Latécoère Aircraft Door Flight Lock Capstone Project

LATÉCOÈRE

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INTRODUCTION

• PROBLEM STATEMENT

This capstone project is about designing and prototyping a locking mechanism to prevent an aircraft door handle from being turned when engaged that satisfies requirements for geometric compatibility, electrical compatibility, and ruggedness, utilizing an electroactive polymer (EAP) as the primary actuator.

• MOTIVATION/ BACKGROUND

Current door lock systems for aircrafts have been using a solenoid as the system actuator for the past 40+ years. This locking mechanism has been reliable for the past years, however with new technology arising, like EAP, this mechanism can be improved by using this type of material, which could potentially reduce the door lock weight with a more robust design, prevent environmental effects like corrosion, and a cost reduction.

• CUSTOMER SPECIFICATION

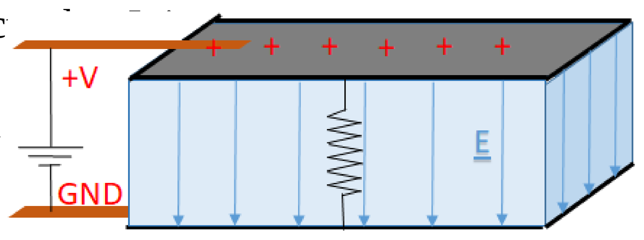
The purpose of the entire specifications is to set requirements for the supply of the equipment concerning the flight lock to be fitted on the 787 passenger doors. In detailed words, the new flight lock should perform at least as well as the previous solenoid one and should take no more space than that. In order to satisfy these requirements, the design should be guided by following specifications:

1. Limit Load on flight lock hook by the cam:
   Fx = 1183 lbf and Fy = 656 lbf with a safety factor of 1.5
2. Temperature ranges:
   Operation Temperature Range: -40 F - +160 F
   Ground soaking temperature range: -65 F - +185 F
3. During Activation Command:
   Fmax = 11 N Dmax = -6 mm
4. Returning position:
   Fmax =19 N Dmax = 6 mm

ANALYSIS BASED DESIGN PROCESS

• PHYSICS BASED MODEL

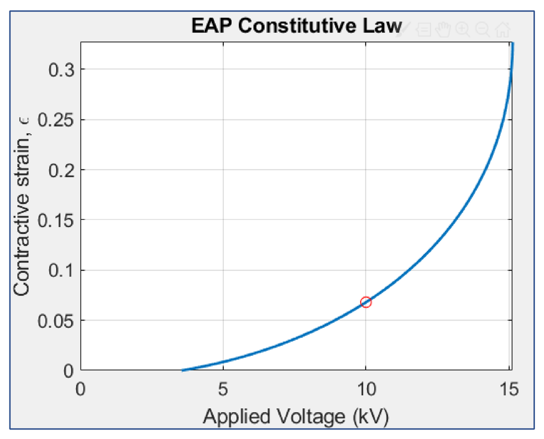
The EAP type chosen for this design is a called a "capacitive elastomer." By alternating layers of compliant elastic film and conductive electrode, contractive actuation is achieved upon voltage application due to electrostatic attraction between elec possible to model individual layers as springs separating the plates of a capacitor.



• EAP Circuit

This produces a formula to predict the power supply voltage needed for a given contractive strain:

$$V(\epsilon) = \left[\frac{2h^2}{\kappa^2\epsilon_0\gamma}(\sigma_l + E\epsilon)(1-\epsilon)^2\right]^{1/2}$$



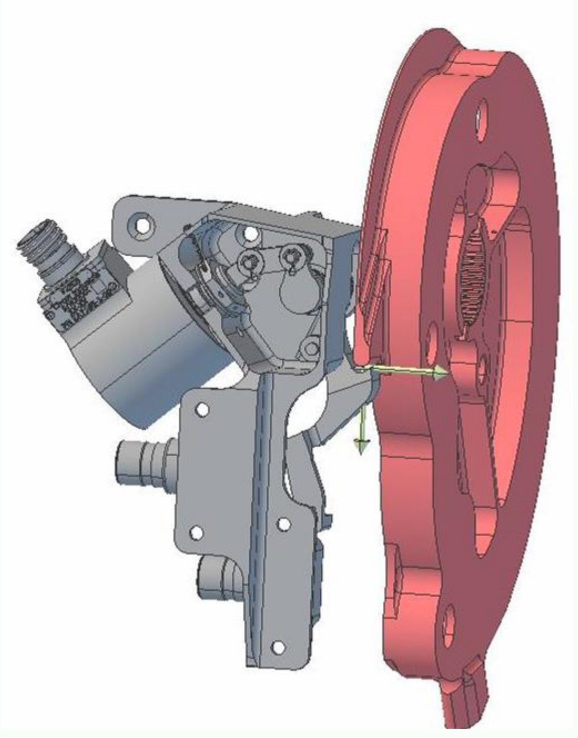
Neoprene film is selected from survey of available commercially available materials based on ease of handling and reducing required voltage.

	Nomenclature	Value
E	Young's Modulus	1.14 MPa
h	Layer thickness	.397 mm
κ	Dielectric constant	6.7
γ	Electrode coverage frac.	60%
σ_l	External load stress	9.5 kPa
ϵ_0	Electric constant	8.854e-12 F/m

Targeting 10 kV input yields the following performance metrics:

Layers required	222	Capacitance	42.7 nF
Max allowable voltage	14.9 kV	Stored energy	2.136 J
Actuation strain	6.8%	Req. dielectric strength	27 MV/m
Estimated height	9.5 cm		

• OPERATING PRINCIPLES

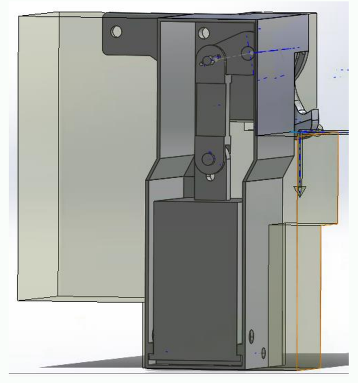


To close the aircraft door in which this assembly will be installed, a cam connected to the door handle lever is rotated clockwise into position. To lock the door, material must be placed in the way of a protrusion on the cam's outer edge to prevent counterclockwise rotation from an attempt to force the door open via its handle. The previous design uses a hook that swings into place when actuated via solenoid. This hook assembly is kept but modified to accommodate the use of an EAP as an actuator.

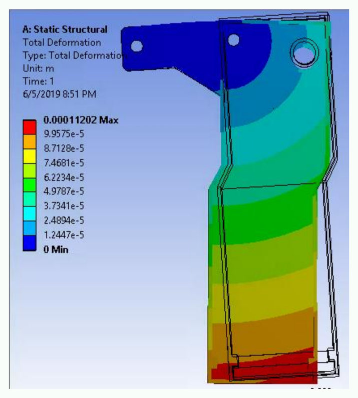
• Locking Mechanism

• CAD MODEL & FEA ANALYSIS

A housing was designed to affix the EAP to the aircraft door and convert the linear actuation to rotation of the cam hook. Finite element simulation was performed to show that forces on the door hook would be safely transferred to the lock mounting points.

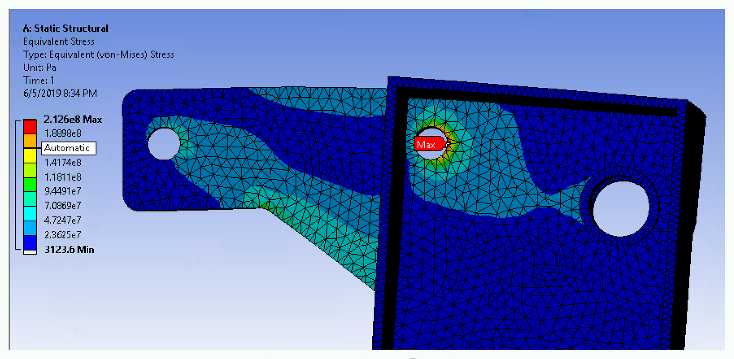


• CAD Housing



• Deformation Analysis

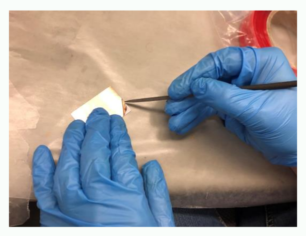
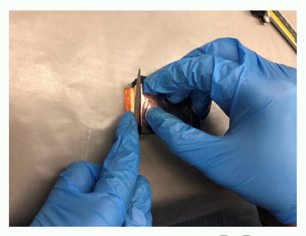
In the most extreme loading cases, the local von-Mises stress does not exceed the yield strength of Aluminum 6061 T6.



• Stress Analysis

• EAP MANUFACTURING

The finished Electroactive polymers (EAP) is about 150 layers and 8cm in length. In terms of its raw materials, we chose to use 40mm x 50 mm neoprene rubber sheet as the elastomer and 30mm x 35mm copper tapes as the electrodes in each layer. The electrode is pasted between layers, with positive and negative connecting tabs extended to the EAP side faces as shown in the pictures below. Since human sweat may affect the conductivity between layers and cause circuit shorting, lab gloves and tweezers were used during the manufacturing process.


• Manufacturing Procedures

• EAP RECIPE SELECTION

Different EAP Prototyping Recipes and Their Test Results

Elastomer + Electrode Material	Adhesive	Test Result
3M VHB Tape + Carbon Powder	N/A	Carbon powder spread out causes shorting
Neoprene + Carbon Powder	Adhesive Spray + Super Glue	Layers are easy to disperse
3M VHB Tape + Copper Tape	N/A	Shorting
Neoprene + Copper Tape	N/A	Performed well displacements

• EXPERIMENTAL SETUP

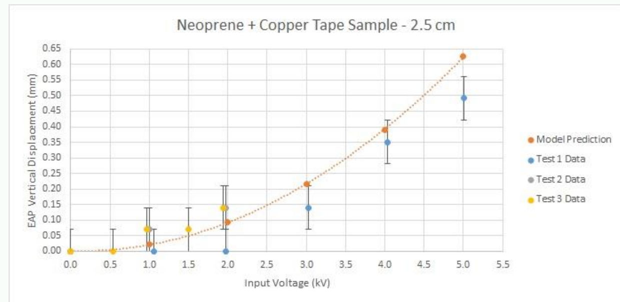
• Testing Setup

A string potentiometer, where the resistance varies based on extension of a steel cable, is used to measure displacement by monitoring its divider voltage on an oscilloscope. The EAP is powered using a high voltage PSU. An acrylic enclosure was built to prevent accidental contact with the charged capacitor.

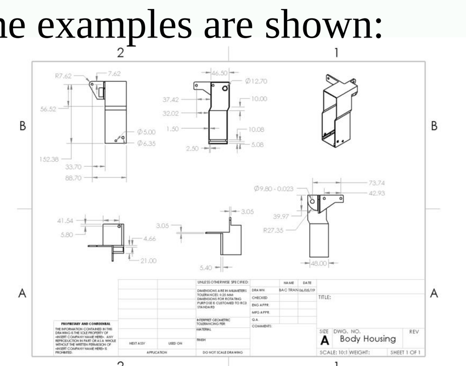
PRODUCT & DETAILED DESIGN

• END PRODUCT

The end product to be deliver to Latécoère includes the 3D printed housing and mechanism, CAD files, FEA files, the EAP prototype, an user friendly version of EAP Matlab model, technical drawings and the entire documentation of this project including detailed design process, test results, future directions and so on. Some examples are shown:



• Test Results



• Technical Drawings

• MEET REQUIREMENTS

According to simulation and test results, the team has proved that:

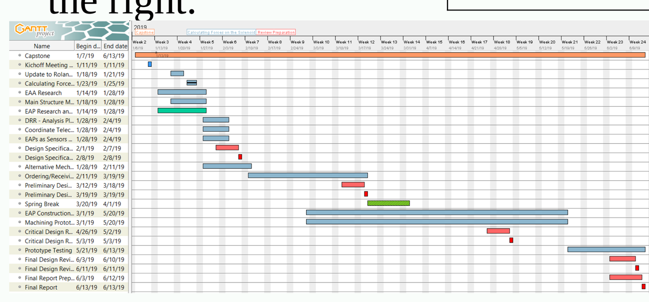
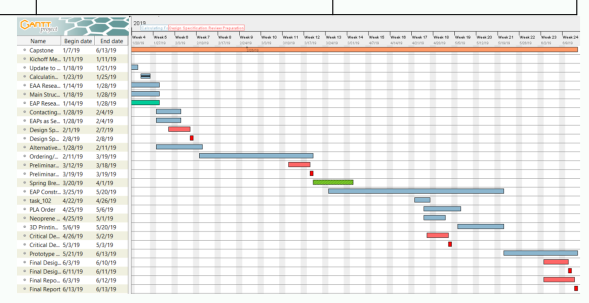
- Current EAP technology can be used to convert electrical signals into physical actuation.
- EAP actuator delivers the necessary force requirement of 19 Newtons.
- The EAP actuator delivers the necessary linear displacement requirement of 6 millimeters to lock the aircraft door.

• BUDGET & SCHEDULE

The total budget of this project is $4000, and only $1300 has been spent at the end of the project. Detailed budget distribution is shown in the table on the right.

• Original Budget Plan vs. Actual Spent

	Budget Allocated	Budget Final
Material Study	$500	$200
Testing	$500	$360
Prototype	$2,500	$740
Flexible Budget	$500	$2,700

• IMPACT & ETHICAL CONSIDERATIONS

Potentially hazardous materials such as cadmium and mercury will not be used. All of the material used and will be used in this project are standard materials, and this product is assumed to be an environment friendly product.

Due to the reliability of the current lock, which has been widely used for the last 40 years, this project will be a proof of concept - that a novel technology that has surfaced in the meantime (EAP) can be applied in this context. The intended result is designing less expensive and simpler than its predecessor.

Parts will be built to meet FAA, Boeing, and RTCA requirements. Utmost diligence will be taken to ensure proper functionality in all foreseeable operating conditions.

• LESSONS LERANED & FUTURE IMPROVEMENT

The largest barrier to performance is precision in manufacturing. At high voltages, creases in external electrodes can lead to arcing to the atmosphere. Additionally, hand stacking is the only method available to us construct an EAP. Extreme diligence is thus required to ensure no contact between adjacent electrodes and a generally clean assembly.

Further research into machine-printed elastomer-electrode composites may serve to address this issue in the future.

• ACKNOWLEDGEMENT

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