USE OF *ADAMS* IN DYNAMIC SIMULATION OF LANDING GEAR RETRACTION AND EXTENSION

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1. ABSTRACT

This paper presents the method in use at Messier-Dowty SA during design process with *ADAMS* software to modelize a landing gear retraction and extension, in order to optimize its behaviour. Such method must involve the following steps : build, correlate and analyze the model, and finally optimize the design through Design of Experiments (DOE).

A practical application of this method by means of *ADAMS* is described, with the example of the optimization of a landing gear design in order to obtain extension or retraction manoeuver times less than a limit required by the aircraft manufacturer specification.

2. INTRODUCTION

Messier-Dowty is the world leader for design, development, production and technical support of landing gears. In Messier-Dowty, *ADAMS* models are used for almost all landing gears dynamic simulations : landing with shock-absorber compression and extension, retraction mechanisms analysis, and also landing gear retraction and extension.

The example here presented is a commuter main landing gear, with a special retraction mechanism piloted by a single actuator : cf figures 1 and 2.

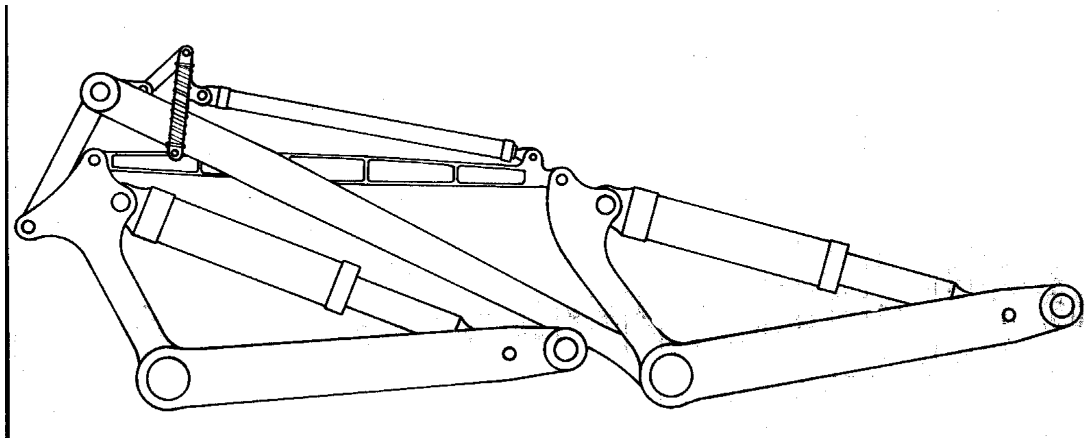


figure 1 : landing gear in up-locked position

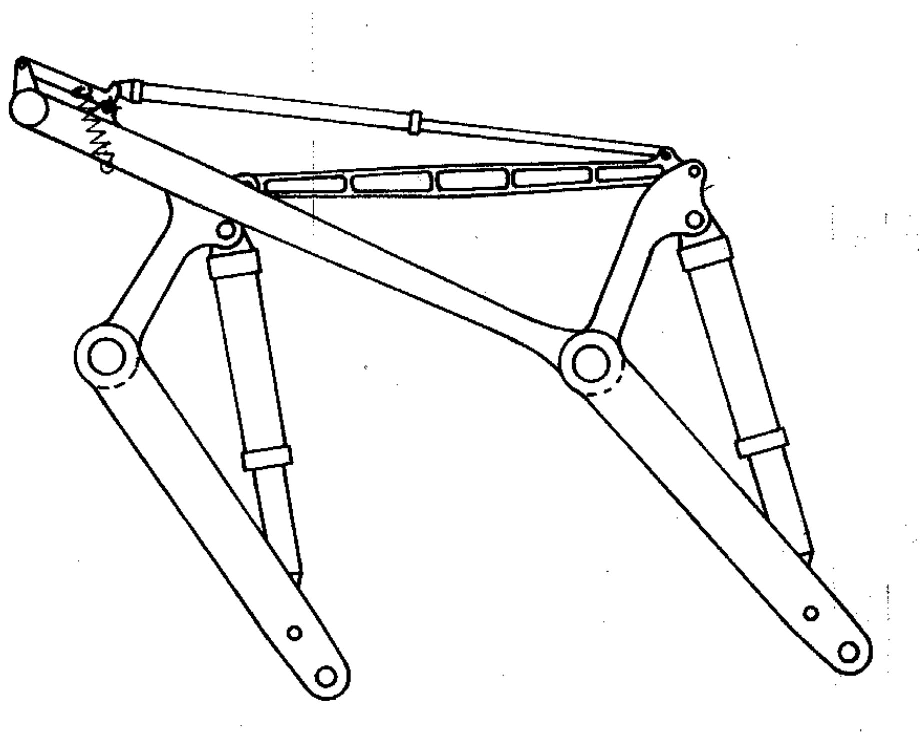


figure 2 : landing gear in down-locked position

3. DEVELOPMENT OF *ADAMS* LANDING GEAR MODEL

3.1 Building the model

Building such a model with *ADAMS* requires some standard techniques : we have to define parts with masses for the landing gear down-locking position, connected with joints, and with aircraft interfaces connected to *ADAMS* "ground" part. Nevertheless, there are some particularities in this landing gear model :

- the equations of motion for the actuator involve hydraulic laws (Bernoulli equations for orifices damping, and pressure-flowrate relation outside the pump) : it appears easier to define some algebraic variables (called "state-variables" in *ADAMS 9*) and to use them in the single-component force which represents the actuator force.

- We have to introduce the aerodynamic loads applied on the landing gear during retraction and extension, whose cause is the aircraft velocity : these loads are described with single component forces, with values obtained from a spline definition of load vs time values.

- As there are a lot of numerical data in a landing gear model (joints geometric positions, parts masses, actuator damping orifices values in particular), it is more convenient to define *ADAMS* numerical variables, which allows to modify them easily, and avoids the use of numeric data inside marker positions and forces expressions (cause of errors in case of data modifications, difficulty of reading the model)

- We can notice that this model has a plane symetry : the use of revolute joints leads to redundant constraints : we have to replace some of them with universal or spherical joints.

- The model for landing gear extension is obtained from the model for landing gear retraction described in down-locking landing gear position, with a preliminary static analysis by piloting the retraction landing gear angle in order to get the up-locking position, and with an inversion of actuator chambers supply.

- For this landing gear retraction model, the dynamic behaviour of the shock-absorber and tyres are not taken into account : they are only described by lumped masses and inertias.

3.2 Validating the model

Because of the complexity of this landing gear retraction/extension model, we have to validate it by steps, first in a very simple configuration, then by adding the other functionnalities.

3.2.1 Kinematics analysis

A simple model test, but which allows an efficient verification of its geometry and constraints, consists in a pure kinematics analysis by piloting the actuator displacement with a MOTION in order to get the landing gear up-locking position : errors in constraint descriptions could be more easily corrected with a simple model and faster simulation times. In particular, kinematics *ADAMS* analysis does not require the description of the actuator dynamic behaviour, so this verification may be done early during the landing gear model development.

The verification of geometry is made in Messier-Dowty by comparing results between *ADAMS* kinematics analysis and an "in-house" software specialised in kinematics analyses of landing gears retraction, which also gives the landing gear up-locking position geometry.

3.2.2 Static analysis

Once the model geometry and kinematics are tested, it is convenient to test it with a static analysis, which also takes into account the mass of the landing gear model and the gravity. *ADAMS* static analysis allows in particular to get the actuator load vs its displacement, as MOTION internal load, without requiring the description of the actuator dynamic behaviour.

Such static analysis gives a criteria for actuator sizing : from the actuator load calculated in up-locking position and the maximum pressure available in the actuator, we can deduce a convenient value for the actuator section.

3.2.3 Transient analysis

The next step consists of testing the model with a transient analysis, with the actuator dynamic behaviour description. Possible simulation failures due to incorrect actuator description may be corrected during this step.

If algebraic equations of the actuator lead to simulation problems, an efficient method to solve them consists by piloting the actuator with a constant single-component-force with a realistic value, and deactivate the single-component-force defined with the numerical evaluation of these algebraic equations : such *ADAMS* transient analysis may be successful, and give the result of these algebraic equations (*ADAMS* calculate them as design variable results, without applicating the result into a single-component-force because of its deactivation), so the verification of these equations is possible. Such technique is yet more efficient to validate differential equations, which may lead to more difficult numerical problems.

3.3 Correlating *ADAMS* model with tests results

Some landing gear retraction and extension tests were made by the aircraft manufacturer, with a previous definition of the landing gear here presented : so it is possible to build this landing gear model (only a few masses were to be changed), to introduce the damping orifice data used for tests, and to simulate with *ADAMS* some retraction and extension analysis to compare with these test results.

Such comparison for a retraction test is shown below : the correlation appears to be convenient, considering that real test conditions are not known very precisely.

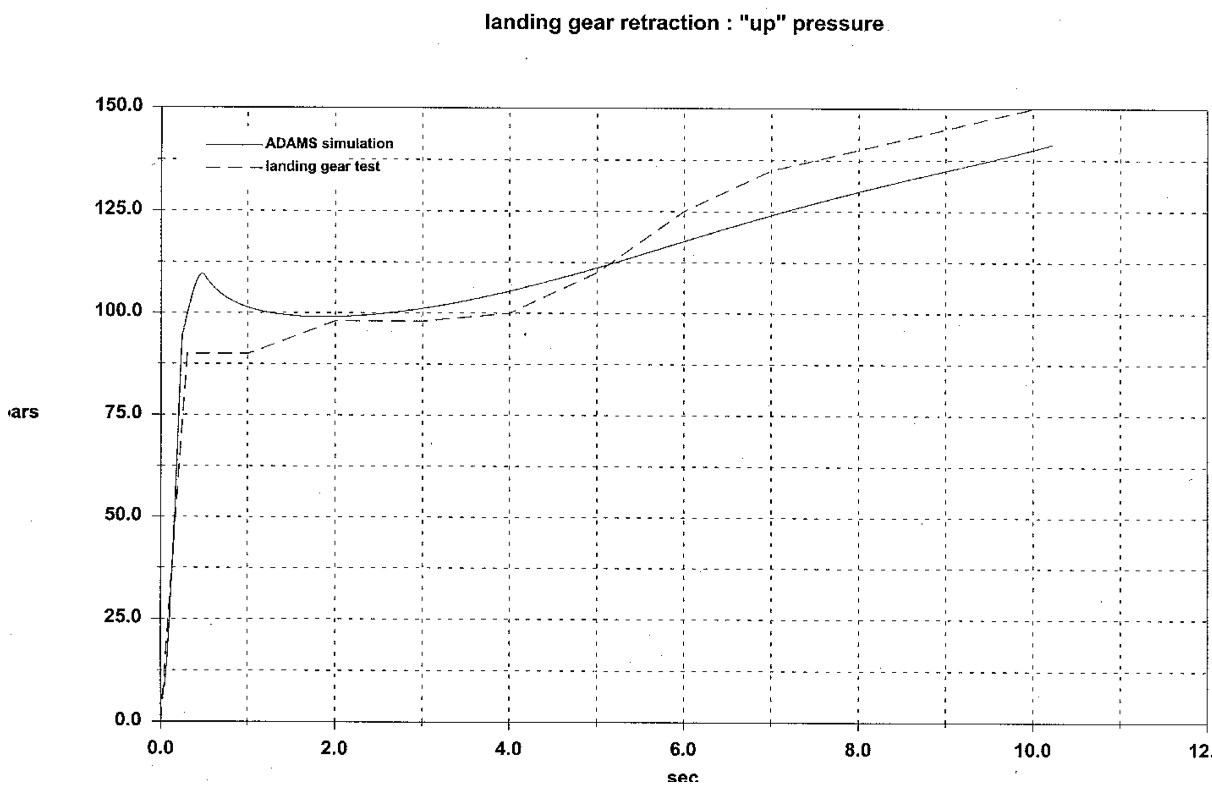
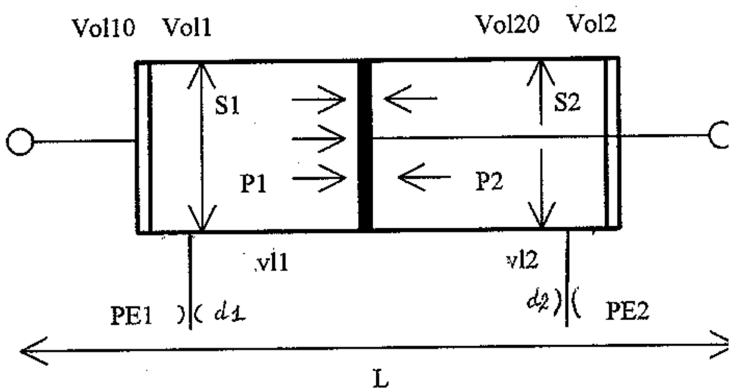


figure 3 : comparison between retraction test and ADAMS simulation

3.4 Optimizing the actuator damping orifices for landing gear retraction/extension

At this step, we have an *ADAMS* model able to simulate transient retraction or extension analysis, from which we can obtain the manoeuver times, and compare them with the maximum time values of about 15 seconds required by the aircraft manufacturer specification.

The next step will consist of optimizing the actuator damping orifices values, in order to satisfy this requirement : cf schema of the actuator with damping orifices named "d1" and "d2".



Such optimization could be done by performing one-factor-at-a-time analysis, which consists of running as many simulation as parameters values modifications : this may be a long process, and may lead to a non-optimal configuration, if all parameters variations combinations are not tried.

A more efficient method is to process a Design Of Experiments (DOE) study, which allows :

- to provide several numerical values for some chosen design parameters inside *ADAMS* model : d1 and d2 in our example.
- to define target values : manoeuver time in our example.
- to manage automatic simulations from all these values combinations.

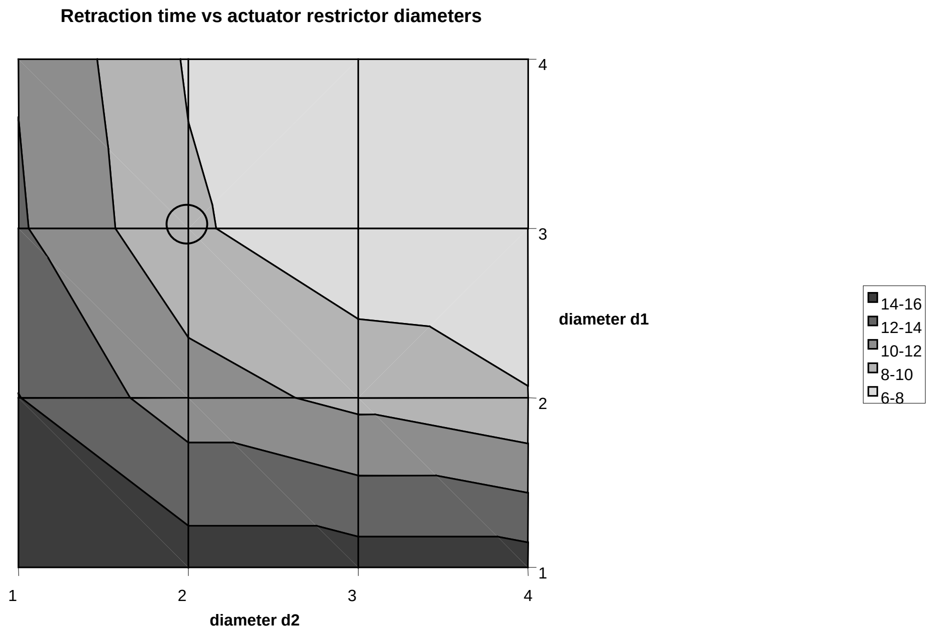
After this analysis, *ADAMS* provides a table with data combinations values and target values associated, as shown below with a test DOE (not the exact d1 and d2 values in this example)

A. .descente_normal.DOE_test.DOE_Results.Trial (NO UNITS)
B. .descente_normal.DOE_test.DOE_Results.verin_d1 (meter)
C. .descente_normal.DOE_test.DOE_Results.verin_d2 (meter)
D. .descente_normal.DOE_test.DOE_Results.MEA_temps_relevage (seconds)

A	B	C	D
1.000000E+000	1.	1.	15.00000
2.000000E+000	1.	2.	8.198910
3.000000E+000	1.	3.	6.755500
4.000000E+000	2.	1.	15.00000
5.000000E+000	2.	2.	5.956033
6.000000E+000	2.	3.	4.399648
7.000000E+000	3.	1.	15.00000
8.000000E+000	3.	2.	5.497022
9.000000E+000	3.	3.	4.379193

Such table can be exported to *EXCEL* in order to get contour plots, which may be more convenient to analyze parameters sensitivity, and to find the more effective combination of input values.

Following diagram shows the retraction time as contour plots, depending from both "d1" (vertical axe) and "d2" (horizontal axe) diameter values (not the exact actuator damping values in this example) : lighter zones correspond to faster retraction times.



We can deduce following conclusions :

- there is a high sensibility of "d1" diameter about retraction time, which is explained by the important value of the actuator S1 full section : if "d1" is not full open, the corresponding pressure drop Δp_1 may generate an important load in "down" chamber (equal to $S_1 \, \Delta p_1$ with a great value of S_1), which opposes to retraction and increases retraction time : lower d1 values correspond to darker zones.

- "d2" diameter values less than value "1" lead to excessive retraction time (greater than 15 seconds)

A convenient choice may be d1 = value "3" and d2 = value "2" (cf contour plot) : simulation of retraction analysis gives a landing gear retraction time of about 8.5 seconds.

4. CONCLUSIONS AND PERSPECTIVES

This *ADAMS* model allows to get a convenient optimization of landing gear retraction and extension behaviour. Nevertheless, a few improvements will be implemented in landing gear models, in particular the introduction of oil compressibility in hydraulic equations (necessites the use of differential equations in addition to hydraulic algebraic equations : *DIF* command).

Another target is to use *ADAMS* models during the pre-design phase, in conjunction with *CATIA* models, in order to optimize the landing gear geometry and kinematics within the constraints required by the aircraft manufacturer : using DOE and optimisation techniques with pure kinematics analysis would be more effective.