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Influence of geometrical imperfections on stresses in cylindrical shells

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ABSTRACT:

Results of the numerical analysis of the shells of storage tanks of 50 000 m^3 capacity with geometrical imperfections are presented in the paper. Results were verified by tensometric tests performed on the real tank. It was recognized that real geometrical imperfections cause increase of stresses in the tank construction by 30%.

INTRODUCTION

The analysis results of the influence geometrical imperfections on the shells of steel tanks for liquids are presented in the paper. The analysis was applied in particular to storage tanks of vertical axis, floating roof, and nominal volume of 50 000 m^3, which are used for storage of kerosene products.

The imperfections in the tank shell result from the changes in the arrangement of external forces stream, and thus of stresses within the shell. These constitute a threat to safe operation and are potentially the cause of phenomena like:

- vulnerability of shell to shape distortion under compressive forces,
- local loss of stability in a fragment of the shell,
- local overload of the main supporting element in the structure of the tank, i.e. the shell.

Apart from the impact of geometrical imperfections on the load capacity and effort of the facilities in use, they also influence the operational conditions of the tanks themselves, in particular the tanks with floating roofs. Very often the nature and shape of geometrical irregularities are revealed during the operation by sudden reaction of some fragments of the shell when emptying or filling the tank. The reaction consists in total change in the nature of the imperfection, e.g. from negative to positive and the opposite. Such effects are particularly dangerous, having significant impact on the changes in material effort and the strength of welds.

Important during acceptance and delivery of a new tank for operation, the issue of evaluating the shell deformation also applies in other situations. During the operation, changes may occur in the shape of the shell, which are caused for example by non-uniform settlement of the object. Always in such a case a question arises: to what extent do identified geometrical imperfections impact the section state of effort? This question further gains in importance when applied to tanks after dozens of years in operation, where next to geometrical defects, corrosion is present, related to the loss of plate thickness, or to a significant degree of pitting.

STRUCTURE OF TANKS

The main element in the structure of the analysed tank type is the steel bottom and shell (Fig. 1). Two parts make up the bottom: the central part and the rim ring. The central part of the steel bottom is made from plates, 8 mm thick. The plates are placed directly on the sand foundation. That part of the tank is surrounded with the rim ring, made from plates, 16 mm thick. The internal part of the ring is placed on the sand foundation, the external one on a reinforced concrete foundation ring (Fig. 2). The bottom plates are joined crosswise with butt welds with the use of pads, the lengthwise contacts are overlapping and fillet welded. The central part of the tank bottom is joined with the rim ring through overlap and fillet welding. The tank bottom is executed from two steel grades: the central part from carbon steel marked S235, and the external – steel marked S355.

The tank shell is made from steel rings, for which the following steel grades are used:

- S355 – for four lower shell rings,
- S235 – for top shell rings.

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Table 3. Maximum stress increase

Stresses	The percent variation for the tanks of the group	
	„A”	„B+C”
$\sigma_{x\,bot}$	2 ÷ 25	0 ÷ 30
$\sigma_{x\,top}$	3 ÷ 12	3 ÷ 22
$\sigma_{HMH\,bot}$	4 ÷ 15	5 ÷ 20
$\sigma_{HMH\,top}$	2 ÷ 15	5 ÷ 25

Thus we are able to claim that the growth of circumferential forces of maximum values 8-12% does not translate directly into identical increase in the circumferential and reduced stresses, which in the case of circumferential stresses ranges between 12 and 25% limits in the case of tanks group marked ‘A’. The other group of tanks, marked ‘B+C’ is characterised by greater rise in the reduced and circumferential stresses.

In order to execute a practical verification of the performed numerical analysis, field tensometer tests of a tank of V=12000 m³ volume were carried out. The tank was characterised by significant shape imperfections in its shell. The tests confirmed the variation in the shell stresses, which referred to individual measurement levels, and the correctness of the performed numerical analyses (Kowalski, 2004a, 2004b).

CONCLUSION

The performed numerical analyses confirmed that the rise in the geometrical imperfection values of the shell and their mutual variations results in dispersion of values of forces and stresses within the same compared levels of the tank height. The value envelopes of circumferential and reduced stresses in the analysed tanks of 50.000 m³ volume allow us to claim that there are no cases when the state of calculated strength of adequate steel grades are breeched. Thus, the operational safety of the facilities is preserved.

Hence, there are no reservations against the values of the admissible deviations during acceptance, referring to the geometry of the tank shell, specified in Polish standard regulations.

Also, the values of admissible geometrical imperfections quoted in the standard regulations have been correctly defined. It should be mentioned, however, that the Eurocode 3 draft that refers to steel shells quotes a very simplified form of the method to define the quality of shell execution as regards the shape regularity. The criteria it lists are much less demanding.

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