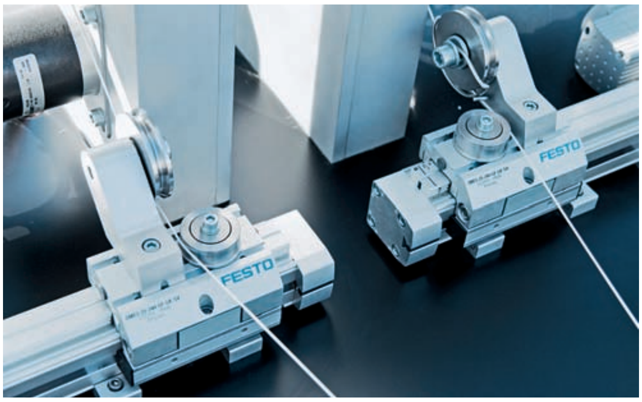
CyberKite

Autonomous kite

Info

An energy-efficient endurance artist

Control unit



Displacement shaft with guide pulleys

As a distinctive airborne company signet, the CyberKite of Festo is an intelligent and energy-efficient master of endurance. Thanks to hybrid technology with integrated aerostatic lift, this kite can fly even in the absence of wind. Its automatic control unit prescribes a flight path for the wing and ensures a mode of flight to match the prevailing wind conditions. The kite wings measuring 6, 12 or 24 square metres, which are controlled with the latest actuation and regulation technology from Festo and are supported by a large number of innovations, represent an incomparable development in the field of autonomous tethered flight systems.

The CyberKite project is based on a unique type of wing. The point of departure was the development of a revolutionary flight system, the Stingray® project, which was realised for Festo in 1998 by prospective concepts AG and was presented to the public at that time. In its voluminous interior, the 72 square-metre wing of the bionic hybrid aircraft provided ample space for helium as an auxiliary lift medium. With the CyberKite, adapted as a particularly light ram pressure wing, a much smaller volume than with the Stingray® is sufficient to hold the entire structure aloft.

The CyberKites are designed as passive pneumatic units operating on the basis of ram pressure. The head-on airflow gives rise to a differential pressure acting on the volume of the wing, which ensures the required stability of the membrane structure. This membrane design principle is very efficient and light. The aerodynamic and aerostatic lift forces are conveyed by profile elements to the underside, from where they are dispersed by a finely ramified system of ropes – the bridle lines. The wing is connected to the actuator system by four flight lines. Despite its flat, elegant form, the bionic Stingray-Kite does not require additional tail units for stabilisation. Adaptive wing adjustment is achieved via the bridle by means of a universal rope transmission. The wing is thus able to fly in a straight line with extended tips, and to bend when negotiating curves in such a way as to expose a sufficient stabilising lateral surface. With a tethered wing system, undesirably high line forces can be rapidly reached in conditions of strong, gusty wind. An adaptive rope transmission was also realised here for the tethering; this can reduce the effect of the wind forces whenever necessary.

New materials extend the limits of performance. Now for the first time, aerofabríx® is being used in a kite. This metallised ripstop nylon, weighing only 29 g/m², is a lightweight and at the same time sturdy fabric developed for use in high-performance parafoils and as a basis for the innovative aerofabríx® flock insulation. The gas cells are made from a 7 or 9-layer film impermeable to helium and weigh less than 26 g/m² – a further high-tech product that can withstand the harsh conditions of outdoor kite flying.

Knowledge of the aerodynamic characteristics of wings is an important prerequisite for automated flight. The turbulent flow around the kite's wings was simulated using numerical methods. The solutions – validated in wind tunnel measurements from the development of the Stingray® – were of valuable assistance in adapting the aerodynamic and mechanical flight characteristics.

For measurement of the wing characteristics and development of the control programmes, highly developed avionics systems were subjected to a weight-loss diet and integrated into a lightweight onboard computer system. With a mass of just over one kilogramme, the CyberKite houses a high-resolution, real-time-capable differential GPS for measurement of position and speed, an inertia platform for description of position and displacement, along with temperature and pressure sensors for a specially developed five-hole probe that measures the head-on flow vector.

The CyberKite's control unit incorporates four rope winches, which wind in and release the two control lines and two tethers. The control lines are used to execute flight manoeuvres, and the tethers counter the force acting on the CyberKite. This arrangement allows

flexible, finely metered control and force regulation of the kite's wings. Control is effected on the basis of travel parameters for the four winches, which are powered by Festo actuator motors of the latest generation.

The two winches with tethers 2.2 mm in diameter allow ascent and descent speeds of up to 1.6 m/s, with tractive forces of up to 2 x 1,000 N. Two further winches for the control lines, each of 1.2 mm diameter, provide the steering movements. The control lines each have a load capacity of 250 N at winding speeds of up to 4 m/s.

For controlled reeling and release of the tethers and control lines, the winches are provided with displacement shafts from Festo, which provide lateral movement to prevent overlapping as a line is drawn in. Via guide pulleys, the lines are conveyed to tensioners, whose torque-controlled servo motors activate finely adjusted friction pulleys. This ensures that all four lines remain taut at all times, thus preventing them from tangling.

To monitor the flight parameters, the tension and angle of all four lines are measured by sensors. The actuators are orientated toward the kite by means of a freely rotating motorised base frame, the so-called yaw module. This unit allows the CyberKite to be positioned in the direction of the wind at all times.

The CyberKite's flight is regulated in accordance with wind conditions and wing size. Various operating modes and adapted flight path settings allow the kite to fly throughout a wide range of wind speeds. Together with the robust flight control system, an automatic load limiter ensures unproblematic operation even of large wings.

The regulation and control philosophy of the CyberKite is not based on rigid tethering, but is rather programmed for intelligent yielding, whereby the force of the wind is made use of through energy-efficient application of the Festo drive units. In the CyberKite's servo motor system, the braking energy from the control movements is not only recovered from the Festo actuators – the wind energy is also used to power them by means of state-of-the-art battery technology and suitably programmed wing manoeuvring cycles. The actuators periodically operate in "generator mode" using the tractive force of lines extended from the kite; the electrical energy gained by this means is fed to the batteries, thereby considerably reducing the system's energy requirements. Under appropriate wind conditions, future CyberKite systems will be operable independently of an external energy supply, using only the force of the wind.

With the CyberKite's wings measuring 6, 12 and 24 m^2 in surface area and the accompanying control unit, Festo is presenting a comprehensive energy-efficient mechatronic concept. EMMS-AS-70 electric drive units, the MTR-AC motor and sensors from Festo make for rapid intervention appropriate to the various flight situations. With CyberKite, Festo is demonstrating the diverse opportunities for application of the company's products in actuator and sensor systems, along with control and regulation technology in automation.

Technical data

CyberKite 6 m²	
Wing span (width, length):	4.31 m, 2.07 m
Surface area:	6 m^2
Volume:	1.24 m^3
Weight:	0.99 kg
CyberKite 12 m^2	
Wing span (width, length):	6.1 m, 2.92 m
Surface area:	12 m^2
Volume:	3.9 m^3
Weight:	2.2 kg
CyberKite 24 m^2	
Wing span (width, length):	8.62 m, 4.14 m
Surface area:	24 m^2
Volume:	9.8 m^3
Weight:	4.2 kg
Control unit	
Motors for tethers:	2x EMMS-AS-70 from Festo
Tether displacement shafts:	DMES-25 with EMMS-AS-55 from Festo
Winding speed:	1.6 m/s at 1000 N traction force for each tether
Motors for control lines:	EMMS-AS-70 from Festo
Control line displacement shafts:	DMES-18 mit EMMS-AS-40 from Festo
Winding speed:	4 m/s at 250 N traction force for each line
Line tensioner actuator:	MTR-AC-40 from Festo
Yaw module drive:	1x EMMS-AS-100 from Festo Planetary gearing from Neugart
Traction force sensors:	4x load cells, measurement amplifier, load centring plate from Burster
Angle measurement sensors:	2x tubular shaft potentiometers from Schuricht
Brands:	Stingray® is a brand of prospective concepts AG, Glattbrugg, Switzerland aerofabríx® is a brand of Dr.-Ing. Alexander Bormann, Berlin, Germany

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