Федеральное государственное автономное
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«РОССИЙСКИЙ УНИВЕРСИТЕТ ДРУЖБЫ НАРОДОВ»

# ТРУДЫ

## НАУЧНО-ПРАКТИЧЕСКОЙ КОНФЕРЕНЦИИ С МЕЖДУНАРОДНЫМ УЧАСТИЕМ «ИНЖЕНЕРНЫЕ СИСТЕМЫ – 2019»

***Москва, 3–5 апреля 2019 г.***

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Т78 **Труды научно-практической конференции с международным участием «Инженерные системы – 2019».** Москва, 3–5 апреля 2019 г. / под общ. ред. М. Ю. Мальковой. – Москва : РУДН, 2019. – 536 с. : ил.

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Приводится содержание основных докладов Научно-практической конференции с международным участием «Инженерные системы – 2019», проходившей 3–5 апреля 2019 г. в Москве. Конференция была организована департаментом Архитектуры и строительства Инженерной академии, Российского университета дружбы народов.

В рамках Научно-практической конференции с международным участием работали 7 секций. Материалы для публикации отобраны Оргкомитетом конференции в соответствии с рекомендациями независимых рецензентов и расположены по секциям. Труды публикуются с сохранением стиля и орфографии авторов.

Труды Научно-практической конференции с международным участием будут представлять интерес для научных работников, аспирантов, инженеров, занимающихся аналогичными задачами, и будут полезны для преподавателей высших учебных заведений математического и технического профиля.

*Подготовлено Оргкомитетом Научно-практической конференции с международным участием «Инженерные системы – 2019».*

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СЕКЦИЯ 3

## ТЕХНИКА
## И ТЕХНОЛОГИЯ СТРОИТЕЛЬСТВА

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# APPLICATION OF SPIRAL AND TWISTED SURFACES TO CONTEMPORARY ARCHITECTURE

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There is an obvious tendency in the contemporary architecture that it is changing from using simple geometrical structures to different spatial forms, having the unique view and symbolizing the dynamics, development and the way forward. Design of buildings characterized by the variety of shapes leads to the necessity to classify these forms and, if possible, to choose a suitable analytical surface for them. Some spiral, twisted and screw surfaces as well as methods of their creation are considered in the article. The possibilities of architectural design based on these surfaces are being studied what is illustrated by a number of impressing examples of buildings and structures.

**Key words**: analytical surfaces, contemporary architecture, twisted and spiral surfaces, helicoid, ruled surface, helical strip, helical surface, helical column surface.

## Introduction

Thinking of the point of the future architecture the assumption has been made that soon the world would come to an understanding of the necessity to transform simple geometrical forms by engraining the dynamic structures, symbolizing the development and supporting the connection of the nature with a human being**.** One of the approaches to solve this problem can be using spiral structures based on the natural forms which can harmonize with the surrounding landscape.

A spiral and its configurations are the basic morphological parameters of the nature's systems on the various structural levels. Moreover, the interaction of centrifugal force and the earth gravitation forth can be a clear symbol of the way forward. Based on the combination of these factors it is possible to state clearly that spiral, twisted and screw buildings will be a perfect solution of architecture's tasks at present and in future. The issue's importance has led to the need to analyze from this point of view the existing buildings and structures as well as the developing projects.

**The aim of the work** was to conduct a comparison of structures with regular analytical surfaces basing on the works of professors S.N. Krivoshapko and V.N. Ivanov [1-3] who studied the geometrical shaping of a great number of analytical surfaces and mage their general classifications. In particular, some analytical surfaces were considered the article, namely, spiral, spiral-shaped and screw, and their shaping and basic equations. Also a comparison was made with some known architectural objects.

Consider some analytic surfaces related to the group of spiral, helical, and twisted surfaces.

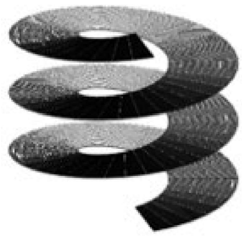

*Fig.1*

*Fig.2*
*membrana.ru/storage/img/v/va3.jpg*

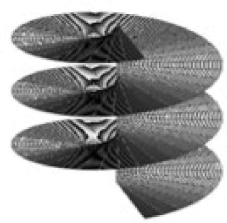

*Fig.3*

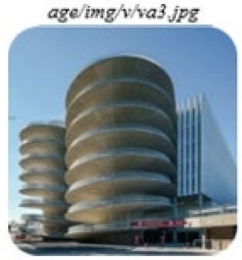

*Fig.4*
*barewalls.com/comp/art-print-poster.jpg*

First we consider the surface of a ***direct helicoid*** (Fig. 1), which is the only ruled surface that belongs to the family of minimal surfaces and refers to closed surfaces. A straight helicoid is formed by the perpendicular intersection of the straight line generator of the helicoid, its rotation and displacement along this axis at a distance proportional to the angle of rotation. The speeds of these movements are constant and proportional [2]. Parametric method of its setting is as follows:

$$x = (r, v) = r\,cos\,v, \quad (1)$$
$$y = y(r, v) = r\,sin\,v, \quad (2)$$
$$z = cv, \quad (3)$$

where ***c*** is the displacement of the generator when it is rotated by *1 rad.*

The Swedish-American company "Plantagon International" proposes to use the surface of a direct helicoid, rotating around a vertical cylindrical column, to create a new type of greenhouse, which was called "Plantagon", Sweden (Fig. 2) [3]. These are vertical farms for "urban agriculture".

***A spiral ruled surface with a direct generator*** (Fig. 3) can be found in everyday life, for example, in relatively new multi-storey car parking in the form of a circular ramp for entry, as was done in the Netherlands (Fig. 4). According to [1] "The spiral linear surface with a direct generator, the perpendicular axis of a straight conical spiral and a tangent to the same spiral is a linear surface of negative Gaussian curvature." This surface belongs to the class of Catalan surfaces [4]. A plane of parallelism is the plane $z = 0$. Parametric equations for specifying the surface are as follows:

$$x = x(u, \varphi) = r_0\,sin\,\lambda\,cos\,\varphi \cdot e^{k\varphi} + u \cdot \frac{cos\,\varphi + k sin\,\varphi}{\sqrt{1+k^2}}, \quad (4)$$

$$y = y(u, \varphi) = r_0\,sin\,\lambda\,cos\,\varphi \cdot e^{k\varphi} + u \cdot \frac{sin\,\varphi + k cos\,\varphi}{\sqrt{1+k^2}}, \quad (5)$$

$$z = z(\varphi) = r_0\,cos\,\lambda \cdot e^{k\varphi}, \quad (6)$$

The angle of the tangent to a straight conical line with the plane $z = 0$ is calculated using the formula:

$$tan\beta = \frac{k cos\lambda}{\sqrt{1+k^2}} \quad (7)$$

***A cylindrical helical strip*** (Fig. 5) is a ruled surface formed by rotating a straight line around an axis and at the same time by a uniform translational motion in the direction of the same axis. The generator is located on the surface of a circular cylinder, whose axis coincides with the axis of rotation, and also remains parallel to the axis in all positions. Parametric equations specifying the surface are:

$$x = x(v) = a\,cos\,v, \quad (8)$$
$$y = y(v) = a\,sin\,v, \quad (9)$$
$$z = z(u, v) = cv + u, \quad (10)$$

where $a$ is the radius of a straight circular cylinder, $v = const$ are the direct generators of the helical strip, u = const are helix lines with the same constant pitch, with the contours of the strip $u = 0$ and $u = b$, where $b$ is the strip's width [5]. An example of using this surface is the "Arganzuela Footbridge" pedestrian bridge in Madrid, Spain (Fig. 6), created by the architectural bureau Dominique Perrault Architecture. The bridge is a "pipe" formed by two cylindrical spiral steel strips opposite in direction [6]. One lane is formed from a metal mesh, and the second is from transverse ribs, thereby providing wind protection inside the bridge and sufficient shade for comfortable walks.

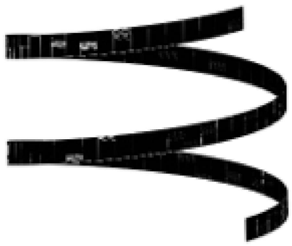

*Fig.5*

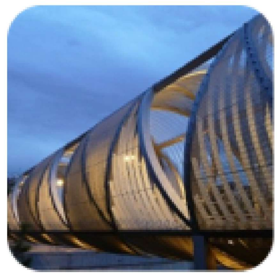

*Fig.6*
*bridge-sall.ru/Foto/Spain/Arganzuela/most_argansuehla.jpg*

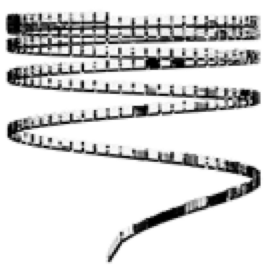

*Fig.7*

*Fig.8*
*arhinovosti.ru/wp-content/uploads/2012/01/Alternative-Car-Park-1.jpg*

***A cylindrical helical strip with a constant width and variable pitch*** (Fig. 7) is located on the surface of a straight circular cylinder with a constant radius $a$ [7]. The angle of inclination $\alpha$ between the tangent to the guide and the XOY plane is in the range from $0$ to $\pi/2$. The surface is set parametrically:

$$x = x(u) = a\,cos\,m\,\pi u, \quad (11)$$
$$y = y(u) = a\,sin\,m\,\pi u, \quad (12)$$
$$z = z(u,v) = b\sqrt{1-(1-u)^2} + v, \quad (13)$$

where $m/2$ is the number of turns when $0 \leq u \leq 1$, where $z$ varies from $0$ to $b$. In this case, the line guide coincides with $v = 0$.

Studio “Mozhao” presented the project of the parking tower “Alternative Car Park” in Hong Kong, China (Fig. 8) at an international architectural competition and won due to the original idea of the building surface, where the cylindrical helical strip is divided into two and completed with a direct helicoid [8].

***The cylindrical-conical screw strip*** (Figure 9) is formed in the same way as a cylindrical screw strip. The difference lies in the generatrix, which moves along a conical helix, with the rectilinear generatrix parallel to the axis of the helix in all positions [9]. Parametric equations for specifying the surface are:

$$x = x(\varphi) = r_0\,sin\,\lambda\,cos\,\varphi \cdot e^{k\varphi}, \quad (14)$$
$$y = y(\varphi) = r_0\,sin\,\lambda\,sin\,\varphi \cdot e^{k\varphi}, \quad (15)$$
$$z = z(\varphi,u) = r_0\,cos\,\lambda \cdot e^{k\varphi} + u, \quad (16)$$

where $\boldsymbol{\lambda}$ is the angle between the axis *OZ* and the generator of the cone, longitude $\boldsymbol{\varphi}$ is the angle between the *XOZ* plane and the moving plane of the axial section, $\boldsymbol{k}$ is a number, $\boldsymbol{r_0}$ is a constant value.

“Malvia”, a minaret of a large mosque in Samarra, Iraq, has a similar structure (Fig. 10). Its name is literally from Arabic means "a spiral shell". The height of the sandstone minaret reaches 52 meters; the width of the square base is 33 meters. Built in 852 to remind of the presence of Islam, the Malviya minaret has been the largest in the world for some time. The unusual form of Caliph Jawara al-Mutawakkil was pushed by the Babylonian concept of a multistage religious building - the ziggurat.

The screw movement of a straight line that intersects the axis of rotation at a certain angle $\Theta$ forms a spiral surface with straight lines forming in the planes of the beam, while moving at one end along a conical spiral. Slope lines are conical spirals, which are described by direct generators. Parametric equations are:

$$x = x(u,v) = (ae^{mu} + vsin\Theta)cos\,u, \quad (17)$$
$$y = y(u,v) = (ae^{mu} + vsin\Theta)sin\,u, \quad (18)$$
$$z = z(u,v) = a\lambda e^{mu} + vcos\Theta, \quad (19)$$

$$x = x(v, \psi) = (a + r\,sin\,\psi)\,cos\,v, \tag{20}$$
$$y = y(v, \psi) = (a + r\,sin\,\psi)\,sin\,v, \tag{21}$$
$$z = z(v, \psi) = r\,cos\,\psi + pv. \tag{22}$$

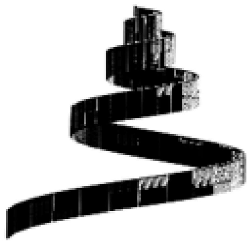

*Fig.9*

*Fig.10*
*bigenc.ru/media/2016/10/27/1235184735/13438.jpg*

*Fig.11*

*Fig.12*
*designboom.com/weblog/images/images_2/erica/814/spiral01.jpg*

In the case of a museum project in Taipei, under the name "Spiral Garden Museum" (Fig. 12), we take $\Theta = \varphi$, therefore, we obtain a spiral conical strip of a zero Gaussian curvature with straight lines in the beam regions (Fig. 11).

***A circular helical surface with forming circles*** (Fig. 13) can be used as a basis for designing water slides, such as the Bodislide slide at the Rodeo Drive water park in St. Petersburg, Russia (Fig. 14) [2]. It is formed by a screw movement of a circle of constant radius. The plane passes through the helical axis, with the helical axis located inside the surface. Parametric equations for specifying the surface are:

*Fig.13*

*Fig.14*
*akvaparki-mira.ru/wp-content/uploads.jpg*

***The surface of the helical column*** can be included both in the class of helical surfaces and in cyclic ones, being a special case of a straight circular helical surface, when ***a <r*** [4]. The parametric equations of the surface are defined as:

$$x = x(\vartheta, \nu) = a\cos\nu + r\cos(\vartheta + \nu), \quad (23)$$
$$y = y(\vartheta, \nu) = a\sin\nu + r\sin(\vartheta + \nu), \quad (24)$$
$$z = z(\nu) = p\nu. \quad (25)$$

In Fig. 15 depicts the surface of a helical column with ***a*** = ***r***. This surface can also have two generating circles. This opportunity was used by the architectural company CDI Gulf International, which developed the Cobra Tower project in Kuwait (Fig. 16).

**Conclusion**. As a result of the study, it was concluded that the creation of spiral-shaped and screw-shaped buildings and structures, which shape coincide with complex analytical surfaces, has been successfully implemented in practice [8-10]. Consequently, this trend in architecture and construction has great potential in the future [11], due to the fact that this type of construction is not only pleasing to the eye, but also quite economical and variable in terms of application, it is perfectly combined with the surrounding nature and meets modern development trends. architecture and construction.

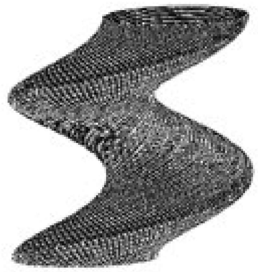

*Fig.15*

*Fig.16*
*budport.com.ua/assets/up-load/userfiles/Olga/1_24.jpg*

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## ПРИМЕНЕНИЕ СПИРАЛЬНЫХ И СКРУЧЕННЫХ ПОВЕРХНОСТЕЙ В СОВРЕМЕННОЙ АРХИТЕКТУРЕ

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В современной архитектуре прослеживается очевидная тенденция: от использования простых геометрических структур к различным пространственным формам, имеющим уникальный вид и символизирующим динамику, развитие и путь вперед. Проектирование зданий, характеризующихся разнообразием форм, приводит к необходимости классифицировать эти формы и, по возможности, выбирать для них подходящую аналитическую поверхность. В статье рассматриваются некоторые спиральные, скрученные и винтовые поверхности, а также способы их создания. Изучаются возможности архитектурного проектирования на основе этих поверхностей, что иллюстрируется рядом впечатляющих примеров зданий и сооружений.

**Ключевые слова:** аналитические поверхности, современная архитектура, спиральные и скрученные поверхности, геликоид, линейчатая поверхность, спиральная полоса, спиралевидная поверхность, поверхность винтового столба.

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