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Materials and Technologies Ensuring Environmental Safety of Reconstruction and Overhaul of Trunk Pipelines

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Abstract. The paper presents an overview of the studies of Russian and foreign scientists exploring the issues of reliable operation of trunk pipelines transporting oil and gas. It is found that subsea pipeline networks pose a greater danger in terms of their functional failures and environmental effects and appear more prone to stress corrosion cracking. Certain materials and technologies are brought into focus to demonstrate that their use allows curbing the environmental expansion or ensures the reliable operation of oil and gas pipelines. It is noted that one of the most promising methods for reconstruction and overhaul of trunk pipelines provide for the application of composite materials to the internal surface of a damaged pipes. The appropriate formulation of composite materials depends on the condition of the internal pipeline cavity. Also, there are scientific breakthroughs which may serve to reduce corrosion activity of clayey soils. Stress is laid on the importance of innovations in the development of technologies and materials ensuring the maintenance of ecological balance in the areas where oil and gas transmission networks operate.

1. Introduction

The electrical and ecological security of any country depends to a certain extent on the normal operation of its oil and gas trunk pipelines, the maintenance of which is a complex task relevant to largely all lifecycle stages, especially when it comes to construction, reconstruction, overhaul and operation of a pipeline. This is primarily due to the specific factors affecting trunk pipelines: exposure to complex natural and climatic conditions, length varying from a few thousand meters to a few thousand kilometers, use of a wide range of heavy-duty machines and mechanisms. Secondly, this is explained by a multifaceted nature of the construction process itself: variability of technologies, construction materials, wear and tear of machinery fleet etc.

The importance of environmental management of trunk pipelines and the issues of preserving the ecological balance during their repair and construction are brought to light by many national and foreign scientists [1-14], and highlighted in the studies of the author of this article [15-18].

Many works [19-22] point to the fact that as the length of trunk pipelines increases, so does the number of emergency situations and the length of pipeline sections requiring reconstruction and overhaul. Thereby, the destructive impact of pipeline accidents on all geosphere layers of the Earth are so immense that the maintenance of ecological balance in the environment, in particular, for the sake of preserving the human population, has grown into a global problem [23-28].

The topics considered in this work are associated with the introduction of new materials and technologies suitable for use in reconstruction and overhaul and ensuring the safe operation of oil and gas trunk pipelines. The work is based on the analysis, synthesis and collation of facts.

2. Problem status

The development of environmentally friendly products [18] is impossible without the use of environmentally safe materials and technologies, as shown in the works [17, 29, 30] describing the reasons for their selection. The analysis of the works [31-35] shows that in the current mix of pipeline network installation, reconstruction and overhaul technologies the requirements for environmental safety are met by trenchless technologies, subdivided into trenchless installation without destruction of the previous pipeline (relining) and trenchless installation with destruction of the previous pipeline (renovation). Relining consists in dragging a new pipeline through the old one, i.e. cladding the old pipeline from inside after its preliminary clearing of deposits and foreign items. The cladding is formed as a sleeve made of unwoven synthetic sheet lined with synthetic film and impregnated with a polymer composition, cold or hot cured, and put in place by dragging a new polyethylene pipe through the old pipeline to form a “pipe in pipe”, with further application of composite materials to the internal wall of the old pipeline. The “pipe in pipe” technology is used for low-pressure pipelines.

The formulation of composite materials depends on the condition of the pipeline internal cavity. According to the study [37], a composite system was developed to repair pipelines where weld seams are damaged to the extent that the loss of wall thickness reaches 80% of the pipe wall. According to [38], 43% emergency situations on gas transmission pipelines in Russia arise due to pipeline corrosion, including 36% - due to stress corrosion cracking (SCC), 6% - due to non-stress corrosion, 1% - due to internal corrosion. The likelihood of destruction of a gas transmission pipeline always depends on the relative depth of stress corrosion cracks. The greater the depth of pipe wall damage, the higher the likelihood of catastrophic accidents. Gas pipelines with a depth of stress corrosion cracks exceeding 80% of the pipe wall, account for 13.6 % of the total length of the existing gas transmission pipelines [38]. Considering the current reduction in the scope of overhaul of gas transmission pipelines [37], the likelihood of incidents is expected to increase in the future. Even if provided with proper corrosion protection, pipelines, exposed to damp environment, are still subject to corrosion damage “caused by moisture penetration through the insulation layer, flaking of the protecting belt or activity of microorganisms, in particular, sulfur reducing bacteria” [39]. In such cases, pitting corrosion quickly develops under the layer of deposits, leading to premature pipeline failure. A case is known when a pipeline with a wall thickness of 4.5 mm was damaged by pitting corrosion in 9 months [39]. It is worth noting that stress corrosion damage is contributed by many factors, but the presence of impurities in the metal used for pipe making (pipe quality factor) plays an important role in the development of stress corrosion cracking [40]. As such, the recent trend in oil transportation features the use of pipes made of reinforced thermoplastic, which eliminates the problem of pipeline corrosion [41]. On the other hand, developments take place that aimed to reduce the corrosive impact of the environment on the pipeline during its operation, including the insertion of sulfur reducing bacteria in iron-rich clayey soils [42].

Also, polymer-bitumen composite materials were developed for anticorrosion coatings of oil and gas pipelines, with the description of the method for their manufacturing [43-45]. To inhibit stress corrosion cracking of gas transmission pipelines, various organic and non-organic inhibiting composites were formulated, which are reviewed in the papers [46- 49].

While relining reduces the throughput capacity of a pipeline, renovation implies destruction of the old pipeline and installation of a new one. As underlined in the paper [34], the key benefits of trenchless installation and reconstruction of pipelines, regardless of the work method, are saving on the cost of materials and workforce and reducing economic costs through shortening the work periods and cutting earthworks. Trenchless technologies of pipeline installation and reconstruction are implemented with a minimum amount of machinery. But this technology is only relatively environmentally-focused because, as it leaves the rests of old pipelines in the soil or on the seabed, it becomes detrimental to the environment. According to the [50], heavy metals, placed in an aqueous environment, adversely affect living organisms and often cause their mutation.

An important aspect of ensuring reliable operation of trunk pipelines, as stated in many of the above mentioned works, and in the [51,52], is the adoption of an integrated approach. It implies that innovations should be in place both to support the selection of materials and technologies and to facilitate the route setting, operation control etc. [53-56].

3. Conclusions

The review of the scientific research works reveals that subsea pipeline networks are more dangerous in terms of their operational failures and environmental impacts. Contemporary studies focused on the environmental effects of reconstruction and overhaul of trunk pipelines show that the primary solutions for reaching the relevant goals include, along with the adoption of new energy efficient and resource efficient technologies, the creation of new materials and products reducing stress corrosion cracks in pipeline body and preventing the development of biocorrosion caused by environmental effects. Although trenchless technologies are considered environmentally friendly, this is not quite the case, because the rests of old destroyed metal pipes are not withdrawn and continue to adversely affect the environment, often causing mutation of biotopes. A solution lies in the development of technologies for overhaul and reconstruction of trunk pipelines that require a minimum amount of machinery and produce as little waste as possible, including recycling of withdrawn parts of old pipelines. It is also important to develop application techniques and create materials for corrosion protection coatings ensuring superb adhesion characteristics in any environment so as to reduce or eliminate pipeline biocorrosion. Notably, the current condition of oil and gas trunk pipelines in Russia and in other countries with the developed oil and gas pipeline transport is such that the ecological situation in the areas where oil and gas transmission networks are located cannot be considered stable.

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