

PIPELINE DURABILITY AND INTEGRITY ISSUES AT THE REPURPOSING FOR HYDROGEN SERVICE IN UKRAINE'S GREEN RECONSTRUCTION

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Abstract.

Challenges in terms of solving the problem of using existing natural gas pipelines in Ukraine for hydrogen operation within the framework of the green energy transition are analysed. The main reasons for the possible loss of integrity of long-operated gas pipelines in the case of gaseous hydrogen transportation are given. The methodological aspects for increasing the sensitivity of mechanical indicators to hydrogen are highlighted. The main attention is paid to the development of damage in steels and the role of hydrogen in this process. The operational degradation of pipe steels is summarised according to their main physical and mechanical indicators, and an assessment of the failure risk is analysed.

Key words: steel, hydrogen transport, operation, hydrogen uptake, embrittlement, fracture toughness, local fracture criteria.

Energy security is crucial for the sustainability of countries, including Ukraine. Hydrogen will play a significant role in a decarbonised energy system and green reconstruction in the coming decades. The European Green Deal was defined as one of the main strategic priorities of the European Union in 2019. In May 2022, the European Commission presented a plan to rapidly reduce the oil and gas consumption, as well as the introduction and use of “green” energy sources (REPowerEU). The development of hydrogen energy, which is part of the policy on the issues of green energy transition, achieving climate neutrality, sustainable energy and strengthening energy security, involves the transportation of gaseous hydrogen through pipelines [1, 2]. Ukraine has an extensive infrastructure for transporting natural gas, which is planned to be repurposed for hydrogen service according to the EU and Ukrainian government policies (the European Hydrogen Backbone initiative, the Central European Hydrogen Corridor, and others) [3].

The realisation of such a prospect of hydrogen transportation by existing natural gas networks exacerbates the issue of violation of pipeline integrity due to the well-known negative impact of hydrogen on the mechanical properties of steels [2, 4, 5]. One of the most important issues is hydrogen embrittlement, as well as a decrease in resistance to brittle fracture of steels as a result of hydrogen impact, which is often responsible for unpredictable low-energy fracture of metal components. Additionally, operational degradation of pipeline steels should be taken into account, since long-term service of gas pipelines causes a deterioration of the mechanical properties of steels [6, 7].

The analysis of serviceability according to key indicators of hydrogen embrittlement of steels of long-term operated gas pipelines, which could lose their initial physical and mechanical properties, is presented in the work. The important role of operational damage in reducing resistance to brittle fracture is considered, taking into account that hydrogen absorbed by the metal contributes to its intensification, and this is one of the mechanisms of the harmful action of hydrogen from the inner surface of pipelines. The development of damage in long-term operated pipeline steels is analysed. It is summing up that the operational damage as a result of the interaction of steels with an aggressive environment inside pipelines under simultaneous action of mechanical loading should be considered a key aspect of the manifestation of hydrogen embrittlement.

It is demonstrated that the application of nonlinear fracture mechanics approaches taking into account the anisotropy of properties of pipeline steels is suitable for the assessment of hydrogen embrittlement with high sensitivity.

Based on the research results of the determination of fracture toughness under the action of hydrogen, local fracture criteria were formulated as the basis for establishing conditions for safe operation of pipelines.

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ПРОБЛЕМИ ДОВГОВІЧНОСТІ ТА ЦІЛІСНОСТІ ТРУБОПРОВІДІВ ПІД ЧАС ЇХ ПЕРЕПРОФІЛЮВАННЯ ДЛЯ ВОДНЮ У ЗЕЛЕНІЙ РЕКОНСТРУКЦІЇ УКРАЇНИ

Анотація.

Проаналізовано виклики з огляду на вирішення проблеми використання наявних магістральних газопроводів України для експлуатації у водні в рамках зеленого енергетичного переходу. Приведено основні причини можливої втрати цілісності тривало експлуатованих газопроводів в умовах транспортування газоподібного водню. Висвітлено методичні аспекти підвищення чутливості механічних показників до водню. Основну увагу надано розвитку пошкодженості в сталях та роль в цьому процесі водню. Узагальнено експлуатаційну деградацію трубних сталей за їх основними фізико-механічними показниками та дано оцінку ризику руйнування.

Ключові слова: сталь, транспортування водню, експлуатація, наводнювання, крихкість, в'язкість руйнування, критерії локального руйнування.

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