JOURNAL OF AIRCRAFT
Vol. 32, No. 4, July–August 1995

Technical Comments

Comment on "Aircraft Landing Gear Positioning Concerning Abnormal Landing Cases"

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THE cases of damage caused by nose-first landings that have recently been reported in Ref. 1 are a clear indication that this subject deserves serious attention and that it is not merely a theoretical exercise. However, while being of interest to the landing-gear designer, the Engineering Note lacks an explanation of why the value of l_2^* should be taken as equal to $0.8l_2$ or less (and as a consequence, why the vertical energy ratio of 1.25 or more is to be used at the nose gear).

The reason may be found in Ref. 2. In the example for nose-gear landing-impact given there, the polar moment of inertia in pitch about the c.g. used a radius of gyration k_{cg} of 44.7% of the spacing between the gears l, compared to the value of k_{cg} of 28.7% that is actually used in the Engineering Note. Reference 2 also showed that the equivalent mass at the nose gear was 2.20 times the "static mass" there, and that this ratio is roughly proportional to the relative size of the moment of inertia in pitch. Then, by taking proportions for the example in the Engineering Note.

Equivalent mass = 2.20 × (0.287/0.447) = 1.40 of the static mass. With the design sinking speed V_{sink} this mass will directly affect the vertical energy that is absorbed by the nose gear. It is close to the value of 1.50 times the normal sinking energy that is suggested in the Engineering Note.

In general, these values for equivalent mass at the nose gear exceed the ones that are specified in FAR 25.725 Airworthiness Regulations. A more exact method of analysis is provided in Ref. 2, however, it should be further noted that the effect of fuselage flexibility will reduce this ratio, particularly on the larger sizes of aircraft.

References

[1]Nelson, R. S., Nelson, R. K., and Bland, J., *Avoiding Airplane Damage on Nose Gear Touchdown*, Airliner—Customer Service Div., Boeing Airplane Group, April–June 1994, pp. 22–25.

[2]Chester, D. H., "The Equivalent Masses at Nose Landing-Gears During Landing-Impacts and when Taxiing over Runway Perturbations," *Israel Journal of Technology*, Vol. 23, 1986/7, pp. 25–31.

Received June 5, 1994; accepted for publication Feb. 14, 1995.

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WE thank Mr. Chester for his thoughtful response to our Note, and generally agree with him that this class of abnormal landing cases deserves serious attention. Naturally, more detailed analyses, such as the suggested fuselage flexibility effect, should be taken into consideration for more practical design following the concept design stage. Nevertheless, as pointed out in the article, aircraft design is well-known as a complicated compromising process, the c.g. position, the k_{cg}, and the total mass are all sensitive to fuel storage allocation/consumption, passenger/cargo arrangement, and weaponry management (attached or fired), thus, a near-optimal design can be achieved generally only in a probabilistic sense even for the simpler cases of vertical takeoff and landing (VTOL) fighter airplanes.

In the Note, a truly simple numerical example was given, there was no attempt to simulate any particular class of aircraft. In contrast to what is proposed in the Comment, l_2^* is not necessary to be equal to or less than $0.8l_2$, in fact, for example purposes, it can be any appropriate scaling numbers, such as 0.85, 0.92, 1.28, etc., as long as Eq. (9) is satisfied [for the given example, $10 \times 1 = (0.8 \times 10) \times (1.25 \times 1)$]. Thus, the scaling factor of 0.8 does not really need further explanation as suggested in the Comment. In that section, it seems that the Comment also suggests that by some rough approximation, a method can be used to obtain an energy ratio close to the correct 1.5 obtained in the Note, but the details of that method are unclear. Since the second paper referred to in the Comment was published in Israel and is not at hand, we are not in a position to evaluate this approach or any other analysis method in that paper, but it is felt that any significant novel analysis method or idea in this respect may try to meet its best audience through *AIAA's Journals*.

Received Nov. 22, 1994; accepted for publication Feb. 14, 1995.

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