Thermal Management Concept Evaluation for a High-Altitude Solar Platform

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Advances in material sciences, batteries, and power electronics greatly benefit the development of new concepts for unmanned aerial vehicles (UAVs). One such concept is the DLR High-Altitude Platform (HAP). This UAV shall essentially operate in the stratosphere and shall be powered by an electric propulsion system, supplied from a combination of solar cells and batteries. Except from serving as an experimental development platform, Earth Observation and Monitorization is its first usage for research purposes. Related UAV concepts can be found in [1,2,3,4,5]

Figure 1. High Altitude Platform conceptual design

More in detail, the High-Altitude Platform (HAP) is planned to be operated by electrical energy, with a cruise altitude of 20 km, and an endurance of 30 days. These conditions are rather extreme for an UAV, leading to substantial challenges in the design process. Along with, uncommon control techniques shall be introduced to guarantee the correct operation of the HAP at these conditions.

This contribution is a conceptual design study of one of the key challenges: thermal management. Unlike conventional aircraft, HAP will be driven by the interleaved use of energy from solar cells during the day and from batteries during the night, being both of them located on and inside the wing, respectively. Their usage in terms of i.e. efficiency and heat capacity directly affects the performance of the HAP. The thermal management must hence ensure that both sources of power lay within their operational temperature range, avoiding overheating and overcooling. The external environment plays a significant role in the analysis too. Since the cruise level is set to be in the stratosphere, the particular atmospheric properties the HAP will face are having an impact on its temperature distribution. Heat transfer processes such as forced convection is harder to estimate and radiation plays a dominant role.

To evaluate the concept, we present a mathematical model based on first principles for the phenomena of conduction, convection and radiation. Setting the focus on the propulsion system, the model structurally contains the HAP wing, which consists of: solar cells, structure, spar and batteries. The model can be coupled with virtual mission data or combined with the flight dynamics model to evaluate the temperature distribution across the wing with reference to Earth flying location, daytime and altitude. We can thus identify the design points of the thermal management and present the results of the conceptual sizing.

In a further step, the model shall be validated. Demonstrating its validity and refining it is an ongoing effort. For the ground case, a wing mockup has been manufactured and equipped with measurement devices. Experimental tests cases have been performed on a runway. The experimental scenario consisted of static and dynamic cases. From the test outputs, a maximum temperature difference between the numerical and experimental approaches of less than 5°C was found. The validation helped to the understanding of the thermal behavior in the wing and serves as a basis for further analysis. Further planned tests will be briefly sketched.

Figure 2. Wing mock up and equipment used for the experimental test cases

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