Development of the Method for Assessment of Potential Zones of Destruction of Process Pipelines

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Abstract. The main technological equipment of hazardous production facilities are column-type devices with piping arrangement, which provide interconnection between individual pieces of equipment. In use process pipelines experience the considerable internal and external loads and impacts that is related to unstable work of the complex technical system and with features of its operation. Exceeding allowable loads can lead to depressurization of pipelines that, if the equipment is located close, can lead to the development of an accident with a "domino effect". Pipeline systems are a source of the increased danger because of a large number of welded and flange joints, stop and control valves, hard conditions of operation and the considerable the volume of the flammable substances moved on them. In this regard there was a need for development of a method which will allow to estimate potential zones of destruction of pipelines at realization of accident with "domino effect"

1. Introduction
Currently, industrial safety at oil and gas facilities is receiving increased attention. That is related to the growing number of accidents in recent years. Objects of the oil and gas industry are classified as hazardous production facilities, which are characterized by high rates of risk of an emergency. During the operation of these facilities the emission of the technological environment into the atmosphere is possible, what may cause ecology damage, and in case of ignition, an explosion or (and) fire is possible, which can lead to significant economic losses and even to human casualties. An analysis of accidents at oil and gas facilities showed that the most common cause of the occurrence of negative factors leading to major accidents and catastrophes is depressurization of pipelines, as a result of the complexity of organizing a high level of control over the reliable and safe operation of pipeline sections operating under the most difficult conditions [1-5].

2. Relevance
About 80% of an equipment of objects of the oil and gas industry are considered worn-out. Because of low labor discipline, interruptions in raw materials and for other reasons reliability and durability of processing equipment decreases that leads to increase in accident rate on production. Today for economic reasons companies in the oil and gas industry are forced to operate equipment prior to their partial or complete failure. Therefore the main actions for safety of operation of an equipment are their timely inspection, diagnosing and examination. Any emergency situation at hazardous production
facilities of the oil and gas industry can lead to the defeat of workers in production, as well as the population living near the enterprise. Lately there was a large number of major fire and explosions at the main oil and gas processing companies of the country leading to the considerable economic and production losses [6-9]. The situation which developed under such circumstances makes negative psychological impact on society and the world financial markets. Thus, in view of high potential danger of objects of the oil and gas industry, there is relevant a question of ensuring safe operation of the oil processing companies existing and being at a design stage.

3. Formulation of the problem
Pipe line systems are a source of the increased danger because of a large number of welded and flange joints, stop and control valves, hard conditions of operation and the considerable volume of the flammable substances moved on them. The causes of depressurization of pipeline systems can be: corrosion and wear, mounting defects, factory defects, and also not design loads.

Process pipelines of oil and gas industry are constructions which are exposed to the widest range of not design loads and impacts of various nature and magnitude. Not design loads and impacts in some cases significantly affect real loading of elements of pipelines, its resource characteristics. Experience shows that the overwhelming majority of major accidents on process pipelines is followed by impact on these designs of not design loads. These are loads associated with spatial movements and sags of pipeline elements and support systems, seasonal variable loads, temperature loads, dynamic loads, the source of which is associated with technological equipment [1-10].

The main processing equipment on hazardous production facilities of the oil and gas industry are devices of columned type. The processes proceeding in columned devices cause presence of a large number of streams of input and output of raw materials and products. It speaks about existence of a set of pipelines which tie the device at the different levels and on all height of a column, and provides interrelation between separate items of equipment. The columned equipment during operation is exposed to a wide range of loads, under the action of which the device is in a difficult stress-strain state, this adversely affects the stability of pipelines and is aggravated by the fact that such loads can't be considered, both during design and operation of process pipelines. Exceeding allowable loads can lead to depressurization of pipelines that, if the equipment is located close, can lead to the development of an accident with a "domino effect". The final fracture of an equipment or collapse is optional to accidents with "domino effect", there is enough depressurization of one of its elements of a piping arrangement, choke breakage, that corresponds to a low degree of damage. At the same time, most likely, the complete instant involvement in accident of dangerous substance won't come from equipment; however there was a risk of further development of accident. The outcome of such a scenario will depend on many factors: the type of material and its parameters, availability and serviceability means emergency protection, the readiness of workers to localize and eliminate the accident [4].

For assessment of the impact of an intense strained state of devices of columned type on process pipelines, it is necessary to develop a method which allows estimating potential zones of destruction of the pipeline at realization of accident with "domino effect" [11-20].

4. Theoretical part
The criterion for assessment of potential zones of destruction of the pipeline can be the ratio of the stress arising in the pipeline at emergence of contingencies to the yield strength of the metal.

\[ k = \frac{\sigma}{\sigma_T} \]

\( k \) is criterion for assessment of potential zones of destruction of the pipeline, where

\( \sigma \) – stress arising in the pipeline at emergence of contingencies;

\( \sigma_T \) – yield strength of the metal.

For assessment of potential zones of destruction the yield strength was chosen as the main indicator \((\sigma_T)\) as it defines operability of the material and the products made of it under the ultimate loads.

\[ \sigma_T = \eta \cdot [\sigma] \]  

\((1)\)
where \( n_T = 1.5 \) is safety factor on a yield strength in accordance with State Standard R 52857.1-2007 "Vessels and apparatus. Norms and methods of strength calculation"; \([\sigma]\) - permissible stress.

Then the criterion for assessment of potential zones of destruction of the pipeline will be equal

\[
k = \frac{\sigma}{\sigma_T} = \frac{\sigma}{n_T \sigma_T} = 1 \quad (2)
\]

5. Practical significance

If stress in the pipeline is less than permissible stress, that is at \( \sigma < [\sigma] \), it means that the pipeline is suitable for further operation, and the category III is appropriated to it, and the criterion for assessment of potential zones of destruction of the pipeline will be equal

\[
k < \frac{\sigma}{n_T \sigma_T} = \frac{1}{1.5} = 0.66
\]

If stress in the pipeline is higher than permissible stress and less a yield strength, that is \( [\sigma] < \sigma < \sigma_T \), then a condition of the pipeline unstable can also happen failure of the pipeline because of existence of defects of base metal, the category II is appropriated to the pipeline, and the criterion for assessment of potential zones of destruction of the pipeline will be equal

\[
\frac{\sigma}{n_T \sigma_T} < k < \frac{1}{1.5} \quad \Rightarrow \quad 0.66 < k < 1
\]

If the stress in the pipeline is higher than the yield strength, that is \( \sigma > \sigma_T \), then a yield limit arises in the pipeline, and when the tensile strength is reached, the pipeline may be destroyed, a condition of the pipeline is critical, the category I is appropriated to the pipeline, and the criterion for assessment of potential zones of destruction of the pipeline will be equal

\[
k > \frac{\sigma_T}{n_T \sigma_T} \quad \Rightarrow \quad k > 1
\]

Categories of dangers of the pipeline depending on criterion for evaluation of potential zones of destruction of the pipeline are presented in Table 1.

| Categories of danger | k |
|----------------------|---|
| I                    | >1 |
| II                   | 0.66<k<1 |
| III                  | k<0.66 |

6. Conclusions

The developed criterion for assessment of potential zones of destruction of the pipeline allows to range an equipment on degree of danger and can be used for a decision making aimed at improving the safety of industrial installations in the oil and gas industry, both at the design stage and during operation, as well as during the diagnostic survey program.

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