Preliminary Design of More-electric Actuation System for Safety-critical Rotorcraft Applications

Authors: Farahani Hashim, Craig Lawson (Cranfield University, UK)

Introduction

The next-generation rotorcraft is forecasted to be greener, safer, and cheaper in terms of operational and maintenance costs, without compromising its performance. The European Aviation Vision 2050 has defined a set of highly ambitious aviation goals for future air transport which is envisioned to be more energy-efficient and sustainable, reliable, as well as affordable; along with meeting societal and market demands. In order to reach such goals, a multi-disciplinary design and development strategy is needed to achieve such high level of integrated system design. This work outlines the high level integrated systems approach in designing a sustainable, reliable, and affordable rotorcraft system.

Problem Statement

The literature currently available on rotary-wing airframe systems modelling reveals a gap in knowledge, in which a complete assessment of the technology in an integrated multidisciplinary manner has yet to be addressed. The methodology proposed within this paper aims to offer an innovative approach in evaluating rotorcraft systems technologies whilst addressing the design complexity and trade-offs associated with the development of future rotorcraft conceptual designs. A set of metrics is defined for assessment of different technologies at aircraft vehicle level in order to perform trade-offs in achieving an aircraft which is energy-efficient, with high level of reliability to ensure safety, and having comparatively less maintenance cost. One of the areas where such improvements can be implemented includes the design of the actuation system.

Literature Review Overview

On a rotorcraft, the actuation system plays an important role in attaining the performance of the Flight Control Surfaces (FCS) specified by the pilot. On one hand, the performance of the actuation system is fundamental to the overall aircraft performance. On the other hand, the primary flight control is indeed critical to rotorcraft safety. As a matter of fact, loss of control in the primary flight control is considered hazardous to the flight safety, which directly relates to rotorcraft reliability. The worst type of cost of unreliability is of course the loss of human lives following an aircraft crash. Following the human fatality cost is the physical losses of the aircraft itself. Unreliability can also lead to flight delays or cancellations, which indirectly affects revenue especially in the commercial aircraft industry.

The fourth major cost of unreliability is cost associated with fault diagnosis, and hence the costs of repairing, removal or replacement of faulty components.

There are three types of actuation systems used in current aircraft to drive the surface motion: the conventional hydraulic actuators (HA) which is the most common type of actuation on current rotorcraft, as well as the more-electric electro-hydrostatic and electro-mechanical actuations (EHA and EMA). The former actuation system powered by hydraulics although has been long established for decades in rotorcraft; is now deemed to be less energy-efficient, by which continuous use of hydraulic power using engine-driven pumps even when it is not needed for actuation resulting to more shaft-power off-take from the engine and thus increasing fuel burn unnecessarily. Further, the inclusion of hydraulic circuits on board requires considerable amount of maintenance work. The latter more-electric technologies remove the large hydraulic circuits thus eliminating the need for constant use of engine-drive hydraulic pumps and laborious hydraulic maintenance tasks. The use of the electrically-powered systems allows electrical power to be fed on-demand thus resulting to more-efficient energy consumption.

Methodology

The methodology adopted for this study includes the identification of the key requirements for the design of rotorcraft actuators at vehicle, system, and sub-system levels. Following this various actuation system configurations is proposed. The cost of each technology towards the environment is assessed by means of an in-house tool called the Rotorcraft Mission Energy Management (RMEM) model which computes the shaft power off-take from the engine which further calculates the fuel burn for each technology. Each rotorcraft configurations is also assessed for safety by means of standard safety and reliability assessment procedures which include top level System Safety Assessment Analysis, Reliability Block Diagram (RBD) method, Fault Tree Analysis as well as Failure Modes, Effects, and Criticality Analyses.

Case Studies

For the purpose of demonstration, three types of rotorcraft actuation systems for primary flight control will be presented: the HA, EHA, and EMA actuations, which in reality representing the current and the potential future technologies for rotorcraft primary flight controls. A simulation of a mission case study will be presented which analyses the total shaft power off-take of each rotorcraft as a function of mission time, as well as the safety assessments for reliability for each of the proposed system as part of the trade-off study.

Conclusion

This research will contribute to the development of a set of methodology to perform multi-disciplinary trade-off assessment for different types of rotorcraft actuation system. Such a methodology is designed so it can be utilized to analyse the feasibility of the installation of any new system technology on rotorcraft. The end goal of this project is to analyse the potential of more-electric helicopters - where gears, clutches and shafts will be partially or fully replaced by electrical transmission, and reducing the need to burn the fossil fuel unnecessarily. It is also aimed that this contribution will open more doors to future research that enables safe helicopter flying that is capable to meet every operational challenge - even the future - that does not cost the earth.