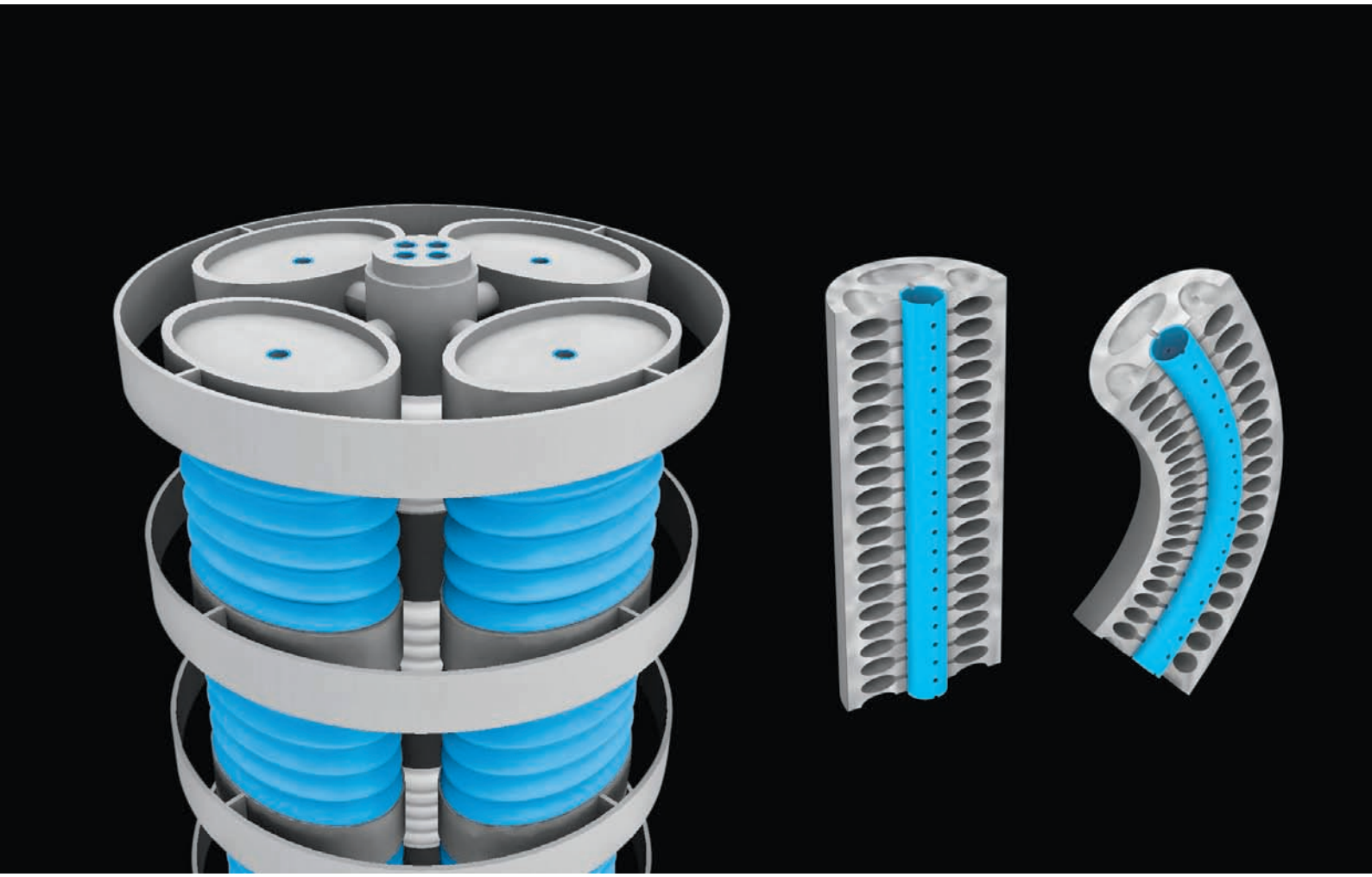
Pneumatic lightweight structures

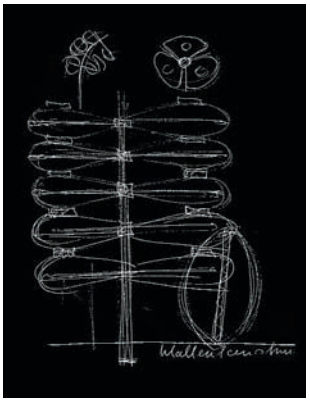
FESTO



Documentation
of development

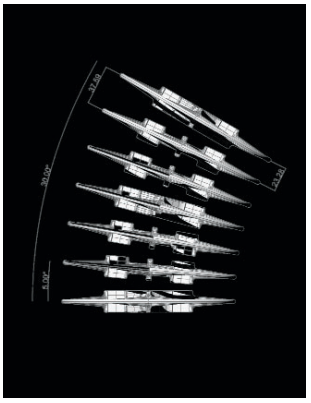
Info

Manoeuvring with innovative lightweight structures



Basic pneumatic phenomenon (sketch)

Displacement element/ modular system

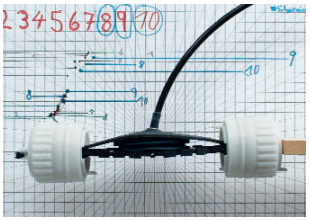


30 degree offset radius

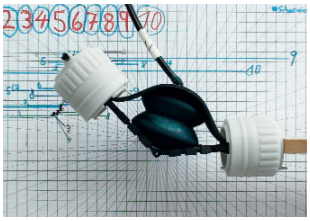
Free spatial movement

A technical focus of the Institute for Technology-Oriented Design Innovations (ITD) at the Offenbach Academy of Art and Design, headed by Prof. Dieter Mankau, is the creative and technological treatment of current bionic issues and already existing knowledge. The Institute's own research and development projects are concerned with adaptively responsive, locally elastic, pneumatic and kinematic structures and systems for lightweight elements. These findings form the basis of new product developments such as adaptively responsive lightweight load-bearing elements for textile construction in architecture, the design of modular care beds for long-term patients and the implementation locally elastic elements for office chairs.

The development cooperation between the ITD and Festo AG & Co. KG is integrated into Festo's Bionic Learning Network. The basis of this cooperation are the concepts developed by Professor Dieter Mankau for pneumatic lightweight structures, along with bionic robotic and automation systems. The focus here is on examining appropriate application-oriented implementation of the basic phenomena, along with elaboration and implementation options with a view to possible practical usage.



Modular element with tyre and overhead belt, without cover



Displacement through pressure application in tyre

The project initially involved a general functional review of both familiar and newly developed principles. A solution for a displacement system with free spatial movement entails linking together pneumatic actuators into several linear functional strands, which are connected and selectively activated in combination with a carrier system to constitute a multi-axis displacement element. In addition to integration of the pneumatic components into a mechanical system, the possibility of implementation as an entirely non-mechanical, adaptive overall system was also considered from the outset. For this purpose, the pneumatic actuators were coated and embedded in highly flexible polyurethane cold foam to form a functional system without mechanical joints or bearings. The resulting structures constitute part of the new field of soft robotics. As non-static systems, these adaptive robots and gripper systems respond both passively and actively to their surroundings and can thus be used in the immediate environment of humans – thereby eliminating the risk of injury. In view of the high complexity involved in realising the prototypes and the highly intricate open- and closed-loop control for the various pressure applications and for generation of negative pressure, this concept has as yet only been implemented in rudimentary form.

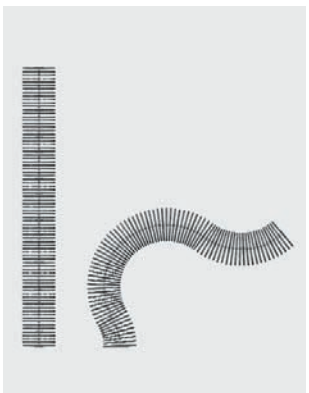
Following a general examination of the basic concepts, the focus was shifted to a principle in which displacement of a pneumatic actuator in combination with an overhead belt brings about a displacement of the entire system. This principle can be implemented in either two or three dimensions and, in addition to displacement defined by bearings or joints, yields non-static structures with a free spatial radius of operation.

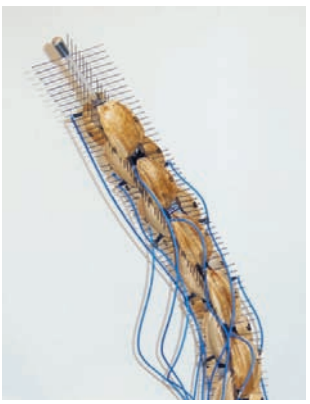
The functional principle of single-axis displacement elements was experimentally tested. This low-complexity pneumatic principle is well suited for simple, adaptive gripping and automation systems. Whereas the two-dimensional displacements are relatively easy to manage in technical terms, complexity increases in the case of a

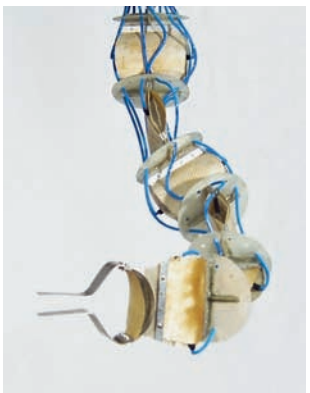
spatial and partly superimposed muscle configuration. The concept of generating multi-axis movement patterns by means of three-dimensional pneumatic structures, with no association of mechanical cause-and-effect relationships, became the new objective.

In a pneumatic, multi-axis movement system free of mechanical joints, the system is self-stabilising thanks to the differentiated pressure applications of the spatially antagonistic muscles; moreover, lightweight structures can be realised with an optimum weight/power ratio. In several prototypes, the effects of various arrangements of the pneumatic actuators were investigated along with their influence on the overall system and the movement patterns. Structures with 3 and 4 actuator strands were implemented in a rotationally symmetrical configuration around the centre of a carrier system. In addition, superimposed and offset arrangements of pneumatic actuators in these systems were examined. The piezo proportional control valves, with a maximum operating pressure of one bar, were integrated into the carrier system. At this pressure, movement patterns can be generated without additional working load. For industrial applications, however, the system must be completely reworked. All components such as actuators, control elements etc. must be designed for a higher operating pressure in order to meet the requirements of possible use in automation.

The experimental set-ups have shown that with the examined principles and structures, lightweight, adaptive and cost-efficient displacement and gripping systems can be generated, which by means of new production methods can be directly adapted to individual customer requirements in rapid manufacturing. The first design studies are currently being drawn up for the simple pneumatic principles, which have already been investigated and confirmed in their function, with the objective of a modular system that incorporates grippers and movement actuators as well as static connection elements etc.







Prototypes of pneumatic lightweight structures (left to right): Schematic representation of displacement movement, 4-chamber system with offset muscular strands, serial connection of linear displacement elements, 4-chamber system with sensors

Technical data

Control: CPX-GE-EV controller/valve terminal from Festo
Software: FST 4.1 from Festo
Valves: 12 piezo proportional valves from Festo
Operating pressure: 1 bar

Prototypes
Three-dimensional systems

4-chamber round system, length 20 cm, 12 pneumatic actuators
4-chamber system, length 130 cm, 26 pneumatic actuators
4-chamber system, length 110 cm, 20 pneumatic actuators
4-chamber system, length 35 cm, 8 pneumatic actuators

4-chamber system with offset actuators, length 80 cm,
22 pneumatic actuators
4-chamber system with offset actuators, length 115 cm,
20 pneumatic actuators

4-chamber modular system, 6 segments each
with 4 pneumatic actuators, maximum length 150 cm

3-chamber system, length 125 cm, 21 large
and 18 small pneumatic actuators
3-chamber system, length 40 cm, 6 large and 3 small actuators

Linear system with offset elements, 5 elements
each with 2 pneumatic actuators, length 75 cm
Linear system with offset elements, 7 elements
each with 2 pneumatic actuators, length 85 cm

Prototypes
Two-dimensional systems

Linear system, length 50 cm, 12 pneumatic actuators

Linear system, length 80 cm, 10 pneumatic actuators

Linear system, length 60 cm, 10 pneumatic main actuators,
8 reinforcement actuators

Linear system, length 60 cm, 11 displaced pneumatic actuators

In addition to the listed prototypes, a number of smaller
experimental set-ups and tests were implemented.

Project partners

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