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Full Length Article

Flexagon grid: a novel method of creating dynamic spatial forms based on the synthesis of tritetraflexagons

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ABSTRACT

In this paper, we describe the method for the formation of spatial mechanical structures of flexagon grids, which aims to improve the technical and constructive qualities of dynamic mechanical systems and enrich the design practice of designers and artists with new materials that harmoniously combine both technical and expressive properties. This method can be regarded as an attempt to respond to the social demand of the modern consumer to surround himself with objects and things of a new reality that, due to the introduction of a dynamic component, at a qualitatively new, including aesthetic level, would satisfy his need for visual and physical comfort. The described structures can be appropriately focused on the improvement of the shape-forming and aesthetic qualities of design products, architectural forms and, in general, the filling of the object-spatial environment with objects with a dynamic component in its functionality and aesthetics. Flexagon grids must be attributed to spatial and plastic solutions, implemented in the framework of the kinetic direction in design and art, with the underlying idea of shape movement.

1. Introduction

The common need of contemporary people in having in their everyday life objects capable to dynamic transform its shape in a short time will inevitably lead to the spread of technologies that can satisfy this request. Described here method of creating dynamic spatial forms based on structural conjunction of tritetraflexagon may become a basis of such technologies. It should be noted that the creation of this method was preceded by the acquaintance of the authors with spatial network sculpture *Galatea* by Stuchebryukov [2] and *waving-things* by Miturich [5]. So, the mentioned kinetic spatial-network sculpture of architect Stuchebryukov [2] consists of twenty-two thousand structurally united safety razor blades and possesses plastic properties mainly due to the original mechanical joint of its constituents and has not any other elements in its composition. Further, it would be appropriate to quote the statement of a famous representative of kinetic art movement, Vyacheslav Koleichuk, who said in connection with a kinetic sculpture of Stuchebryukov [3]:

> ...the object ... resembles the construction of the network structure of mathematician Chebyshev ... in which the change of the spatial shape occurs only due to changes in network corners. Transformation ... resembles a small performance of shape-making, happening in front of the audience. In the hands of the author, the steel fabric begins to pour, becoming a cylinder, a dome, a cone, resembling scales of fish or snakes. The work has a great gaming potential, causing emotional and intellectual empathy of the viewer.

Engineering and technical creativity of Miturich included description and creation of apparatus reproducing the wave motion observed in organic nature in insects and animals. He wrote [6]:

> ...I was interested in the problem of revealing the true patterns of the dynamics of living beings in flight, navigation and ground movement. ... Understanding the wave nature of the movement, I managed to implement a number of wave device vehicles.

In the 1930s, he proposed the propeller in the form of a fish body for vessels, gliders, airplanes and airships [7] and a propulsion device for ships in the form of a flexible fish body [8]. In general, he offered nine technical ways to solve the principle of wave

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motion for flight apparatuses and planning in the air, for swimming in water and sliding on its surface and for movement on the ground, a mechanism of motion that exists only in nature [6].

The theoretical justification, historically foreseeing the appearance of flexagon grids, was given by Chebyshev [1]. In his work [1] were reflected the mathematical principles of transformation of spatial structure due to changes in network angles. This work is concerned with networks with equilateral cells involved in the formation of curvilinear surfaces. Chebyshev gives mathematical proof that matter, curving to cover some body, does not change anything except the angles of inclination of warp threads and weft threads, while the length of threads remains the same [1].

2. The method of creating flexagon grids

2.1. Description of the proposed method

The essence of the method is combining the flexagon loops (tritetraflexagons) into mechanical spatial reversible structures. Note that tritetraflexagons are a kind of flexagons with three square surfaces. Fig. 1 shows the scheme for manufacturing a tritetraflexagon [4] with front and rear side of the sweep.

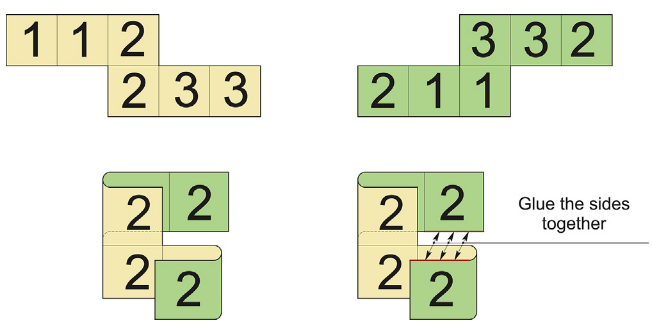

Fig. 1. The scheme for creating a tritetraflexagon.

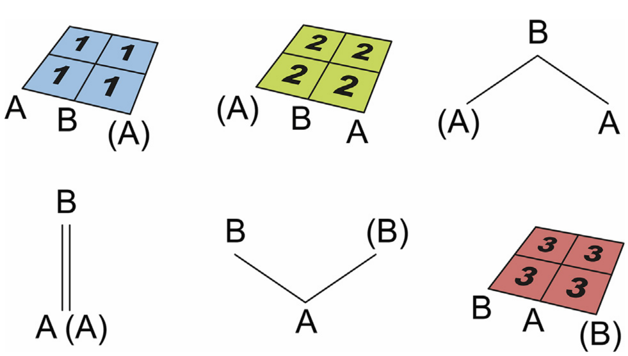

Fig. 2. The principle of operation of the tritetraflexagon.

The principle of its operation is illustrated in Fig. 2. The order of execution of the paper model of the flexagon loop is shown in Fig. 3. Thus, the flexagon grid should be considered a spatial mechanical honeycomb structure; the basis of the reversible properties of the joints is the use of the topological properties of the tritetraflexagon.

2.2. Structure of loops

A composite version of the flexagon grid consists of the following parts (see Fig. 4): "bed", "connection" and "latch". The "connection" axes enter into the lugs of the "bed", providing a reciprocal action to connection. The purpose of the latches is to keep the structure assembled.

The sequence of assembly of the flexagon loop is shown in Fig. 5 and a section of a loop of a flexagon grid is shown in Fig. 6.

2.3. The principle of combining the flexagon loops

The formation of assembling structures of flexagon grids appears by connecting them with joints as shown in Fig. 7. The use of a hinged joint in this case is due to its versatility, both in the formation of rigid-cell (non-deformable in the cells) structures, and in those embodiments of structures in which the cells, in the process of spatial transformations of the flexagon grid, are deformed in the faces. The latter case is typical for the cellular scheme of combining flexagon loops (tritetraflexagon) into grids (see Figs. 8e, 11).

2.4. Schemes of flexagon grids

Preliminary analysis revealed the following main types of flexagon grids suitable for practical use in the creation of utilitarian and/or aesthetic objects (see Fig. 8).

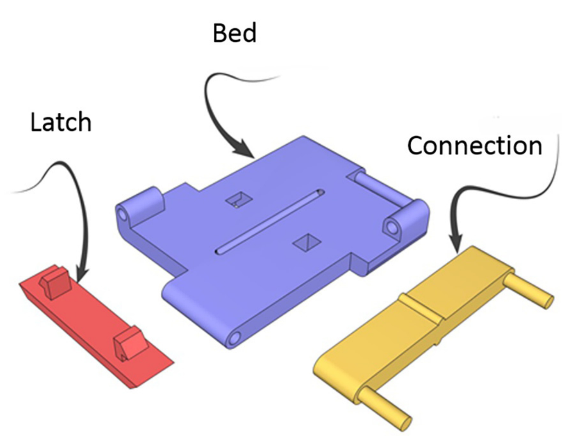

Fig. 4. Details of the loop of the assembling flexagon grid.

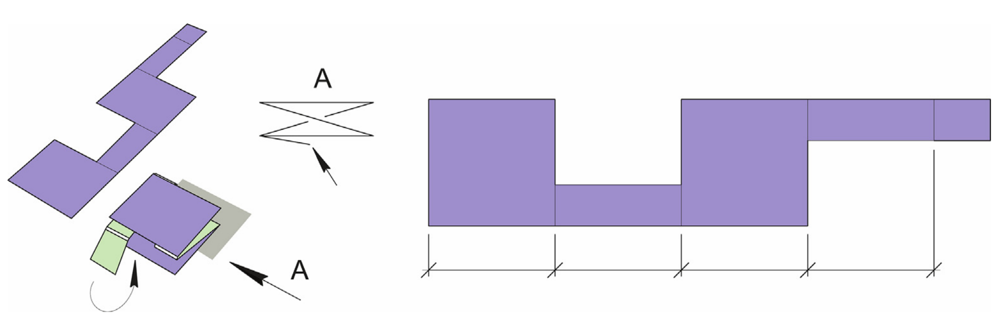

Fig. 3. The sweep and the procedure for making a paper model of a flexagon loop.

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