World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:14, No:11, 2020

Improvement of Electric Aircraft Endurance through an Optimal Propeller Design Using Combined BEM, Vortex and CFD Methods

Authors : Jose Daniel Hoyos Giraldo, Jesus Hernan Jimenez Giraldo, Juan Pablo Alvarado Perilla

Abstract : Range and endurance are the main limitations of electric aircraft due to the nature of its source of power. The improvement of efficiency on this kind of systems is extremely meaningful to encourage the aircraft operation with less environmental impact. The propeller efficiency highly affects the overall efficiency of the propulsion system; hence its optimization can have an outstanding effect on the aircraft performance. An optimization method is applied to an aircraft propeller in order to maximize its range and endurance by estimating the best combination of geometrical parameters such as diameter and airfoil, chord and pitch distribution for a specific aircraft design at a certain cruise speed, then the rotational speed at which the propeller operates at minimum current consumption is estimated. The optimization is based on the Blade Element Momentum (BEM) method, additionally corrected to account for tip and hub losses, Mach number and rotational effects; furthermore an airfoil lift and drag coefficients approximation is implemented from Computational Fluid Dynamics (CFD) simulations supported by preliminary studies of grid independence and suitability of different turbulence models, to feed the BEM method, with the aim of achieve more reliable results. Additionally, Vortex Theory is employed to find the optimum pitch and chord distribution to achieve a minimum induced loss propeller design. Moreover, the optimization takes into account the well-known brushless motor model, thrust constraints for take-off runway limitations, maximum allowable propeller diameter due to aircraft height and maximum motor power. The BEM-CFD method is validated by comparing its predictions for a known APC propeller with both available experimental tests and APC reported performance curves which are based on Vortex Theory fed with the NASA Transonic Airfoil code, showing a adequate fitting with experimental data even more than reported APC data. Optimal propeller predictions are validated by wind tunnel tests, CFD propeller simulations and a study of how the propeller will perform if it replaces the one of on known aircraft. Some tendency charts relating a wide range of parameters such as diameter, voltage, pitch, rotational speed, current, propeller and electric efficiencies are obtained and discussed. The implementation of CFD tools shows an improvement in the accuracy of BEM predictions. Results also showed how a propeller has higher efficiency peaks when it operates at high rotational speed due to the higher Reynolds at which airfoils present lower drag. On the other hand, the behavior of the current consumption related to the propulsive efficiency shows counterintuitive results, the best range and endurance is not necessary achieved in an efficiency peak.

Keywords : BEM, blade design, CFD, electric aircraft, endurance, optimization, range
Conference Title : ICHEP 2020 : International Conference on Hybrid-Electric Propulsion
Conference Location : Jeddah, Saudi Arabia
Conference Dates : November 16-17, 2020