TEST RIG PROTOTYPE FOR TESTING OF NOSE LANDING GEAR ELECTRICAL ACTUATOR DESIGNED FOR PASSENGER AIRCRAFT

Zbigniew Skorupka, Wojciech Kowalski, Rafał Kajka
Institute of Aviation

Summary

Due to ecologic and economic reasons modern industry uses electrical drives and steering systems. Aviation is in this trend but restrictive safety and reliability requirements are the reasons of slower progress than in rest of the industry. In this article authors want to show process of designing, making and implementing test rig prototype for testing electrical actuator designed for front landing gear steering system of passenger aircraft

1. AIRCRAFTS ELECTRICALLY ACTUATED SYSTEMS

In modern engineering solutions electric drives are replacing older hydraulic and pneumatic systems. It is natural process due to computer based control systems which are based on electric signals processing and analysis. Hydraulic and pneumatic control systems require special (dedicated) mechanoelectric interfaces in order to enable computer based control. Some of the elements of hydraulic or pneumatic systems are simple to direct to control via computers but some of them (one can say that most of them) are controlled indirectly by interfaces mentioned above what can cause not satisfactory performance and accuracy of driven object most often compared with too high mass of the system.

In recent years ecological aspect is also taken into account. Oil based systems are extremely pollutive because of oils used as working fluids (problems with oil leakage, waste and utilization). In aviation SKYDROL oil is commonly used due to wide range of temperature in which it preserve nominal parameters but is very harmful for people managing it as well as for the environment.

Due to problems mentioned above, electrical systems are natural successor of current fluid and air based systems. In aviation electrical systems are tested for many years thanks to what many systems in airplanes are now electric based on servomechanisms used for steering flaps, ailerons, rudders or slots.

Big machines require heavy duty landing gears with efficient actuating systems in order to control them (retraction, brakes, nose wheel steering). Such parameters are now available by use of hydraulic systems.

Landing gear engineers are working on reliable and efficient electric steering system for passenger aircrafts nose landing gear wheels. Such work need to be done due to fact that in near future only landing gear will need hydraulic power system. Such configuration will be too heavy and too expensive for airplane owners. Also ecological aspect of electrical systems is a factor for landing gear control system change.

2. TEST RIG GENERAL REQUIREMENTS

Due to problems shown above, consortium was created in 2005 out of European aviation, SME and universities. Consortium successfully gained UE founding for design and tests of electrical control system for Airbus A-320 nose landing gear (fig. 1).

Fig. 1. Airbus A-320 (source Airbus)

Project was named „Distributed and Redundant Electromechanical nose gear Steering System", acronim DRESS. The consortium was formed out of companies such as AIRBUS, SAAB, MESSIER BUGATTI, MESSIER DOWTY, EQUIPEARO, INSTITUTE OF AVIATION and others. Institute of Aviation role was to design and manufacture test rig for testing electric actuator for A-320 nose landing gear.

Range of tests to be made was wide. It consisted series of tests which purpose were to simulate as many scenarios as possible during landing gear operation. Tests were divided into two groups: dynamic and quasistatic. Range of parameters for each group is shown in table 1.

Table. 1. Selected test rig parameters

Quasitatic tests module main parameters - ATCSS	
Maximal angular rotation	+/- 90°
Maximal angular speed (quasi static response)	18°/s
Small angular rotation	+/- 5° at up to 2 Hz (dynamic response of the electrical steering system control loop)
Dynamic tests module main parameters - DCSS	
Maximal wheel rotation speed	120% take off Velocity
Maximal unbalanced mass weight	2,5kg
Maximal unbalanced mass mounting radius	290mm
Maximal angular oscillation	+/-5°
Time to speed up	>10min
Time to speed down	>2min
Emergency braking time	>20s
Maximal speed	4000 rpm

Dynamic tests consisted of rotation about L/G vertical axis with high speed rotation of L/G wheels (ex. just after touchdown) and added imbalance to the wheels which simulated tyre damage or runway roughness.

Quasistatic tests consisted of (rotation about L/G vertical axis):

• low frequency rotations to the desired position
• opposition of rotation from desired position

These tests were designed to simulate the resistance between the wheels and the airstrip surface, occurring during aircraft ground maneuvers. Additional condition was the possibility of implementation of the both groups of tests for various shock absorber deflections.

Due to above requirements it was necessary to design universal test rig. Universality requirement could not be met with a rigid structure due to the radically different motive needs for two groups of tests. It was decided to use a test rig modular design with common basis. As basis main frame with electric actuator, movable support and fixed bearing support was used. Interchangeable modules for dynamic (DCSS) and quasistatic tests (ATCSS) were mounted to the frame and to the shaft which is extension of dummy landing gear used in tests (fig. 2).

3. TEST RIG CONCEPT

The design of the test rig had to meet several requirements of the test procedure, safety requirements and have sufficient durability needed to carry out researches. First, a test rig must be designed in order to be neutral in the process of research its characteristics did not influence the obtained tests results. It was to be obtained for example by choosing such a structure in order to move test rig natural frequencies outside the measurement range of the test object parameters. At first it was thought that test rig should be designed in configuration that would reproduce real L/G mounting conditions i.e. to put L/G in vertical position as it is mounted in the airplane. This design was abandoned due to inability to reduce test rig natural frequencies to the desired level (not neutral for tests results) and due to not enough vertical space in target laboratory. Also operation and maintenance of such configuration could be too difficult.

After examination of the horizontal test rig configuration (fig. 2), it appeared that the change in orientation from vertical to horizontal simplifies design, increases the safety of operations, allows to meet the condition of natural frequencies and does not significantly affect the quality of tests results.

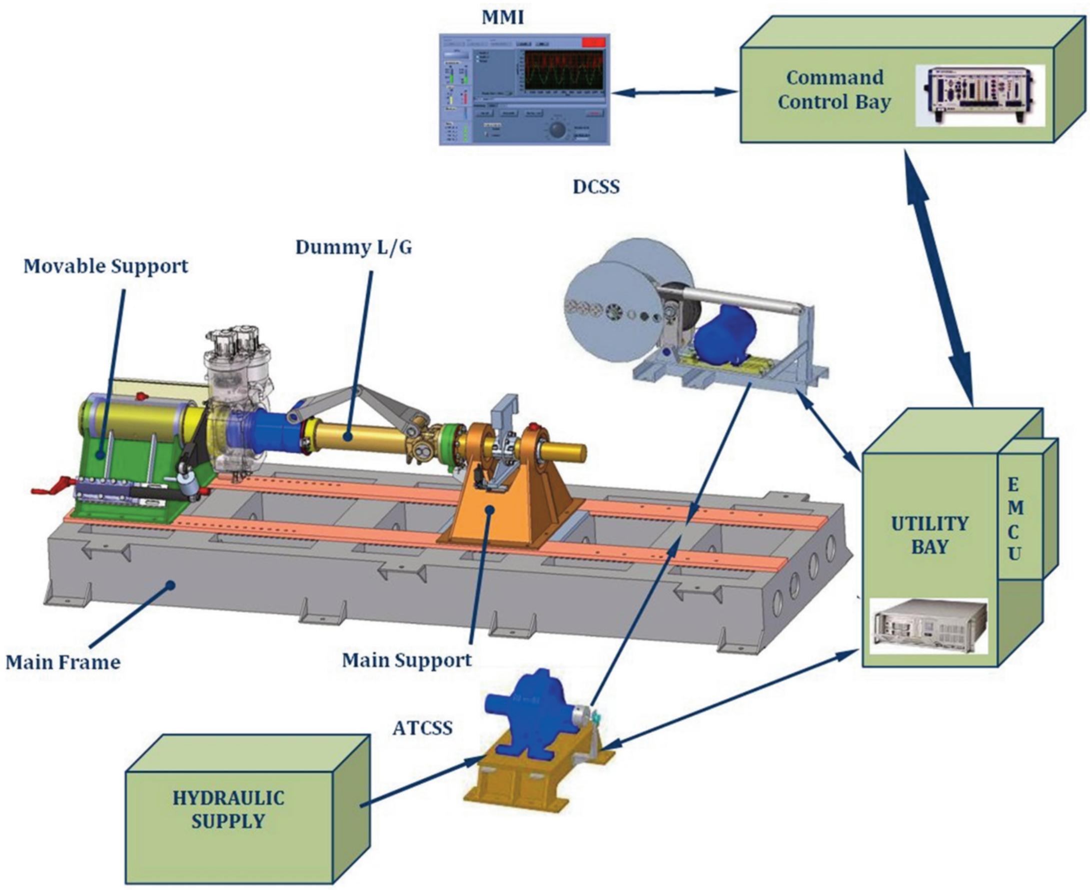

Fig. 2. Diagram of the nose landing gear electrical actuator test rig (source IA)

4. TEST RIG DESCRIPTION

As it was mentioned above, test rig was designed as modular construction consisting of three modules. First module consists of main (fixed) frame with two supports and dummy landing gear with electric actuator mounted to it. First support is movable in order to enable changes in shock absorber deflection. This support is also landing gear mounting base what resulted with necessity of adding stiffness representative which simulates real stiffness of L/G mounting in actual A-320.

Second support is used as base reference for whole test rig assembly. It is also mechanical safety module against excessive shaft rotation during tests (maximal shaft rotation is defined for each series tests separately). There are also sensors mounted to the test rig base module. These sensors are for acquiring parameters needed for test rig monitoring purposes as well as for actuator test results analysis.

4.1. QUASISTATIC TESTS MODULE – ATCSS

Quasistatic tests module (ATCSS) consists of hydraulic motor, backlashless clutch (which connects hydraulic actuator shaft with dummy L/G shaft) and hydraulic control system. After analysis of different actuators, it turned out that only the hydraulic motor is able to provide the required tests performance. Use of hydraulic motor was necessary because of huge amount of torque needed in tests as well as for stability of torque during tests with rotations in radial range of 180o (90o each side). Worth noting is the fact that the target user of the system wanted that the hydraulic installation is adapted to the hydraulic fluid “SKYDROL” commonly used in aviation because of the small parameters scattering due to the temperature changes.

It is necessary to remember that “SKYDROL” is an extremely aggressive liquid and requires a special types of hydraulic (pipes made of special rubber and stainless steel, special types of seals) and mechanical parts (special coating paint which is resistant to corrosive factors.)

Fig. 3. Quasistatic tests module - ATCSS (source IA)

4.2. DYNAMIC TESTS MODULE − DCSS

Dynamic tests module (DCSS) is composed of an electrical acceleration system (with the asynchronous motor controlled by inverter and aviation grade wheel as drive for dummy L/G) mounted to the frame and driven discs mounted on a shaft of dummy L/G. Discs simulate wheels of a real aircraft. Discs can be equipped with unbalance masses on various radiuses. Imbalances accompanied with radial speed of the discs can produce various levels of torque excitations used for dynamic stability and durability tests of electric actuator (table 1.).

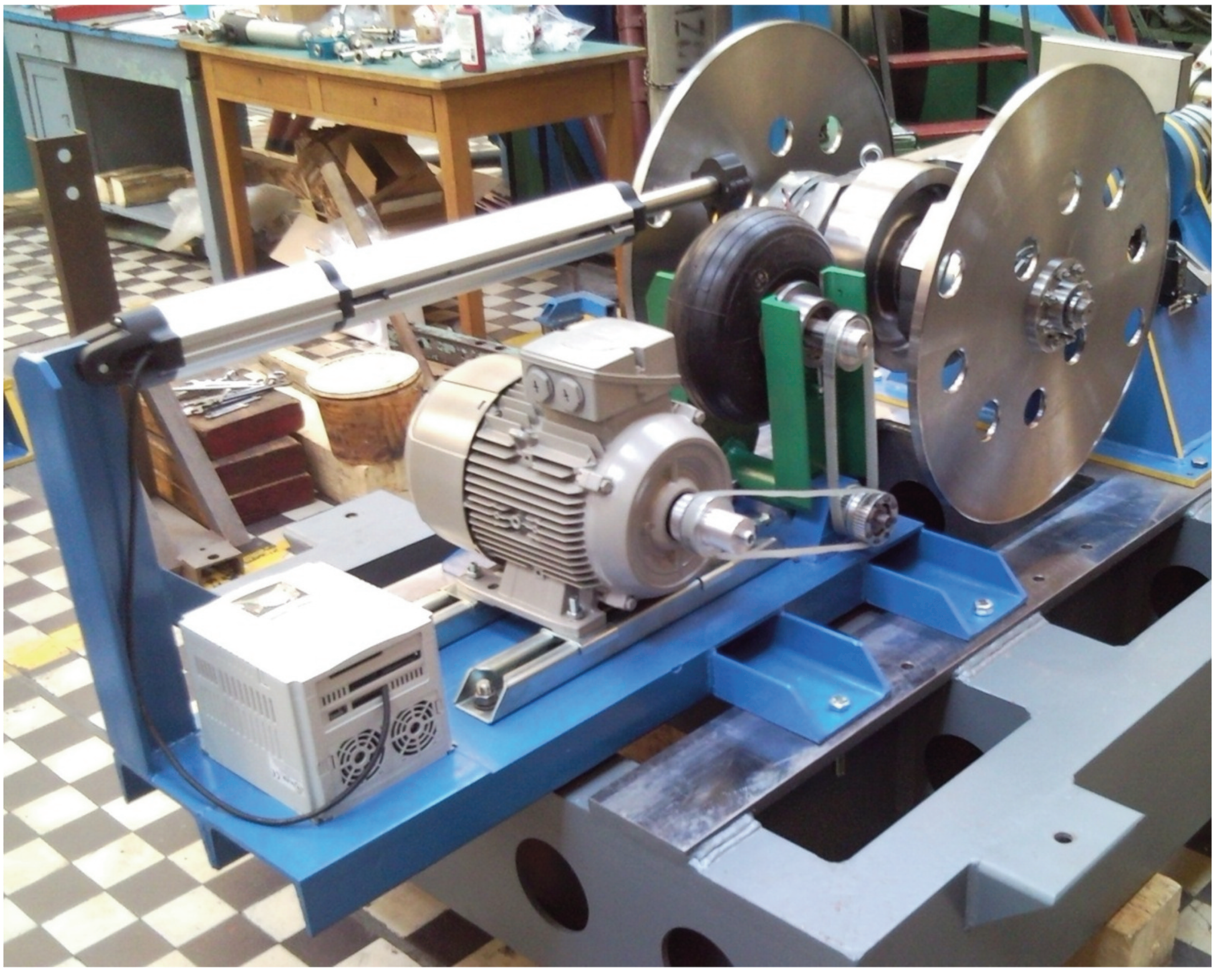

Fig. 4. Dynamic tests module - DCSS (source IA)

4.3. CONTROL SYSTEMS

Test rig control system consists of two electrical cabinets. In first of them, called Utility Bay (UB), there are all direct control devices for test rig and electric actuator are located.

UB devices:

• high and low voltage power supplies
• test rig sensors signals conditioners
• electromechanical devices for control and safety systems (ex. relays)

Utility Bay is also used for acquiring and send test rig signals to PXI computer control system, mounted in second cabinet called Control Command Bay (CCB). PXI computer is acting under the control of real-time operating system and is used for analyzing signals acquired from the test rig and for generating control signals based on acquired ones.

PXI computer is connected to the regular PC computer with installed LabView application for visual control of the test rig (MMI – Man Machine Interface, fig. 5). Block diagram of control system is shown in Figure 6.

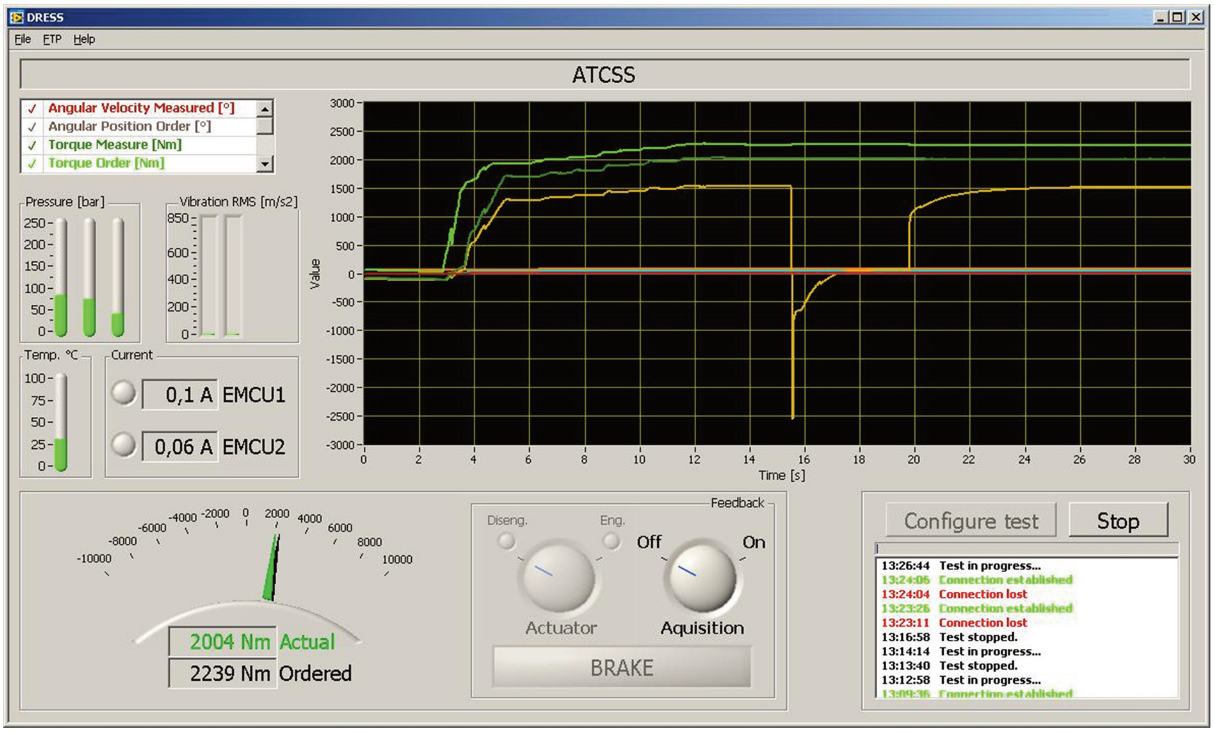

Fig. 5. Example of MMI screen (source IA)

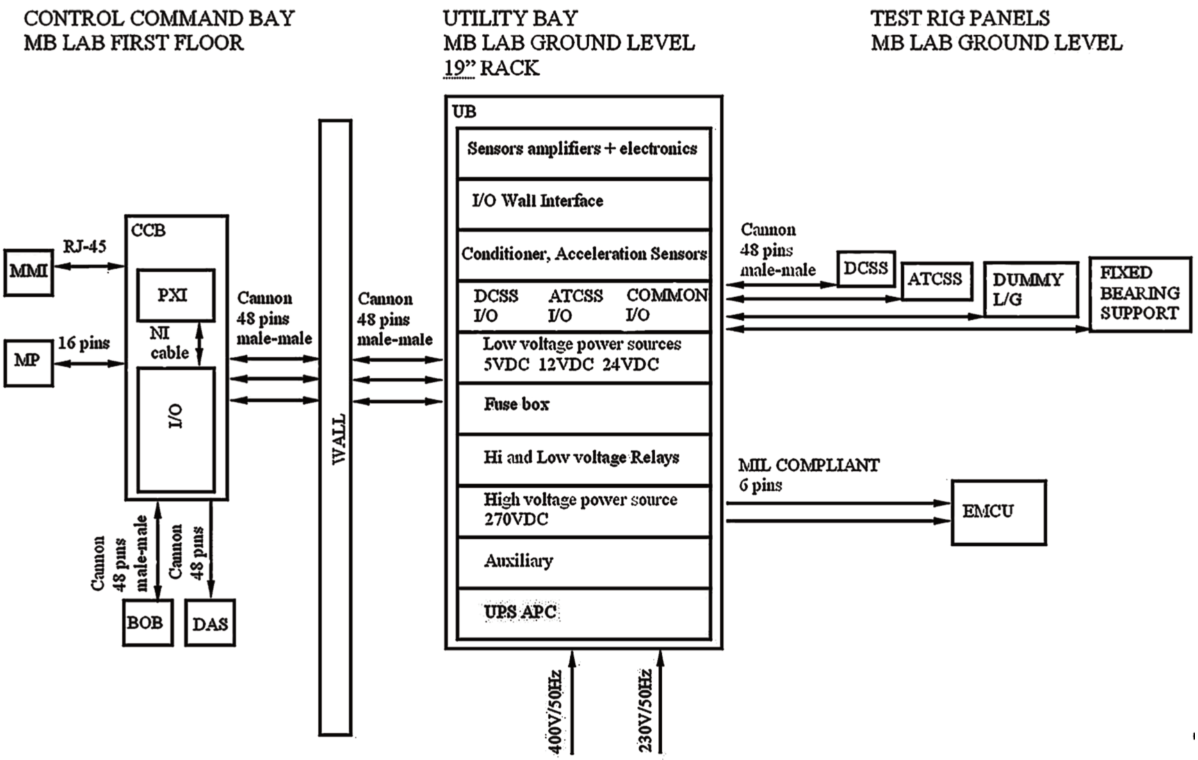

Fig. 6. Test rig control system block diagram (source IA)

5. TEST RIG MANUFACTURE

Manufacturing process of the test rig was not easy task because of its size and required manufacturing precision of the test rig components. Mechanical parts of the test rig were made entirely in Polish factories. The existing manufacturing base is entirely sufficient to perform even project like this one.

Assembly of the test rig was performed entirely by Landing Gear Department staff. Comprehensive staff was able to meet this challenge as well as it was able to cope with design of the test rig. Electrical and hydraulic control systems were manufactured in cooperation with specialized companies. However, the design of both control systems was made by Landing Gear Department staff.

Software, as well as control systems, was written by co-operating firm based on the detailed design and guidelines made by Landing Gear Department staff. The software has been optimized for the target user in accordance with his recommendations.

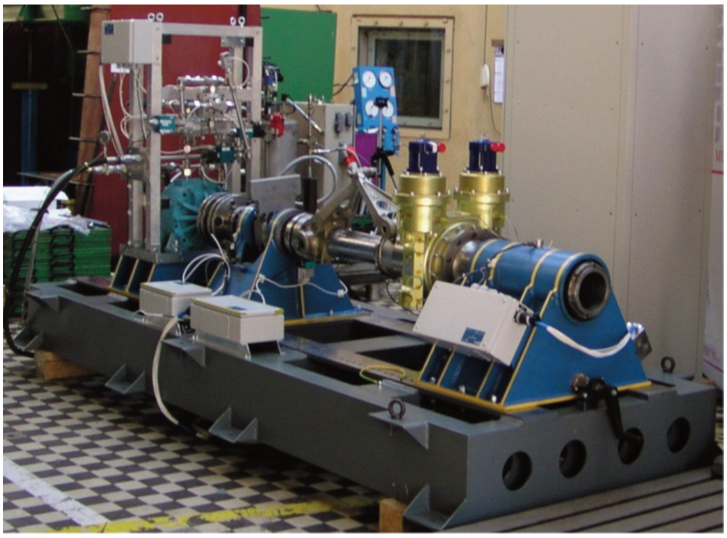

Fig. 7. Assembled test rig (source IA)

6. TEST RIG ACCEPTANCE TESTS

Assembled test rig was put under several acceptance tests. First stage of tests was a safety audit preformed by Bureau Veritas in order to check compliance with CE markings required in target laboratory.

The next step of acceptance procedure was to check all functionality of the test rig before performing any tests. There were performed tests for DCSS module safety and functionality (ex. spinning electric motor, checking if drive an driven wheel is connected well). In ATCSS module operation of all valves, the direction of movement of the hydraulic motor, the presence of leaks was checked.

After test rig check in manual mode, calibration tests were performed for both modules. During calibration tests dummy landing gear rotation was locked due to safety of the electric actuator which at the time wasn't complete (control modules weren't ready then). Electric actuator control modules were to be installed in target laboratory after test rig delivery.

Because test rig wasn't mounted permanently to the ground, it was impossible to carry out all tests of DCSS module due to vibrations generated by the unbalanced masses mounted to the DCSS discs.

Acceptance tests were successful but it was necessary to make some improvements on the test rig. Main modifications were made in DCSS by changing electric motor acceleration curve, due to high power consumption during acceleration phase.

The tests also provided information on the functionality and parameters of the test rig various components what can help to carry out the numerical simulations of test rig behavior. Such simulation can be used during design process of another test rig.

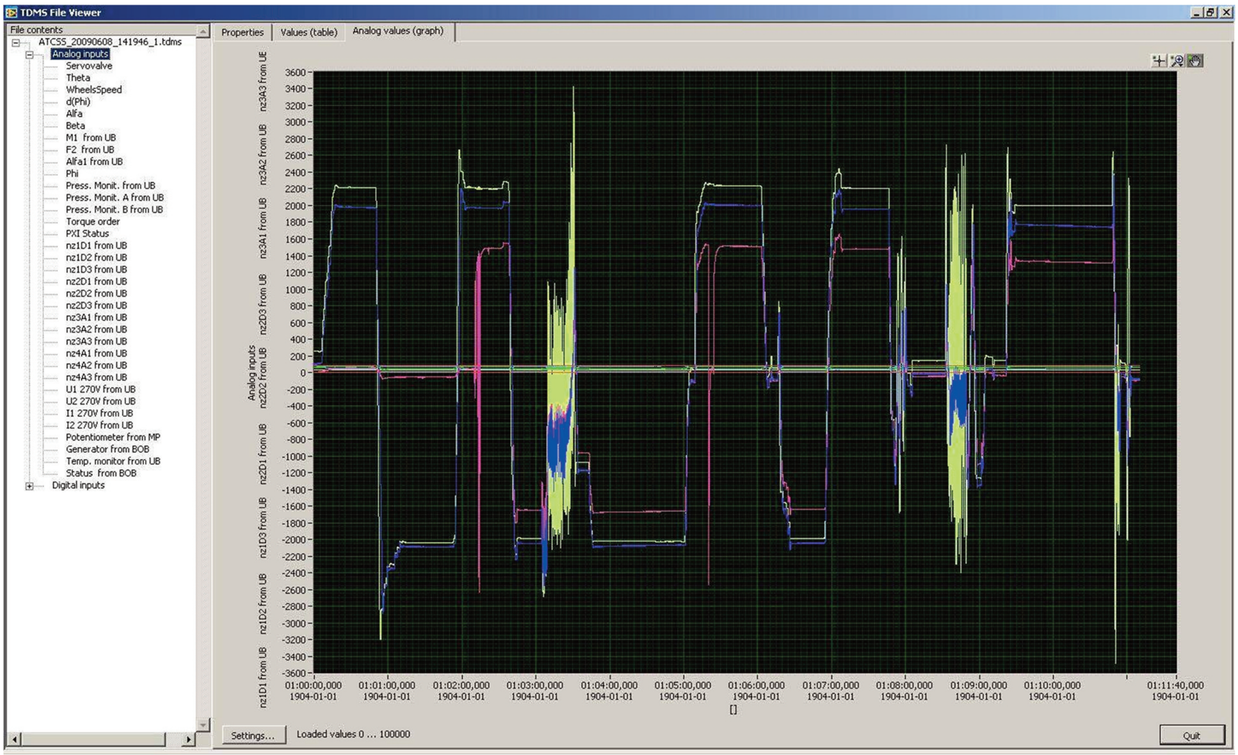

Fig. 8. Example graph of ATCSS test (p=80bar, torque=2000Nm, PID {0,005 ,0 ,0})

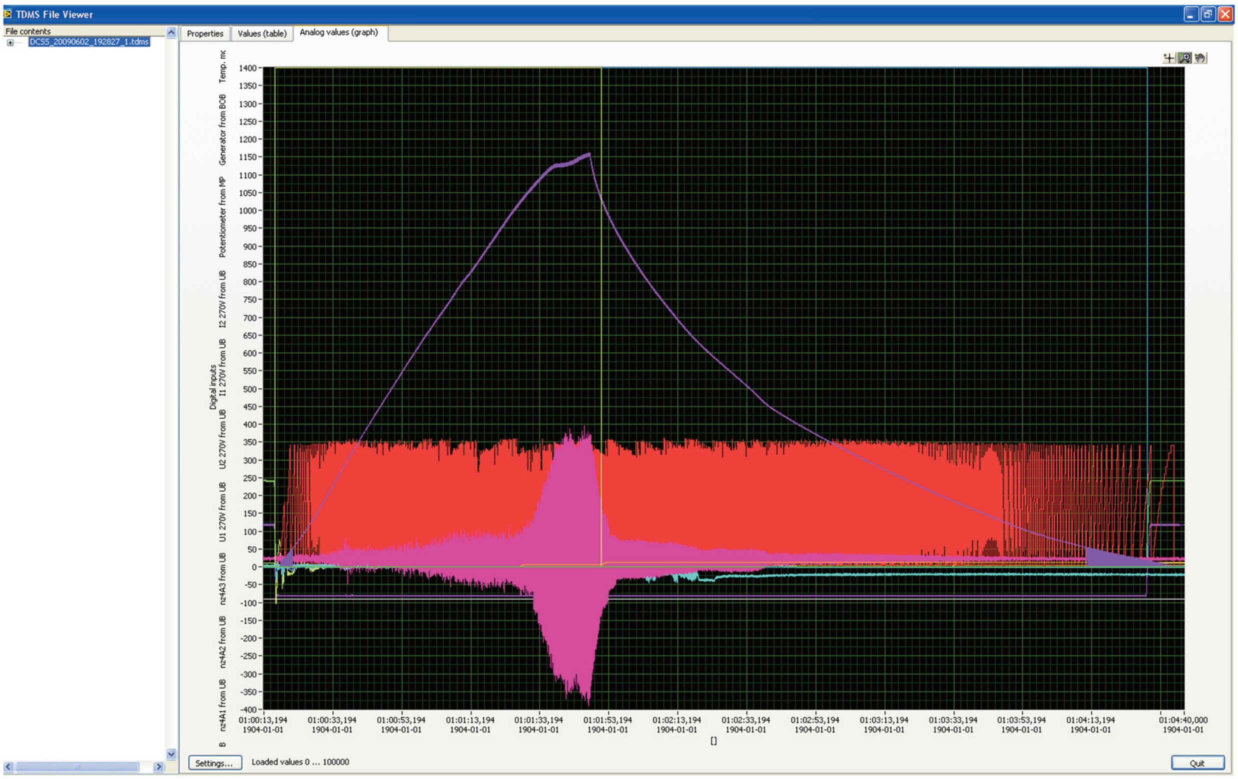

Fig. 9. Example graph of DCSS test (nmax=1150 rpm, free run out, unbalance masses m=2,5kg, r=0,27m, automatic acceleration, mechanical blockade on mechanical limiter)

7. CONCLUSIONS

Test rig for testing nose landing gear electric actuator was a great challenge for Landing Gear Department engineers. Test rig level of complexity due to size of tested object, demanding tests requirements and problems with finding manufacturers of such non-standard components made this project good opportunity to test design and logistic skills of Landing Gear Department staff.

Electric actuator test rig was crucial component of DRESS project due to necessity of reference tests results made on actual device to numerical analysis made by other consortium partners. Data comparison (from tests and simulations) will enable in the future of making more optimized electric actuator for another types of airplanes.

Thank to experience gained during project, IA Landing Gear Department is able to design and implement more test rigs not only for internal purposes but also for external clients.
Fully assembled test rig is shown in the figure 5. In the same picture there is also IA Landing Gear Department team which made the test rig possible.

Fig. 10. Landing Gear Department team with fully assembled test rig (source IA)

REFERENCES

[1] **Wołejsza Z., Kowalski W. i inni:**„ State of the art in landing gear shock absorbers". Transactions of the Institute of Aviation, No 181, Warszawa 2005

[2] **Siemens PLM Software Solid Edge web materials:** http://www.plm.automation.siemens.com/en_us/products/velocity/solidedge/index.shtml

[3] **Currey N.:**„Aircraft Landing Gear Design: Principles and Practices", AIAA Education Series, 1989

[4] **Wołejsza Z., Kowalski W.:** „RTO-TR-AVT-092 Qualification by Analysis, Final Report of the NATO RTO Research Task Group AVT-092"., Chapter 8 – LANDING GEAR, 2009

[5] **Wołejsza Z. , Kowalski W., Kajka R.:** RTO-AVT –152 on:„Limit-Cycle Oscillations and Other Amplitude-Limited, Self Excited Vibrations (NATO/PfP Unclassified), „Elimination of Shimmy" phenomenon in case of nose landing gear, AIAA Education Series, 2008.

PROTOTYP STANOWISKA DO BADAŃ ELEKTRYCZNEGO AKTUATORA PODWOZIA PRZEDNIEGO DUŻEGO SAMOLOTU PASAŻERSKIEGO

Streszczenie

Ze względu na ekologię oraz ekonomię wszystkie dziedziny mechaniki coraz częściej korzystają z napędów i sterowania elektrycznego. Lotnictwo nie jest poza tym trendem, jednakże ze względu na konieczność zapewnienia niezawodności i bezpieczeństwa, prace nad wykorzystaniem układów elektrycznych postępują wolniej niż w innych gałęziach przemysłu. W poniższym artykule, autorzy pragną przedstawić proces projektowania i wdrożenia stanowiska do badań elektrycznego układu sterowania podwoziem przednim dla dużego samolotu pasażerskiego.