Parametric geometric model of a spherical helical platform

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Abstract. The paper presents a parametric spherical model of a helical surface, which is used in the design of structures of helical platforms. This design is intended to serve the inner surface of spherical tanks. Presentation of the control program using dependent and mathematical models for constructing external and internal contours of the sites.

1. Introduction
In the oil and gas and petrochemical industries, spherical reservoirs are used for storing oil products, fuel gases and volatile substances under pressure. Figure 1 shows an example of the use of such tanks.

Figure 1. The park of spherical tanks

Spherical tanks in operation should undergo a comprehensive technical inspection, the purpose of which is to determine the safe operation, timing and completeness of future surveys, the need to repair or exclude from operation these tanks with certain technological parameters [1]. Consider a three-dimensional model of a spherical helical platform with its components, presented in Figure 2. This model is designed to serve the internal surface of spherical tanks. [2].
The design of a spherical helical platform can be applied in dimensions that can exceed 600 m³. The proposed design provides ease of maintenance of a spherical tank, necessary to maintain the inner surface of the tank, and provides safe movement of workers. Weight reduction is achieved due to the absence of staircases and stepladders for the transition between levels. A patent for invention RU 2679210 has been obtained for this product.
2. Parametrization of a geometric model

The study of mapping by orthogonal projection of the surface onto a plane has been the subject of a significant number of papers: [3 - 5] and others. In these works, the differential characteristics of a two-dimensional surface or an algebraic surface of higher dimension are mainly determined.

In this work, the spherical helix lines of the outer beam are located by intersecting the surface of the helicoid with the surfaces of the hemispheres displaced along the axis (Figure 3). The upper hemisphere is displaced along the axis to the internal hemisphere by an amount equal to the helix pitch of the helicoid.

Spherical helixes of the inner beam of the site are located by intersecting the surface of the helicoid with the surfaces of the spheroids halves displaced along the axis (Figure 3). The upper part is displaced along the axis to the lower part by an amount equal to the step of the helix helix.

![Figure 3. Construction of spherical screw lines of platform ebb](image)

1 – line for construction of the outer beam of the site;
2 – line to build the internal beam of the site;
h – construction helix pitch.

2.1. Mathematical model

The sphere and helicoid curve of crossing (Figure 4a):

\[ A(s, h) - B(s, h) = 0 \rightarrow \begin{pmatrix} x(s, h) \\ y(s, h) \\ z(s, h) \end{pmatrix} - \begin{pmatrix} X(s, h) \\ Y(s, h) \\ Z(s, h) \end{pmatrix} = 0; \]

\[ 0.95R < Z(s, h) < 0.8R. \]

The ellipsoid and helicoid curve of crossing (Figure 4b):
\[ A'(s, h) - B(s, h) = 0 \rightarrow \begin{pmatrix} x'(s, h) \\ y'(s, h) \\ z'(s, h) \end{pmatrix} - \begin{pmatrix} X(s, h) \\ Y(s, h) \\ Z(s, h) \end{pmatrix} = 0; \]

\[ 0.95R < Z(s, h) < 0.8R. \]

The curve of crossing of surfaces is presented in Figure 4.

**Figure 4.** Spherical screw lines

a – line plot for the outer beam of the site

b – line plot for the internal beam of the site

Where:

**Equation of sphere:**

\[ A(s, h) = \begin{pmatrix} x(s, h) \\ y(s, h) \\ z(s, h) \end{pmatrix}, \]

\[ x(s, h) = R\sin(s)\cos(h); y(s, h) = R\sin(s)\sin(h); z(s, h) = R\cos(s); \]

\[ s = 0 \ldots 2\pi; h = 0 \ldots \pi; \]

\[ R \text{ – the radius of sphere.} \]

**Equation of Ellipsoid:**

\[ A'(s, h) = \begin{pmatrix} x'(s, h) \\ y'(s, h) \\ z'(s, h) \end{pmatrix}, \]

\[ x'(s, h) = R_1\sin(s)\cos(h); y'(s, h) = R_1\sin(s)\sin(h); z'(s, h) = R_2\cos(s); \]

\[ s = 0 \ldots 2\pi; h = 0 \ldots \pi; \]

\[ R1 \text{ and } R2 \text{ - the ellipsoid radiuses.} \]

**Equation of single-blade helicoid:**

\[ B(s, h) = \begin{pmatrix} X(s, h) \\ Y(s, h) \\ Z(s, h) \end{pmatrix}, \]

\[ X(s, h) = [s]\cos(h); Y(s, h) = [s]\sin(h); \]

\[ Z(s, h) = \Delta h; \]

\[ \Delta = \text{step of the screw line.} \]
Based on this mathematical model, the algorithm shown in Figure 5 was developed.

![Flowchart](image)

**Figure 5. Construction algorithm**

2.2. Control program
For this three-dimensional model, all necessary parameters and dependencies are specified, which form the basis of the control program shown in Figure 6. The parametric model allows to obtain a spherical helical platform for a wide range of volumes of ball tanks (from 600 m$^3$ to 40000 m$^3$). To do this, it is
enough to set the volume (V) or the diameter (D_vnut) of the projected tank, as well as the pitch of the screw.

![Figure 6. Control program](image)

Main dependencies:

**Ball inner diameter:**

\[ D_{vnut} = \frac{3V}{4\pi} \]

**Screw length:**

\[ L = \sum_{i=1}^{n} L_{i\text{coil}} \]

Where:

\[ L_{i\text{coil}} = D_{i\text{cp}} \cdot \pi \]

\[ D_{i\text{cp}} = \left[ 2 \cdot \sqrt{\left( D_{vnut}/2 \right)^2 - \text{Shoulder}_i^2} \right] \]

\[ \text{Shoulder}_i = \frac{D_{vnut}}{2} - 250 - h_v/2 \]

\[ \text{Shoulder}_{i=2\ldots n} = \text{Shoulder}_i = 1\ldots (n-1) - h_v \]

**Number of consoles:**

\[ D_{\text{cons}} = L/\delta_{\text{cons}} \]

### 3. Conclusion

The presented parametrization of a spherical helical platform and a mathematical model for constructing the curves of intersection of surfaces allows you to get a helical platform for a wide range of volumes of
ball tanks (from 600 m$^3$ to 40,000 m$^3$) and determine the basic parameters of the new product, such as the number of turns, the length of the curve, etc., its designing.

The presented parametric model is used at the stage of pre-design study of the ball tank to estimate the number of turns of the internal platform, as well as weight and cost.

Currently, in the oil and gas and petrochemical industries, the construction of internal forests in the form of a spherical helical platform has not been encountered in world practice. However, its use will improve the performance of spherical tanks.

4. References

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