Iacob-Liviu SCURTU, Sanda Mariana BODEA, Ancuta Nadia JURCO, Horea George CRISAN

METHODS FOR THE REPRESENTATION OF THE HELICOIDAL SURFACE

Abstract: *In this paper there are presented the graphical methods to determine the parameters of an helicoidal stairs. The first part of this paper shows the used methods to generate the helicoidal curves using descriptive geometry methods. It has represented the state of the art of the generation of a helical surface studies. The second part of this study shows the helical stairs surface representation using descriptive geometry methods. For the representation of the helicoidal stairs are used two projections, the front and top view. A method of the stairs representation is solved using CAD modelling dedicated software. Following the helical surface representation in both methods, has been achieved a comparative study by using two representation methods. Conclusions about these two representation methods are presented in the end of this paper.*

Key words: *descriptive geometry, helix, helicoidal surface, stairs, right helicoid, CAD representations.*

1. INTRODUCTION

Descriptive geometry is a part of the engineering which contribute substantially to growth of the education and training of the industrial and civil engineering specialists by using the graphical representations methods.

In this paper are presented two methods for represent a helical surface, with practical application to build a spiral staircase. The first part of the paper presents the classical representation method of the cylindrical helix. In the second part the helix is modelled and represented using dedicated CAD software.

From the oldest times the helical surfaces are very common in technical applications. An important application, since ancient times is the Archimedes' screw water pump used to water transportation (278-212 B.C.). The screw presented in figure 1, consists in a cylindrical tube which have inside a coaxial helix. When the end of the cylinder is placed in a water tank and the helix is rotated, the water is pushed to the higher level [7].

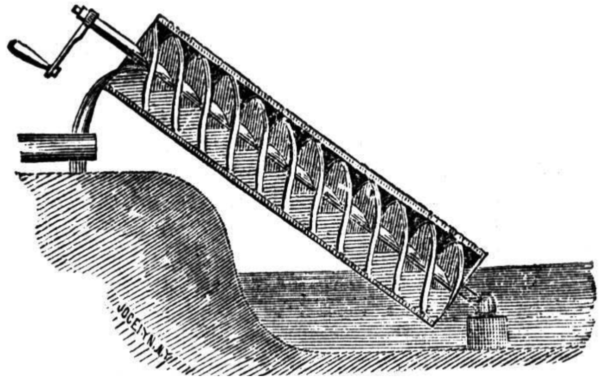


Fig. 1 The Archimedes' screw [7].

The most popular use of the helicoid surface in architecture is the staircase. Most of the spiral stair have a central pole, offering great resistance. According to the plane and the catenoid the helicoid is the third minimal surface, discovered by Jean Baptiste Meusnier in 1776 [2]. The applications of the helical surface are the spiral staircase and the helicoidal water slide [8].

Amazing architectural spiral staircase is designed by Giuseppe Momo in 1932 at the Vatican Museums.

Fig. 2 Spiral staircase of the Vatican Museums [3].

The stairs are composed from two separate helixes, one to leading up and the other helix to leading down. That separate helixes are twisted together in a double helix formation [3]. In figure 2 can be observed the shape of this stairs.

Fig. 3 Spiral ramp of parking garage, Berlin [4], [9].

Most frequently applications of the helicoidal surface used in civil engineering is the way ramp of parking garage. In figure 3 is presented the way ramp of the parking garage from Berlin [3], [11].

Among the great buildings of the world with a twisted shape can be mention: Torso Tower, Malmo, Sweden, Infinity Tower, Dubai, and Revolution Tower, Panama [3]. In mechanical engineering the helicoidal surface is applied in generation of the triangular or trapezoidal thread profile [2].

2. CYLINDRICAL HELIX

To drawing the front and top view projections of the helical line described by the point M (m, m') on the cylindrical rotation surface the length of the pitch *p* and the cylinder surface are divided into eight equal parts.

Knowing that for rotation of the generator with a division, the point moves along the generators also a division, the successive positions of the point M are determined. The projections of the helical line are obtained by joining the points. The front view projection of the helix line has the shape of a sinusoidal waves and the top view is overlapped with the cylinder projection.

Developing of the cylindrical surface the helix line is transformed into a right line, because the displacement of the point M is constant.

Graphical construction of the helix is solved dividing the base circle in twelve parts. In figure 4 are presented the graphical representation of the helix twisted on right hand [1].

The helix pitch is determined by the helix arc between two consecutive intersections points with the same generator. The helix is determined when are given the cylinder parameters, the origin, the pitch, the twisted direction or the helix angle.

Helical surface generated by the straight line is a ruled surface, that is determined by the helical axis, the helical motion parameter and the generating line position.

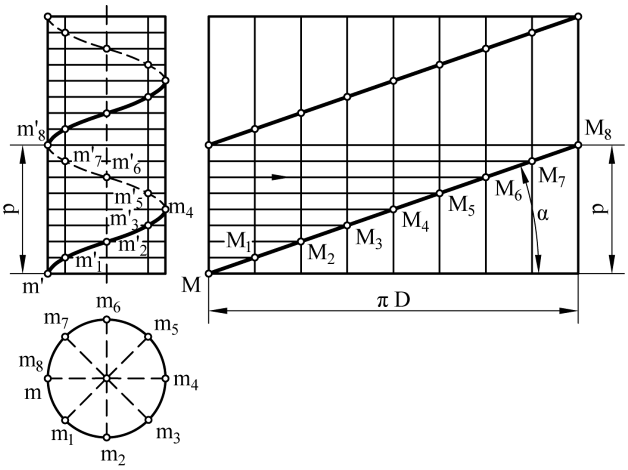


Fig. 4 Helical line representation and development [3].

Depending on angle between the generation line and the helix axis, the surface can be called right or oblique.

In case of the right helicoid the helix angle is equal to 90°, and if the angle is different to 90° the helicoid is oblique [6]. Usually all the staircase has a central core, which reinforces the staircase. In figure 5 the central core is represented by the cylindrical surface with *d* dimeter.

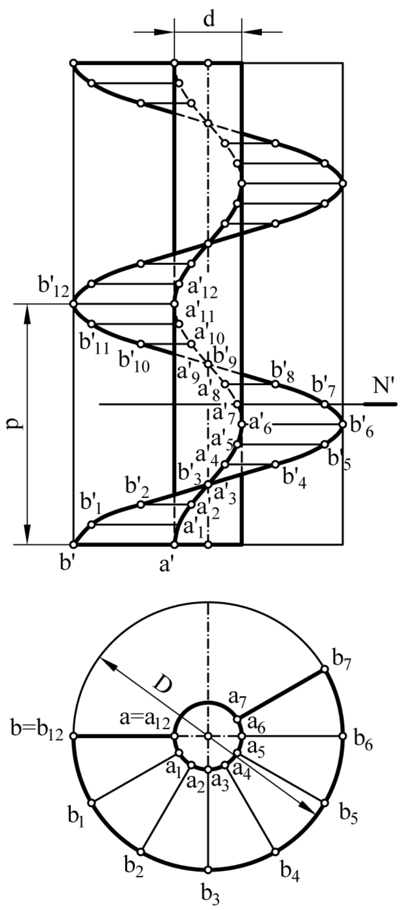


Fig. 5 Right helicoid surface representation [6].

The right helicoid representation is presented in figure 5. The helicoidal surface is generated by the trace of the AB segment ends. The plane section of the helicoidal surface is given by the A_7B_7(a_7, b_7, a'_7, b'_7) points.

3. GRAPHICAL REPRESENTATION

In this section are presented two methods to represent and develop the surface of the helicoidal stairs. Exterior diameter of the stairs is equal to 2 m, height of the stairs is equal to 4.760 m and the central pole has diameter equal to 0.2 m. This type of staircase can be used into homes designed with two floors.

3.1 Descriptive geometry representation

Appling descriptive geometry representation the surface of the helicoidal stairs is presented in figure 6. The external surface of the stairs is developed, determining the necessary area of sheet metal. For determining the developed helicoidal surface is enough to developed the helical line.

The sheet metal surfaces are developed on the cylinder developed surface. For develop the cylinder surface it is necessary to divide the cylinder in top view into twelve equal parts. In the front view the pitch of the helix is divided also into twelve equal parts. The cylinder length from the developed surface is given by the arc length.

This length is taken from the top view and is placed twelve times. In this case the slope of the stairs is equal to 18°.

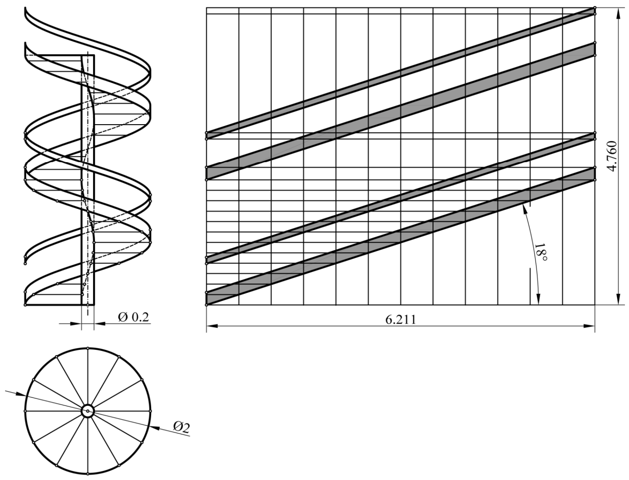
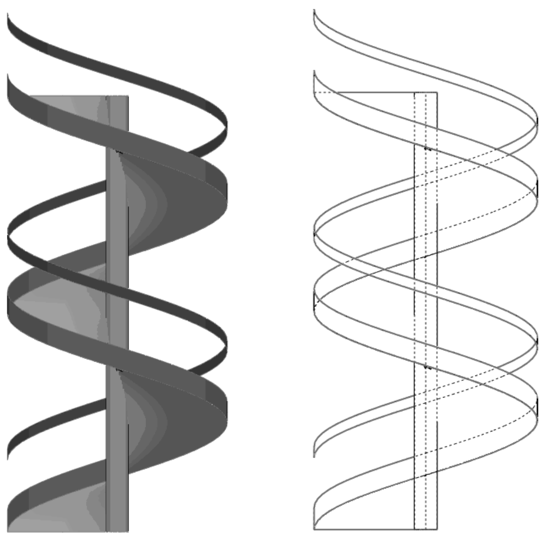


Fig. 6 Representation of the helicoidal surface.

3.2 CAD representation

In the latest period computer graphics is increasingly used in industrial design process. Using the CAD software allows a faster product design, having a better result than by using classical design method.



a) b)

Fig. 7 The sheet metal staircase.

Figure 7 present the staircase surface modelled in SolidWorks software. Appling the tools existent in the software the helicoidal surfaces are represented.

First is drawn the central pole of the stairs. Twisted on this pole is generate the surfaces of the stairs and the sheet metal of the protection fence. In figure 7 are presented just the sheet metal parts who can be developed.

Using modelling techniques, developed surface of the sheet metal stairs is done in CAD software, presented in figure 8. Sheet metal of the fence stairs are developed together, represented in figure 8 by the Sheet 1 and the Sheet 2

Using the Flatten surface command from the surface module existed in SolidWorks toolbar the sheets are automatically developed.

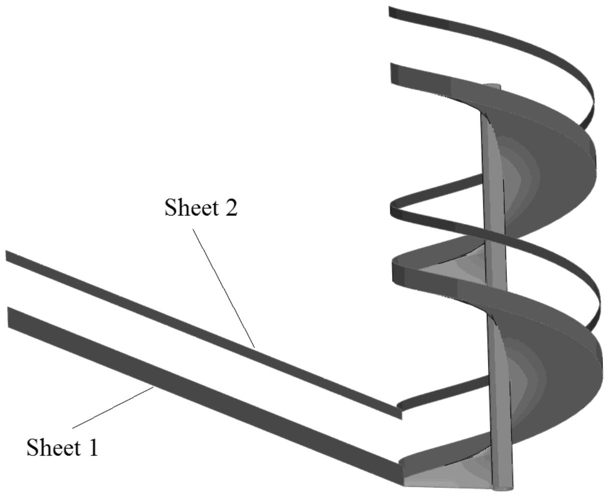
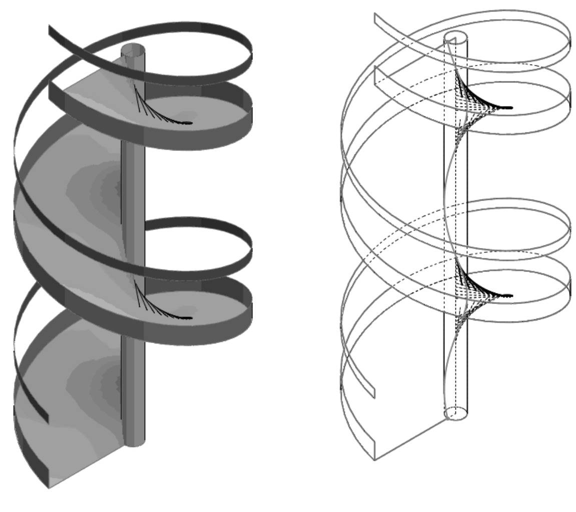


Fig. 8 Developed surface of the sheet metal.

For a better visualization of the helicoidal surface of staircase modelled in SolidWorks is represented in axonometric view in figure 9.



a) b)

Fig. 9 Axonometric view.

In figure 9a is presented the shaded sheet metal surface and in figure 9b is presented the wireframe model in which can be seen much better the staircase geometry.

4. RESULTS

Comparative results by using this two representations method are presented in table 1.

Table 1

Comparative results between two methods

	Descriptive geometry method (area m^2)	CAD method (area m^2)
Sheet 1	2.48	2.51
Sheet 2	1.242	1.26

The results presented in table 1 are obtained by using these two representation methods. In this table the resulted area for each sheet are compared, developed in both methods. The results show that the CAD modelling and representation method is the most accurate method.

5. CONCLUSION

This paper presents a comparative study between two methods to represent and develop of the sheet metal component of the spiral staircase. First method can be used easy by the engineers, provide advantage of applying knowledge learned during university studies. The second methods involve the use of the computer aided design software. This method is most widely used, because it is a more accurate method than the classic method and faster to generate the results. The weaknesses of this method is the high price of the dedicated software and the necessary training of the engineers.

The rapid development of the industry has forced the CAD software to be use in large scale. The use of the descriptive geometry methods is recommended to design the unique products.

REFERENCES

[1] Bodea, M., Scurtu, L. (2016). *Descriptive geometry and technical drawing (Geometrie descriptivă și desen tehnic)*, Risoprint publisher, ISBN 978-973-53-1902-1, Cluj-Napoca.

[2] Botez, M. (1982). *Descriptive geometry (Geometrie descriptivă)*, Didactic and pedagogic publisher, Bucharest.

[3] Enache, I., Ivanceanu, T., Buzila, V. (1982). *Descriptive geometry and technical drawing - Syntheses and applications (Geometrie descriptiva si desen tehnic-Sinteze si aplicatii)*, Didactic and pedagogic publisher, Bucharest.

[4] Inzerillo, L. (2012). *Helicoid and Architectural application (L'elicoide e le sue applicazioni in architettura)*, Journal: DISEGNARECON, vol.5, Issue 10, ISSN 1828-5961.

[5] Marza, C., Cimpean, D., Corsiuc, G. (2015). *About the geometry and the applications of the twisted surfaces,* Journal of industrial design and engineering graphics, Volume 10, Special Issue ICEGD.

[6] Orban, M. (2004). *Descriptive geometry -Syntheses and applications (Geometrie descriptivă-Sinteze și aplicații)*, U.T. Press Publisher, ISBN 973-662-020-4, Cluj-Napoca.

[7] Rorres, C. (January 2000). *The turn of the screw: optimal design of an Archimedes screw,* Journal of hydraulic engineering, Vol. 126, Issue 1, pp. 72-80, DOI: http: //dx.doi.org/10. 1061/(ASCE)0733-9429(2000) 126:1(72).

[8] Surynkova, P. (2012). *3D Geometric modeling, International conference on communication, media, technology and design*, Istanbul.

[9] http://www.oobject.com/category/18-spiral-ramps/, Accesed: 2017-03-15.

Authors:

Lecturer Liviu-Iacob SCURTU, Technical University of Cluj-Napoca, Dept. of Automotive Engineering and Transports, E-mail: liviu.scurtu@auto.utcluj.ro, tel. 0040264401610.

Assoc. Prof. Sanda Mariana BODEA, Technical University of Cluj-Napoca, Dept. of Automotive Engineering and Transports, E-mail: sanda.bodea@auto.utcluj.ro, tel. 0040264401610.

Asist. Prof. Ancuta Nadia JURCO, Technical University of Cluj-Napoca, Dept. of Automotive Engineering and Transports, E-mail: ancuta.jurco@auto.utcluj.ro, tel. 0040264401610.

Asist. Prof. Horea George CRISAN, Technical University of Cluj-Napoca, Dept. of Automotive Engineering and Transports, E-mail: horea.crisan@auto.utcluj.ro, tel. 0040264401610.