Landing gear shock absorbers guidelines

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Abstract. This paper is based on an old paper presented by Eng. Ermanno Bazzocchi almost seventy years ago [1] and is here presented again in his memory, to take the opportunity for showing to young generation of engineers how applied research was performed and presented when the computer age was not still born. The topic is on landing gear shock absorber design guidelines, and it has been selected because of the importance of such device for airplanes, which represents a very important system for the efficiency of the entire aircraft. The original paper [1] has represented a milestone for the design and dimensioning of landing gear shock absorbers highlighting parameters which often have not been discussed so clearly in papers which came later in the scientific literature and therefore the idea of collecting those information and revisiting them in a modern framework has been particularly exciting. It is in the idea of the authors that revisiting fundamental classic papers and projecting them in a modern scenario could be beneficial for the real understanding of the physical aspects of aircraft systems, covering calculations which could not being performed because of low computing power. Classic papers were forced to strongly rely on physical understanding from which creating simple models to correlate experimental data and theoretical calculations. Such physical background should not be lost, but hopefully improved by the actual computer power and this paper is an attempt proposed to the scientific community for discussing on the validity of such an approach.

Introduction

The aircraft landing gear is one of the most critical part of an aircraft, being this system responsible for ensuring the safety of the payload during take-off, landing and for the taxiing procedures, too. The general arrangement of the landing gear consists of the shock absorbers, retraction mechanism, steering, shimmy control, tires, wheels and brakes. It represents about 3.5 to 7 percent of the gross weight and from 2 to 4 percent of the aircraft sales price.

The design of landing gears has been considered one of the more challenging and technically satisfying engineering task, since it demands expertise in mechanical and structural engineering, hydraulics, kinematics, materials and a very good understanding of detail design.

For these reasons, but even more to bring back memories, we remember, in the year of the first centenary of the Italian Air Force, Eng. Ermanno Bazzocchi, the designer of one of the most iconic aircraft, the MB-339, which still successfully equips the national aerobatic team, the PAN.

In 1955 Eng. Bazzocchi publishes in the magazine L'Aerotecnica a work on the design of one of the main elements of the landing gear of an aircraft, the shock absorber, based on a presentation held the previous year at a scientific congress in Paris.

This work has been taken up again in this article as evidence of its technical-scientific validity, after almost seventy years, and above all for the organization and setting given by the author to this work. An attentive technician who reads this work with dedication comes out capable of designing and realizing the structural component under discussion and with the modern tools of calculation and assisted design, can enhance concepts that at the time of its first draft could not be optimized due to lack of calculation tools.

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The main wish behind recalling this work, underlining its importance and highlighting its merits, is to show young researchers how significant it can be to revisit past experiences, when the low computing power was overcome by knowledge of the physics of the problem as well as by a thorough ability in the use of engineering tools. From the authors of this article viewpoint, there is the hope to have been able to convey the pleasure of having revisited an important scientific document, [1], that still represents a milestone in the design of aircraft landing gear, together with other “well-seasoned” papers, [2] and [3].

Mechanics of the landing gear

One of the possible schemes of the landing gear considers that it is attached to a rigid mass which has a degree of freedom for the vertical displacement, only. Both the systems, mass of the airplane and landing gear constitute a 2-dof system, fig. 1(a). To obtain energy dissipation, the hydraulic fluid is forced to flow at high velocity because of the telescoping strut. To maximize such dissipation, the passage of the hydraulic fluid through the orifice should be properly designed by defining a variation of the orifice area by introducing a metering strut which controls the size of the orifice and governs the performance of the shock absorber, fig. 1(b). The balance of the forces is reported in fig. 1(c) which shows the mutual interaction between the tire and the strut.

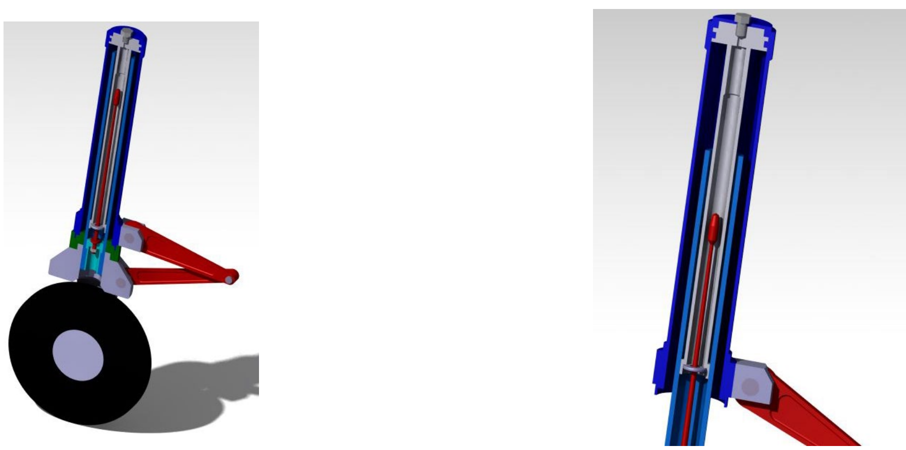

Figure 1 – Schematic of a typical landing gear (left) and shock absorber (right)

One of the most interesting aspects emerging by comparing the results of [1] and [2] is the choice of the plane for their representation. Ref. [1] uses a force versus displacement representation for the behavior of the landing gear. Ref. [2], on the other hand, presents the results in force, or displacement, versus time plots. This latter could appear more intuitive, as generally is for a time behavior of parameters, while the force versus displacement may appear a bit more difficult, but it is result (and efficiency) related, regarding the design of the landing gear because it gives an easy representation of its efficiency and opens to opportunities for improvements, if any.

Equations of motion

The approach for writing the equations of motion follows a common path which initially studies each component separately, then they come together for assessing the full behavior of the landing gear. This general approach may be split in modelling a passage from one to two degree of freedom system-or, which is equivalent, to an initial motion of the tire only and, reaching a certain force, activating the shock absorber, too. In [1] this latter approach is followed along with an engineering procedure which assumes, due to the short time, a static behavior of the tire, before defining the complex behavior of the shock absorber. Ref. [2] instead, employs the passage from 1 to 2-dof system in a chronological sequence which computes also the initial conditions for the beginning of the second phase, when the inertia, weight and lift forces become sufficiently large to overcome the preloading force in the shock strut due to the initial air pressure and internal friction.

The overall dynamic non-linear equilibrium equation for a 2-dof system is given by the following relationship:

$$\frac{W_1}{g}\ddot{z}_1 + \frac{W_2}{g}\ddot{z}_2 + F_{V_g}(z_2) + L = W_1 + W_2$$

where the subscripts 1 and 2 refer, respectively, to the upper mass (typically the partial mass of the airplane on the shock absorber) and the lower mass (typically the tire with its systems mass), L is the lift force and F_{V_g} is the vertical force on tire.

The previous equation uses physical degrees of freedom for representing the equilibrium. Clearly it needs to be manipulated for explicitly showing the main parameters before being integrated and becoming effectively useful for designing the shock absorber.

A different approach, more energy based, is used in [1], ending with one scalar non-linear equation which is stepwise integrated according to the time evolution of the physical phenomenon. Such equation, appeared at the time of Ref. [1] as impossible to solve, is written as

$$v v_a^2 \frac{dv_a}{dC_a} + v_a(A + B) - A = 0$$

where $v = v_p + v_a$ is the sum of the velocity of the tire and the shock absorber, and A and B are variables grouping several parameters as the stiffness of the tire and the shock absorber.

Results

Based on the previous equations, mainly those of Ref. [2], computer codes, [8], have been developed, tested and used for correlating laboratory measurements and numerical results. Fig. 2 presents the results obtained from the discussed methodologies and applied in comparing predictions with experimental measurements for a general aviation landing gear.

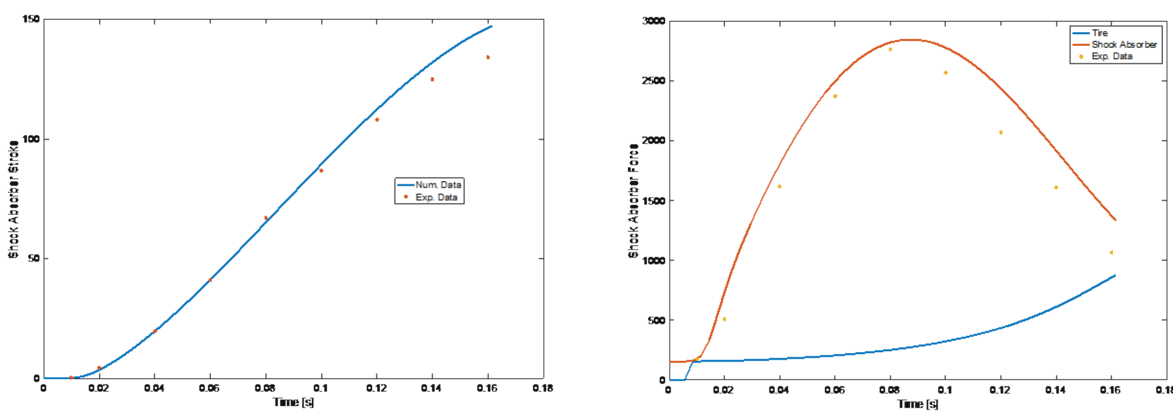

Figure 2 – Numerical-Experimental correlation of shock absorber stroke (left) and force (right) versus time, according to Ref. [2]

Figure 3 shows the results which can be obtained during the design phase of the main elements of a landing gear equipped with a shock absorber, together with the definition, for example, of the geometry of the metering pin, fig. 4, for reaching a specified value of the absorbing efficiency in some specific landing condition.

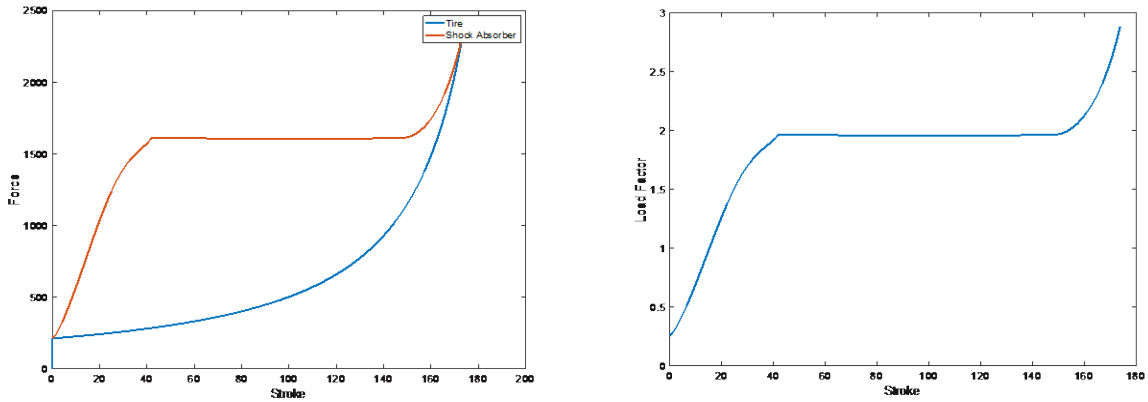

Figure 3 – Force and load factor versus landing gear stroke for designing and verification purposes, according to Ref. [1]

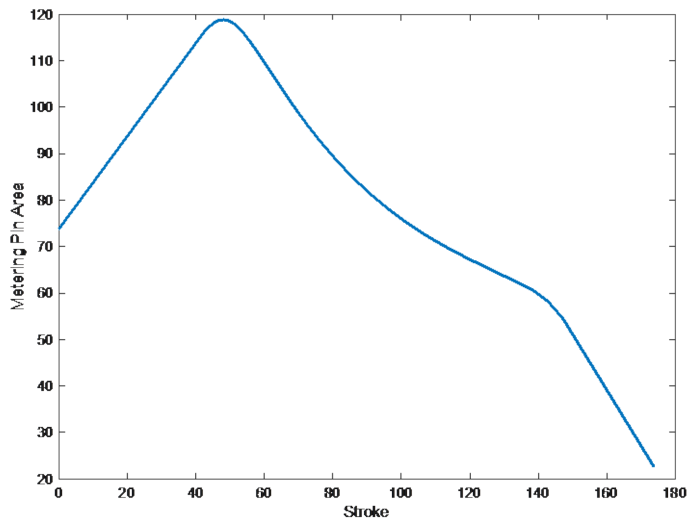

Figure 4 – Metering pin area versus landing gear stroke

Conclusions

The main purpose of this article has been to resume some old papers on the design and analysis of landing gear and to review considering modern computer technologies, trying to evidence the importance of their content and how they are still useful in the actual environment.

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