CALCULATION OF STRESS-DEFORMED STATE OF TANK WALL HAVING DEFECTS: NEW INSPECTION REQUIREMENTS

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Oil and oil products storage vertical steel tanks are hazardous industrial facilities. In accordance with the ruling documents of Rostekhnadzor they have to be periodically inspected in the course of operation and the defects found are to be eliminated.

The existing regulations establish criteria of permissible defects: considering wall dents as well as vertical deviations of vertical steel tanks (VST), for wall irregularity etc. However, based on calculations performed by expert organization it is allowed to operate VST having wall defects.

In order to stipulate well-founded operation conditions for VST having defects, methods of stress-deformed state calculation of VST have been developed. They allow imitate behavior of tanks considering real operation parameters: wind and snow loads, interaction of VST structures, actual defect parameters.

The existing regulation documents specify measurement of only maximum dent tongue which is insufficient to develop its model. In order to perform stress-deformed state calculation additional requirements have to be placed on results of defects measurement. The present work is based on a series of calculations. It contains recommendations on number and frequency of dent tongue measurement during tank inspection.

Storage tank VST-5000 has been selected as a subject of research (test subject). It is a vertical steel tank having capacity of 5000 m^3. There are hundreds of such tanks available at various oil and gas producing and transporting companies. Therefore stress-deformed state calculations of VST wall are crucial for assessment of resource to operate them safely.

Study of grid step dent measurement influence on stress-deformed state value has been performed for dents having linear dimensions (length and width) from 0,75 up to 4,5 m and tongue 82 mm. During the study of dent tongue measurements have been performed with a step of 5 cm. There have been 3600 points of dent tongue measured (fig.1). It is evident that creation of such a dense measurement grid during inspection is extremely time-taking. Therefore in order to determine minimum required grid step for dent tongue measurement study of dependence of tank wall having dent stress-deformed state on measurement pitch. In the course of the study 24 model tanks having dents measured with pitch (step) of 5, 10, 20, 30, 40, 50 cm have been created.

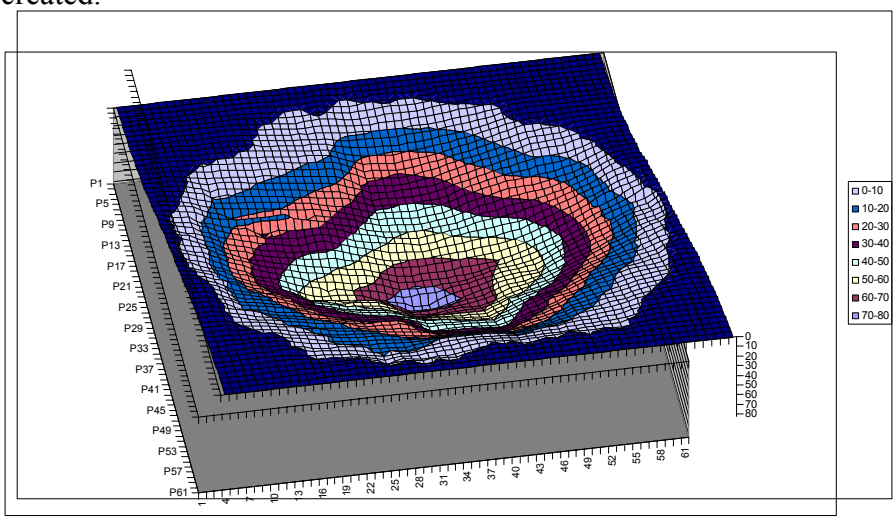

Fig.1 3600 points of dent tongue.

The calculations of stress-deformed state were made by VST walls modeling using finite elements method in ANSYS. Loads and degrees of freedom was applied to model:

– all degrees of freedom set to zero at bottom;

– uniformly distributed load from roof and snow applied to the top of the wall (mantle ring);

– hydrostatic pressure;

– vapor pressure.

Walls stress and displacements were established after calculation (fig.2). Maximum stress and displacements depend on points of dent tongue are shown on fig.3-4.

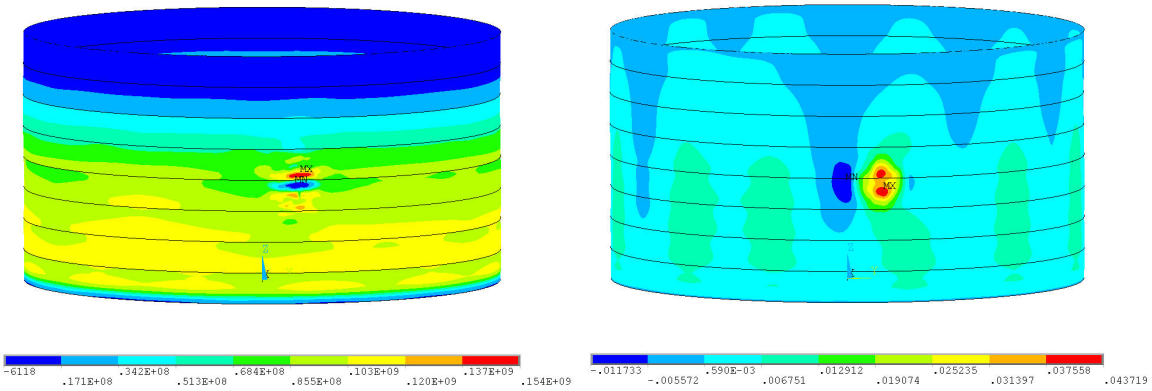

Fig. 2. Middle stress (left) and displacement (right) for dent 3x3 m and 20 cm step.

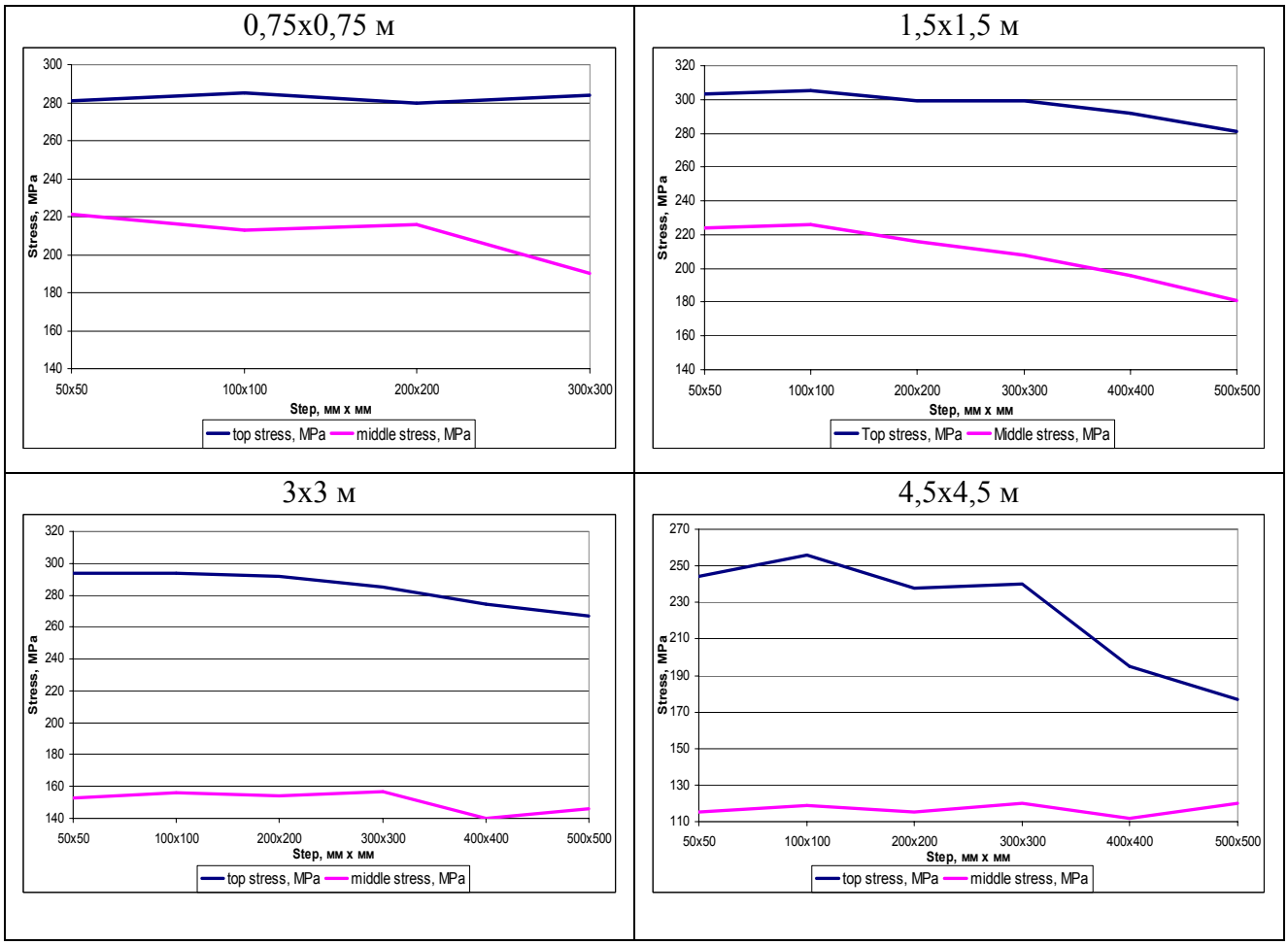

Fig 3. The dependence of maximum stress in dent zone from dents step.

As shown on fig.3 rising step cause lowering middle and top stress, so the danger of dent can be underestimated. Stress local peaks are generated by node positions changing after approximation with power function.

As the true it was received stress calculated for dent with 5 cm step. The dependence of calculating errors from dent step are shown at fig.4.

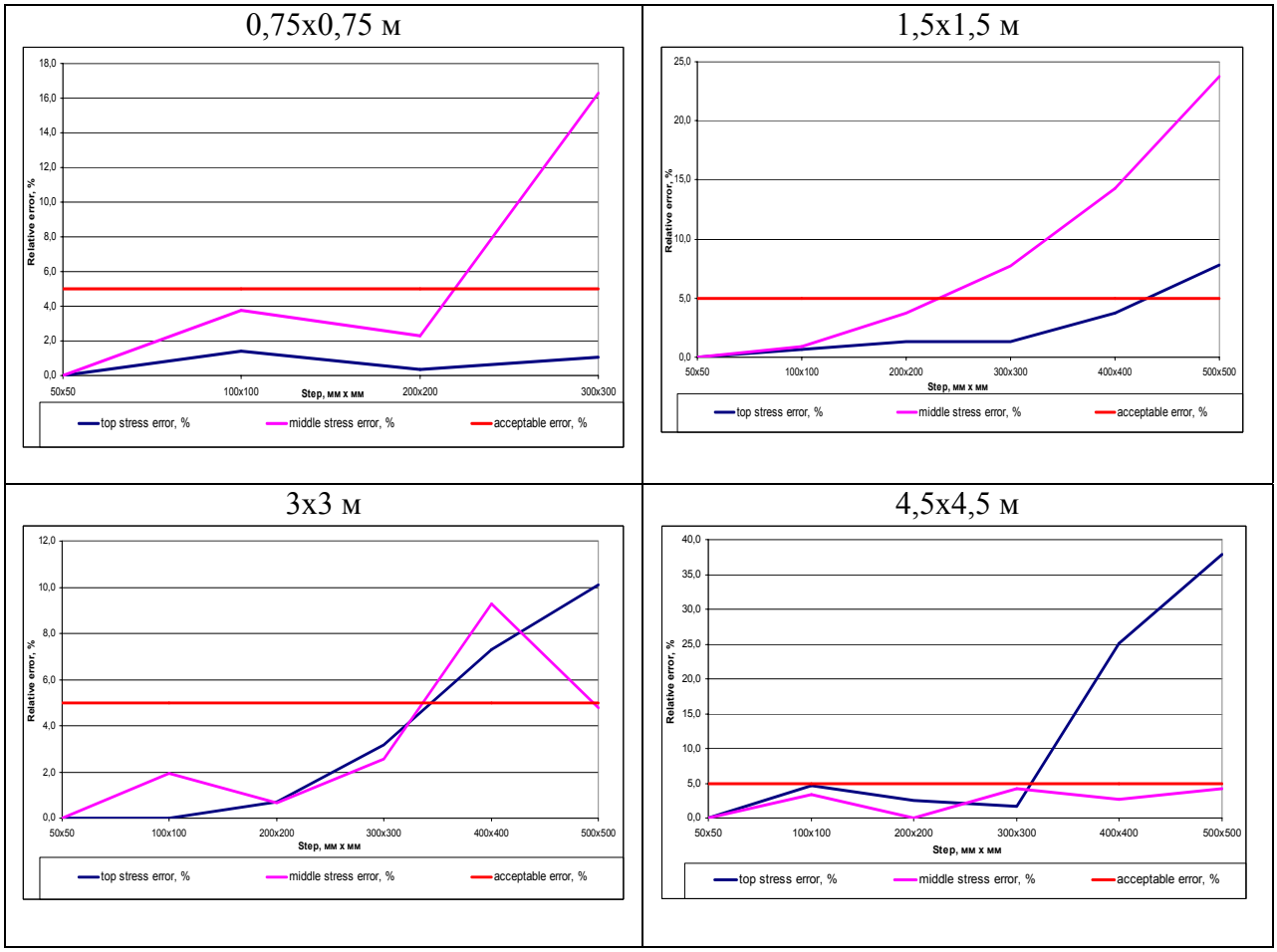

Fig. 4. The dependence of calculating errors from dent step

As a result of calculations load distribution and radial movements of the wall in dent area depending on grid step have been determined. It has been found that the maximum allowable measurement grid step to ensure the required calculation accuracy of 5% for dents having linear dimensions have to be:

- up to 0,75 m - 100x100 mm;
- from 0,75 up to 1,5 m - 200x200 mm;
- from 1,5 m up to 3 m - 200x200 mm;
- from 3 m up to 4,5 m - 300x300 mm;
- more than 4,5 m - 300x300 mm.

Conclusion:

1 The dependence of dent grid step and stress was established.

2 Maximum dent grid steps were established for the required calculation accuracy.