Title: Application of Model Based System Engineering (MBSE) methods in designing hybrid and electric propulsion system for aircraft

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Abstract:

When analysing CO_2 emissions for transport it is noted that aircraft are not the largest emitters, but unlike other forms of transport, aircraft emit pollutants at altitude and thus contribute to the formation of cirrus clouds. These clouds act like a blanket: on the one hand, they reduce the amount of heat provided by the Sun, and on the other, they prevent excess heat from radiating from the earth's surface, which is particularly important during the night. For this reason, the introduction of zero- and low-emission propulsion systems in aviation is needed.

Although large passenger aircraft account for almost all emissions, General Aviation (GA) is a better starting point for introducing changes and developing new solutions in aviation as has been seen in the past. This is due to the greater variety of GA aircraft and the flexibility in design. In addition, the current level of development of some of the alternative propulsion components and their characteristics especially with regard to weight only allows their use in smaller aircraft.

One of the problems associated with the use of alternative propulsion systems in aviation is the lack of historical data on which the conventional aircraft design process is based and the need to integrate the new parameters that characterise alternative propulsion systems. For this reason, designing an aircraft from scratch for a new propulsion system is a lengthy and costly process. In addition, and especially in the case of hybrid propulsion, an further aspect to analyse is power strategy, which directly affects aircraft range and performance. This strategy defines how different energy sources contribute to driving the propellers, either at a constant rate or varying based on the flight phase and factors such as the available energy level.

The purpose of this dissertation is to develop an adaptation of the aircraft design process for alternative propulsion systems. The main assumption on which the developed adaptation of the design process is based is to relate the values of the main forces acting on the aircraft to its design parameters. To achieve this, parametric models of the alternative propulsion systems and the aircraft are developed and integrated into the design process using a Model-Based Systems Design (MBSD) approach, which allows for the replacement of missing historical data with model-based data. Furthermore, the proposed adaptation also allows for closer cooperation between aircraft manufacturers and propulsion system and energy storage suppliers.

The propulsion model enables the determination of the required parameters of its main components based on the aviation mission for which the aircraft is designed. Knowing these parameters allows for estimating the size and weight of the components, which in turn supports an optimal airframe design using the parametric aircraft model. This approach makes it possible to analyse the propulsion parameters in a very short period of time, select an appropriate strategy for its operation when more than one energy storage is used, investigate various flight mission parameters and develop an optimal airframe concept, taking into account from the outset the integration of the main components of the alternative propulsion.

An adaptation of the aircraft design process developed in this thesis was applied to design a GA aircraft concept for four people with hydrogen fuel cell-based electric propulsion.

This approach is universal and can also be applied to drones or other types of aeroplanes also with conventional propulsion system.