PLACE OF LOAD'S APPLICATION ON THE CYLINDRICAL BODY – DOES IT HAVE AN INFLUENCE ON DISTRIBUTION OF NORMAL STRESSES WITHIN IT

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Abstract:

For analysing of distribution of stresses and deformations in the steel cylindrical silos is very often used finite element analysis. Vertical load by the stored product could be applied on the upper edge of the cylindrical shell or on its internal surface. The first approach facilitates the load's application and accounting of the results. The second method of modelling is closer to the reality. Naturally, the two ways of loading will show the different results but how big will be the difference? Big or negligible? For the purpose of the research, two steel cylindrical shells on the six supports are modelled. They are axially loaded on the upper edge or on the internal surface. One shell is ideal, and the other has imperfections, symmetrically entered to the vertical axis. Researches are conducted using following methods for analysis:

a) LA – linear (elastic) material and small deflections;
b) MNA – non-linear material and small deflections;
c) GNA – large deflections of the elements and elastic material.

Key words:
steel silo, loading, meridional normal stresses, imperfections, effective height

1. Introduction

Steel silos are kind of facilities, which are studied and continue to be researched by many scientists. Of particular interest is interaction between discrete columns and the thin - walled steel shell above them. For analysis of their compressed and deformed status in their common joints, very often are used numerical computer models. As detailed they are as correct will be the results. Having in mind a large number of received finite elements, which requires a big calculation power of the computer and time for calculation, some simplifications often are made in the models. For instance considering the symmetry in the facility and loading on them, only one part of them is researched. In addition, often the vertical load from stored product is applied on the upper edge of the cylindrical shell [1,3,7,8-13]. On other hand, the axial impact of the stored product is a distributed on surface load, due to friction and it is applied on internal surface of the cylindrical body. Based on that premise, in a research [14] the author had simulated vertical loading from the product as a distributed load. However, it caused some difficulty in accounting of results in the numerical models. It raises the question, can we for the sake of speed and convenience to apply the vertical loads by product to the upper edge of the cylindrical shell? Or they should be simulated as distributed on surface loads which values on the height are determined according to EN 1991-4:2006 [4]? Obviously, there will be differences in obtained results, but will they be considerable?

2. Numerical model

For the purpose of the research, using software ANSYS [2], is modelled steel cylindrical body with diameter D = 4 000 mm, height H = 8 000 mm and thickness by the whole height t = 4 mm, see fig. 1*a*. The cylinder "steppes" on six supports with dimensions in plan 125×125 mm. In order to ensure stiffening of the cylinder in the radial direction, at 50 mm below the upper edge and on 50 mm above lower edge are placed rings with section L100×8 mm, welded on edge. All elements are made by steel S235, with mechanical parameters according to the standard EN 10025-2:2004 [6].

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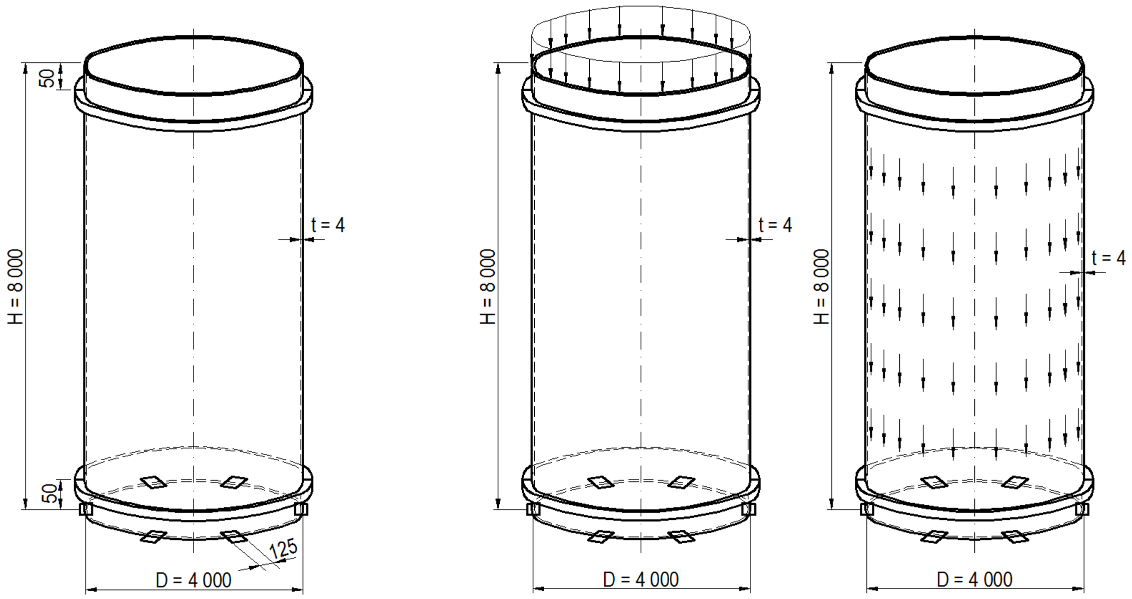


a) dimensions b) way of loading

Fig. 1 – Numerical model – dimensions and ways of loading

The elements in the numerical models are entered as shells (shell181) with their real thickness. The maximum dimension of finite elements is 50 mm.

The loading is applied in two manners - on upper edges of the steel shell and on internal surface, as distributed load. The load acts axially - from top to the bottom, and has total value of 800 kN.

A second numerical model is created to account the influence of imperfectness in the cylindrical body. In that model were entered imperfections, symmetrically to the vertical axis, with maximal radial deviation ± 50 mm, see fig.2. The radial deviations have very big values to underlying their influence.

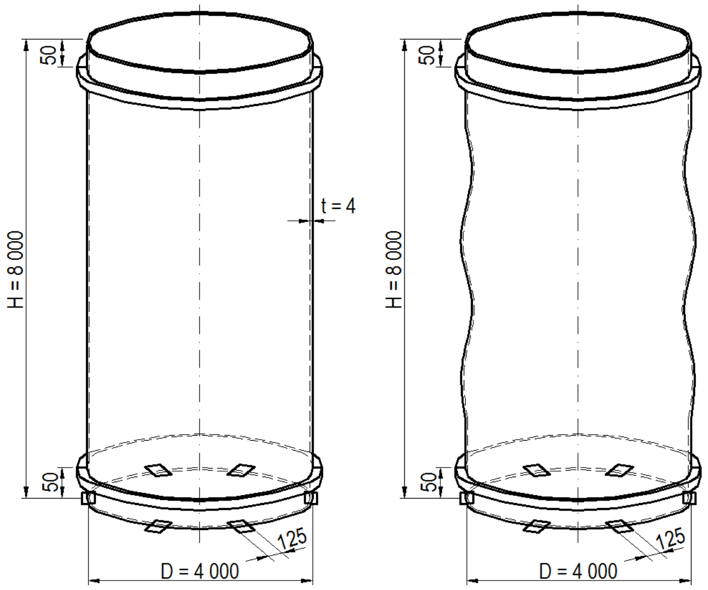


Fig. 2 – Researched shells – ideal and with imperfectness

Option “symmetry” in ANSYS is used to facilitate the calculations. It allows to study only a part of constructions with axis of symmetry and symmetrical loading, see fig. 3.

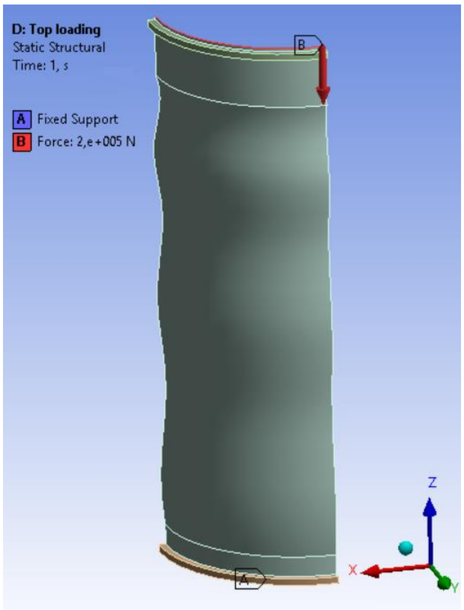


Fig. 3 – Loading on part of symmetrical shell with imperfections

The two above mentioned numerical models (with perfect shell and with imperfections), in which the loadings are applied on the upper edge of the shell or on its internal surface, are researches using methods for analysis as follow:

a) LA – linear (elastic) material and small deflections, see EN 1993-1-6 [5];

b) MNA – non-linear material and small deflections;

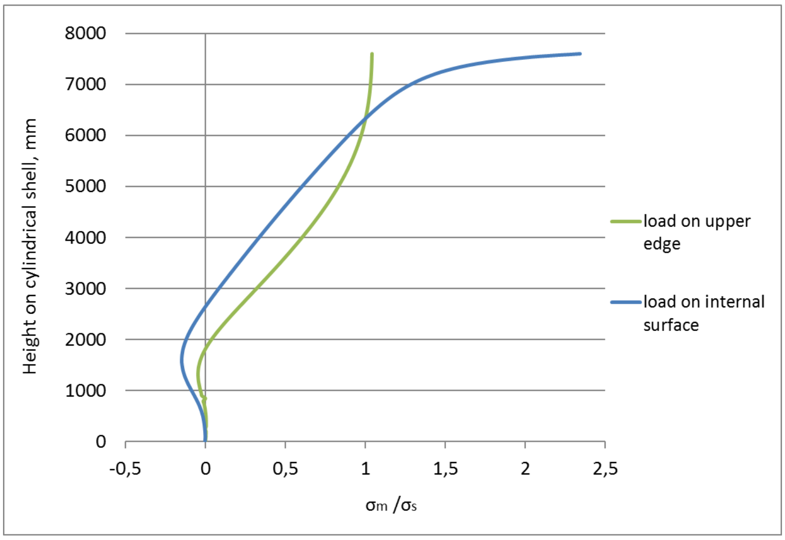
c) GNA – large deflections of the elements and elastic material.

For the ideal shell it was used additionally GMNA – non-linear material with large deflections.

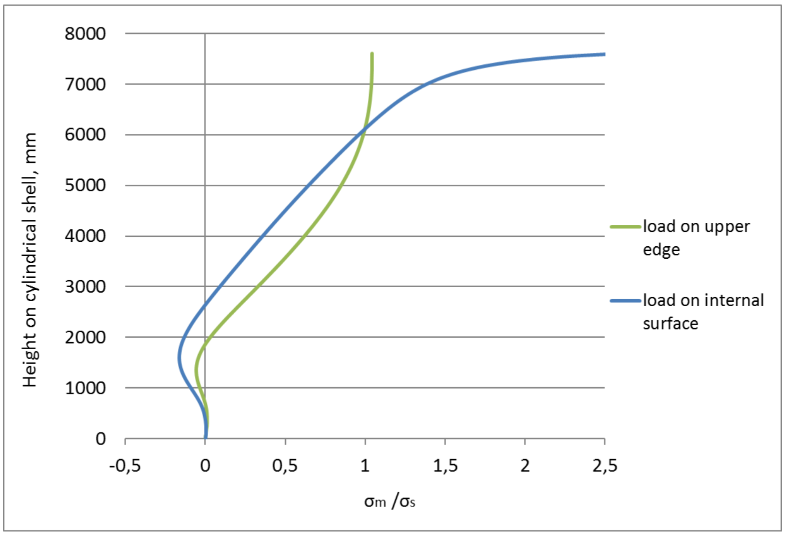
In the researched models are accounted on their height the meridional (axial) normal stresses above supports σ_s and in the middle between them σ_m. By their relationship σ_m/σ_s it is possible to determine where the two values are equal, i.e. where is the end of the active zone on the H_{cr}.

3. Results

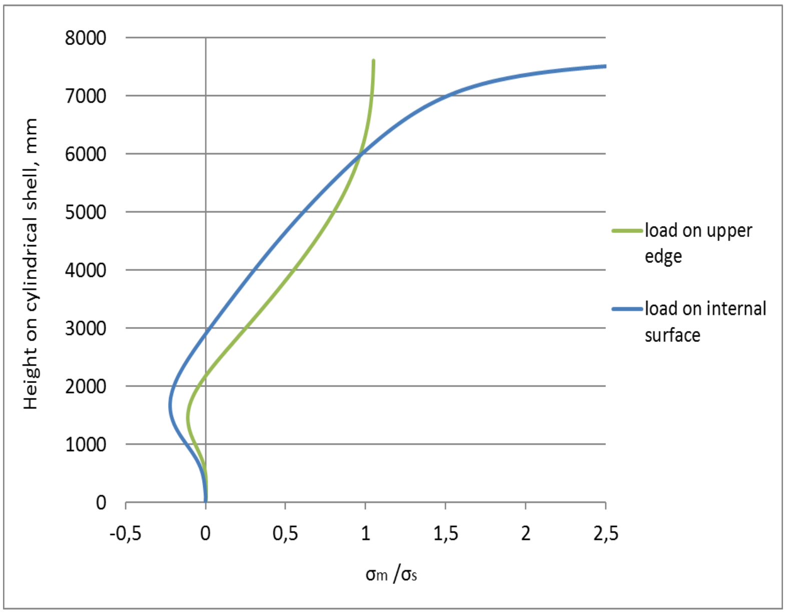
On Fig. 4 and Fig. 5 could be seen the results of the research.



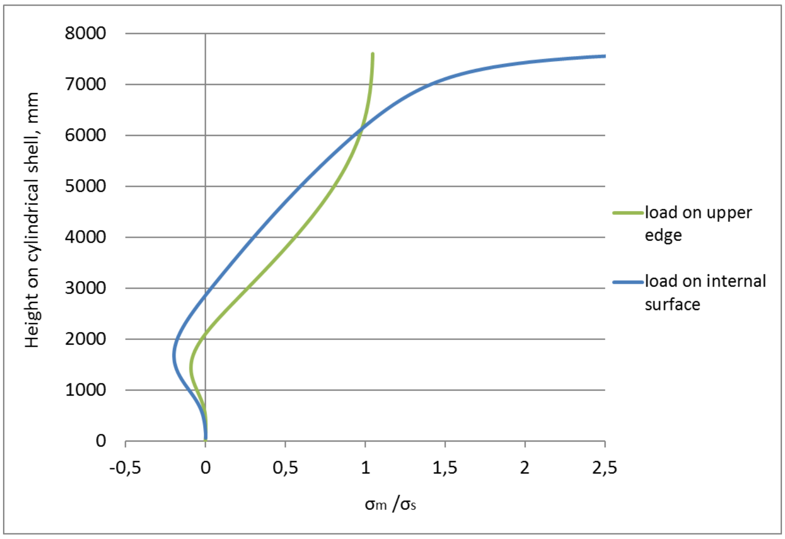
a) LA – linear (elastic) material and small deflections



b) MNA – non-linear material and small deflections

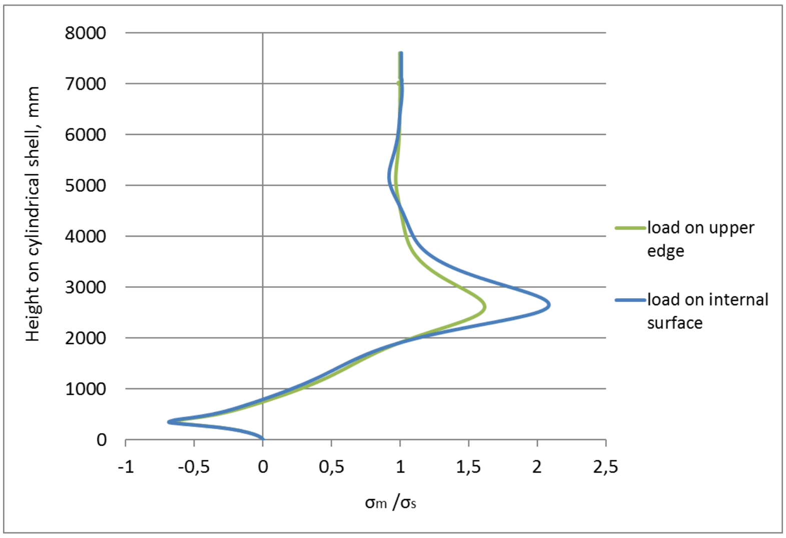


c) GNA – large deflections of the elements and elastic material

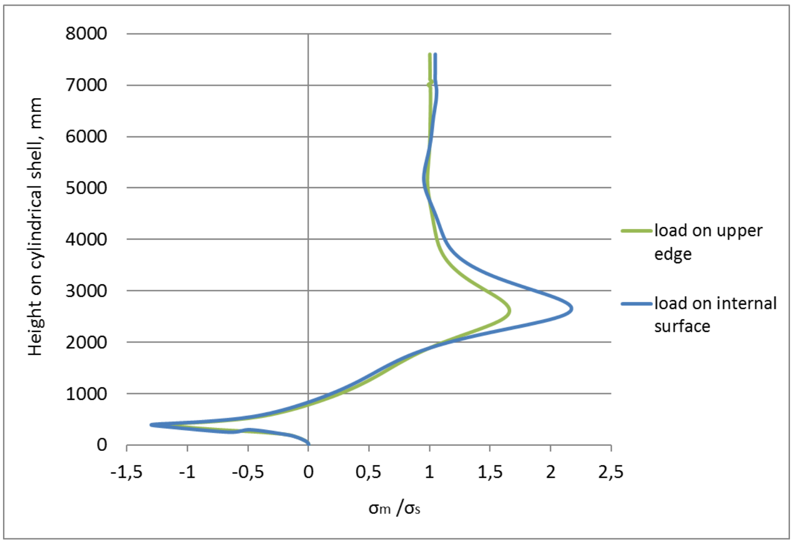


d) GMNA – non-linear material and large deflections

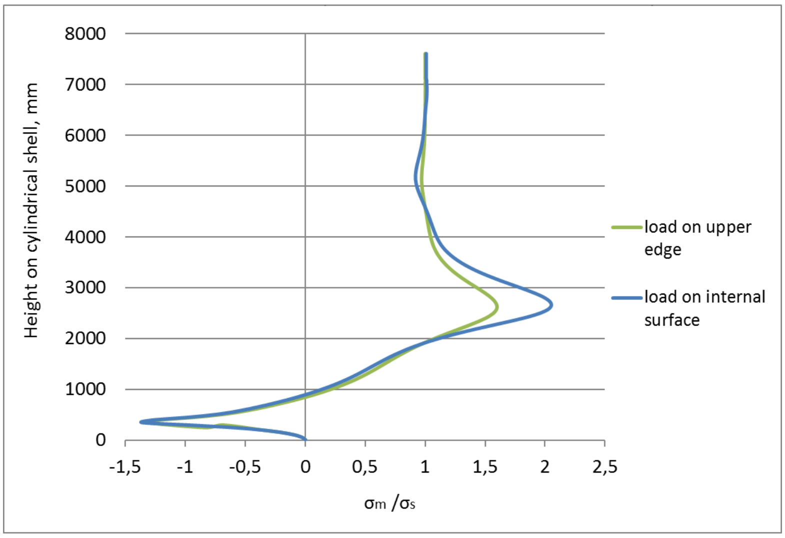
Fig. 4 – Relationship of the stresses σ_m/σ_s in the ideal shell



a) LA – linear (elastic) material and small deflections



b) MNA – non-linear material and small deflections



c) GNA – large deflections of the elements and elastic material.

Fig. 5 – Relationship of the stresses σ_m/σ_s in the shell with imperfections

The following conclusions could be drawn by graphics on Fig. 4 and Fig. 5:

a) the place of application of the loadings on the cylindrical shell does not change the height where the normal stresses above the supports σ_m and in the middle between them σ_s equalize their values;

b) the place of application of loadings has an influence on the values of the relationship of the normal stresses σ_m/σ_s , but does not change the shape of diagrams;

c) including an material or geometrical nonlinearity in the analysis have its influence, for instance increases the values of the relationship σ_m/σ_s in the shell with imperfections, but again without changes of the shape of diagrams;

d) the imperfections have the most considerable influence on distribution of the meridional stresses on the height;

e) in case of axial loadings on the cylindrical body, in the middle between the supports are reported tensile meridional stresses;

4. Conclusion

The closest to reality modelling of structures is a prerequisite to the most reliable results. This is related to need of large computational power of the used computers, a lot of time for calculation and/or difficult accounting of the obtained results. Therefore, some simplifications are done but they should not decrease the quality of the research. In considered above case, the easier and faster application of vertical loading on the upper edge of the cylindrical shell does not have an influence on determining of the height of the critical zone. But there is a difference of the values of the relationship of normal stresses σ_m/σ_s , without change of the shape of the diagrams. Here more considerable is the influence of the imperfections of steel shells. Unfortunately, they are arbitrary and could not easily and quickly be introduced at the design stage.

Gratitude

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