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BIONIC DESIGN – THE HUMAN TOUCH OF TECHNOLOGY

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1. Prologue – What is bionics?

The word “bionics” is derived from a combination of the two terms “biology” and “technics”. This young interdisciplinary research field links biology to, in particular, the engineering sciences, architecture and mathematics. The aim of bionics is to apply natural problem solutions to the field of technology in order to benefit from the “inventions of nature”, which have developed and have become optimized over millions of years. In this process, bionics reveals striking parallels and analogies between biology and technology and becomes a driver of technical problem solutions, which are more “natural” and thus more environmentally friendly. For example, forms of communication used between animals provide excellent ideas for the technology of audio, video and data transfer systems.
Living systems offer valuable models for new conceptual approaches.
Products able for future must be eco-intelligent, that means, they must be all at once: functional, easy to repair, not wasting resources, durable and recyclable. Biological products in natural systems already meet with these requirements. Biological systems have a limited lifetime, are fully biodegradable and thus totally recyclable. Nature never produces waste. The animate world is a closed system. Whatever is left behind by one organism is recycled by another and thus returned to the cycle, creating a network technology par excellence. This aspect is becoming more important for developing new products, for example with regard to employing material. The less material used, the more renewable rawmaterial used, and the more recycled materials used, the lower the burden on resources and the more saving of energy can be achieved. The professional assessment of the environmental effects of a product is based on a holistic balance sheet of all factors from the production of the materials through the manufacturing process and product use phase until the “end of life”. Major development objectives are therefore the use of energy-saving components and environmentally-friendly maintenance technologies, the selection of environmentally-friendly materials and corresponding recyclable bonding and joining technologies. Three aspects have to be long-lasting developed and brought down to a common denominator: Ecology, economy and technology.
Festo has devoted itself to the maxim ‘learn from nature and be inspired by suggestions from biology for technological solutions’, i.e., to use bionics in a conscious way.

2. Airtecture – Neologism derived from "Air" and "Architecture"

Inspired by the Y-shaped joints in the wings of dragonflies, the Y-shaped columns of Airtecture were developed as the sole vertical supporting elements of an innovative pneumatic structure. With a floor area of 375 m² and an enclosed interior space volume of 2,250 m³, a building construction based on an exoskeletal structure thus rises 6 meters upward without any pressurization of the interior – like classic air supported halls. Infilled by parallel, rectangular, pneumatic wall components – also a

novelty since air pressurized elements usually come in cambered shapes – a multifunctional space in an unknown cuboid form in an air-supported building was created. Dynamically stabilized by a flexible exoskeleton consisting of fluidic muscles, Airtecture automatically adjust to continuously changing environmental conditions like wind, temperature and air pressure variations. Due to the use of air as the sixth building material (following stone, leather, wood, metal and glass), Airtecture consists of only 6 tons of membrane material, which – when folded up – can be stored in a 40 ft container and transported without problems.

Figure 1. Airtecture

3. Airquarium – Neologism derived from "Air" and the Latin for "Water"

Inspired by raindrops hitting water and forming natural cupolas, the principle of classic inflatable structure was fundamentally innovated with Airquarium. With a diameter of 32 meters, a height 8 meters and the use of a novel, highly transparent/translucent membrane material based on synthetic caoutchouc, Airquarium combines the characteristics of spatial dimension, lighting and environmental friendliness in a congenial way (in the event of a fire the membrane material only emits steam consisting of water and vinegar). A membrane torus filled with 120 tons of water serves as the foundation of the structure. It encircles the cupola at its base line - interrupted only by the entrance tunnel - and seals on the bottom. By draining the water, Airquarium can be quickly dismantled, packed into a standard container and transported to any location on a flatbed truck. Airquarium – the truly mobile structure.

Figure 2. Airquarium

4. Cocoon – A New Meaning

Inspired by insect cocoons, the extremely light inflatable emergency tent with an integrated air mattress was created. Eliminating the need for support poles, three-dimensional air elements – so-called airbeams – allow for extremely reduced weight and quick assembly and disassembly via a compressed air cartridge or commercial quality air pump. The airbeams, in part transparent, allow daylight to enter the tent and the interior light (safety light) to serve as a visible beacon outside in case of emergency. The outer shell of the tent is stretched between the airbeams and consists of multi-layered reflective sheeting that reflects body heat back into the interior and prevents low outside temperatures from cooling the occupants inside the tent. Cocoon can be compressed into a very small volume due to the use of extremely lightweight materials.

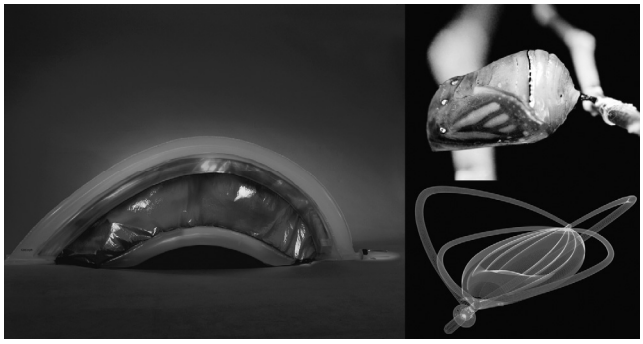

Figure 3. Cocoon

5. SLEEP – Brand Name of an Office Sleeping Pillow

Inspired by a shark's egg sac, the office sleeping pillow – developed in the "Pneumatic Structures" division – prevents keyboard imprints on the forehead. The pillow is protected by patent.
Although the office sleeping pillow seems totally innocuous and even humorous at first glance, it does call attention to a noteworthy medical fact: research has shown that several short naps during a workday can considerably improve performance and concentration.

Figure 4. Sleep

6. Funnbrella – Neologism derived from "Funnel" and "Umbrella"

Inspired by chanterelle mushrooms, what quite likely is the world's largest single stem inverted umbrella was created, only supported in the middle.
A (slightly cambered) square 31.6 meters on a side covers an area of 998 square meters. The clustered support column that splays outwards weighs only about 59 tons including the umbrella splines in order to mechanically pre-stretch the membrane, which has a weight of only 1,270 kg. The supporting

framework is engineered to support an asymmetrical load of snow resting on just half the umbrella surface and, at the same time, hurricane winds of up to 200 km/h.

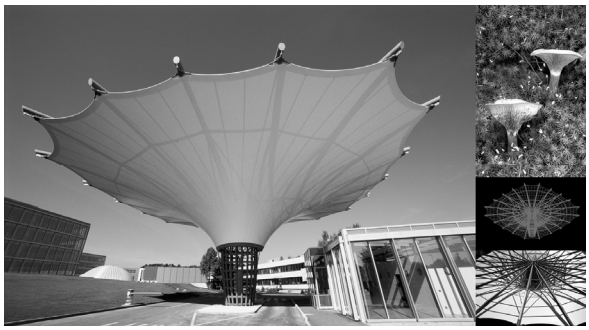

Figure 5. Funnbrella

7. Fluidic Muscle –Term derived from "Energy Transfer Medium" and "Muscle Tissue"

Inspired by the layered muscle fibers of leeches, the artificial muscle was created as a tubular structure with layers made of elastomere and stabilizing elements (textile layers). As an actuator, it can be operated with either compressible or non-compressible fluids. By building up an interior pressure using a fluidic medium, the tube contracts along its length. It resembles a three-dimensional, scissor-like structure and serves as the actual transmitter of the contraction. Contrary to that, the elastomere first and foremost serves to hermetically seal off the medium.

The advantages of the Fluidic Muscle compared with traditional actuators are, among others, the initial force of up to ten times at the same nominal diameter, a fraction of its own weight, absolutely no stick-slip effect and very simple positioning via regulation of the internal pressure. The enormous agility of the Fluidic Muscle is shown in its superior behavior in acceleration and deceleration. The simplicity of the make allows the actuator to be cut with a normal pair of scissors when required and fixed in cone clamps ready to operate. There are no moving parts, and the membrane contraction system consists of only three different components. Each part can be exchanged or reconfigured by the user oneself. Unlike other actuators, no lubricants or coolants are needed.

On further advantage – especially in hazardous environments where preventive measures must be taken against explosion – is that there are no electronic components; and only pure pneumatic contro. is applied.

7.1 Micro Muscles

Now that 40 mm, 20 mm, 10 mm, 5 and 3 mm muscle diameters are ready for production, 1 mm and smaller muscles are currently being developed. A biocompatible matrix material allows utilization in highly future-oriented areas, for example, for minimally invasive surgery, endoscopy and microprothetics.

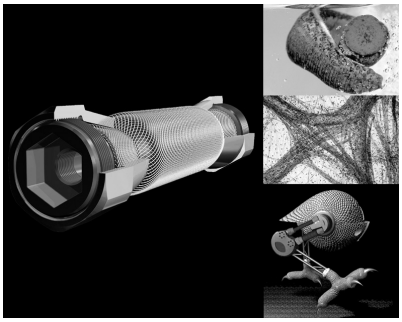

Figure 6. Fluidic Muscle

8. Hot-Air Airship – Steerable and Quickly Assembled/Disassembled Shell

Inspired by new membrane technologies, the first four-seat hot-air airship was created whose tail and side steering gears are pneumatic structures. The investment cost is one-fifth that of a traditional helium airship. Another advantage is the fact that, with the assistance of the accompanying cross-country vehicle, one can fly the airship in one location today, and the next day in another location that would be beyond the reach of the airship itself. This is enabled by the release of the gas – in our case hot air, the production of which only costs € 100. Contrary to that, a blimp of the same size would have to release helium worth € 74,000 and would need the same amount for the refill on the following day. In addition, airships cannot be flown from one location to another in all weather conditions. This is why our mobile hanger is made of cutting-edge composite materials; the maximum weight of 7.5 tons is not exceeded, hence the vehicle is not subject to Sunday restrictions, which apply to trucks of greater weight.

Figure 7. Hot-Air Airship

9. Hot Air Balloon – Balloons Drifting in an Ocean of Air...

Inspired by jellyfish, which fluidly flex their body membrane and move in the same fluid, the membrane of the hot air balloon is pre-stretched in a similar fashion. If the medium is heated, lift is created and the hot air balloon moves with air in air.

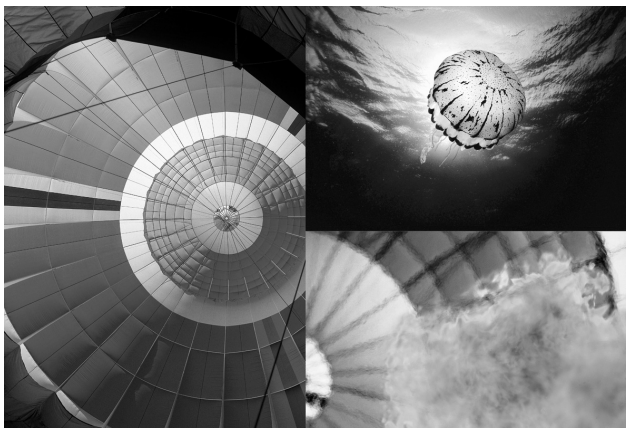

Figure 8. Hot-Air Balloon

10. Gas Balloon – ... with either Hot Air or Gas

Inspired by deep-sea jellyfish, the balloon shell is filled with a lighter than air gas and drifts in the compressible fluid, air.

Figure 9. Gas Balloon

11. Pneumatic Balloon Baskets – Pneumatic "Airbag" Structures instead of Wicker Baskets

Festo offers an innovative substitute for the traditional hot air balloon basket made of wicker, used in ballooning for almost 200 years, with an innovative balloon basket that is a pneumatic structure. The basket has a modular structure with up to five individual pneumatic elements; the elements resemble the air chambers of a rubber dinghy and, due to the materials developed for Airtecture, are extremely robust. These "air pillows" act as airbags when landing; most of the energy released during a hard landing is directly absorbed by the deformation of the pillows. The risk of injury to passengers is minimized since the surface of the material – unlike wicker baskets – is smooth. In the event of a water landing, the swimming basket is convincing with best possible distinctive feature.

When the air is released from the chambers, the basket can be disassembled and packed into a suitcase. The modular structure of the basket also allows for the replacement of individual elements if any are ever damaged, thus considerably reducing the chance of having to replace an entire basket.

Minor damage can be easily repaired – like one would with a bicycle inner tube. Furthermore, this construction offers the highest degree of safety since only one chamber would be affected by a leak. And even if one or several elements fail, the basket will retain its shape.

A version specially developed for gas balloons carries water in "pockets" along the exterior of the wall elements as ballast.

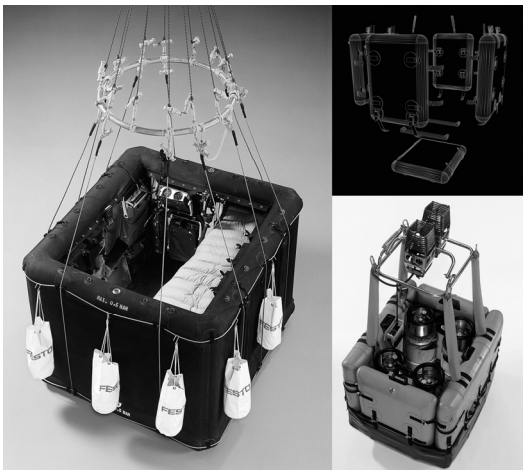

Figure 10. Pneumatic Balloon Baskets

12. Air – The Sixth Building Material

We have been able to demonstrate that, inspired by models from nature, the universal medium "fluid" can be used as a building material and constructive tool in sometimes surprising and unexpected ways. For example, ubiquitous air has become the ultra-lightweight sixth building material after the use of stone, wood, metal, ceramics/glass and membranes (from fur to textiles). As an allegory to Goethe's "wicker basket" we show that ‘pneu’ as a natural principle functions as a technological analogy and, for example, delivers an innovative replacement for the classic wicker basket that has been used by balloonists in an almost unchanged form since 1783.

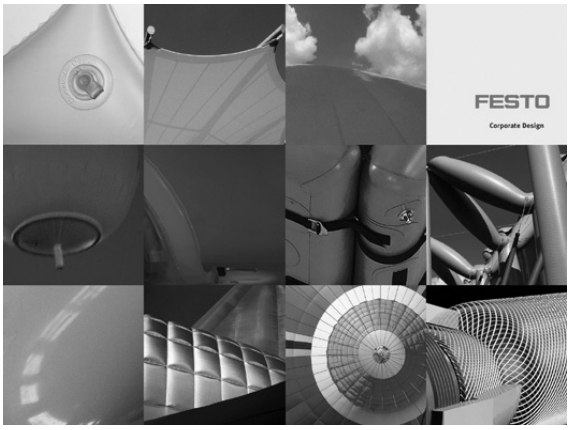

Figure 11. Built with Air…

13. Epilogue

We have to be aware: The constructive world of technology will not change through biology. The end product will always remain technological, and technology always implies an active intervention into the ecological systems and thus a manipulation of sensitive interactions. However, we can decisively influence the technological end products and co-design them in a bionic way. We thus have the hope that we will again get closer to nature through our technology and to act with it instead of against it. Now, our human power of innovation is being challenged to create artificial natural products that harmonically integrate into the global eco-system. Our big hope is on bionics as truly “green” technology.

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