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Simulation of Direct Drive Electromechanical Actuator with Ballscrew

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Abstract

The paper contains the description of electromechanical actuator (EMA) dynamic mathematical model developed by TsAGI in the frame of European-Russian collaborative project «RESEARCH» for the direct drive electromechanical actuator which was under CESA company development. The model was implemented within the MATLAB/Simulink software. The major focus of the model is the modularization and scalability of actuator components, as well as the focus on actuator mechanical non-linearities in the region of low input control signals as well as the possibility to use that model for flight mission cavity thermal analysis. The model has various switchable levels of components detail, which provides a balance between the accuracy and the value of the integration step in dealing with a variety of modeling tasks. Due to the possibility of taking into account a number of factors it can be used for tasks of two types. At first, it can be used for tasks requiring small integration step and high precision simulation of high-frequency processes (detailed analysis of the static and dynamic characteristics of EMA, the optimization of actuator heat dissipation, controller setting, etc.). Also it can be used for the tasks requiring rapid model calculation (analysis of the closed-loop stability «aircraft-flight control system-actuator», actuator characteristics evaluation, etc.).

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Keywords: direct drive EMA, electromechanical actuator, ballscrew, backlash, friction, simulation, Simulink;

1. Introduction

Fuel burn reduction has become the priority for aircraft operators due to environmental and cost implications. Such interest has encouraged the aerospace industry to look at ways of minimizing fuel consumption, concluding

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that the approach towards a More Electrical Aircraft (MEA), i.e. an aircraft that uses electricity to operate its consumers, could provide some benefits. This approach tends to remove hydraulic actuators and the hydraulic systems, as they require a significant amount of maintenance, are heavier and more energy consuming [1, 2].

Despite the potential benefits such as weight reduction, increased safety and reliability, lower consumption, reduced maintenance costs, etc. electrical actuators are not fully embraced by the industry due the limitations they present in their current development stage, which prevent them from being used massively or in critical areas, such as aircraft primary flight controls actuation [2]. These limitations are high actuator weight, safety concerns due to the jamming probability of electromechanical actuators, thermal behavior and electromagnetic compatibility issues.

The intention to solve these issues through the development, manufacturing and experimental validation processes was the basis for the co-founded Russian-European R&D project called RESEARCH [www.research-project.aero] which objective was the development of the regional jet elevator control system based on electrically powered actuators: electromehcanical (EMA) and electrohydrostatic actuators. The development of EMA for this system had being performed by CESA company. The actuator's overall view and main characteristics are represented below.

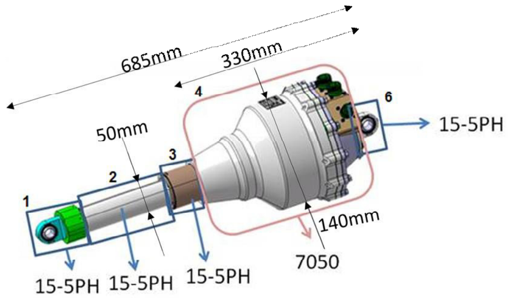

Fig. 1. EMA isometric view (CESA).

Table 1. EMA parameters.

Stroke	±75 mm
Supply voltage	270 VDC
Maximum rod velocity	80 mm/s
Rated velocity at max op. load	70 mm/s
Maximum operating load	30 kN
Stall load	45 kN

Being a highly critical application with lots of cross-related physical domains to be taken into account, the development of such system should rely on wide and intensive simulation activities through the whole development cycle. As the result the development of the detailed EMA dynamic mathematical model was started by the consortium in order to obtain static and dynamic actuator characteristics assessment and detailed evaluation, to tune the electronic control unit (controller) parameters, to check the elevator control system thermal behavior through the complete flight mission profile and to confirm the compliance of the closed control loop «aircraft – flight control system – actuation system» parameters with the requirements (stability margins and step responses parameters), as it's well known that the actuators characteristics (especially in the region of small control signals) can drastically influence the stability of an aircraft [3]. In addition, the possibility to provide to the industry the highly detailed and validated model which can be used within further EMA development programs on the early design stage is obvious.

2. Model Description

The EMA model was developed within the MATLAB/Simulink software with the use of the following principals: