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LOCATION OF THE MOST DANGEROUS ZONES OF VERTICAL VESSELS TO INSTALL SENSORS OF MONITORING SYSTEM

Abstract: *The method of definition design model of vertical vessels for the program ANSYS, distribution strain-stress state analysis, dangerous zones selection.*

Key words: rectification column, monitoring system, finite-element method, strain-stress state, dangerous zones.

I. Introduction

There are more than 45 thousand of hazardous production facilities of different types and patterns of ownership in the Russian Federation. Of them, only more than 8 thousand of fire explosive facilities are in industry [1].

At the present time exact criteria of identification of hazardous production facilities (HPF) have been introduced in the Russian Federation. According to these criteria, such HPF have been divided into four classes of hazard: I hazard class – hazardous production facilities of extremely high hazard; II hazard class — hazardous production facilities of high hazard; III hazard class — hazardous production facilities of average hazard; IV hazard class — hazardous production facilities of low hazard [2].

Depending on the hazard class, there are defined measures of state regulation. At HPF of the I hazard class a permanent supervision is performed by The Federal Service for the Supervision of Environment, Technology and Nuclear Management (Rostekhnadzor) and organizations operating the HPF.

Also, a supervision should be provided for facilities, on which occurred various emergency situations such as escapes, fires, explosions, etc. in violation of technology regulations, operation conditions, working modes and other events during operation. These events have a substantial impact on technical condition of the facilities, as a result, the possibility of their further operation is questioned. However, it would be more effective and expedient to extend technical lifetime of the equipment, but only providing confidence of the possibility to prevent further potentially negative sequence of events.

Concept of the permanent supervision (monitoring) over the condition of the HPF equipment includes the creation of technical diagnostics system (TDS) built in the production, i.e. aggregation of resources, volume and performers required to ensure safe operation. This TDS will provide technical condition monitoring of the facility and watch out for the most dangerous zones.

To solve these tasks the best way is to set up a complex diagnosis monitoring system (hereinafter monitoring system) on the monitoring facility.

II. Statement

Fig. 1. The rectification column before the accident

Vertical vessels are widely used among HPF. One of such vessels is a rectification column (hereinafter the column) which is used for separating hydrocarbon fraction into propane and propylene.

The column is a steel welded vertical vessel which was manufactured in 1978. The column consists of a cylindrical body welded of 29 shells, 2 torispherical heads and technological nozzles (fig. 1). Also, the column has 174 four-flow sieve plates. The total height of the column is 82520 mm. The column has a heat-insulating layer 100 mm thick. The shells of the body and the torispherical heads are made of steel TTStE36 (equivalent 17Г1С).

Because of regulatory characteristics exceedance of operating procedure there was an accident: a seal failure in the pipe connection zone with heat-exchange unit at the bottom, which led to the fire. As a consequence, the heat-insulating layer was destroyed under the influence of the impulse wave and fire, maintenance platforms and ladders were partly destroyed (fig. 2).

Fig. 2. The rectification column after the accident

Based on the results of the industrial safety expertise conducted after the accident it was determined that the column had a deviation from the vertical axis (a roll). The deviation of the column top is 506 mm, that may cause roll increasing and lead to further possible scenarios of negative developments. These scenarios are:

- a fall of the column;
- local perturbation formations of geometric shapes (wrinkles), and thus through cracks formation and seal failure of the column body.

In order to prevent them, it was decided to install a monitoring system. The solution of 3 questions is required to do this:

1. to locate of the most dangerous zones;
2. to analyze and choose hardware and software, methods to test an initiation and growth of defects, and stresses in the most dangerous zones;
3. to determinate indicator intervals based on the analysis of strain-stress state and found defects.

This article deals only with the first task - location of the most dangerous zones to install sensors of the monitoring system on the sample of the selected object.

III. Results

To locate the most dangerous zones refined calculations were performed by finite element method (FEM) taking into account general and local stresses in accordance with [3] and [4], par.5.5.

A surface model of the column was created in the system of three-dimensional solid and surface design named Autodesk Inventor in accordance with:

- drawings of the producing plant;
- drawings of the supply-lines;
- an as-built drawing of the column roll;
- an actual geometry of the facility.

The geometry of the surface model showing the main elements is presented in fig. 3.

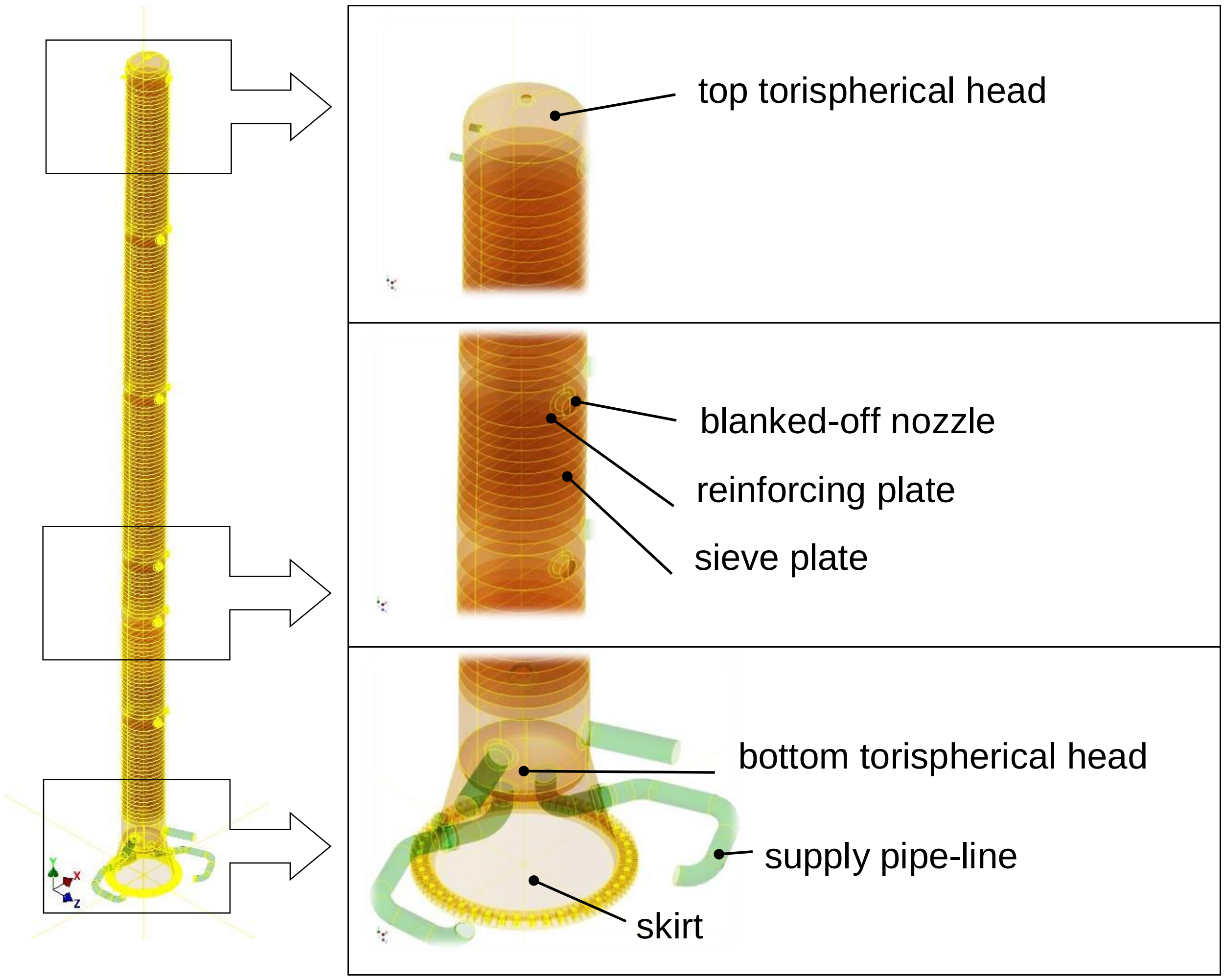


Fig. 3. The surface model geometry

The surface model was imported into a universal software system of finite-element analysis named ANSYS, where a design model of the column was created. The design model of the column was created on the basis of:

- the surface model of the column;
- a report on the results of ultrasonic thickness measurement;
- a report on the results of metal study.

After that, a finite element mesh was generated in ANSYS automatically. Dimension of the model totalled 340160 nodes.

Calculations were performed on a multiprocessor workstation with the following characteristics:

- CPU Intel Xeon 2686w 4.5 GHz;
- RAM 32 Gb, PC3-2400 DDR 3;
- graphics accelerator NVIDIA Tesla C1060;

- 4 SSD Intel X25 160 Gb standing in raid 1 to increase the speed of data exchange.

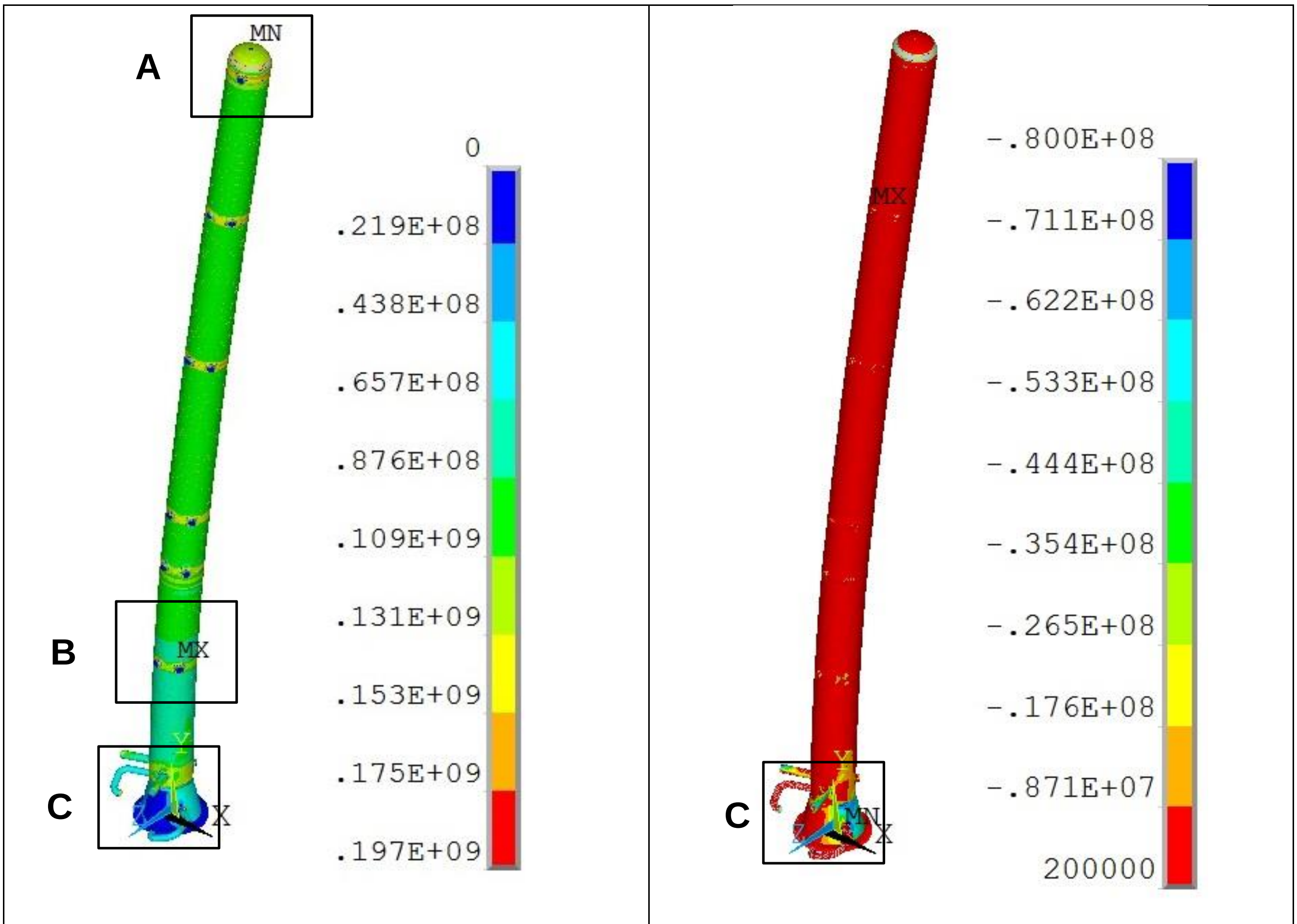
The calculations took about 2 hours with a 4-step load application.

To determine the dangerous zones a combination of design loads (design pressure, dead weight, thermal effect) was applied to the design model under different directions of wind pressure.

In accordance with [3], par.1.2.16, stress analysis, excluding stress concentration, was carried out under the hypothesis of linear elastic material behavior.

As an example, the strain-stress state of the column is considered when wind pressure is directed towards its initial displacement.

The results of the analysis are presented in the form of isosurface of stresses (fig. 4).



a) b)

Fig. 4. Isosurface (scale factor 25) of:

a) stress intensities, [Pa];

b) principal stresses in the 3-direction, [Pa]

The torispherical heads are the elements with a sharp change of geometry shape, that leads to high equivalent stresses initiation in them. With increasing height the wall thickness of the column decreases from 28 mm to 21 mm, that leads to equivalent stresses increasing of the column top. For these reasons, the column top with the torispherical head is a zone with increased equivalent stresses (fig. 4, zone A).

There are no sieve plates in areas with welded nozzles, that leads to decreasing of shell stiffness and increased membrane stresses. In addition, areas with welded nozzles are stress concentrators with maximum equivalent stresses (fig. 4, zone B).

Also, we can see a lower zone (fig. 4, zone C) with maximum stresses, located in areas of welded lower nozzles, where additionally the maximum bending moment is created.

The highest compressive stresses locate in the skirt, because tensile stresses from internal pressure don`t act on it.

The initial deviation of the column top (506 mm) doesn`t impact on its strain-stress state.

IV. Conclusions

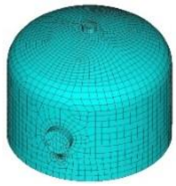
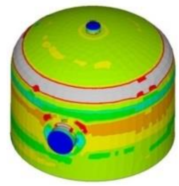
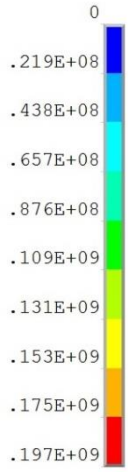
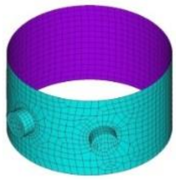
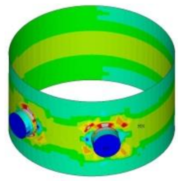
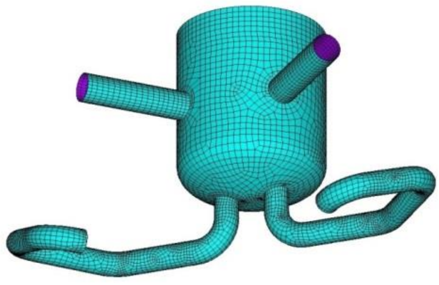
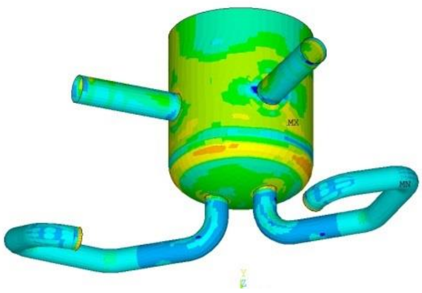
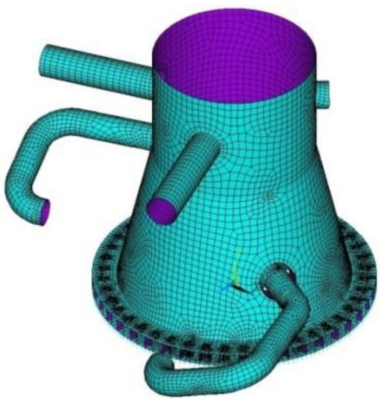
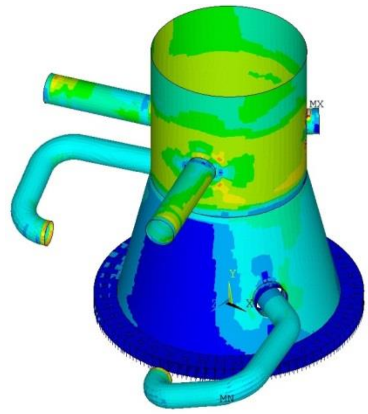
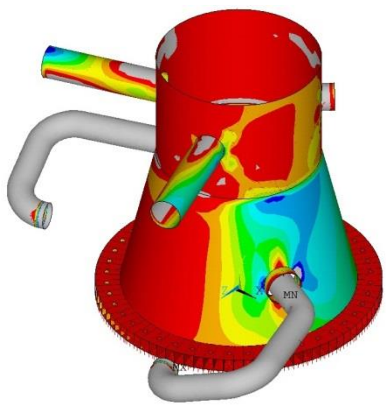
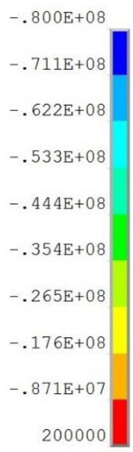
As a result, to install sensors of a monitoring system the next zones were chosen (table 1):

A - the top zone (the last shell and the torispherical head - elevation from 79700 to 82520 mm).

B - the zone of maximum stresses (the maximum value of equivalent stresses - elevation from 15400 to 17400 mm).

C - the bottom zone (the skirt and the first shell, the torispherical head - elevation from 0 to 6490 mm).

Table 1. Dangerous zones

<table>
<tr><th>Zone</th><th>Finite element mesh</th><th colspan="3">Isosurface of</th></tr>
<tr><td>A</td><td></td><td></td><td rowspan="4">
</td><td rowspan="4">stress intensities, [Pa]</td></tr>
<tr><td>B</td><td></td><td></td></tr>
<tr><td rowspan="3">C</td><td></td><td></td></tr>
<tr><td rowspan="2"></td><td></td></tr>
<tr><td></td><td>
</td><td>principal stresses in the 3-direction, [Pa]</td></tr>
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Based on the located most dangerous zones, the installation of monitoring system sensors (e.g. acoustic emission, strain-gauge) is planned to identify the initiation of defects and their development, and also to monitor the stress-strain state in these zones.

Evaluation of the stress-strain state allows to locate the most dangerous zones, which are necessary for monitoring, and reduce the number of installed sensors, thereby reducing the cost of the monitoring system.

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