



“Distributed and Redundant Electro-mechanical nose wheel Steering System”



DRESS early achievements presentation – Paris Air Show 2009

1. PROJECT CHARACTERISTICS AND OBJECTIVES

1.1. Background

In the large commercial aircraft market, landing gear systems are currently operated using hydraulic power. It has been widely recognised that there's a need from a social and environmental impact to improve the efficiency of aircraft and their associated systems. Alternative power source (electric) strategies are considered for aircraft systems, that are traditionally hydraulically powered. Several research programmes, currently underway, are taking more electric aircraft technologies through the final validation phase prior to deployment on aircraft programmes. Continuous efforts are also being made by the aircraft manufacturers and the air traffic control sector to fully automate the aircraft approach, landing, ground manoeuvres and take-off. This will increase the air transport system efficiency by allowing the aircraft to operate in all weather conditions. Due to the current aircraft steering system loss objective, airworthiness regulations impose a minimum visibility that would allow the pilots to safely regain manual control in case of steering system loss.

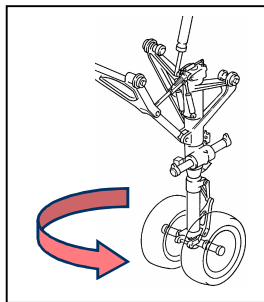


Fig. 1. Nose wheel

1.2. Objectives and Scope

DRESS aims to develop a steering system that increases significantly the levels of reliability and availability. This will provide the aircraft with true, all-weather (zero visibility) operational capabilities. Additionally, it will make it compatible with an automated ground guidance system, offering significant aircraft operational improvements and enabling more efficient air transport. DRESS meets the requirements of the More Electric Aircraft, incorporating electromechanical actuation technology. It also evaluates a modular control architecture based on a digital bus network, offering reconfiguration capabilities.

1.3. Project organisation

DRESS achieves this technology breakthrough by investigating in both fields of system architecture and electro-mechanical actuation. It brings together 13 actors of the European aeronautics industry including an aircraft manufacturer (AI), a landing gear manufacturer (MD), two Systems and Equipment manufacturers (SAAB, MB), a Research Institute (IA), five universities (INSA, UHA, UCL, UCV, BUTE), and three SMEs (TTTech, EAT, SPAB).

- MB : Messier-Bugatti, France
- SAAB : SAAB Avitronics, Sweden
- AI : Airbus, UK
- MD :Messier-Dowty, France
- INSA : Institut National des Sciences Appliquées, France
- UCL : Université catholique de Louvain, Belgium
- UCV : Universitatea din Craiova, Romania
- BUTE: Budapest Univ. of Technology and Economics, Hungary
- UHA : Université de Haute-Alsace, France
- TTTech: TTTech, Austria
- EAT: Equip'Aero Technique, France
- SPAB: Stridsberg Powertrain AB, Sweden
- IA : Institute of Aviation, Poland

2. SYSTEM SPECIFICATION

The first stage of the project was to define the technical specification of the new, electrically actuated system. In order to identify the needs without focusing directly on the current hydraulic system, a functional analysis was performed. The criteria were identified based on the performance, the safety, the reliability, the operability, the weight, the environmental conditions, etc. A technical specification for an airworthy system was issued. Later on, some technical requirements not applicable to the system lab demonstrator were released in order to fit with the budget and objectives of a research project. Some key specification parameters and features are summarised here. The maximum mechanical power required is around 1kW. The maximum angular speed is 20°/s. It must be possible to tow the aircraft with the nose wheel free to rotate. The loss of steering function probability objective was set to 10^{-9} per flight hour, well above the current system values. The system robustness against shimmy is a key requirement. The specification was regularly updated and will be improved at the end of the project after experiments have been held and all lessons have been learnt. The outcome of this will provide a better way to define future systems.

3. SYSTEM ARCHITECTURE TRADE OFF STUDIES AND SELECTION

3.1. Actuator architecture

Trade-off studies were performed to define the mechanical path topology and size the reducers and electric motors. A top-down generation of architectures combined with a bottom-up filtering with respect to technological constraints led from a very high number of solutions at functional level to a limited number of embodied architectures. The motor and power control electronics study was run in parallel. Fig.2 depicts the final trade-off between three architectures, highlighting the arrangement eventually selected for DRESS. An active/active configuration is used, where each mechanical path provides half of the required effort. The worm gear technology was selected with torque summing at turning tube level. In case of failure, the fault path can be declutched and the wheel is steered using one path only. The study validated the choice of the high power density, split-phase permanent magnet, synchronous, Stritorque motor. Fault tolerance at motor level was not needed and a state-of-the-art, single channel architecture was used for each motor.

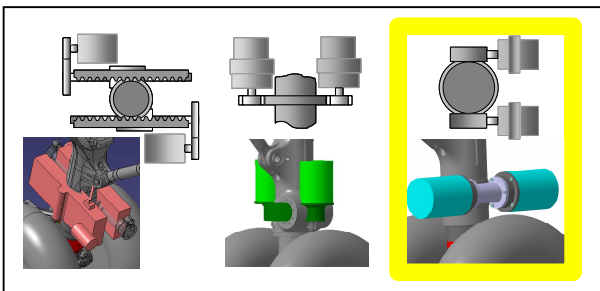


Fig. 2. Final actuator trade off

3.2. Control system architecture

The system architecture shown in Fig.3 is based on a deterministic time triggered field bus.

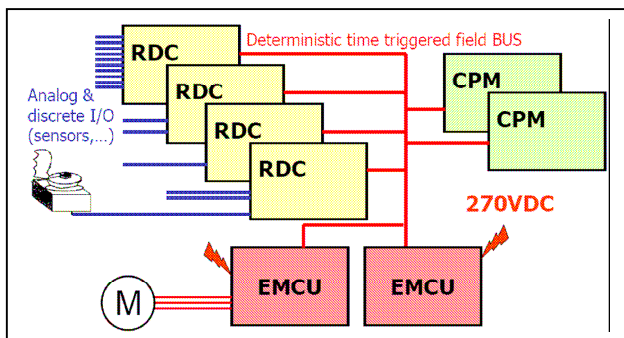


Fig. 3. Control system architecture selected

The bus connects the:

- Electric Motor Control Unit (EMCU) that drives the electric motors

- Remote Data Concentrator (RDC) that manages the inputs and outputs
- Core Processing Module (CPM) that handles nodes dedicated to computation

It is an open and modular architecture, meaning that additional functions and nodes can easily be added.

4. DEMONSTRATOR DESIGN AND MANUFACTURE

4.1. Electric motor and power electronics

The system thermal behaviour was a key issue. As a result, thermal studies were carried out, investigating several system mission profiles. Fig. 4 shows an electric motor and power control unit designed and manufactured according to system trade off choices.

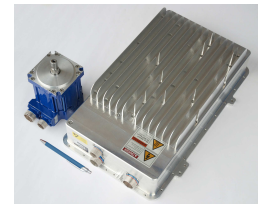


Fig. 4. electric motor and power control electronics

4.2. Actuator Mechanical Transmission

Detailed design of the actuator mechanical transmission followed after the architecture selection. Components were selected for procurement and parts were machined. Two prototypes were assembled. Fig.5. presents one DRESS prototype.

The housing is made of a single block aluminium. It is a fully sealed assembly, sized to withstand -55°C to 85°C , suitable for the DRESS demonstrations.



Fig. 5. Mechanical Transmission

4.3. System control units

RDC and CPM were designed for laboratory conditions only. Control laws were developed to comply with the distributed architecture before implementation in the hardware. Each node is composed of an Input/Output card designed especially for DRESS, plugged to a TTP module. Compliance to develop nodes by different partners after agreement on a communication data base specification was demonstrated. This allowed for trouble-free communication between the RDC and the EMCU.



Fig. 6. RDC unit

5. SHIMMY PHENOMENON STUDIES

5.1. Shimmy: a dynamic phenomenon

Shimmy is a dynamic phenomenon illustrated in Fig.7. It results from coupling of the landing gear dynamic (torsional and bending) modes with the tyres. Shimmy can be catastrophic and was identified as a key design parameter for the electric steering system.

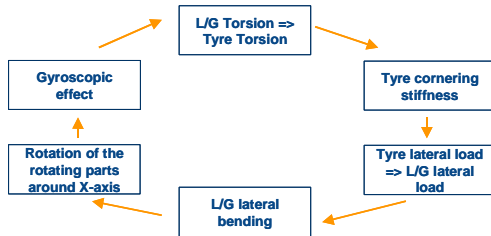


Fig. 7. Shimmy phenomenon schematic

5.2. Criteria for landing gear stability

Criteria were identified to assess the stability of the Nose Landing Gear, damping the oscillations and defining the maximum wheel deflection due to given perturbations.

5.3. Sensitivity analysis results

The objective was to perform an actuator and landing gear parameters sensitivity analysis versus stability criteria. The study has shown that the leg structure remains the main contributor to the shimmy phenomenon. A coupled steering system/leg structure is needed to optimise the nose gear stability. The DRESS electromechanical steering induces a lower risk of coupling between torsional and bending modes compared to the current hydraulic system. This conclusion will be confirmed by dynamic experiments. An assessment process correlating models and tests was also defined.

6. DEMONSTRATOR TESTING

6.1. Electric motor and power electronics

Component testing was performed on the electric motors and power control units to validate their performances and correlate the associated functional and thermal models.

6.2. Mechanical transmission

Testing on the mechanical transmission during actuator assembly was performed to measure stiffness, friction, efficiency of isolated components, whenever possible. The loads were applied manually without using the electric motors.

6.3. Actuator standalone tests

One DRESS prototype was tested, supplying the electric motors without antagonist torque load on the turning tube interface. For this, one actuator path was used to load the other path. thermal tests were performed to investigate if the system duty cycle defined in the specification was achievable. Environmental tests with controlled temperature in the range of -55 to 85°C were also conducted. Fig.8 is a picture of the test installation.

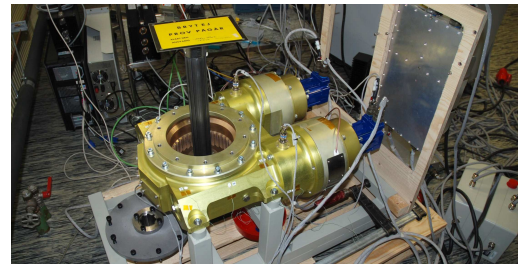


Fig. 8. Actuator tests

6.4. System tests

The complete system is currently being tested using a bench that was designed and manufactured especially for the DRESS project. The bench includes a dummy landing gear with some adaptable parameters. The landing gear angle is controlled by the DRESS actuator, while two different antagonist torque control systems can be used. A "classic" low frequency antagonist torque module applies the effort with an hydraulic system, as shown in Fig.9.

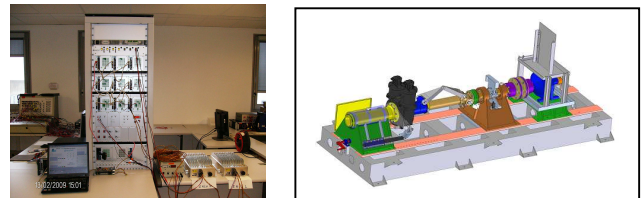


Fig. 9. System test with low frequency torque generating system and control bay

In order to apply torque with frequency up to 60Hz, and correlate shimmy modelling studies, a dynamic module is used. The torque is generated using unbalance wheels as shown on the Fig.10.

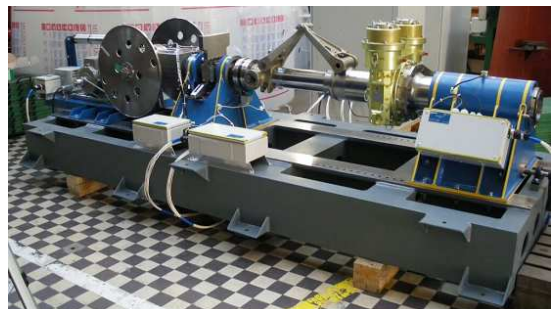


Fig. 10. System test with high frequency torque generating system

7. MODELLING ACTIVITIES

Modelling and Simulation was extensively used in the design, in order to define and evaluate the DRESS performance and behaviour. A simulation plan was defined. One difficulty of the project was to control the model assembly, ensuring good interfaces and managing confidentiality. Seven partners contributed to the complete DRESS model, as shown in Fig. 11.

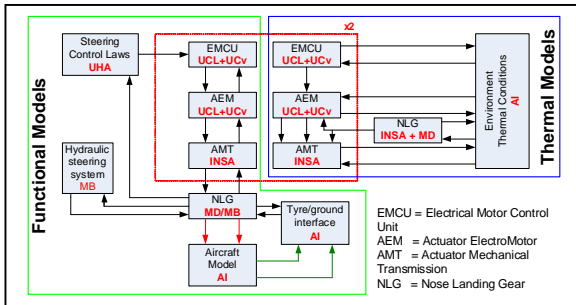


Fig. 11. Model assembly schematic

Matlab/Simulink was used as common platform for simulation at component, system, and aircraft level. Other specific tools were used for particular studies, such as structural and thermal analyses. Ground manoeuvrability studies were also performed at aircraft level to assess the steering performance. Consistency between physical tests and simulations was ensured in order to get the best possible correlation with testing and to identify the model parameters. The first performance assessment and comparison between hydraulic and electromechanical technologies has already been completed. The results indicate that DRESS performs better than the hydraulic system. The models are currently being upgraded with test results before making the final assessment.

8. AIRCRAFT COMPLIANCE ASSESSMENT

At the time of issuing this document, the DRESS final assessment is still to be performed. Therefore, only early conclusions can be drawn. The system will be evaluated considering all physical test reports and simulation results. The objective is to assess the compatibility of the DRESS solution for a future aircraft, and in particular the areas that follow.

- System performances and shimmy sensitivity: Modelling results indicate better performance for DRESS compared to the hydraulic system and gives confidence in robustness against shimmy. Backdriveability enabling towing was ensured by

modelling and should be confirmed experimentally.

- Weight: The DRESS actuator is heavier than hydraulic actuator even with optimised design. Global assessment is needed at aircraft level.
- Safety: The DRESS reaches higher safety objectives compared to the current hydraulic system. The appropriate values for a future aircraft must be set.
- Operability/ Maintenance: The impact of an all-electric nose wheel steering with regards to maintenance considerations is to be assessed.
- Cost impact: Cost reductions are anticipated by the DRESS solution, however these are to be evaluated in detail.

CONCLUSION

The DRESS project is fully progressing with final assessment to be performed before the end of 2009. This study of an all-electric steering system already provided very useful information on the following areas:

- Electromechanical actuation
- Components (reducers, motors, bus)
- Active/active actuator control
- Shimmy phenomenon with EMA
- Distributed and modular system design.

Additionally, questions about the specification and the constraints associated to an all-electric, nose wheel system, were raised. This is also an important outcome. In order to design a new, optimised solution in the future, it is required to reconsider or precise some technical requirements. The DRESS achievements can be used as basis for future designs.

More details on www.dress-project.eu

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