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Powered by artificial muscles

Airships that «swim» through the atmosphere

Conventional propeller driven airships have their disadvantages. They are inefficient, and thereby wasteful of energy, and they are noisy too. Empa scientists are looking to solve both these problems by using a technology which is simultaneously very advanced and yet simple in concept – their design lets an airship "swim" through the air like a fish moving through water. That this idea could become reality thanks to the development of electroactive polymers (EAPs) is demonstrated by the first flight trials as well as computer simulations. The EAPs need further development, however, and their reliability and useful lifetime must be improved.

Quiet, maneuverable and efficient airships would be ideal for carrying out a range of tasks at various altitudes in the atmosphere, such as monitoring, reconnaissance, remote sensing, acting as static communications platforms or even as a novel means of advertising. Today's airships, however, suffer from low efficiency, being driven by propeller. The simple rule is, the larger the airship the faster the propeller must turn to overcome the vehicle's aerodynamic resistance. The rate of rotation and diameter of the propeller are limited by the velocity of sound, for if the tip of the propeller moves faster than this speed a crackling noise similar to that made by helicopter rotors is produced. This is caused by acoustic shock waves which cause the propeller blades to flutter, generating an enormous sound level and at the same time reducing the efficiency yet more. And of course the power of the driving motor cannot simply be increased at will to compensate for this effect.

Swimming like a trout – through the air!

If the patented idea of Empa researcher Silvain Michel and his team becomes established, then the airship of the future will be a non-rigid airship (blimp) that glides through the air as silently and using the same means of propulsion as a trout swimming in a brook – by bending its body in one direction and simultaneously moving its tail in the opposite way. The technically simplified version of this trout-like motion, using three rigid, interconnected body segments, is known in scientific jargon as the "bending-rotation-stroke", say Michel. "This technique can be transferred directly from water to air", he explains further. "A blimp moving through the air is, in terms of the physics involved, exactly the same as a fish moving through water. In both cases a body is moving through a fluid and is subject to the same laws of fluid dynamics." The new propulsion technique, combine with a sleeker, trout-like shape, doubles the efficiency of the blimp design from an aerodynamic point of view.

Drive mechanism merged into aircraft hull

Electroactive polymers, which Empa has also been developing for use as artificial muscles, are practically tailor made as the power source for a propulsion system based on the swimming action of fish. EAPs consist of elastic polymer films which, when subject to an electrical voltage, become thinner and expand in area as a result of the mechanical forces which occur (see box). Regardless of whether this deformation is used to propel an airship, move an object or replace damaged muscles, it occurs silently and efficiently. Because they convert electrical energy directly into mechanical work without the need to use electric motors and gear systems EAPs reach energy efficiencies of up to 70 per cent. Compare that with an internal combustion engine, which depending on the type achieves an efficiency of just 25 to 30 per cent. In the Empa airship, the EAPs will form a part of the hull, so the “motor and gearbox” will melt into the body of the vehicle, as Michel puts it. The new propulsion system allows a high degree of maneuverability, as any trout can demonstrate. And finally, there is one factor which is a disadvantage from the point of view of aerodynamic resistance but which has advantages in terms of the power supply – the upper side of enormous hull of the airship offers enough surface area for flexible solar cells, ensuring that the necessary energy is available to power the blimp.

Flying radio aerials?

Chubby airships can therefore theoretically be propelled following an example from nature. This is practically possible thanks to EAP technology, for experiments by the Empa scientists show that these devices can achieve the deformation levels and stresses required by the propulsion system. In addition, they must also be capable of expanding and contracting by some 15 per cent during the “bending-rotation-stroke” – the two movements in opposite direction made by the blimp’s hull. This is a value which EAPs can meet without any problem. But there is still a fair amount to be done in the Empa research laboratories, as Michel knows. “The next task is to find a way of constructing the EAPs so they simultaneously meet the aerostatic, aerodynamic and structural requirements.” Michel’s team also need to increase the operational life of the devices. Only when they are capable of functioning reliably for long periods can one think of replacing expensive satellites or noisy helicopters with EAP-powered blimps. Then they could be used to silently observe animals in their natural habitat, or as television relay stations for transmitting sports events, or even as communications platforms – floating aerials for mobile telephone systems, for example.

How do EAPs work?

Electro active polymers convert electrical energy directly into mechanical work. An elastic membrane made of polymer material is made to deform by subjecting it to an electric field, and when the voltage is removed the membrane regains its original size and shape. Both sides a polymer film is given a very thin coating of electrically conductive graphite, to which the voltage is applied, the device then acting as a compliant electrical capacitor. The electrostatic forces cause the surfaces of the membrane to draw together, compressing the material and causing its surface area to increase.

Technical information

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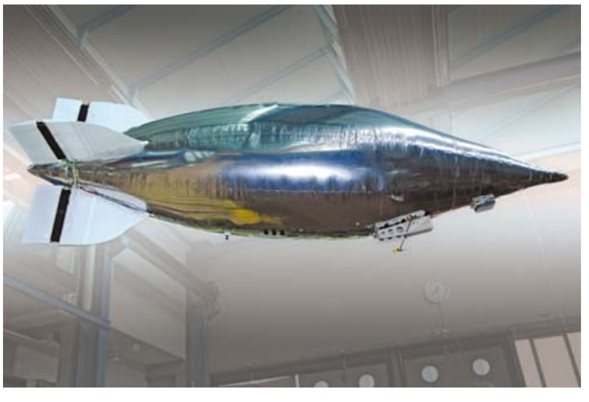
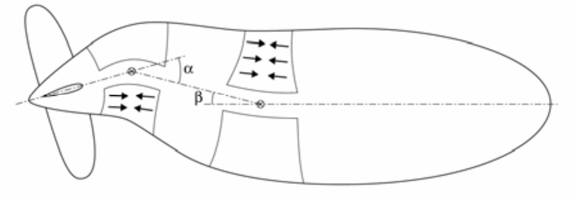
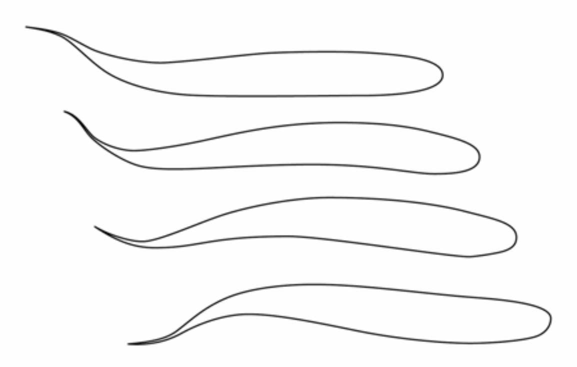


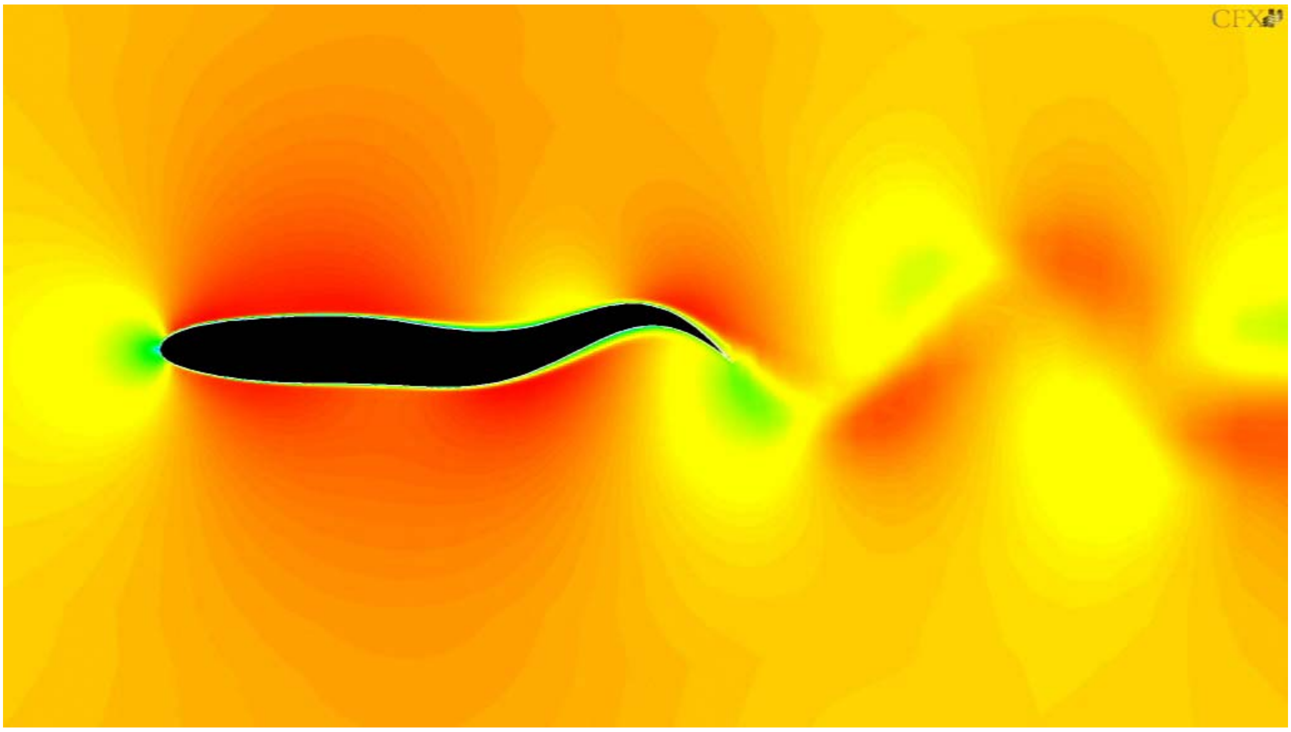
In initial tests with simplified models the EAP actuators move the rudder.



The EAPs merge into the airship hull at four points. When activated they expand, causing the hull to execute the “bending-rotation-stroke”, a technically simplified version of the motion of a fish in water.



By bending its body in one direction and moving its tail fin in the other, a trout moves forward through the water with minimal resistance.



The motion of the trout was simulated on the computer at the ETH Zurich. This provided the Empa researchers with additional data on the aerodynamics of the situation.