An Investigation Of Electroactive Polymer Materials As A Mechanism Of Ice Removal

Researcher; Akshay Gupta, Faculty Adviser: Dr. John Hall

Abstract

Electroactive polymers (EAP) are a class of smart materials which exhibit a shape change under an applied voltage. They have been shown to working in subzero temperatures and have relatively higher deformation capabilities. These polymers would serve as a mechanical method to remove accumulated ice from a surface. They are similar to deicing boots currently used, which expand pneumatically and break off the ice. These materials can be installed on surfaces which go under icing situations, and then be actuated when needed to break the ice off. Icing is specifically a problem on wing structures used in airplanes, wind turbines, helicopters, etc. Ice formation on airfoils changes the angle of attack of the wing and causes stalling of the wing, thus rendering it inefficient. Unlike traditional mechanical systems which can only cover parts of the surface, EAPs can be used to span the entire surface and provide protection against ice. They also use less energy, are lightweight, have a faster response rate and are not fragile like pneumatic systems. The experiment consisted of building an ionic polymer metal composite which is an ionic EAP. This was then be attached to a metal surface in the shape of a wing. This whole setup was then subjected to freezing conditions which would result in ice formation on it. The deicing capabilities would then be tested by actuating the EAP and recording the observed effects. The experiment would then be repeated multiple times with different ice thicknesses and varied time periods for which the structure was subjected to icing environment.

Background

Ionic EAPs are polymers in which actuation is caused by displacement of ionic groups and water molecules inside the polymer due to an applied external field. They require low voltage for actuation but due to the ionic flow, they need higher electrical power. They have a practical advantage over other forms of EAPs. Ionic polymer electrode composites are types of Ionic EAPs, which consist of a thin ionomeric membrane with electrodes, usually metals, plated on its surface. They show very high deformations on an application of low voltage and are very active actuators.

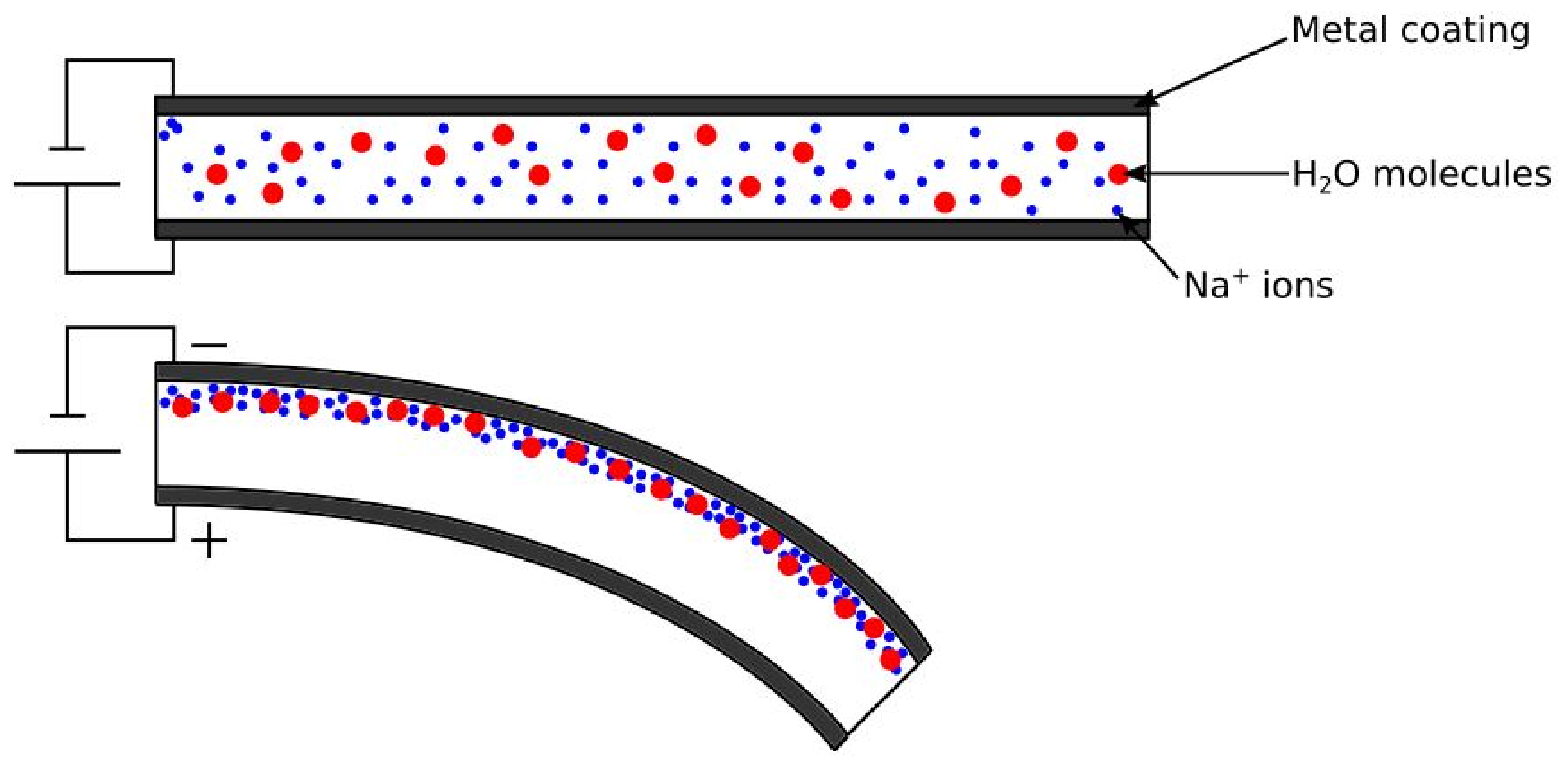

Figure: Deformation of an IPMC when an electric field is applied

The cations in the ionic polymer-electrode composite are randomly oriented in the absence of an electric field. Once a field is applied the cations gather to the side of the polymer in contact with the anode causing the polymer to bend.

Methods

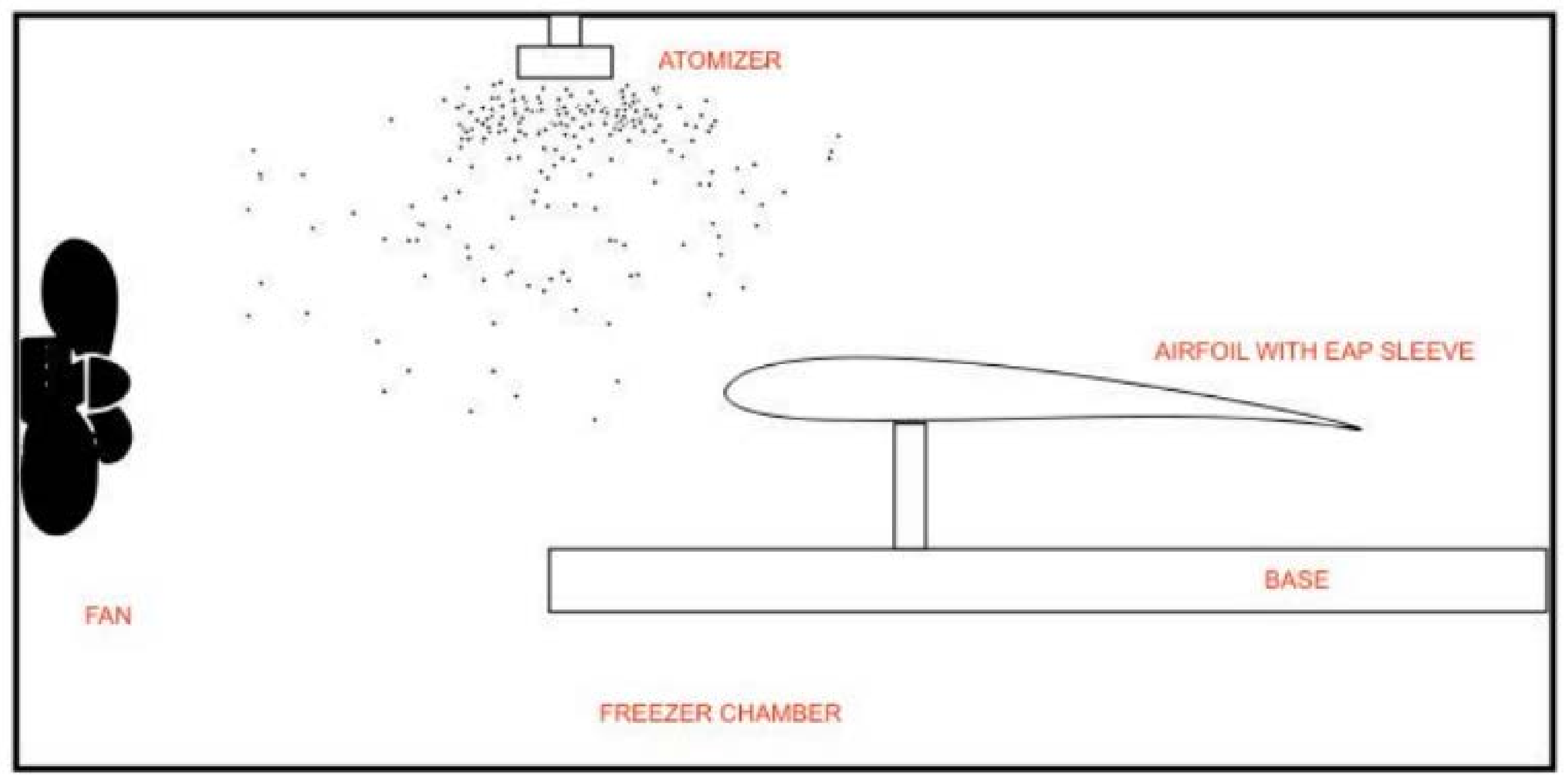

Figure: Sketch of experimental setup

The Electroactive polymer (EAP) is used in the form of a sleeve that wraps around the wings of the aircraft. When electric current is passed through it, the sleeve morphs and the subsequent deformation breaks up the ice build up. To better explain the working, we designed an experiment that can be used to show the workings of the EAP sleeve. The entire setup is housed inside a freezer that mimics the atmospheric conditions at approximately 30,000 feet. The airfoil on which the EAP sleeve will be attached is housed inside, on a base. A fan is used to mimic airflow over the airfoil, while an atomizer is used to spray mist. We plan to use this mist to mimic the supercooled water droplets that form in the atmosphere.

Figure: Computer Aided Model of setup

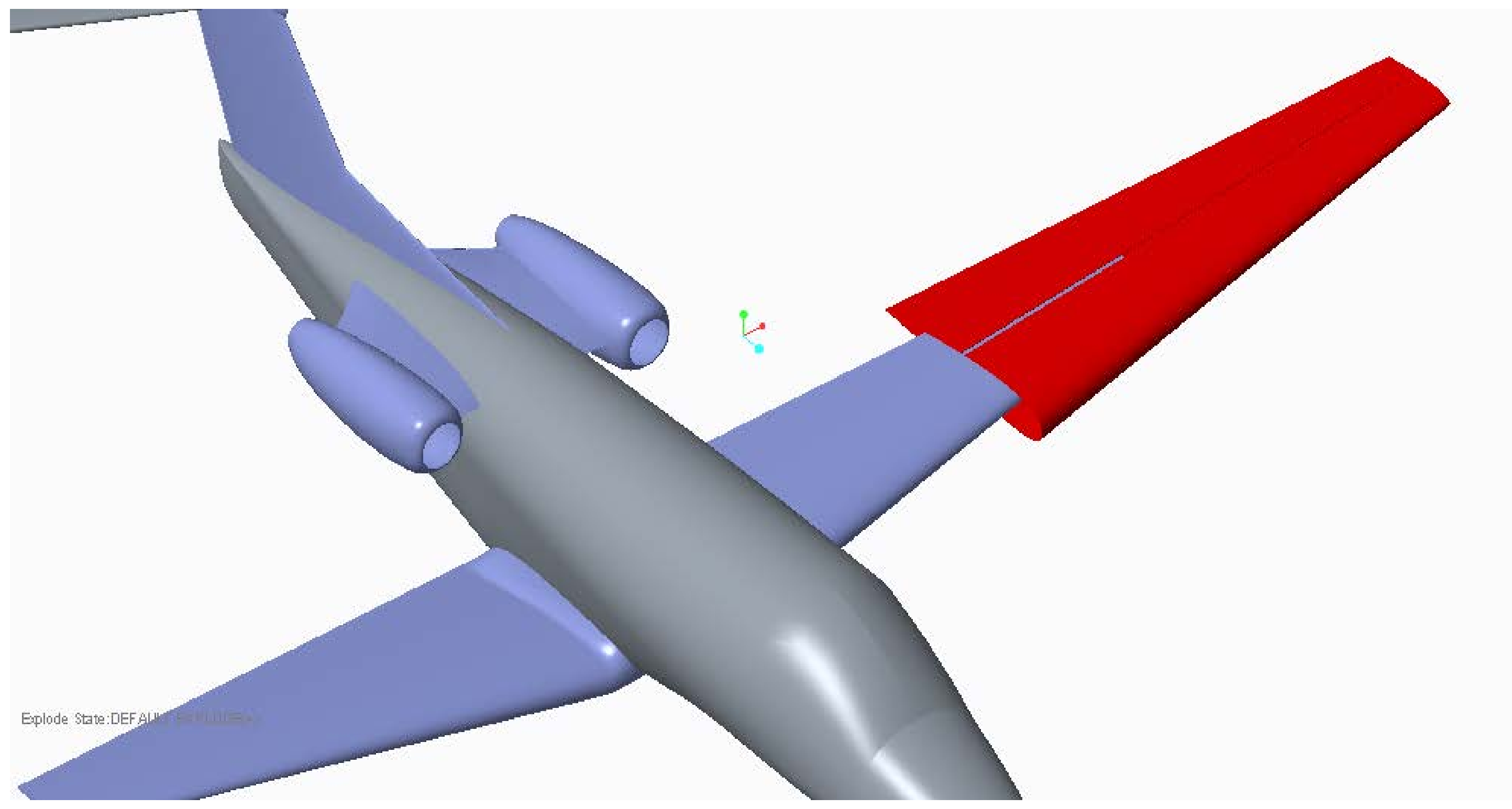

Figure: Proposed product design

Discussion

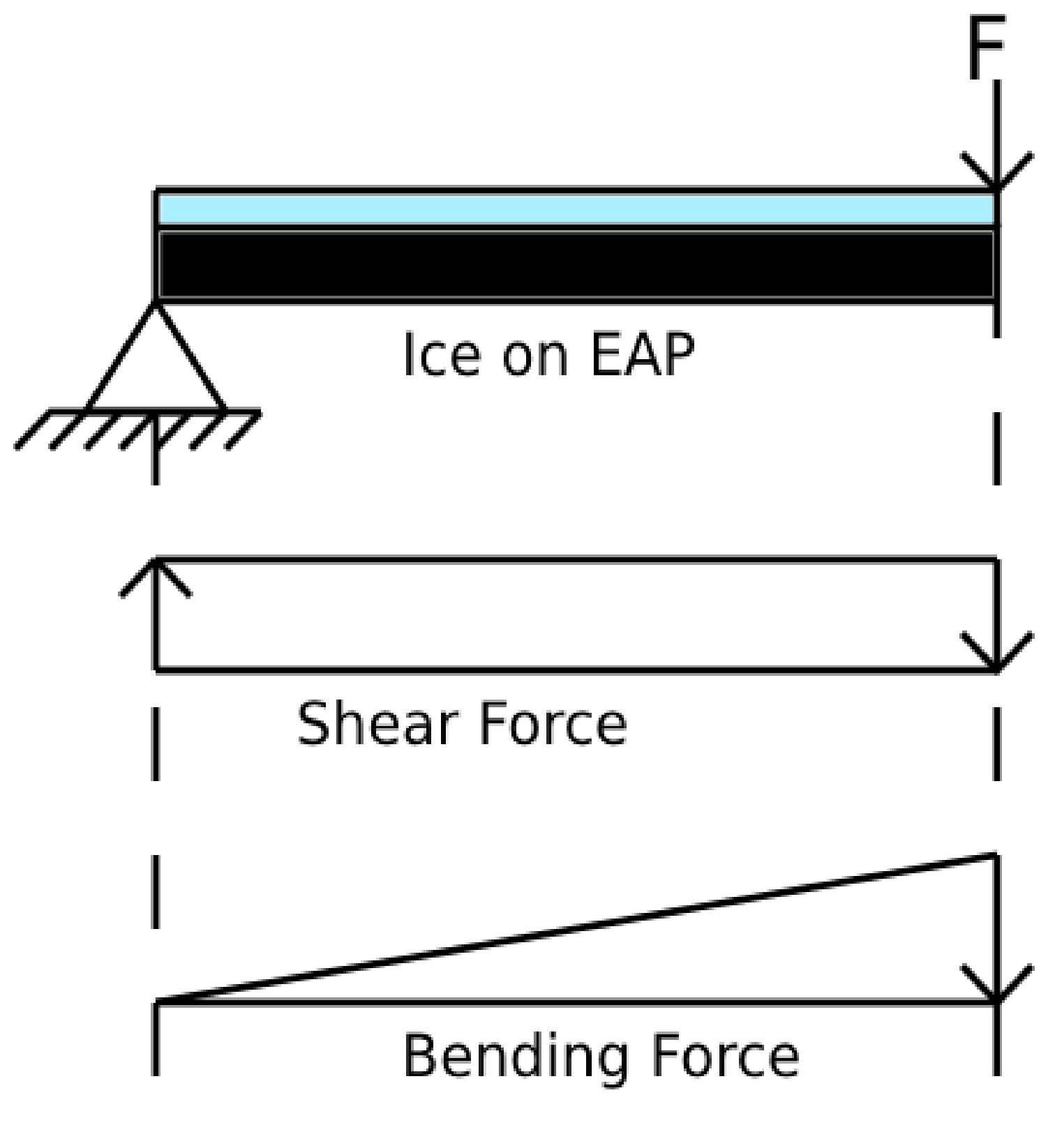

Figure: Theoretical analysis

- •F = 40 times the weight of the polymer

- •Bending force Causes the Ice to shatter and fall off
- •The stress generated is equivalent to 1000 psi, which can break a ¼ inch thick ice layer

Figure: Preliminary Testing

Further testing will be able to test for the behavior and efficacy of the method on an actual wing surface. The described process will be repeated for many thicknesses of ice to measure different desirable quantities such as power capacity of the material, the time period to complete one cycle of deicing, and the force output changes that the material might exhibit given multiple cycles of use. This data will then be used to scale the model and also ascertain the amount of ice (thickness) the sleeve can remove in an Airfoil configuration, the amount of power the product will use, and the life expectancy of the product given the metrics collected. Non-dimensional analysis will be performed on the given structure and collected data so as to scale it to a full scale model which will better validate the product until further testing.

References and Acknowledgment

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