INFLUENCE OF LANDING GEAR SHOCK ABSORBER DAMPING ON AIRFRAME LOADS AND ACCELERATIONS

Dietmar Fleischer*, Mattia Melis and Cyrille Vidy

**AIRBUS Defence and Space*
Rechliner Str., 85077 Manching, Germany
dietmar.fleischer@airbus.com

ABSTRACT

An important step during aircraft (A/C) design is the estimation and determination of the occurring loads and accelerations acting throughout the A/C. These loads can be distinguished between e.g., manoeuvre loads, gust loads or ground loads, respectively. Ground loads originating from conditions where the A/C is in contact with the ground via the Landing Gear (LG), can be divided into static ground loads (steady braking, turning, jacking or towing) and dynamic ground loads (A/C taxiing over non-smooth runways or A/C landing impacts). These loads form a fundamental input for A/C design and their derivation has to follow certification and regulation rules, cf. [1].

Therefore, in the early phase of LG and airframe (A/F) design when the underlying database is small or not yet matured in terms of LG and overall A/C data, especially the ground loads are mainly based on bookcase formulae, cf. [2]. This introduces a high amount of conservatism into the respective loads calculation. By employing rational methods, i.e. simulation of the A/C behaviour more realistically with a multi-body simulation (MBS) model, a reduction of conservatism can be achieved, [3]. Then, the MBS model consists of a flexible undercarriage model (i.e. wheel, tyre and shock absorber) connected to an airframe model of the A/C.

For low aspect ratio wing A/C, e.g. fighter A/C, with a rather stiff airframe the approach of using a flexible LG model attached to a rigid airframe in the respective MBS model is sufficient for the LG and airframe loads computation. This approach does not hold for a high aspect ratio wing A/C with increased flexibility of wing and fuselage. For transport A/Cs or long endurance UAVs (LEUAVs) the airframe flexibility significantly influences both the LG loads and the airframe response. By introducing a flexible LG model connected to a flexibly modelled airframe, the loads and accelerations at the LG and A/F reach realistic levels, [5], [6], [7].

In this work the focus is on ground loads generated by A/C landing impacts for a LEUAV. With a given MBS model based on a flexible model of LG and airframe, loads and accelerations are assessed. Two A/C mass configurations are considered with respective trimmed flight conditions in terms of sinkrate and A/C forward velocity following CS 25 regulation paragraphs, [4]. Furthermore, the setting of the main landing gear shock absorber damping is varied in order to reduce loads and accelerations on airframe level. Therefore, tyre forces, airframe attachment loads (also known as pintle forces) and accelerations are analysed and compared for the MBS model as well.

The MBS model of the LEUAV is realized with the commercial MBS software VI Aircraft, [9], which is mainly an MSC ADAMS, [8], preprocessor with additional features i.o. to facilitate the modeling effort. For the A/C at hand which is of similar shape and size as the Eurodrone, [11], shown in Figure 1 (left), the landing gear is a conventional tricycle type with a single wheel nose landing gear (NLG) retracting forward while the single wheel main landing gear (MLG) struts are retracting inwards Figure 1 (right). MLG and NLG are in a conventional telescopic configuration, equipped with oleo-pneumatic shock absorbers. Furthermore, the

application of aerodynamic forces and moments based on respective tabulated data is also realized as it is a crucial part of the landing simulation with a trimmed initial flight condition prior to the landing impact.

Figure 1: Eurodrone configuration (left) and the LEUAV NLG and port MLG MBS model (right)

The flexible airframe forms a separate MBS part and is based on the extraction of a modal neutral file from a respective finite element model (NASTRAN, [10], structural dynamics model) considering 267 eigenmodes (including 6 rigid body modes). The connection of the undercarriage model to the flexible A/F is realized via interface nodes which geometrically correspond to the attachment pintle points of the LG. Respective interface parts located at the interface node's location assure that forces are transmitted from the LG to the flexible airframe. A critical damping of 0.0 is used for all modes below 0.5 Hz (i.e. representing the A/C rigid body modes). For structural modes with an eigenfrequency above 0.5 Hz a critical damping value of 0.01 is applied.

The LG and the wheels are modelled in detail as far as respective data is given. Hence, the available characteristics of the tyres and shock absorbers (tyre-deflection-curves, S/A gas springs, S/A damping, etc.) were considered together with the respective LG and wheel part masses. In order to take the LG flexibility into account the LG stiffness is modelled via S/A travel (SATs) dependent spring forces in longitudinal and lateral direction at the wheel axle intersection point for both the MLG and the NLG, respectively.

Two different settings of MLG S/A damping in compression are applied (shown in Figure 2 left – positional damping) in order to assess the effect on the airframe loads and accelerations, while damping setting V1 represents the optimized MLG S/A damping characteristic (with constant recoil damping). Special attention is directed to wing root as well as respective engine monitoring station loads and accelerations. The pitch acceleration vs. time at the engine's centre of gravity (cg) is shown in Figure 2 right.

Preliminary results show significant reductions in acceleration levels at the engine for the optimized damping setting and further loads reductions.

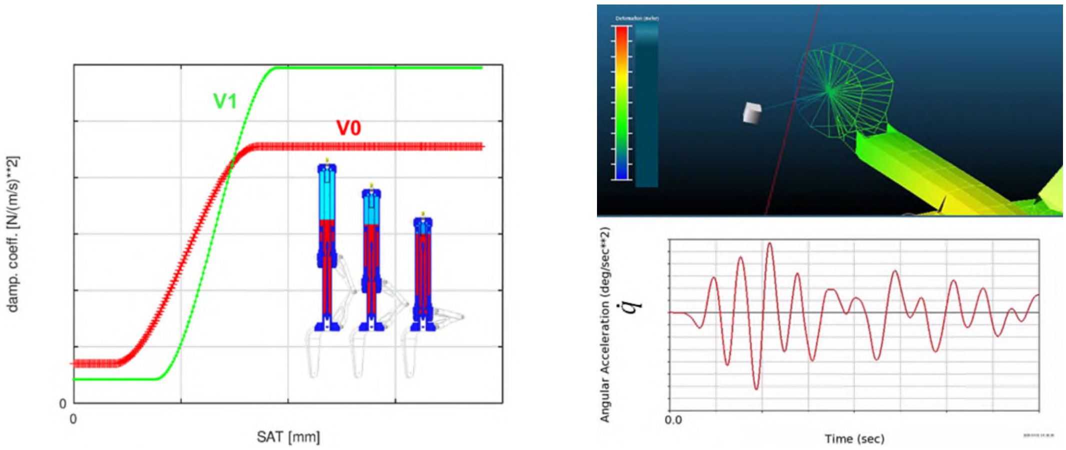

Figure 2: S/A damping coefficient vs. SAT (left); pitch acceleration vs. time of engine cg (right)

References

[1] D. P. Raymer, *Aircraft Design: A Conceptual Approach*, AIAA Education Series, 1992.

[2] N. S. Currey, *Aircraft Landing Gear Design: Principles and Practices*, AIAA Education Series, 1988.

[3] H. B. Pacejka, *Tyre and Vehicle Dynamics*, 2nd Edition, reprinted 2007. Butterworth-Heinemann, Oxford, 2007.

[4] EASA Certification Specification for Large Aeroplanes CS-25 - *GROUND LOADS* section, CS 25.471 to CS 25.519 plus concerning/respective Appendices.

[5] T. Stachiw et al., *The Effect of Airframe Flexibility on Dynamic Landing Gear Loads*, Carleton University Ottawa, 2019.

[6] W. R. Krüger, S. Cumnuantip, *Assessment of Dynamic Landing Loads by a hybrid Multibody/Full Finite Element Simulation Approach*, Deutscher Luft- und Raumfahrtkongress DLRK 2018.

[7] P. D. Khapane, *Simulation of Landing Gear Dynamics Using Flexible MBS Methods*, International Congress of the Aeronautical Sciences ICAS 2006.

[8] MSC.Software Adams 2020, Version 2018.0.0

[9] VI-Aircraft 2020.19.0.40301, VI-grade GmbH

[10] MSC Software Corporation, *MSC Nastran Dynamic Analysis Users Guide*, 2019

[11] https://www.airbus.com/en/products-services/defence/uas/uas-solutions/eurodrone