UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Servei de Gestió de la Innovació

Morphing surfaces made of slidable rods

The Challenge

Shape morphing surfaces and tubes are used in a wide variety of fields. These include biomedical devices (stents, endoscopes, catheters), soft robotics (artificial muscles, grippers, wearable exoskeletons and active textiles), adaptive/organic architecture or deployable structures in aerospace.

All these technologies rely on the straining of the underlying material (e.g. rubber in a pneunet), which is inherently limited, or on rotations of structural elements (as in pantographs, origami or kirigami), which lead to “locking” of the morphing mechanism. Thus, the morphing capacity is limited. Furthermore, each morphable surface system is specifically designed for a specific morphing program (e.g. deploy a space antenna from tubular to nearly flat or shorten an artificial muscle by inflating a braid), and hence are not versatile in nature. A key challenge in this field is a balance between deformability and controllability. A very soft rubber is very deformable but not controllable. To direct deformation, stiff inclusions such as wires can be introduced, at the cost of reducing the amplitude of morphing. Some pin-jointed structures or origami are very controllable (“1 degree-of-freedom” deployment) but at the expense of very limited morphing versatility.

The Technology

The technology relies on the mechanical concept that by assembling surfaces made out of slidable rods, such surfaces can achieve extreme morphing by sliding the rods non-uniformly. The physical realization of such meta-material is very easy since it only needs a collection of rods with suitable inter-locking geometry made out of any elastic material, see Fig. 1 for 3D printed rods and their geometry. As such, this technology is scale-free.

Such surfaces made of slidable rods can adopt a wide variety of shapes. For instance, an initially straight tube can morph into a flat annulus, a bulged tube, a trumpet, a basket (Fig. 2), a sphere, or a cone (not shown). A mathematical model validated with experiments shows that this single tubular device can adopt essentially any axisymmetric smooth.

Non-axisymmetric morphing is also possible. See Fig. 3 for different bending modes, possibly combining twisting and bending of the rods.

Innovative advantages

- Unlimited local deformation granted by unlimited sliding enables extreme morphing.
- As opposed to sparse pin-jointed or braided structures, this technology provides a continuous envelope with tunable porosity.
- In stent applications, a continuous envelope reduces the stress concentrations and tissue damage.
- In space antennae or solar sail applications, our continuous tubular structures can be efficiently packed in a space-craft to be later deployed into nearly planar or curved shapes. .
- In tubular devices made with our technology with a pneumatic chamber, shortening can be coupled to rotation, enabling simple rotational artificial muscles, which with current McKibben muscles require complex assemblies.
- A single mechanism can implement bending and inflation of tubular devices,
- Functional morphing is accompanied by an aesthetically appealing change of helicity of the rods on the surface. (the basket in Fig. 2 flipped upside down).
- Shape can be programmed by suitably controlling the mechanical properties of the constituent rods, for instance using their geometry.

Current stage of development

A complete mathematical theory has developed to understand this new principle of morphing and to predict the mechanical properties of the meta-material surfaces. There are prototypes built 3D printing, ranging from rods with sub-micron features (two-photon lithography) to rods with centimeter features (filament 3D printing). The morphing capability and mechanics of these prototypes (Figs. 1, 2, 3) have been tested and the mathematical theory has confirmed, which thus provides a solid conceptual foundation to engineer devices based on this technology.

Applications and Target Market

We envision three different fields of application: Soft robotic/biomedical devices, Design and architecture and Space deployable structures.

Reference number
MKT2021/0175_H

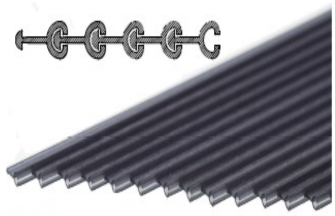


Fig. 1

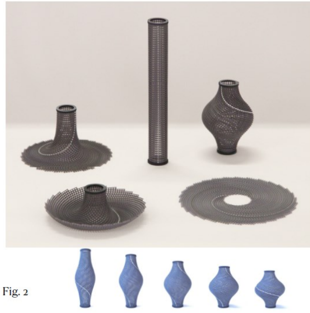
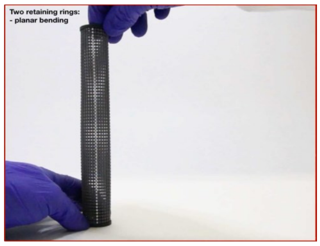
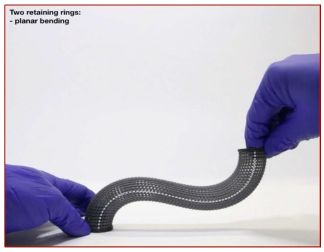


Fig. 2





Business Opportunity
Technology available for licensing with technical cooperation

Patent Status

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