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Corrosion durability estimation for steel shell of a tank used to store liquid fuels

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Abstract

An original approach to forecasting the remaining safe service time of a corroded steel shell of a tank used to store liquid fuels is presented for the case where the reconstruction or repair is not planned. The estimated durability is determined by the forecast corrosion progress described based on the previous trends catalogued during earlier, periodically performed checks of the monitored structure. The analysis is conducted numerically on a three dimensional model of a tank, precisely replicating the real, imperfect geometry. Influence of the degradation due to the corrosion is superimposed over geometrical imperfections specific to the considered tank and identified as a result of geodetic measurements. Interaction of both phenomena results in local stress concentrations determining the durability sought for.

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1. Introduction

The reliable estimation of the forecast time to failure for a corroded steel shell of a tank being in service belongs to the basic duties of the personnel serving at the fuel base where the considered tank is located. The time, during which such tank, subjected to the evaluation of its technical condition, will be able to safely resist the loads applied

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to it in spite of the weakening due to the progressing corrosion degradation, if no corrective actions are planned in the future resulting in partial or even total reconstruction of the shell, including its strengthening, is of interest here. The knowledge of such forecast durability related to all the tanks in the base allows for a rational management of the resources through appropriate planning of all logistic activities, and in particular preparation of the timetable of economically justified modernization works if necessary.

The progressing in time reduction of the cross section of structural elements constitutes the basic factor taken into consideration during the analyses dealing with estimation of the corrosion weakening of such the elements. This reduction directly affects not only their bearing capacity but also the rigidity. An additional destructive effect of the corrosion is known as well, induced by the weakening of the internal structure of the material, but this phenomenon is too difficult for quantification, as to be reliably accounted for in formal models specified to determine the forecast corrosion durability of the tank shell. Influences of this type have been considered by the Authors of this paper, and their preliminary quantitative estimates were published among others in [1]. It is also worth to cite here the more general works [2] and [3], dealing with the corrosion effects specific to the structures of petrochemical industry. The corrosion weakening effect for the tank shell may be estimated with probabilistic methods as well. An approach proposed in the paper [4] may be treated as an example here, as well as the algorithm prepared by the Authors of this paper, presented among others in [5]. Due to the inherent complexity of the analytical model, in spite of taking into account the random nature of the corrosion process, the estimates will be burdened by the locality constraint, which may result in the incompatibility with the results obtained for the tank treated as a whole. Presentation of a numerical procedure allowing for a reliable prediction of the corrosion progress, as specified for the considered tank, based on the previous trends of the corrosion process intensity catalogued during cyclically performed evaluations of the technical condition of such the tank is the objective of the present paper. The proposed rating takes into account only the influence of the locally variable thinning of the shell during the years passing in service. Nevertheless, in the Authors' opinion, due to the individual approach to the rating as well as application of the three dimensional numerical model replicating the real tank geometry instead of the ideal one with if need be assumed arbitrarily patterned imperfections, this model yields highly reliable results. This fact should make the considered approach highly attractive to the users.

2. Replication of the real tank geometry

In the analysis performed by the Authors it is assumed that the case of the completely filled tank erected in such a manner that the bearing capacity of the vertical welds is at least equivalent to the bearing capacity of the adjacent steel sheets is authoritative for the determination of corrosion durability of a corroded tank shell. This means, that the possible exhaustion of the bearing capacity will occur in the corroded steel sheets subjected to the hoop tension, and not in the welds, which are stronger than the adjacent sheet metal. Let us note, that the case of the empty tank subjected to the combined wind and internal underpressure, leading to tank destruction by the loss of stability through shell denting, is expressly omitted from the analysis, in spite of being undoubtedly interesting from the scientific point of view. It is widely known that the shell bearing capacity is very sensitive to imperfections, especially those of geometrical character, specifying the deviations from the perfect cylindrical shape. This is especially true in the case of compressive meridional and/or latitudinal forces acting in a shell. The tank shell imperfection sensitivity problem has been considered in many papers, for instance in [6], [7], [8] and [9]. In the case analyzed in this paper, where the shell is subjected to the hoop tension, the influence of imperfections is substantially less pronounced. One may even state, that the tensile hoop stresses will to a large extent negate the influence of possible imperfections arising first during the erection and later on during the service of the considered tank. Nevertheless, the influence of such imperfections may be substantially more pronounced, than the sole corrosional weakening of the steel sheets. Besides, both phenomena will superimpose, locally generating the stress concentrations, which may result in exhausting the shell bearing capacity. Because of that, in the Authors' opinion, during the analysis recommended in the current paper one should depart from the arbitrarily assumed imperfection pattern, even such one which seems to be the most adverse with respect to the bearing capacity of the considered tank shell, and replace it with a model representing the real geometry of the filled tank, obtained as a result of geodetic measurements performed during each evaluation of the tank technical condition. Of course this course of action is associated with the assumption that the assumed geometry will not change substantially in the future,