Experimental assessment of an active flap device

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During the past thirty years, noticeable consideration has been devoted to the improvement of rotary-wing vehicles, with respect to noise, vibrations and performance. The main rotor of helicopters, and more precisely the blades themselves have been the subject of numerous optimization studies. Passive means [1 to 5] have been at first considered such as advanced plan-forms, airfoils, structure designs. Subsequently, other approaches such as HHC or IBC have been also successfully tested, although none of these could achieve the level of being used on commercial helicopters [6]. More recently, due to significant progress in the field of smart materials, innovative concepts such as active flaps or active twist started being studied. Within the Active Flap Rotor project, ONERA and DLR addressed the challenge of designing a wind tunnel scale rotor blade featuring a trailing edge active flap. According to numerical simulations of such a rotor, it could be demonstrated that significant gains would be obtained for both BVI noise radiated in descent flight and vibration level transmitted to the fuselage throughout a large flight domain [7,8] provided optimized flap deflection laws would be applied. In order to be able to alleviate vibrations typical of a four-bladed rotor, the flap deflection laws can feature components up to 5-per-rev.

Alongside full-scale flight tests of a rotor with active flaps planned by ECD [9], ONERA and DLR plan to test a flap-equipped rotor in both S1MA and DNW wind tunnels. Therefore, an active device featuring an actuator and a flap, which would be suitable for either wind tunnel or full-scale applications, was designed by ONERA. The actuator technology is based on an off-the-shelf design developed by a french company named CEDRAT. This concept mainly consists in a metallic elliptical frame along the major axis of which a piezo-electric stack is located. When electrical power is supplied to the stack, the latter expands and hence incurs a shortening of the minor axis of the frame. A specific cinematic linkage between actuator, flap and blade was designed. Such an innovative design, for which a patent has being applied for by ONERA, allows to avoid the use of conventional bearings which are prone to friction and wear, especially under the centrifugal loads which are encountered when the blade is rotating. The principle of the active system is presented on figure 1.

Before starting the manufacture of a whole set of test blades, the behavior of the active device, under the various loads that it would be submitted to once mounted on the rotor, had to be checked. In a first step, the operation under centrifugal loads was characterized. This could be achieved by installing the active device in a dedicated closed frame (to avoid any aerodynamic influence) which was itself mounted atop a hover test rig (BRAVoS) located at ONERA. Both the steady and unsteady operations of the device could then be validated under centrifugal loads similar to those the device will have to cope with in S1MA and DNW wind tunnels. Figures 2a and 2b illustrate the unsteady deflections at various actuation frequencies for 0 g and 2000 g conditions.

Once the good behavior under centrifugal loading demonstrated, attention was paid to the actuation under realistic aerodynamic loads and more precisely to the maximum performance achievable in terms of flap deflections. A specific 2D model was hence designed, manufactured and tested in ONERA S3MA wind-tunnel. It is made of a blade section, in which the active system is embedded. The whole model is mounted on a special hydraulic rig which allows variations of the angle of attack of the model. The test matrix was established in order to match as closely as possible the future test conditions of S1MA and DNW, as far as Mach numbers, airfoil angles of attack, flap deflections and actuation frequencies are concerned. The comprehensive test campaign included both open and closed loop sequences, as well as transfer function recording. Figure 3 illustrates the influence of aerodynamic loads on the flap deflection angle for an airfoil angle of attack of 4 degrees. The behavior of the active system was found to be very satisfactory at moderate airspeeds, although some improvements remain to be made on the controller to achieve nominal behavior throughout the whole flight enveloppe.

An active device featuring a piezo-electric actuator and a trailing edge flap is now available and thoroughly evaluated. This device, once finely tuned, will be implemented in the blades of a four-bladed rotor model to assess the benefits of an active flap in terms of noise, vibration and performance.

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Figures

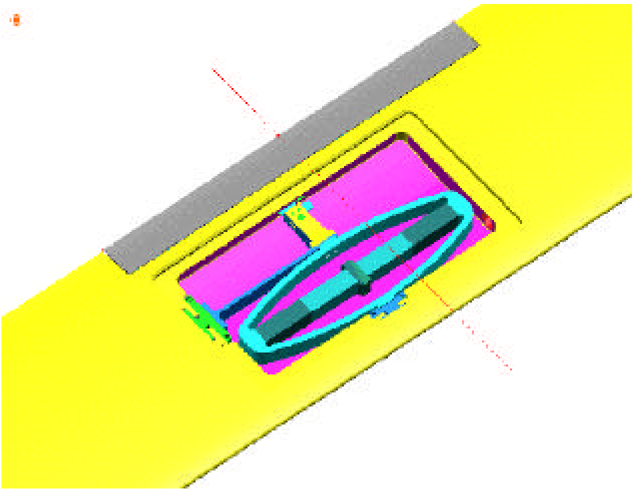
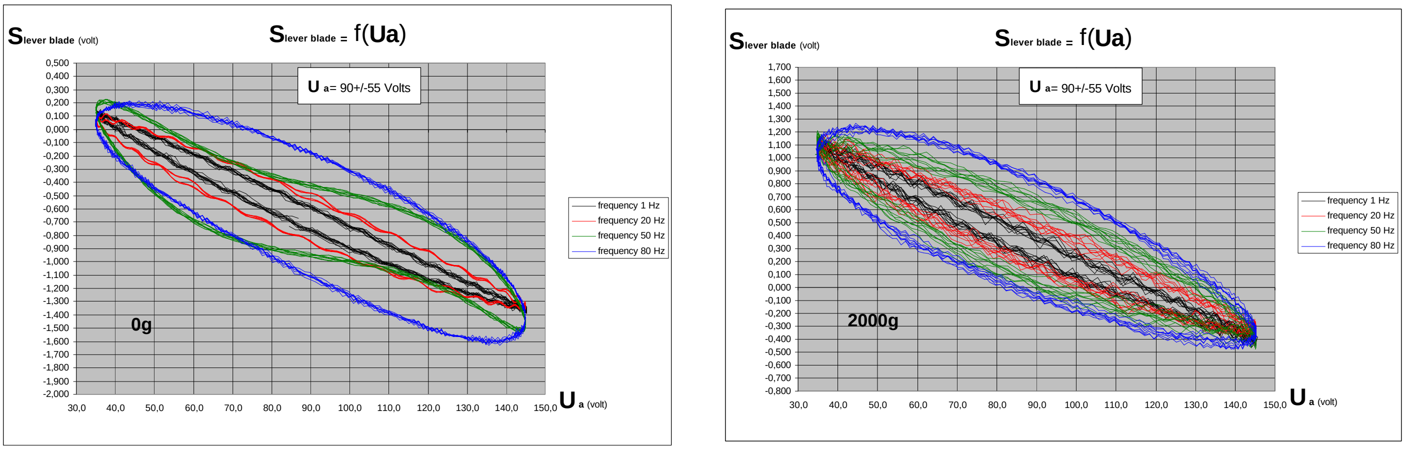


Figure 1- Principle of the active device



(a) (b)

Figure 2 – Flap deflection = f(input voltage) under 0G (a) and 2000G (b)

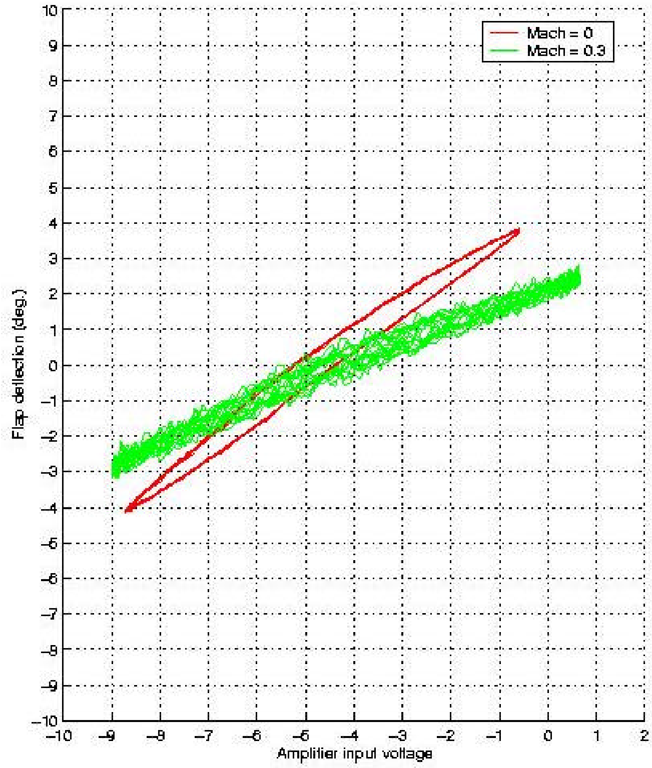


Figure 3 – Influence of aerodynamic loads on flap deflection