SELF-TRIMMING TRAILING-EDGE FLAPS FOR GLIDERS (FLAPOMATIC)

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In 1980 a new and simple mechanically working system for self-adjusting trailling-edge flaps has been developed by Akaflieg München, student flying group at the Technical University. In the following this system and its performances on different gliders is described.

At the end of the thirties sailplane designers began to use wing profiles with variable camber to decrease drag. Especially on the new laminar airfoils this was an effective method to shift the dip on the polar curve and thus to gain a minimized drag relative to the necessary lift for all flight conditions.

From the beginning the problem was to set the flaps precisely, because to a certain lift coefficient of a profile only one best flap deflection exists. In today's sailplane the flaps are set by hand according to the indicated airspeed. But the lift coefficient depends on both airspeed and load factor, too many limiting quantities even for good pilots.

That is why several self-trimming systems for flaps have been developed:

One of them became popular with the "Hirth Acrostar" motorplane (Fig. 1a). There the trailing-edge flap is stiffly connected with the elevator control. When

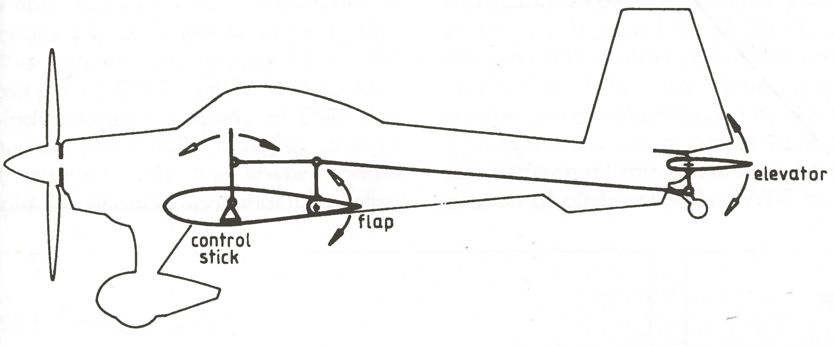

Fig. 1a. "Hirth Acrostar" flap steering.

the pilot pulls the control stick, the elevator moves up and the flap downwards. This steering is simple and light, but generates an enormous stick force. In some cases the abrupt decrease of lift leads into dangerous flight positions when the pilot quickly pushed the stick, especially on landing approaches. Professor Eppler improved this system, but it never came into series production.

Akaflieg Aachen developed a hydraulically working system (Fig. 1b). There the flap is moved referring to the angle of attack indicated by a wind vane at the fuselage nose. This equipment is much too expensive, too heavy and the load factor is not measured directly.

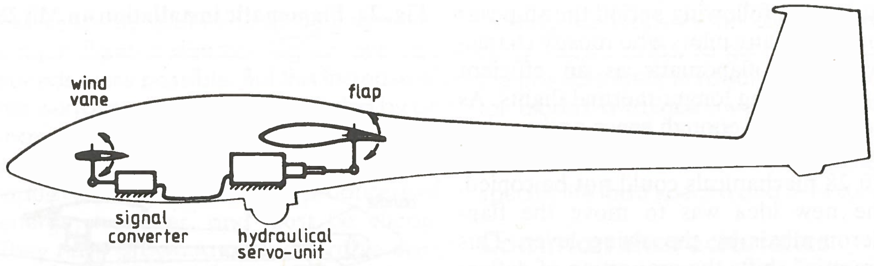

Fig. 1b. Akaflieg Aachen's servo control.

Also the idea of automatic flaps that is utilised on fly-by-wire combat aircraft (e.g. Grumman X-29) is not acceptable for sailplanes.

What sailplanes need is a simple, cheap, light and failsafe system that should not be a steering mechanism but a control device. The two limiting quantities for the lift coefficient (and that means for the flap deflection) – load factor and airspeed – should have a direct input to the system. This is possible when the system works by an equilibrium of two moments:

One is a moment of force, generated by a mass at the end of a swing lever. This moment is influenced by the load factor (Fig. 2a).

The other is the hinge moment of the flap, influenced by the airspeed (Fig. 2b). If flap and swing lever are rigidly connected (Fig. 2c), the two moments will find a point of balance for each flight position. The coherence between angle of attack, flap deflection, lift and drag coefficient can be theoretically derived for non-cambered airfoils. But even when the non-linear relationsships between these four quantities are allowed for the best transformation ratio between the two moments can be found, also for cambered wing profiles (e.g. LS-3 automatic).

Up to now the flapomatic has been successfully tested on three different gliders: The first was a quarter-scale model airplane of Akaflieg München's Mü 28. This radio-controlled glider was equipped with

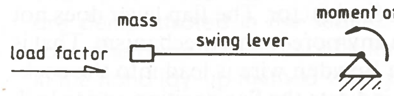

Fig. 2a. Moment of force, influenced by load factor.

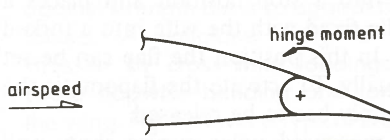

Fig. 2b. Hinge moment, influenced by airspeed.

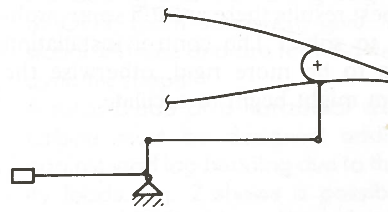

Fig. 2c. Equilibrium of the two moments.

a four-channel PCM-telemetry-system. This system transmitted data of CAS, angle of attack, load factor and flap deflection to a ground receiver during the flight tests. The evaluation of these data showed an accuracy of the flapomatic that encouraged us to fit the original Mü 28 with the same system.

The first flight on Mü 28 took place on August 8, 1983. Shortly after, the testing of the flapomatic began, and now no pilot would fly this glider with flapomatic off, especially in advanced acrobatics. The wing has a non-cambered Wortmann FX 71-L-150/20 profile with a 20% chord flap and a deflection of ± 20°. The swing lever is supported on both sides of the landing gear box and rigidly connected with the flap lever, which serves as both lever for manual flap operation and flap position indicator. The flapomatic is set out of action only for the purpose of take-off or landing by some sort of disc-brake that prevents the swing lever from moving. The brake is set and released by a handle on the flap lever. A knob on top of the flap lever serves as emergency operation to set the brake. The swing lever is damped by a hydraulic shock-absorber of a motorcar to prevent oscillations of the flapomatic.

After the successful tests with the Mü 28, Akaflieg München decided to fit their LS-3 with the flapomatic (Fig. 3b). Within nine months the system was designed, calculated, manufactured and installed. The flight tests began in August, 1984. During the following period the ship was flown by many pilots who mostly characterized the flapomatic as an efficient support during longer thermal flights. As there was not enough space on board of the LS-3 to install the necessary parts, the Mü 28 mechanicals could not be copied. The new idea was to move the flap-aileron-mixer by the swing lever. This "pre-mix" shifts the proportion of deflection between flap and aileron according to the load factor. The flap lever does not move anymore in this mechanism. That is why a Bowden wire is lead into the cockpit to indicate the flap position and to lock the flapomatic: For this purpose the pilot pulls the swing lever with the Bowden wire into a stop position and places a handle fixed with the wire into a forked lock. In this position the flap can be set manually. To activate the flapomatic the wire only has to be released.

The measured polar curves show well how the flapomatic enables the glider to be flown on the envelope curve, so minimizing the drag.

For best results there are still some problems to solve: The control installation needs to be more rigid, otherwise the system might begin to oscillate.

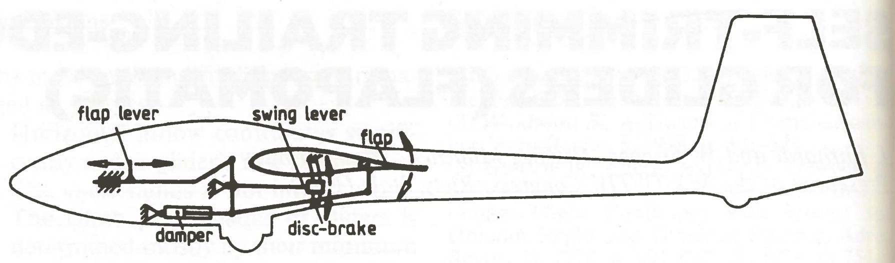

Fig. 3a. Flapomatic installation on Mü 28.

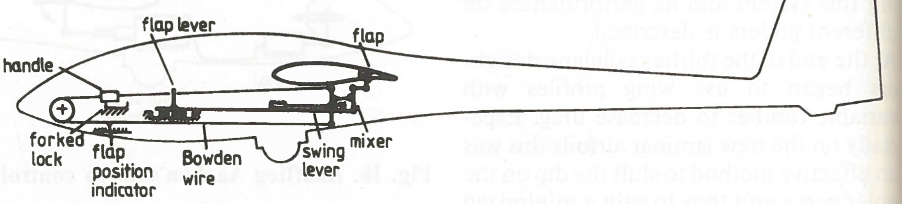

Fig. 3b. Flapomatic installation on LS-3.

The possibility for oscillations should be suppressed by some kind of damping.

The structure of the whole plane must be able to withstand the strengthened gust loads, generated by a increased c_L-α-slope.

The wing profiles should be optimized to gain a high hinge moment and to stretch the range in airspeed between maximum and minimum flap deflection.

Other publications on this topic:

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