Resilient Cyclic Knots for Studying of Form-Finding Methods

Dmitri Kozlov
Research Institute of Theory and History of Architecture and Town-planning
Russian Academy of the Architecture and Building Sciences
21-a 7th Parkovaya St. Moscow, 105264, Russia
E-mail: kozlov.dmitri@gmail.com

Abstract

The paper is dedicated to pedagogical uses of cyclic periodic knots made of resilient filaments. It describes one of my recent experimental workshops. The aim of the work was to design and build a large-scale model of dome-like form and elaborate an algorithm of its form-finding process.

Last year in Moscow I organized a workshop for the students of Moscow Architectural Institute. The aim of the workshop was to introduce to the students some of the new ideas and principles of physical form-finding based upon the properties of resilient cyclic knots. Today, when digital form-generation methods have become predominant in architectural and design education, the experimental exploring of alternative approaches to modeling and form-finding is especially important for students. The combination of physical and digital form-finding experiments helps them to understand the mathematical background common to both of these methods.

My form-finding method derives from the fact that cyclic periodic knots made of resilient filaments behave as kinetic form-finding structures [1]. Knots of this type must have a large number of physically contacting crossings functioning as the vertices of surfaces. The crossings slide along the resilient filaments and the filaments at the same time twist around their central axis. The waves on the filaments move and change their lengths to adapt to the current disposition of the contact crossings. Thanks to these properties the knots change their geometry as a whole and create vertex or point surfaces with an arbitrary Gaussian curvature. The complicated knots of this type I designated as NODUS-structures [2].

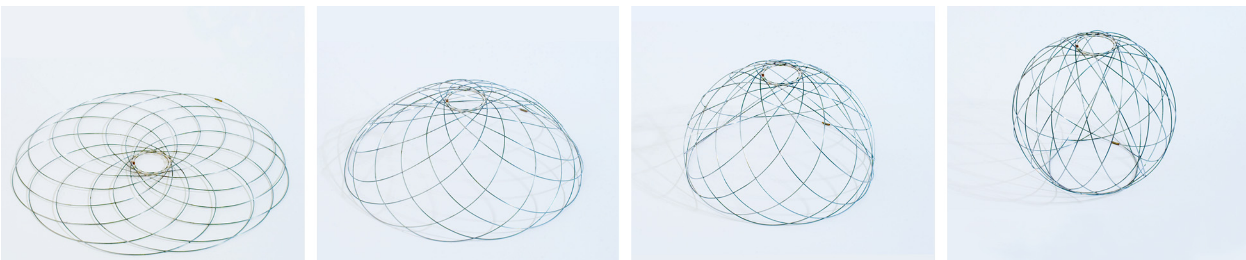

Figure 1: *Stages of transformation of resilient cyclic knot of steel wire.*

I took as a prototype one of my steel wire NODUS-structures that is a Turk's-Head-like non-alternating knot with 13 loops or bights and 12 leads (Figure 1). The material we used for the model was fiberglass wire around 4 mm in diameter coated in orange plastic divided into 13 modules of equal length corresponding to 13 loops of the knot.

We started our work by devising a detailed algorithm of the assembly process and depicting it as a series of pictures drawn on a computer. Each stage of the algorithm consisted of the order of connection of the corresponding module with the previous one and the order of its weaving through all of previous modules. The passing of the module in a crossing point over and under another module was marked as plus (+) and minus (−) signs correspondingly. This sequence of over- and undercrossings was used as a reference guide to make the structure of the chosen non-alternating knot correctly.

Figure 2: *Process of algorithmically assembling of fiberglass wire modules into knotted structure.*

As a preliminary step we placed a ring in the center of the future structure and attached it to the floor to fix the central opening of the structure and tense it. Then we began the assembly of the structure, adding the modular elements of the knot, forming its loops and interweaving the modules according to the algorithm (Figure 2).

Figure 3: *Fixing central and peripheral openings of the structure with rings and the final shape of model.*

After we had finished all of the algorithm stages, we detached the central ring and tested the transformation of the structure. It worked similar to the small wire model though it was not so stiff. Then we transformed our structure into the form of a truncated sphere and added another fixing ring on the peripheral opening (Figure 3). As a result the whole structure became stretched inside the waves of the fiberglass wire and compressed at the contact crossings.

Though for this experimental work was taken the simplest NODUS-structure that formed parts of spherical surfaces, it would be interesting to continue this work and try to design and build large scale structures of such forms as hyperboloids, tori, pretzels, self crossing, one-side and knotted surfaces, because the given method of form-finding may be extended to practically unlimited variety of surfaces [1] This experiment may serve as good practice of physical modeling and form-finding for students as well as production of new pieces of kinetic art.

References

[1] Kozlov, D. (2012) Knots and Links As Form-Generating Structures. In: Bruter C., ed. *Mathematics and Modern Art: Proceedings of the First ESMA Conference* [Symposium organized by European Society of Mathematics and Art, held at the Henri Poincaré Institute, Paris, July 19-22, 2010], Proceedings in Mathematics, Vol. 18, Berlin: Springer-Verlag, 105-115.

[2] Kozlov, D. (1991) Polymorphous resilient flexible shaping structures “NODUS” for space and other extreme environments, In: Bell, L., ed. *Proceedings of the First International Design for Extreme Environments Assembly (IDEEA)* [Symposium organized by Sasakawa International Center for Space Architecture, University of Houston, Houston, Texas, November 12-15, 1991], Houston: IDEEA USA, 259-260.