Computer-aided design the spherical helical platform intended for the internal surface maintenance of spherical tanks

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Abstract. This paper presents the new construction - spherical helical platform and the method for obtaining spherical helical surface used in the designing of new platforms. This platforms intended to serve an inner surface of the spherical tank. The mathematical models for external and internal contour of helical platform are presented in this paper. The outer and inner contours of the helical platform are obtained by intersecting the curve of the helicoid with the curves of the sphere and the ellipsoid.

1. Introduction
The spherical tanks are used to store pressurized fuel gases and easily evaporating substances. Park spherical tanks is shown on the Figure. 1. Depending on the function spherical tanks differ in capacity and operating pressure.

Figure 1. The park of spherical tanks
All spherical (ball) tanks which are in operation have to undergo comprehensive technical examination [1]. A main objective of comprehensive technical examination is definition of a possibility of further safe operation, terms and completeness of the subsequent inspections, need of repair or an exception of operation of the spherical tank at the set technological parameters. A preparation of the spherical tank for full technical inspection is made by forces of the enterprise owner and carried out in such sequence:

- release of the spherical tank from a product
- installation of caps
- removal of the remains of a product
- cleaning of an internal surface of the spherical tank
- lighting installation
- preparation of welded seams and the main metal for carrying out nondestructive control methods of a kachestvaa of metalgraphic researches.

The purpose of internal survey is determination of defects on the internal surface of the spherical tank [1]. At internal visual survey are subject to obligatory check:

- condition of the main metal of a cover
- local deformations, dents are also made buldge out
- condition of welded connections of designs of spherical tanks according to requirements of projects, Construction Norms and Regulations, standards on the corresponding types of welding and types of welded seams.

In the modern petrochemical and oil and gas industry for survey and service of an internal surface of the spherical tank use a scaffolding. Two types of a scaffolding were widely adopted:

- in the form of an internal rotary ladder (Figure 2) which is executed under the copyright certificate [2];
- in the form of the internal multilevel woods from circular platforms with transitions between levels (Figure 3).

Figure 2. Internal rotary lader
Shortcomings of the first design are:
- need to manually move a ladder on a necessary position;
- possibility of application only on spherical tanks up to 2000 m$^3$, because of significant increase in mass of a product when providing conditions of durability that leads to impossibility of manual movement without use of additional resources [2];
- complexity of carrying out paint and varnish and other works.

Figure 3. Multilevel construction woods

Shortcomings of the second design:
- Big mass of a product;
- Complexity of evacuation of personnel because of existence of ladder marches and step-ladders as the main way of movement between levels.

History of design and construction of the spherical tanks of various capacity built in the USSR, the USA, Germany, Japan, Great Britain Germany and other countries since the beginning of the 20th century and till present [3, 4] shows that for service of an internal surface of tanks with a capacity up to 2000 m$^3$ widely use an internal rotary ladder, (look at Figure 2). For tanks with a capacity of 5000 m$^3$ and more use the multilevel woods (look at YouTube: Inside of a LPG storage tank Erection part 7, URL: https://www.youtube.com/watch?v=o-Hf8wXDajg), or “industrial mountaineering” [3].

The largest producers of vessels for transportation of liquefied natural gas: (Daewoos Shipbuilding & Marine Engineering, Hyundai Heavy Industries, Samsung Heavy Industries, Mitsubishi Heavy Industries) establish for survey and service of an internal surface of tanks the platform with a rotary arrow [7], as shown in Figure 4.

Figure 4. Platform with a rotary arrow
Development of a new scaffolding for service of an internal surface of spherical tanks which is executed in the form of the screw spherical platform (Figure 5) is presented in this article. It is possible to apply a structure of the spherical screw platform in the wide range of the sizes of spherical tanks (volume more than 600 m$^3$). The offered constructive scheme provides convenience of service of an internal surface of the spherical tank and safety of movement of working personnel. Decrease in weight is reached due to lack of ladder marches and step-ladders for transition between levels.

![Three-dimensional model of the spherical screw platform](image)

**Figure 5.** Three-dimensional model of the spherical screw platform

1 – screw beams of the platform;  
2 – platform flooring;  
3 – protection;  
4 – platform consoles;  
5 – internal surface of the spherical tank.

The design of a scaffolding offered in Figure 5 has’nt analogs in the world. The next prototype is a scaffolding in the form of the internal multilevel woods (look at Figure 3). In this regard on this work the patent application for an invention "A screw scaffolding" is submitted.

2. **Mathematical model of spherical screw lines of the platform**

To questions of a research of display orthogonal projection of a surface on the plane devoted works: [5 - 6], etc. In them, some differential characteristics of a two-dimensional surface or algebraic surface of bigger dimension generally are defined.

The spherical screw line of an external beam of the platform decides by crossing of a surface of the sphere (Figure 6) on a surface of a helicoid (Figure 7).
**Sphere equation:**

\[
\begin{align*}
    f(a,b) &= \begin{pmatrix} x(a,b) \\ y(a,b) \\ z(a,b) \end{pmatrix},
\end{align*}
\]

Where

\[
\begin{align*}
    x(a,b) &= R \sin(a) \cos(b); \\
    y(a,b) &= R \sin(a) \sin(b); \\
    z(a,b) &= R \cos(a);
\end{align*}
\]

\[a = 0...2\pi; \quad b = 0...\pi; \quad R - \text{the sphere radius.}\]

**Figure 6.** The schedule of the sphere in the Mathcad software product

**Single-blade helicoid equation:**

\[
\begin{align*}
    h(a,b) &= \begin{pmatrix} X(a,b) \\ Y(a,b) \\ Z(a,b) \end{pmatrix},
\end{align*}
\]

Where

\[
\begin{align*}
    X(a,b) &= a | \cos(b); \\
    Y(a,b) &= a | \sin(b); \\
    Z(a,b) &= \Delta b; \quad \Delta - \text{step of the screw line.}
\end{align*}
\]

**Figure 7.** The schedule of the helicoid in the Mathcad software product

**The equation of a curve of crossing of surfaces of the sphere and helicoid:**

\[
\begin{align*}
    f(a,b) - h(a,b) &= 0 \rightarrow \\
    &\begin{pmatrix} x(a,b) \\ y(a,b) \\ z(a,b) \end{pmatrix} - \begin{pmatrix} X(a,b) \\ Y(a,b) \\ Z(a,b) \end{pmatrix} = 0;
\end{align*}
\]

\[0.95R < Z(a,b) < 0.8R.\]

The curve of crossing of surfaces is presented in Figure 7.
Figure 8. The schedule of a curve of crossing of surfaces of the sphere and helicoid in the Mathcad software product.

The spherical screw line of an internal beam of the platform is by crossing of a surface of an ellipsoid with a helicoid surface (see Figure 7), as shown on the Figure 9.

**Ellipsoid equation:**

\[
\begin{align*}
& x(x, a, b) = \sin(a) \cos(b), \\
& y(y, a, b) = \sin(a) \sin(b), \\
& z(z, a, b) = \cos(a),
\end{align*}
\]

Where \(x(x, a, b) = R_1 \sin(a) \cos(b);\)
\(y(y, a, b) = R_1 \sin(a) \sin(b);\) \(z(z, a, b) = R_2 \cos(a);\)
\(a = 0...2\pi;\) \(b = 0...\pi;\) \(R_1\) and \(R_2\) - the ellipsoid radius.

**The equation of a curve of crossing of surfaces of an ellipsoid and helicoid:**

\[
\begin{align*}
& f(f, a, b) - h(a, b) = 0 \rightarrow \begin{pmatrix} x(x, a, b) \\ y(y, a, b) \\ z(z, a, b) \end{pmatrix} - \begin{pmatrix} X(a, b) \\ Y(a, b) \\ Z(a, b) \end{pmatrix} = 0; \\
& 0.95R < Z(a, b) < 0.8R.
\end{align*}
\]

The spherical screw lines of external and internal contours of the platform received by crossing of a surface of a single-blade helicoid with surfaces of a spheroid and the sphere are presented on the Figure 10.
Figure 10. Spherical screw lines of external and internal contours of the platform

The result of plotting of crossings of a surface of a helicoid with the surfaces of the sphere and a spheroid by means of a CAD a "KOMPAS-3D " is presented on the Figure 11.

Figure 11. Three-dimensional model of a spherical screw surface

3. Conclusion

The presented mathematical way of receiving curves of crossing of a surface of a helicoid with the surface of the sphere and a spheroid allows to determine key parameters of a new product (the spherical screw platform) prior to design of a product: quantity of rounds, curve length, etc. Also it can serve as a part of uniform system at automation of design of this product.

The presented spherical screw surface can be used at a stage of pre-design study of the spherical tank for assessment of quantity of rounds of the internal platform, its weight and cost.
Now in the modern oil and gas and petrochemical industry the design of the internal woods in the form of the spherical screw platform did not meet in world practice. However its application will allow to improve operational qualities of spherical tanks.

4. References

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