal control system, based on a dynamic mathematical model of the production process, which solves the control task of the processing installation in stationary mode and optimizes the operation of the installation in dynamic mode. The peculiarity of ARCS-systems is that many controlled variables of the production process cannot be measured in a real pipe heater, and obtained by analytical modeling using virtual analyzers.

The software product UniSim Design of Honeywell Corporation (figure 2) was used as a medium for creating a computer predictive model of the furnace production process.

4. Conclusion

The model of the furnace coil length of 60 m of heat-resistant low-alloyed steel 15X5M has been developed. With the help of built-in utilities UniSim Design, the calculation of the process of formation of carbon deposits inside the coil of the pipe heater was made depending on the operating modes, the values of technological parameters and the duration of the operation. The value of the estimated criterion is the rate of carbon-producing (more than 0.8 kg/day per unit area of the inner surface of 1 m²), corresponding to the maximum permissible level of coking coil of the pipe heater.

The model in UniSim Design allows you to analyze the operation of the furnace in real-time, to verification the algorithms and proposed solutions to improve the level of fire and industrial safety.
References

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