The Sizing of a Cozy Mark IV Landing Brake Actuator
by
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The proper sizing of an electric landing brake actuator is a topic that is frequently discussed on internet mailing lists and forums. At least one person has done a hand calculation of the loads and determined that a popular actuator that is used on many canard aircraft (Thomson Electrak 1, 12 VDC, S12-17A8-04) is under-sized for a Cozy Mark IV. This actuator has a 4" stroke and a 75 lb rating. On the other hand, reality trumps theory, since many people use this actuator on their aircraft and none have ever had it stall due to an aerodynamic overload at normal operating speeds.

Since I was mentoring a high school student at my workplace that was looking to learn about aerodynamics, I thought this would make a good senior project for her. I had her investigate this issue by analyzing the above actuator, which I have installed on my Cozy Mark IV project. All geometry is specific to my installation, but there should only be slight variations for other builders (my brake opens 58°). Her analysis started with hand calculations, and then moved on to higher fidelity analysis using 2D and 3D Computational Fluid Dynamics (CFD). Based on the results, we then decided to conduct a load test of the actuator. Her summary of this project follows …

There are two forces contributing to torque about the landing brake hinge, and the net torque must be zero while the landing brake is deployed. For the hand calculations, the aerodynamic drag was calculated using the equation $F = C_D \frac{1}{2} \rho v^2 A$, approximating the landing brake as a flat rectangular plate. Based on the classic text on drag by Hoerner (Fluid-Dynamic Drag, 1965), a flat plate that is normal to the flow has a drag coefficient of 1.17. This value was used along with the projected area of the brake to account for the angle of the brake relative to the flow. For the hand calculations, the drag force was assumed to act at the geometric center of the brake. Similar calculations were done for the lift. The torque was calculated by multiplying the resultant force normal to the brake by the distance from the hinge line to the center of the brake (7.6"). The required actuator force was calculated based on its attachment point, which is closer to the hinge (4.0"), so that the net torque is zero.

Based on the hand calculations, the require actuator force to hold the brake open at 100 kts is 210 lbf. Note that all calculations were done at sea level. However, since this approach made large assumptions, such as ignoring the presence of the bottom of the plane, higher-fidelity methods were explored. For the first refinement, an analysis using 2D CFD was performed at 80, 100, and 120 knots. The grid, which contained a cross-section of the landing brake and surrounding region, was developed in Pointwise (http://www.pointwise.com/), and CFD analysis was performed using CFD++ (http://www.metacomptech.com/).

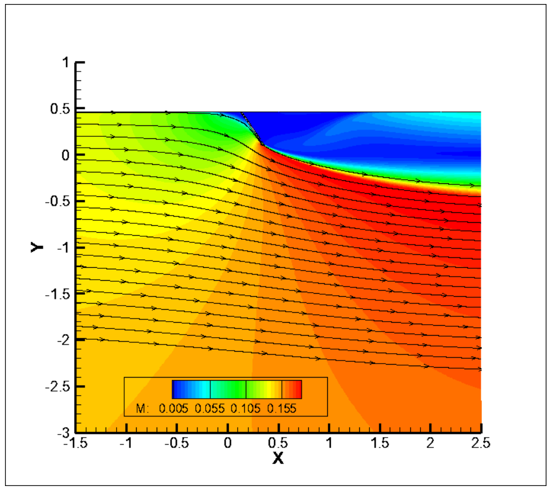

Figure 1. Mach number plot from 2D CFD

As can be seen in Figure 1, the speed of the air was increased as it left the trailing edge of the landing brake, and was reduced in front of the brake by the fuselage bottom. There was also a large area of slow recirculation behind the landing brake. The results were used to calculate the torque about the hinge. Following the same reasoning used in the hand calculation, this torque was used to find the force of the actuator. At 100 knots, this method gave a result of 174 lbf, a significant reduction from the hand calculations, but still higher than the rated load of the actuator. It was determined that the force of the air was not actually applied at the center of the landing brake, 7.56" from the hinge, but rather only 6.79" from the hinge, which partially explains the difference in the required force of the actuator. Equations indicate that the force of the air, and thus the force of the actuator, should be proportional to the airspeed squared. This hypothesis was tested with the three speeds used for 2D CFD. Within 1.3% error, this proportionality was found to be true, so it was concluded that in this case, it is valid to find the required forces at other speeds by scaling the result at 100 kts.

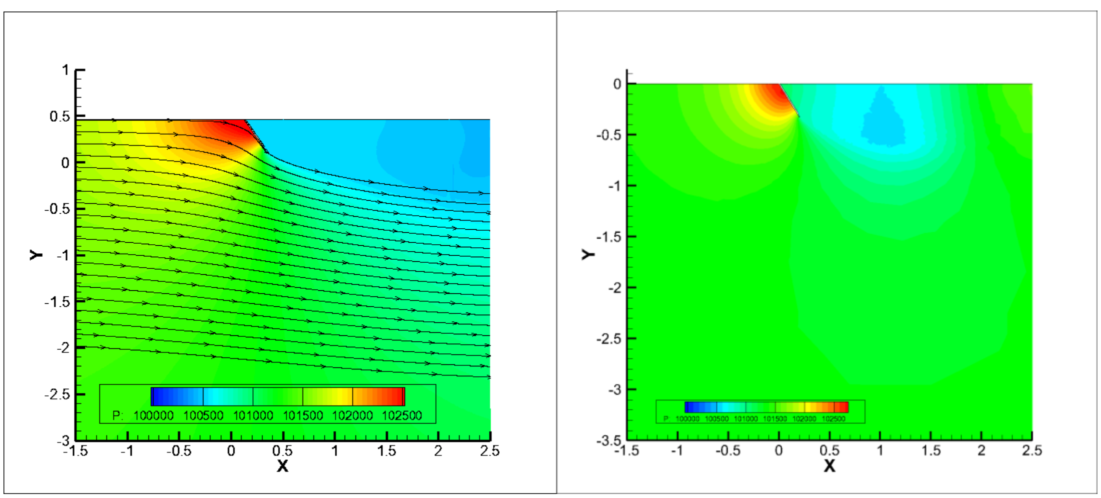

Figure 2. Center cut of pressure (Pa) plot from 2D (left) and 3D (right)

To allow the air in the model to flow around the sides of the landing brake, providing a more accurate approximation for actual conditions, 3D CFD was also explored. The mesh was again created in Pointwise, with over ten million cells. The grid made use of a symmetry plane cutting through the center of the landing brake, so that only half of the landing brake and surrounding region were modeled. CFD analysis was performed using CFD++ at 100 knots. As shown in Figure 2, the results showed general similarity to the 2D solution, but with a smaller region of recirculation behind the landing brake. Using the same calculation method as for the 2D case, the actuator force was found to be 134 lbf. This was another substantial reduction, but still exceeded the rating of the actuator.

The actuator specifications list a maximum dynamic load of 75 lbf. This dynamic load is less than the required force to open the actuator fully at 100 knots, so the calculations indicated there was a possibility that this type of actuator would be unable to fully deploy the brake at 100 kts and even lower speeds, although this has not been reported by the user community. Additionally, the actuator has a static load rating of 300 lbf. If the actuator is not moving, it can withstand much higher forces. Based on the contradictory results, a test was performed on the actuator to determine its true capabilities. A load was placed on a plate above the actuator, which was then extended and retracted vertically. This was done in 5 lbf increments, and the average current was measured for each run.

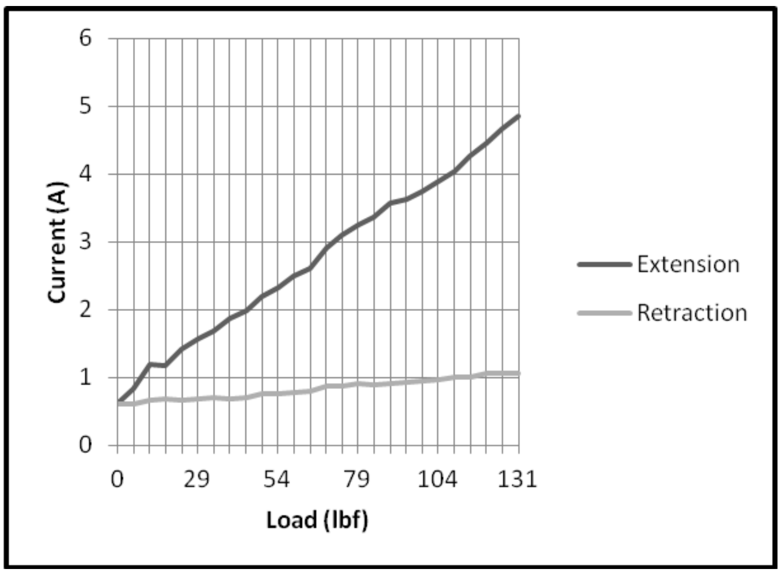

Figure 3. Average current during extension and retraction of actuator

The user manual recommends a 6A fuse. This value was not exceeded even as the actuator out-performed its rated performance and raised loads of up to 136 lbs, which was the upper limit of testing (136 lb data is not shown in Figure 3 due to the 5 amp limit of the ammeter). This load is greater than the maximum load that would be experienced in opening the landing brake at 100 knots. As seen in Figure 3, the graph of load versus current is linear, so it can be extrapolated that the maximum load under which the actuator could open is 167 lbf with an average current during extension of 6A, which corresponds to 111 knots. In flight, the force of the actuator would vary during landing brake deployment, reaching the calculated values only as it approaches its maximum angle of opening. The test was extremely conservative since the actuator had to lift the full load over its complete range of motion.

Force of Actuator (lbf)	Velocity (KCAS)	Significance
48	60	Somewhere near stall speed?
75	75	Rated dynamic load of actuator
134	100	Assumed brake deployment speed
167	112	Where average current = 6 A
300	150	Rated static load of actuator
489	191	Never exceed speed

Table 1. Relevant values for force and corresponding airspeed

Table 1 summarizes the important values calculated from the 3D CFD results. Some of the values also incorporate results from the physical experiment with the actuator. As a result of this research, it can be concluded that the most commonly used actuator for this application, the Thomson Electrak 1, is capable of exerting sufficient force to open the landing brake of a Cozy Mark IV aircraft at typical deployment speeds, as expected. Is this the best choice of actuator? It is clear that the rated loads are being exceeded, but we have not seen any reports of failure of the actuator. The load rating for this actuator was very likely selected to provide a specific extension speed; however, higher forces can be generated at slower speeds without exceeding the amperage limit of 6 amps. Larger actuators are available for those that are concerned, but they take up more space in the rear passenger footwell and probably weigh more too. The choice is left to the reader.

Since we have characterized the current draw vs. force output of the actuator, the next logical step would be to instrument a flying Cozy Mark IV landing brake actuator and measure current draw at various IAS's during LB extension. From this, we could extrapolate actual landing brake loads and compare them to the hand calcs, 2D, and 3D analysis for validation. Since we don't have a flying airplane to use for this experiment, maybe someone else would like to perform this task?