ARMLIGhT

Design, development and manufacturing of an electro-mechanical actuator and test rig for AiRcrafts Main LandIng Gear acTuation systems

State of the art – Background

The use of electrical Power On Demand systems in place of hydraulic systems are becoming the norm in all new aircrafts developments. The continuing need to reduce overall fuel burn on the aircraft leads to the use of more electrically powered systems.

In an attempt to reduce weight and cost -by diminishing fuel consumption-, improve environmental impact –reducing use of hydraulic fluids and lowering fuel burn particles-, and to some extent increase safety and reliability, A/C designs are leaning towards the "All Electric Aircraft (AEA)" concept. Although, this concept may seem feasible nowadays, AEA major challenges need to be overcome:

· Safety and reliability: prove electrical systems maturity and assure the operation in the event of any possible failure.
· Mass and Volume optimization: miniaturizing devices such as IC, gears or motors.
· Harsh environment including:

- Thermal constraints: as there is no fluid which could be used as a natural refrigerator, need to evacuate heat through other methods arise.
- High Vibrations.
- EMI / EMC: adequate electrical protections are necessary to protect electronic circuits.

The benefits of the electric A/C are clear and some applications are being already targeted with the introduction of electric motors as a replacement to hydraulic ones or even the removal of a complete hydraulic system. Such achievement has recently been accomplished in A380 and A350 aircrafts with 2 electric 2 hydraulic circuits architecture (2H2E).

The absence of hydraulics also greatly reduces costs and simplifies maintenance activities. Diminution of operating costs will be patent in the forthcoming years as these A/Cs operate on a regular basis. The objective in a midterm is to eliminate another hydraulic circuit (1H2E) using the remaining one for landing gear and some primary flight control actuation until the AEA is achieved in a long-term horizon.

Regarding Landing Gears, there are multiple actuators required for stowing, deployment and steering during take-off, landing & taxiing to and from the runway. Actuators have been mostly hydraulic and much of the More Electric Aircraft research involves investigating electrical alternatives.

A good sample of the existing sizes, pressures, strokes and load capacities used on different aircrafts are (All actuation systems presented here has been designed, developed, manufactured and certified by CESA):
· Main Landing Gear Retraction actuation of Eurofighter, Airbus 350 and Airbus A400M;
· Nose Landing Gear Retraction Actuation of AIRBUS A330-340, AIRBUS A340-500/600, AIBUS A380 and A400M;
· CLG retraction actuator of A-340

Objectives

The ARMLIGhT project includes the design, manufacture and testing of an innovative and smart Electro-Mechanical Actuator for the study and validation of a future complete all-electric landing gear actuation system. ARMLIGhT actuator is based on a modular and efficient approach that integrate easily exchangeable electric and mechanical components with sensors and control strategies that allow automatic and autonomous safety control.

The ARMLIGhT Electro-Mechanical Actuator includes its dedicated Electronic Control Unit, a Built In Test equipment to detect potential failures and a anti-jamming device to guarantee compatibility with emergency actuation. Different configurations have been studied and evaluated to determine the optimum system architecture from a technical point of view. Volume, mass, electrical consumption, power to mass ratio, reliability, durability and safety are concepts that drives the development.

The implementation of the electro mechanical actuator on the aircraft poses different technical challenges that have to be carefully addressed in order to achieve a competitive solution. The objectives of the project are the following:

- To achieve the large required force at the main landing gear: The implementation of the EMA in the MLG is a challenge from mechanical integration perspective due to the limited space envelope available that affects directly to size and weight of the EMA.

- To ensure the mechanical integrity of components: usually the main landing gears components are subjected to a harsh vibration environment, with significant mechanical shocks. The effect of the unsprung mass requires a careful assessment of all the elements involved as well as the connection to the vehicle structure. The mechanical integrity is of particular importance to connectors and sensors implemented on the motor.

- To ensure thermal stability: The thermal transients must be analyzed in detail to ensure a robust and durable condition within the design envelope.

- To ensure a safe operation even in the case of failure: it has to be ensured that the failure in the electro-mechanical actuator or power electronics does not compromise the emergency extension operation.

- To ensure that the EMA meets the previous objectives with maximum power to weight ratio.

The ARMLIGhT system was tested and validated at several stages: Virtual validation at model level and finally actual experimental validations of the complete system through both on-ground and in-flight test campaigns.

For this validation purpose, the ARMLIGhT project design, manufacture and tune a Test Rig for ARMLIGhT Electro-Mechanical Actuator validation. ARMLIGhT Test Rig allowed installation both in Copper Bird® and in the ATR (Avions de Transport Regional) passenger cabin. The test bench also includes its own control system, inertia load simulation of the Main Landing Gear involved weight and counter-load actuator with its hydraulic and electric power supply systems.

This innovative concept of ARMLIGhT actuation system, fully electrically powered, is the result of a multi-disciplinary approach that considers: modularity, compactness, assembly easiness, user friendliness, process autonomy and safety in an integral way, assuring a positive environmental impact, with an increase in the quality and reliability of the main landing gear actuation systems.

Description of work

During the whole duration of the project CESA have been managing the consortium and relationship with Alenia by means of teleconferences as well as internal meetings.

After EMA and Test Benches set-up, tuning and qualification campaign in Tecnalia and CESA facilities, the Consortium priority was to perform all validation and qualification tests in order to comply with Copper-Bird and Flight demonstrator time windows available, in close collaboration with the Topic Manager, Labinal and ATR personnel. All work, tests results and discussions are reflected in internal documentation that was transferred between the consortium and Alenia. Official deliverables preparation and closure, although important and imperative, is a task that the consortium faced mainly after delivery of the equipment.

Once the integration of the In-Flight Test bench Assembly had been correctly checked, final In-Flight testing took place on March 7th 2016. It consisted of a batch of tests performed in the ATR72-600 aircraft during more than one month of work and on-site support. ARMLIGhT In-Flight Test bench assembly was tested integrated in the aircraft. Performances when supplied and commanded by the aircraft electric supply was successfully demonstrated.

EMA with On-Ground Test Bench performances were validated at Copper-Bird installations at Labinal Power Systems facilities in Paris.

These sequential and complementary validations assures a reliable, safe and efficient performance of the demonstrator and provide data for a deep concept evaluation

The actuator implements three different control modes commanded by the ECU: Active, Damping and Antijamming mode.

One of the most important tests performed are the ones focussed on the emergency operation by means anti-jamming system. Thanks to the antijamming design, functional tests could be required as a Pre-flight check to assure the correct behaviour of this emergency operation avoiding hidden failures. The proposed solution could be reengaged easily by a pre-saved sequence

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Results

a) Timeline & main milestones

The project had a total duration of 48 month. The complete specifications were agree between the consoriutm and Alenia by month 19. The Preliminary design review took place on month 9 and the final design review on month 15. The EMA with the On-Ground test Bench delivery took place on August 2015 (M38) to Copper-Bird installations at Labinal Power Systems facilities. A second unit of EMA with the In-Flight Test Bench was delivered to ATR in January 2016 (M43) for in-flight test campaign.

b) Environmental benefits

The technologies presented will open the door to high performance, environment friendly and economic aircraft operation by better exploiting available weight reduction potentials of new design philosophies without compromising the existing, high aerospace safety requirements. These technologies are also enabling contributions to sustain or even improve safety of aircraft operation by means of more affordable and efficient integrated sensing / actuating technologies. ARMLIGhT project will contribute to achieve the objectives of reducing the aircraft operational cost and reducing the environmental impact by providing manufacturing capabilities to fabricate metallic system and equipment components and structures. IATA figures show that if an aircraft reduces its weight by 100 kg, it will save four kg of fuel in each flying hour, and that every kilogram of fuel saved reduces CO_2 emissions by 3 to 3.3 kg, that is, 0,12kg CO_2 emissions are produced per kg of weight of the aircraft and flying hour.

c) Maturity of works performed

Main characteristics for ARMLIGht actuator is a linear actuator with inverted screw architecture with an anti-jamming system located inside screw able to disconnect the Landing Gear from screw avoiding in this way, any possible mechanical single failure (even screw jamming) assuring the extension of the Main Landing Gear in any case. Its dedicated electronics (ECU) is connected to a DC power supply network at 270VDC for normal extension/retraction operation. ECU also includes the necessary electronics to control the BLDC motor and to manage the auxiliary 28V BLDC motor that controls anti-jamming electromechanical system allowing always Gear extension.

The dedicated test bench is able to apply a programmable counter load on a linear actuator by means of a hydraulic actuator ensuring steady loads in high dynamic load curves, as well as in static load applications.

Taking into account the activities and results obtained, the Technology Readiness Level (TRL) achieved within the project is between TRL 5-6. A demonstrator has been developed and manufactured, and the different components (EMA and ECU) are fully integrated and tested in a simulated environment. A dedicated test bench has been developed to test all performance and operational conditions of the system. Therefore, TRL 5 has been achieved. TRL 6 has been partially achieved through functional and environmental testing and in-flight activities described in sections 3 to 5.

Picture, Illustration

Image 1. ARMLIGhT EMA actuator performing tests at ATR aircraft flight demonstrator

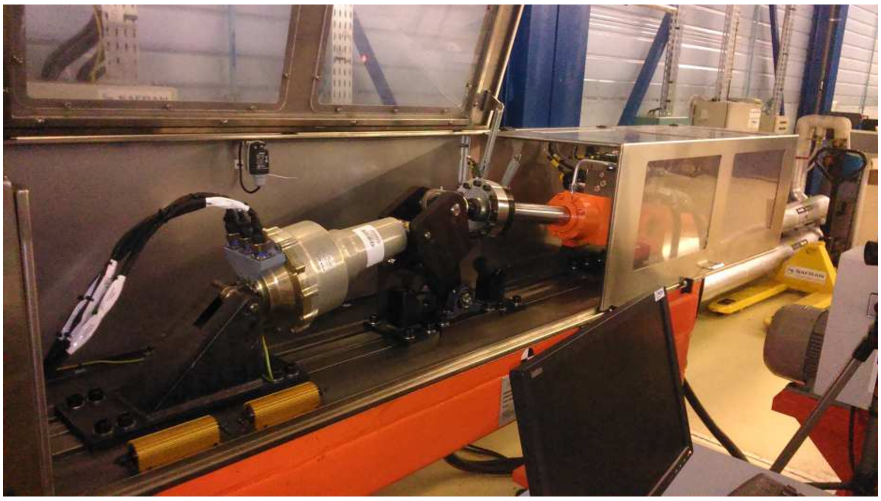

Image 2. ARMLIGhT EMA actuator performing tests at Copper-Bird Installation at Labinal Power Systems facilities

Project Summary

Acronym: **ARMLIGhT**

Name of proposal: **Design, development and manufacturing of an electro-mechanical actuator and test rig for AiRcrafts Main LandIng Gear acTuation systems**

Technical domain:

Involved ITD: **Green Regional Aircraft (GRA)**

Grant Agreement: **298176**

Instrument: Clean Sky JU

Total Cost: **748,030.00** €

Clean Sky contribution: **473,692.00 €**

Call: **SP1-JTI-CS-2011-2-GRA-03-005**

Starting date: **01/07/2012**

Ending date: **30/06/2016**

Duration: **48 month**

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