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DEVELOPMENT OF PROTOTYPE ELECTRO-HYDROSTATIC ACTUATOR FOR LANDING GEAR EXTENSION AND RETRACTION SYSTEM

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ABSTRACT

More Electric Aircraft (MEA) or All Electric Aircraft (AEA) is intensively researched and developed all over the world to reduce total Aircraft power consumption, and thus total operation cost. In MEA or AEA development, Aerospace Research and Technologies activity are focusing the area of Electrical Power system, Flight control, Engine system, Environmental Control System and Landing Gear System. [1] We are focusing the Landing Gear Actuation System and as our 1st step we have developed prototype ELECTRO-HYDROSTATIC ACTUATOR (EHA) for Landing Gear Extension and Retraction System (LGERS) application. The prototype EHA was designed and tested to evaluate the performance, weight and reliability to apply the future Aircraft application. From our prototype model development, we have clarified the technical issues to be improved or considered in the future MEA or AEA application.

KEY WORDS

EHA, LGERS, More Electric Aircraft

NOMENCLATURE

AEA : All Electric Aircraft
BIT : Built-in-Test
ECU : Electronic Control Unit
EHA : Electro-Hydrostatic Actuator
EMI : Electro Magnetic Interference
LGERS : Landing Gear Extension and Retraction System

MEA: *More Electric Aircraft*

INTRODUCTION

We are developing prototype ELECTRO-HYDROSTATIC ACTUATOR (EHA) for Landing Gear Extension and Retraction System. Our final target is to replace all of the conventional

hydraulic actuation system with electrical system to comply with future ALL ELECTRIC AIRCRAFT. The following system is our scope;

- (1) Landing Gear Extension and Retraction System,(LGERS)
- (2) Brake Control system.
- (3) Nose Wheel Steering Control System.

This time, we have designed and developed the EHA for LGERS application. For our development study, the following Commercial Aircraft was targeted;

- 1 Passengers : 100~150 Seats
- 2 Aircraft Weight : 50 ton (MTOW)

Illustrations

1. Function of EHA

To fully replace with the conventional hydraulic Retraction Actuators, the following LGERS functions were incorporated in the EHA functions;

- (1) Normal Extension and normal Retraction
- (2) Snubbing Mechanism (in Actuator)
- (3) Emergency Extension via free fall extension
- (4) Protection for Jamming/Over Load
- (5) BIT(Built-in-Test) Function by Control Unit
- (6) Failsafe Function by Control Unit

The items (4), (5) and (6) were incorporated only for EHA application.

2. Structure of EHA and its Operation

System architecture is shown in Figure 1. The EHA consists of the Hydraulic Power Unit and Electronics Control Unit (ECU). Hydraulic Power Unit consists of the hydraulic linear actuator with snubber function, hydraulic manifold, pump and DC brush-less motor. DC brush-less motor rotates both directions under the control by the ECU. Pump generates the high pressure to the hydraulic manifold, and the hydraulic manifold controls the hydraulic flow to the Actuator. That is, when the Motor rotation is "CW", the actuator is extended and vice verse. To achieve the extension and

retraction time as same as the conventional LGERS system, the ECU controls the motor rotation speed and also monitors the extension and retraction time. When the ECU is powered off, the Bypass valve in the hydraulic manifold is always de-energized. In this status, the full area port in the Actuator is hydraulically connected to the annulus chamber. When the emergency extension is triggered, the bypass valve is de-energized and the Landing Gear can be extended by the free fall extension.

3. Key Technology for EHA Development

Our key technology for compact Actuation Mechanism is Hydraulic Reservoir in the internal of Piston Rod. The most important purpose of prototype EHA is clarification of the function and performance of the Hydraulic Reservoir in the internal of Piston Rod as shown in Figure 2.

The EHA system generally equips a full-volume reservoir outside its cylinder that compensates the fluid volume caused by the difference of volume between annulus chamber and bore chamber. Our new concept EHA equips the reservoir built into the piston rod ("Dead space") as shown in Figure 2. It is possible to save its weight and space envelope. In the case of insufficient volume in the piston rod, an additional reservoir which is smaller than a full volume reservoir may be installed on the outside to compensate a lack of fluid. Effect of current prototype Actuator against Full Outside reservoir Actuator from our Study;

Weight:

6 % Weight Reduction by Full Outside Reservoir Actuator (About 3 kg Reduction Estimated)

Volume (Envelop):

1250 cc Volume Reduction by Fully outside Reservoir Actuator (1250cc is nearly equal to the volume of $\phi 70\text{mm} \times L300\text{mm}$ cylinder estimated)

4. Design Specification and Performance

The following is our Prototype EHA design specification and performance;

Input Power :

- 1 MIL-STD-704E DC270V 180Amax
- 2 RTCA-DO-160D Section16 Category A
- 3 DC28V 6A max

Power Consumption : 9.33kW

Hydraulic Fluid: MIL-PRF-5606 for Prototype only

Regulated Pressure: 210 bar (3,000 PSIG)

Environmental Temperature

EHA -55 deg C to 70 deg C
Controller -55 deg C to 70 deg C

Pump:

Constant Displacement piston pump
1 Rotation Bi-directional

2 Output Volume of rotation
0.11 ciper(1.8mL/rev)
3 Target Revolution 14850rpm (Retraction)
12000rpm (Extension)

Electric Motor:

1 Type: DC BRUSHLESS MOTOR
2 INPUT POWER: AC270V, 3 ϕ
3 OUTPUT POWER: 9.33kW
4 RATED SPEED: 14850rpm (Retraction)
12000rpm (Extension)
5 RATED TORQUE: 6.0N-m

The prototype EHA is shown in Figure 3.

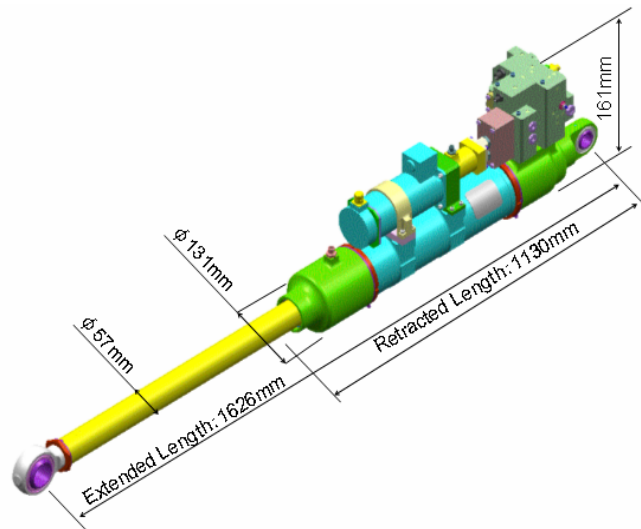


Figure 1. Three-dimensional View of prototype Landing Gear EHA

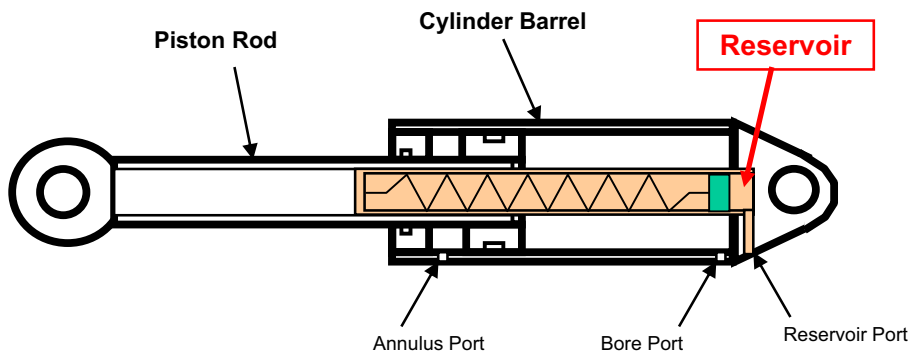


Figure 2. Internal Hydraulic Reservoir in Piston Rod bore Structure

5. Engineering Validation Test

The following tests were carried out for our design

validation of the Prototype EHA;

(1) Normal Extension and Retraction Testing

- to our design requirement
- (2) Emergency Extension Test to our design requirement
 - (3) High and Low temperature test to RTCA DO-160D Section 4 Category D2
 - (4) Vibration test at Full retract position to RTCA DO-160D Section 8 Category T
 - (5) EMI test for Motor and ECU to RTCA DO-160D Section 21 Category H

From our Engineering Validation Test, we have got some feedback to improve our future design.

6. Lessons Learned

From our prototype design development of Landing Gear EHA for 100-150 seats class Commercial Aircraft application, we have some lessons learned as follows;

- (1) We can not visually check the fluid volume in the in-Piston-Rod reservoir.
 - To incorporate the Pressure Gauge to visually check the fluid volume.
- (2) To increase the reliability to the actual Commercial aircraft application.
 - To refine the hydraulic circuit. In addition, the detail reliability analysis should be carried out to optimize our design.
- (3) To enhanced the anti-vibration performance.
 - To optimize our design of hydraulic manifold to reduce the weight and volume, and installation to make the C.G. lower.

These lessons learned will be incorporated in our further development of the Landing Gear EHA to achieve the optimized EHA for the future MEA.

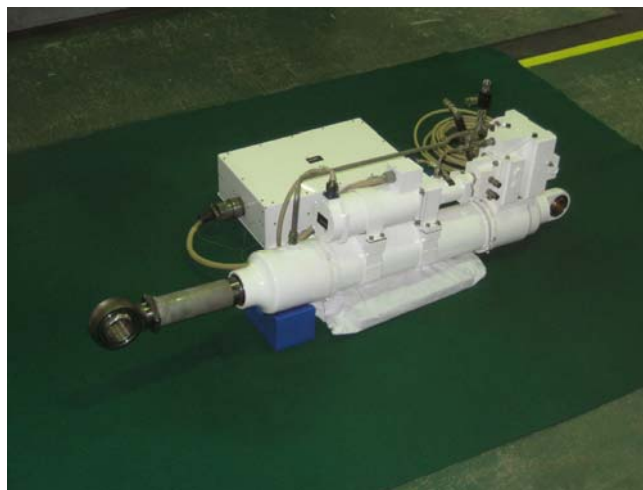


Figure 3. Overview of prototype Landing Gear EHA

Table 1 Design Specification of prototype Landing Gear EHA

Descriptions	Specifications		Remarks
Size	Full Extended Length	1626 mm (Nominal)	
	Full Retracted Length	1130mm (Nominal)	
Stroke	496mm (Nominal)		
Rate	Extending Rate	41mm/sec	496mm/12sec
	Retracting Rate	58mm/sec	496mm/8.5sec
Load (External)	Extension Case	54kN	
	Retraction Case	107.6kN	

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1. Power Optimized Aircraft R&T Website; <http://www.poa-project.com/>