RESILIENT CYCLIC KNOTS FOR STUDYING OF FORM-FINDING METHODS

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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 transformable dome with tent covering and elaborate an algorithm of its form-finding process.

In the summer of 2012 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].

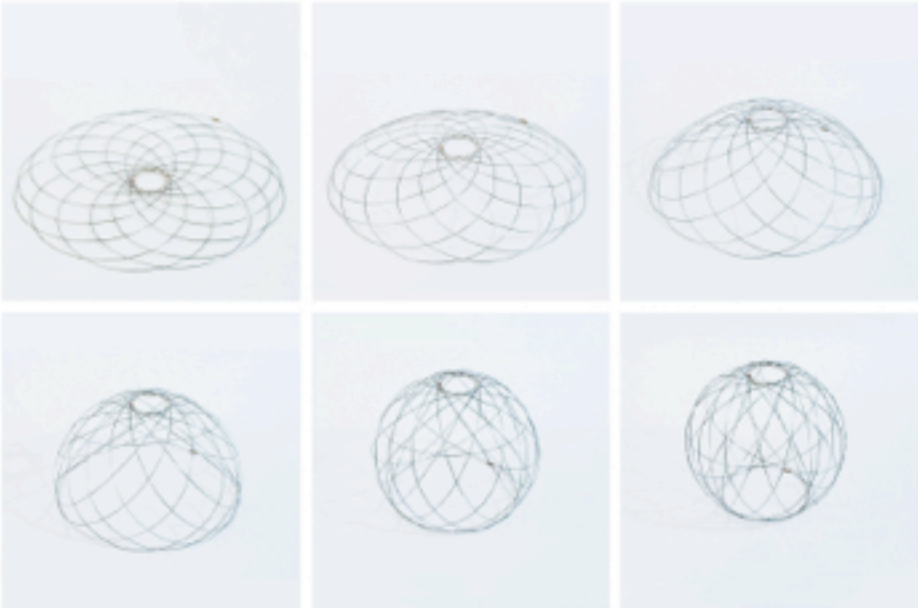

Fig. 1 Stages of transformation of resilient cyclic knot of steel wire

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 (Fig. 1). Though this knot was made of a single piece of wire I proposed to the students to build the scale model of a large transformable dome of 5 meters in diameter with tent covering (Fig. 2).

Fig. 2 Dome and tent design

It would be difficult and inappropriate to weave such a big structure with the single continual piece of filament material. Because we intended our model to copy not only the final shape of the dome but also the process of its assembly and erection (Fig. 3), we decided to divide it into 13 modules of equal length corresponding to 13 loops of the knot.

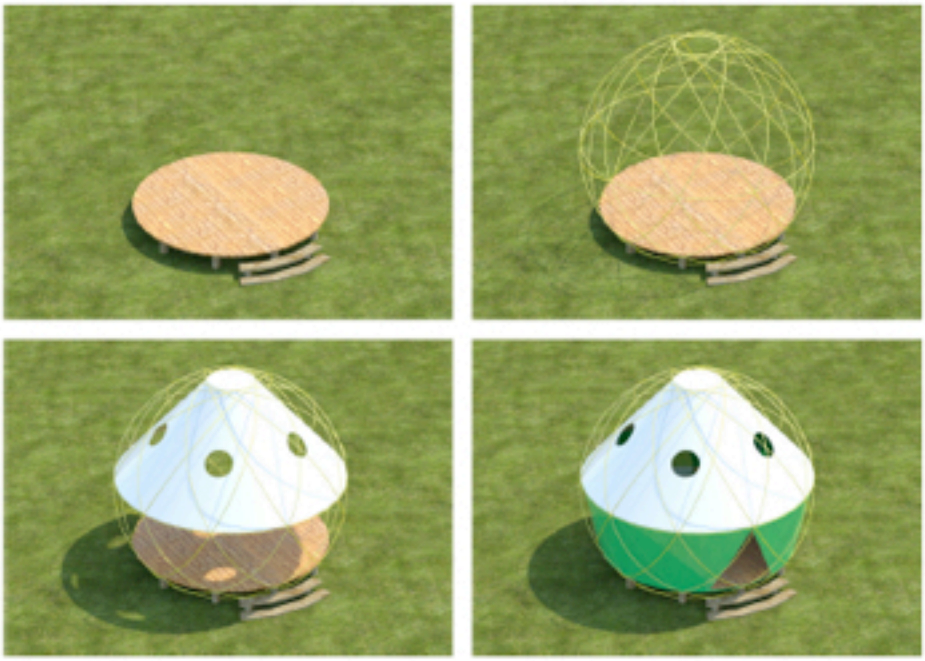

Fig. 3 Process of erection of the dome and tent

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. This lightweight and non-conductive material is very suitable for the modeling of resilient cyclic knots and links though its bending abilities are limited to some minimal radius. Values of radii less than this minimum may result in breakage.

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 (Fig. 4). This sequence of over- and undercrossings was used as a reference guide to make the structure of the chosen non-alternating knot correctly.

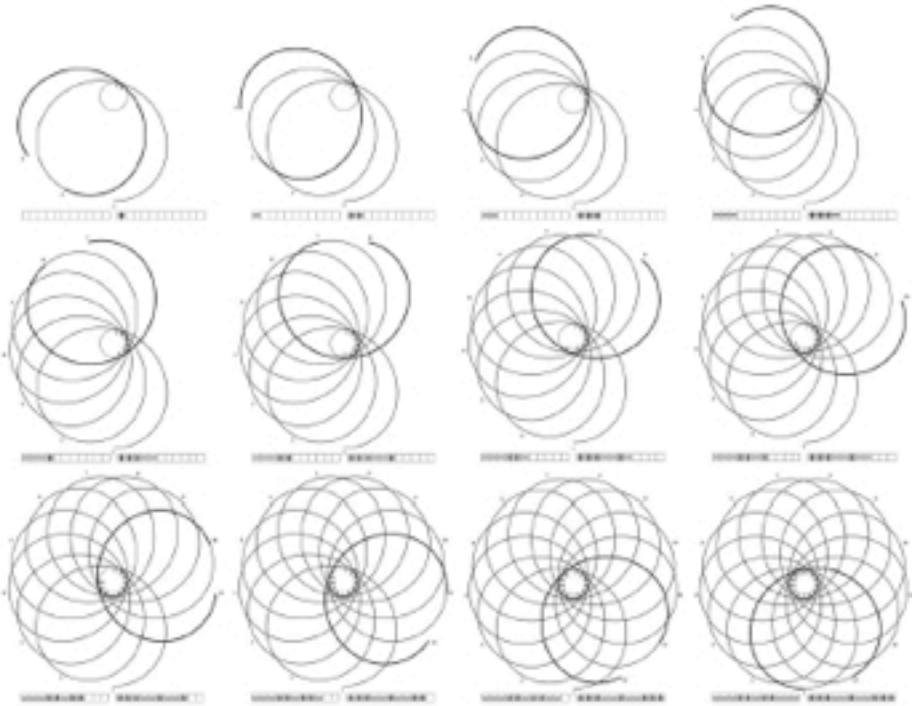

Fig. 4 Algorithm of assembly process

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 (Fig. 5).

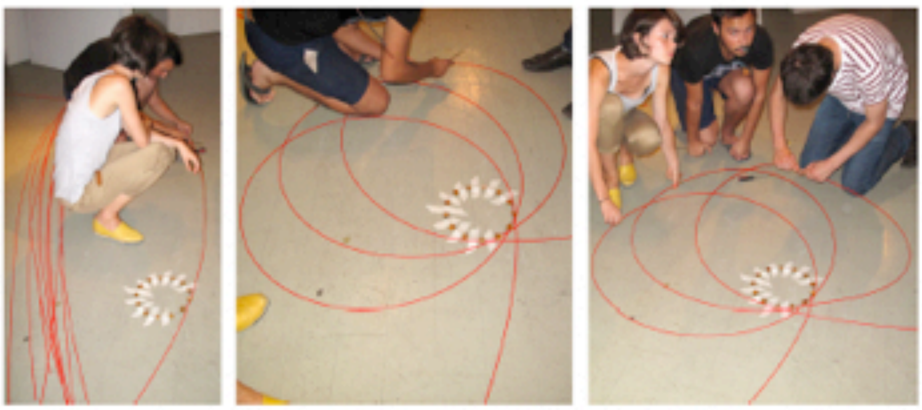

Fig. 5 Assembling of fiberglass wire modules into knotted structure

After we had finished all of the algorithm stages, we detached the central ring and tested the transformation of the structure (Fig. 6). It worked similar to the small wire model though it was not so stiff.

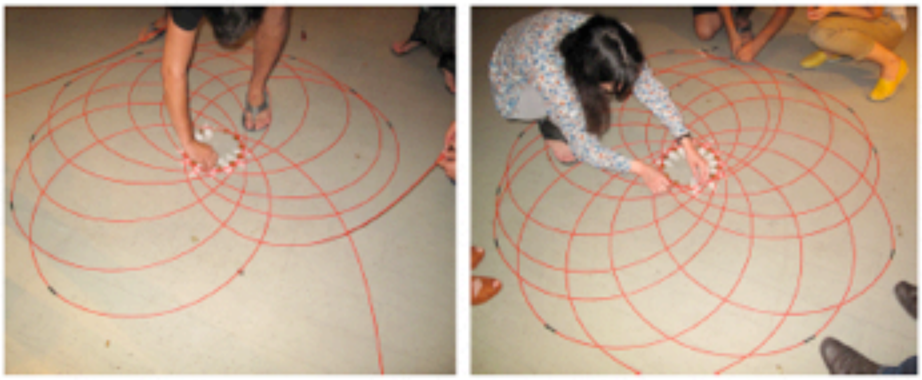

Fig. 6 Fixing central and peripheral openings of the structure with rings

Then we transformed our structure into the form of a truncated sphere and added another fixing ring on the peripheral opening (Fig. 7). As a result the whole structure became stretched inside the waves of the fiberglass wire and compressed at the contact crossings.

Fig. 7 Finding the final form of model

The next work was in finding the form of the tent covering and in searching of different ways how to fix the tent to the dome (Fig. 8).

Fig. 8 Experiments with tent covering

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 [3]. 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

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