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ON DYNAMIC SPIRAL PATTERNS - POLYGONAL FRAMES INSCRIBED IN CIRCULAR SECTIONS OF QUADRIC SURFACES

Aleksandar Čučaković [1]
Magdalena Dragović [2]
Svetlana Shambina [3]

Abstract

Spiral forms, nowadays actual, especially in the area of architecture and design, were the inspiration point for an creative geometrical research. Acquainted with different approaches, present in practical and theoretical sense, from empiric creations to parametric modeling, we chose to explore the dynamic patterns which appear in spiral shapes generating process.

Since the term "spiral" is directly connected to circles we aimed our investigation to quadric surfaces with circular sections, where inscribed polygons obtain the spiral form by "twisting". We observed the series of inscribed polygons as dynamical spiral patterns of scaled frames, according to the geometry of the basic quadric surface. This investigation includes surfaces: cone, sphere, ellipsoid and elliptic hyperboloid. Three types of regular polygons are here included: triangle, square and pentagon.

3D model presentation of dynamic spiral patterns is performed in engineering software Auto-CAD. While considering the possibilities in application of such creations (models), some optimal intersecting surfaces are discussed.

Key words: *spiral patterns, helix, quadric surfaces, polygonal frames*

[1] Aleksandar Čučaković, PhD, associated professor, University of Belgrade
[2] Magdalena Dragović, PhD, assistant professor, University of Belgrade
[3] Svetlana Shambina, PhD, assistant professor, Peoples Friendship University of Russia, Moscow

1. INTRODUCTION

The expression that "everything is constantly changing and moving very fast…" would be an attempt to describe contemporary life style. The architecture, i.e. design have their responses to this concept in dynamic movements of the building's facade elements (surfaces), changeable in time dimension. Such architecture offers David Fisher. His "buildings are endowed with movement and are able to change their shape over the time" [9]. Here, the static observer has dynamic experience of the four-dimensional architecture. Vis-a-vis to the static observer the one in a motion, inside or outside the spiral structure, has a similar experience of the architecture [6]. Both offer an amazing dynamic effects which become the inspiration "origins" of our research. We focused the attention on the specific geometric topic: dynamic spiral patterns generated by spiral movement of the unit – a regular polygon.

Figure 1*. The Twist Bridge over the Vlaardingse Vaart, Netherlands, by West 8 Architects, 2001.* *http://www.west8.nl/projects/bridge_vlaardingse_vaart/*

The dynamic spiral movement of the constructive "frames" on the pedestrian bridge in Netherlands derived an interesting example of dynamic spiral pattern (Fig.1). The origin geometric shape is a prism like with square base. The most common spiral patterns originated from prismatic geometric shapes with various types of the polygonal base. The other unusual kind of shapes, presented here, have their origin geometry referred to the 2nd order surfaces - quadrics: cone, sphere, ellipsoid and elliptic hyperboloid.

2. THE DYNAMIC SPIRAL PATTERNS CONCEPT

The most common spiral structures are generated by spiral movement of the "structural frame", i.e. unit, along the axis of

rotation. The important elements for the spiral surfaces classification are:
1. the frame shape: polygonal or curved (regular or non regular),
2. if the frame shape is constant, or variable in size,
3. the axis of rotation: straight line or a curve (planar or spatial) and
4. the relation of a plain containing a polygonal frame and the axis of rotation: perpendicular or non-perpendicular.

Our research concerns generation process of some specific spiral structures which geometric origins are quadric surfaces. The process begins with the system of inscribed polygons inside circular sections of the origin surface. In order to obtain spiral structure, i.e. an dynamic pattern, each polygon-frame rotates for a predefined angle.

Several prototypes of dynamic spiral patterns, presented in Table1 use some adopted criteria necessary for their construction:

- type of the regular polygon inscribed in the circular section of the origin surface
- fill rotation angle (sum of partial rotations) - $\varphi/^o$
- partial rotation "step" – $s/^o$
- number of partial rotations – n
- number of circular sections – n+1

Table 1. *Overview of the origin surfaces and necessary criteria for obtaining the dynamic pattern*

	Surface type	**Polygon type**	**φ**	**S**	**n**	**n+1**	**Contour line**
1.	CONE	Triangle	120^o	5^o	24	25	straight line
2.	SPHERE	Square	90^o	5^o	18	19	Circle
3.	ELLIPSOID	Pentagon	72^o	4^o	18	19	Ellipse
4.	ELHY	Pentagon	72^o	6^o	12	13	Hyperbola

The category of the spiral surfaces, containing polygonal cross-sections, elaborated by Ivanov, is called polyhedral "box type" surfaces [3]. Here, the author presented the analytical approach to the topic, while some magnificent applications in the contemporary architecture were reported by Shambina [5]. An multidisciplinary approach to similar topic offered Converso in the project of "Nagashima" lamp's prototype [1], which provided continuity of all the projects phases: from geometric design to technology processing, by "digital bridges"[1].

[1] "Digital bridges" are the procedures that establish a dialogue between two or more software programs [1].

The basic construction principles of the dynamic pattern are presented in Fig. 1 a, where the origin surface is a cone and polygon unit is a regular triangle. The "wireframe" 3D model is generated.

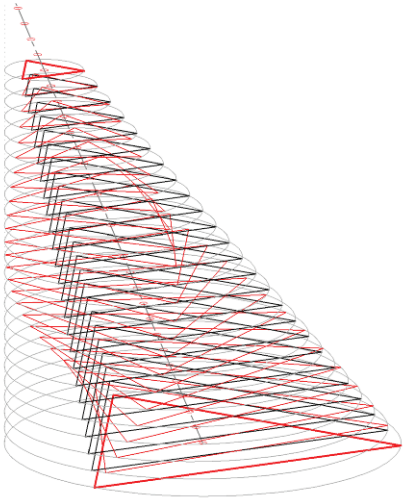


***Figure 1**. Wireframe 3D model of the system of rotated polygons; Origin surface - CONE; polygon unit - regular triangle*

The idea of remaining the identical position of the starting – "entrance" and the ending – "exit" polygon conducted the rotation fill angle $\varphi = n \times s$, where φ is the central angle over the edge of the basic polygon (fig.2) This principle resulted with dynamic patterns of *type A*.

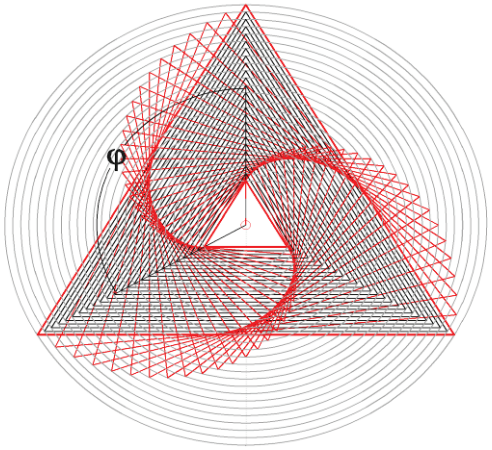


***Figure 2**. Spiral pattern view - line of polygon centers appear as a point;* ($\varphi = 120^o$, n=24, $s=5^o$) *Origin surface - CONE; polygon unit - regular triangle*

The final model of the dynamic pattern requested dimensions (thickness) of the frame unit. Hence, the square cross section of the frame is added (Fig.3). 3D model structure included both: solid model of the spiral-twisted object and frames (Fig.3a). All the models of type A, shown in Table 2, were created by using advanced software's modeling tools in Auto CAD software.

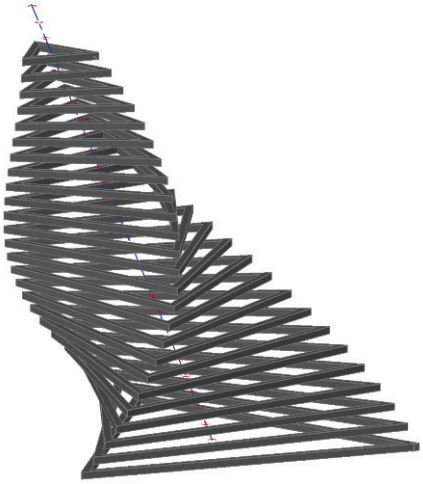


Fig.3 *3D frame structure model A*

Fig.3a *3D solid structure model A*

The previous author's investigation of the similar topic included practical aspect of employment of dynamical patterns, where the optimal intersection shape played the role of communication [2]. The

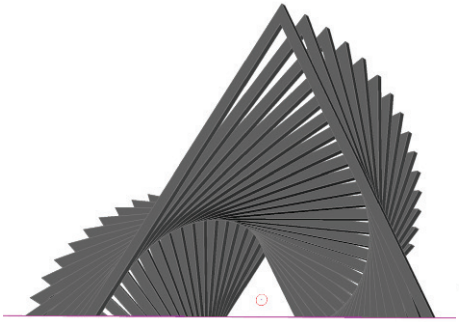


Fig.4 *An intersection with a plane*

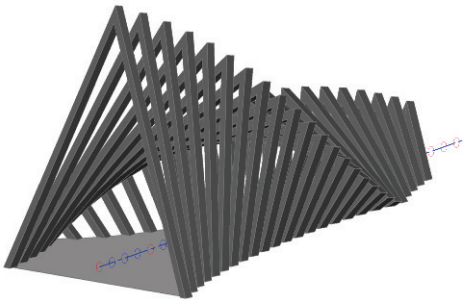
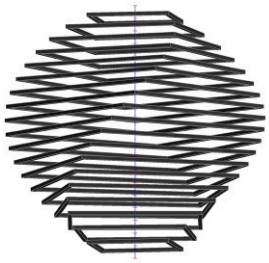
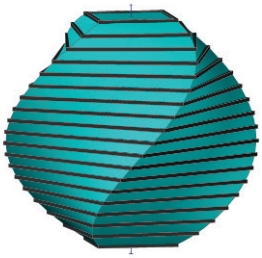
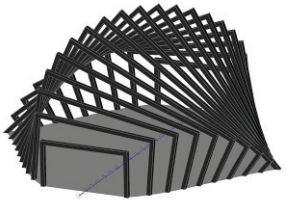
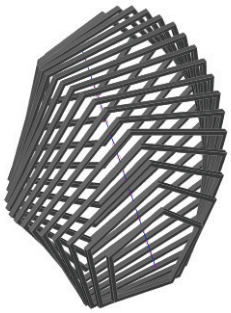
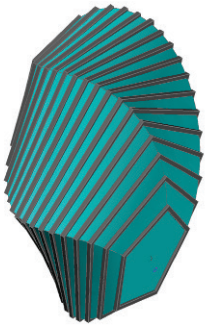
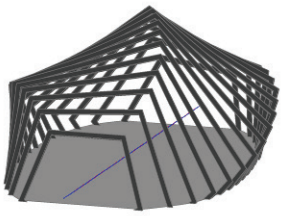
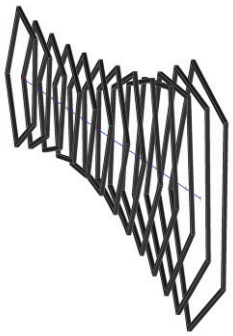
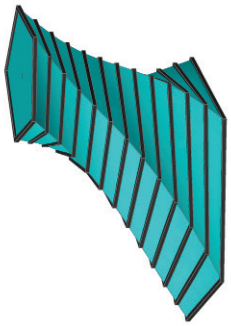


Fig.4a *Axonometric view*

3D frame structure model is intersected with the plane parallel to the line of centers, containing one edge of the smallest triangular frame. As the result, an attractive dynamics appear inside of spiral pattern over the irregular curved geometry of the "floor" surface (Figs.4 and

4a). Each pattern (Tab.2) has been analyzed, and cut in a manner that its dynamics retain (regarding the line of centers).

***Table 2**. The dynamic patterns of type A inscribed in the origin surfaces*

	The frame model A	The solid model A	Intersection model A
2. SPHERE			
3.ELLIPSOID			
4. ELHY			

The variation of the previous concept with spiral movement of a basic frame (polygon) along the axis passing through the centers of polygons came with idea that line of centers could be some other line. The basic construction principles of the new dynamic pattern of Type B are presented by detailed explanations and figures, in the case of origin surface – cone and a polygon unit – regular triangle (Fig.4).

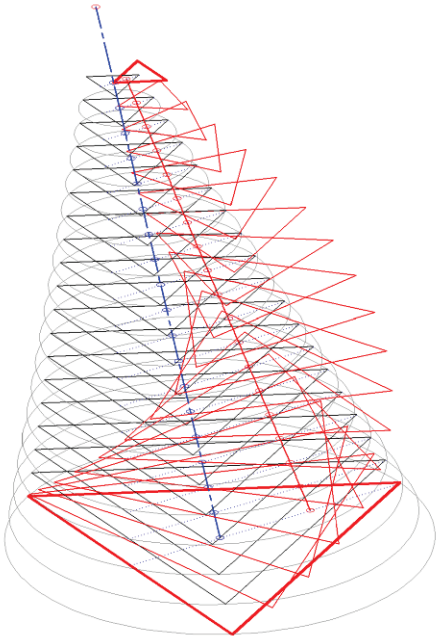


Figure 5. *Wireframe 3D model of the system of rotated polygons; Type B; Origin surface - CONE; polygon unit - regular triangle*

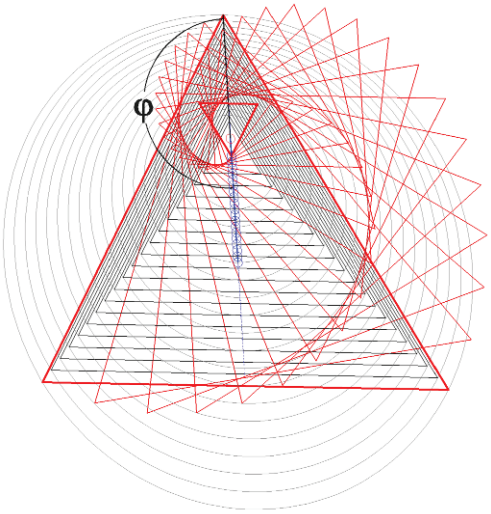


Figure 5a. *Spiral pattern view - a new line of polygon centers appear as a point;*(φ=180^o, n=24, s=5^o) *Origin surface-CONE; polygon unit -regular triangle*

The new adopted criteria, regarding the line of base points – centers of polygon's rotation, rely on the principle that the base point is a midpoint of radius connecting center of the polygon end the polygons vertex (Fig.5a-c). Hence, in the case of origin surface - cone, line of the base points is a straight line, while in the cases of origin surfaces: sphere and ellipsoid, this line is a planar curve. The adopted polygon's fill rotation angle is $\varphi=180^{o}$.

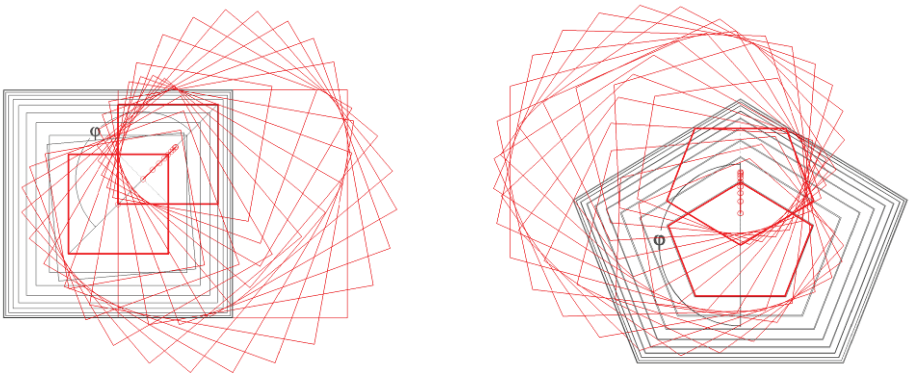


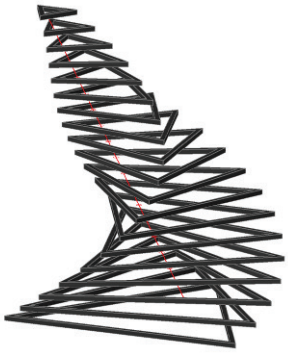
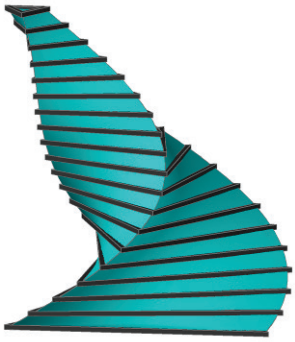
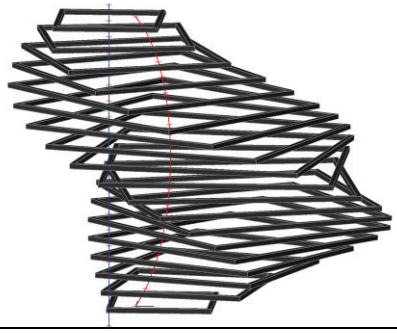
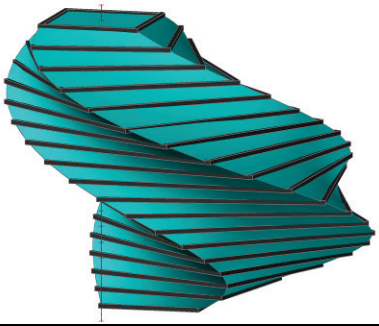
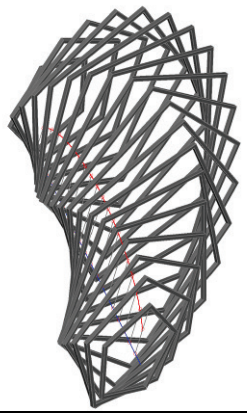
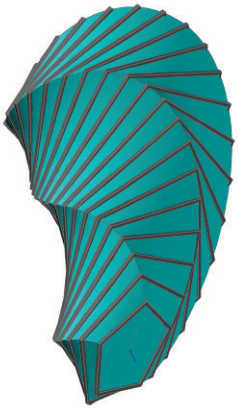
Fig.5b-c Spiral pattern view; Polygonal units: b)square, c)pentagon

The final form of all three frame dynamic patterns and 3D solid models of the spiral structures are presented in Table 3.

4. CONCLUSION AND FURTHER INVESTIGATIONS

Parametric modeling and advanced computer modeling software solutions have produced several significant innovations in "spiral design" of various "products": architectural design of buildings [4] and bridges [8], eco-installations, pneumatic architecture installations [7], furniture peaces [1], etc. The dynamic spiral patters and their shapes are for sure non-limited topic for further investigations. We believe that the types of dynamic polygonal patterns - A and B, presented in this paper, as well as 3D models of spiral surfaces that the patterns are incorporated in, have a significant place in a wide creative base for the innovative future design. Beside its creative role, in general, here presented topic has its educative aspect in the advanced Descriptive Geometry level concerning: elaboration of circular sections of quadric surfaces, 3D spiral structures modeling, prototyping and computer programming. In such manner, in further investigations we will include all of this roles into our consideration.

***Table 3**. The dynamic patterns of type B inscribed in the origin surfaces*

	The frame model B	The solid model B
1. CONE		
2. SPHERE		
3. ELLIPSOID		

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