Preliminary calculation of the landing gear of a military training aircraft

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Abstract: *The paper presents a preliminary calculation method, which is easy to apply for pre-dimensioning the landing gear. Preliminary calculation of the landing gear includes estimating the loads on landing and determining the position of the nose landing gear and the main landing gear of a military training aircraft. Another purpose of the preliminary calculation is to ensure the stability of a military training aircraft on landing and take-off, as well as to ensure the lateral stability of the aircraft during ground operations such as taxiing, landing or take-off.*

Key Words: *Nose landing gear, main landing gear, landing, take-off*

1. INTRODUCTION

The landing gear is one of the critical subsystems of an aircraft, because the safety of the whole aircraft and the human crew on board depends on it. The need to design a landing gear with low mass, low volume, high performance, long service life and low maintenance costs has been a major challenge for landing gear designers.

The landing gear is often configured together with the aircraft structure due to its substantial influence on the structural configuration of the aircraft (strengthening the area in which the landing gear is attached, the installation area of its actuators and ensuring the space for the retraction of the landing gear assembly into the aircraft structure).

The landing gear must occupy a minimum volume to reduce the need for space when it retreats into the body of the aircraft. In addition, the mass must be minimal to increase the performance of the aircraft. It is desirable that the lifespan of the landing gear be equal to that of the aircraft.

The purpose of the landing gear on an aircraft is to provide a support and running system during taxi, take-off and landing operations. The landing gear is designed to absorb and dissipate the kinetic energy of the landing impact, thus reducing the impact loads transmitted to the aircraft structure.

The landing gear also facilitates the braking of the aircraft using a wheel braking system of the main landing gear and ensures steering of the aircraft on the ground by means of a steering system of the wheel / wheels of the nose landing gear in order to allow the towing for the aircraft.

On all military aircraft the landing gear is designed to be retractable to minimize the aerodynamic drag of the aircraft during flight and thus, to increase the performance of the military aircraft.

The preliminary calculation of the landing gear for a military training aircraft includes estimating the loads on landing and determining the position of the nose landing gear and main landing gear based on technical data available in this phase of the project.

Additionally, the preliminary calculation allows to ensure the stability of a military training aircraft on landing and take-off, and ensures the lateral stability of the aircraft during ground operations such as taxiing, landing or take-off.

Fig. 1 Landing gear for a military training aircraft [6]

Military training aircraft are equipped with a tricycle landing gear (a nose landing gear and two main landing gears positioned left and right under the wings) in a strongly reinforced area as shown in figure 1.

2. PRELIMINARY CALCULATION OF THE LANDING GEAR

2.1 Calculation of landing loads and positioning of landing gears

The position of the center of gravity of the aircraft (CG) occupies two limit positions, one to the front and one to the back: CG_{fwd} and CG_{aft}, respectively, depending on the loads (fuel, ammunition, other equipment, pilots) and the position of these loads in the aircraft.

Determining the CG position as accurately as possible is very important for the good positioning of the landing gear.

If the CG position is not set exactly in the right place, it may cause the aircraft to tip back, tip over or tip to one side during landing or taxiing. It is also very important that on landing, the weight on the main landing gear is large enough so that its brakes can ensure efficient and sufficient braking of the aircraft.

For the calculation of landing loads on nose landing gear and main landing gear, the scheme shown in figure 2 and a series of calculation relationships are used.

The maximum nose landing gear load is calculated [1, 2, 3, 5]:

$$F_{n\,max} = \frac{l_m + l_n - l_l}{l_m + l_n} W \qquad (1)$$

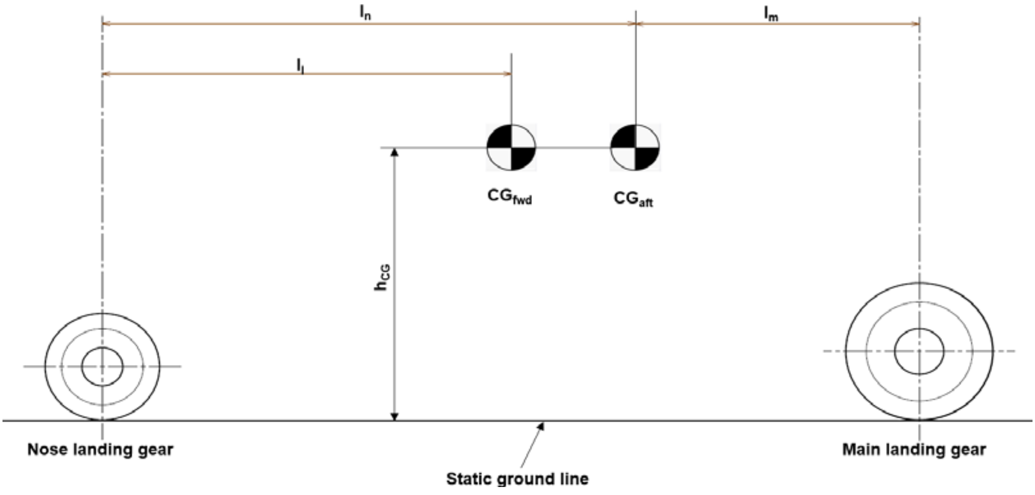

Fig. 2 Dimensions used in calculating landing gear loads

The minimum nose landing gear load is calculated [1, 2, 3, 5]:

$$F_{n\,min} = \frac{l_m}{l_m + l_n} W \qquad (2)$$

The maximum main landing gear load (for all main gear struts) is calculated [1, 2, 3, 5]:

$$F_{m\,max} = \frac{l_n}{l_m + l_n} W \qquad (3)$$

where l_m, l_n, l_l are as shown in figure 2 and W is the maximum calculated weight of the aircraft.

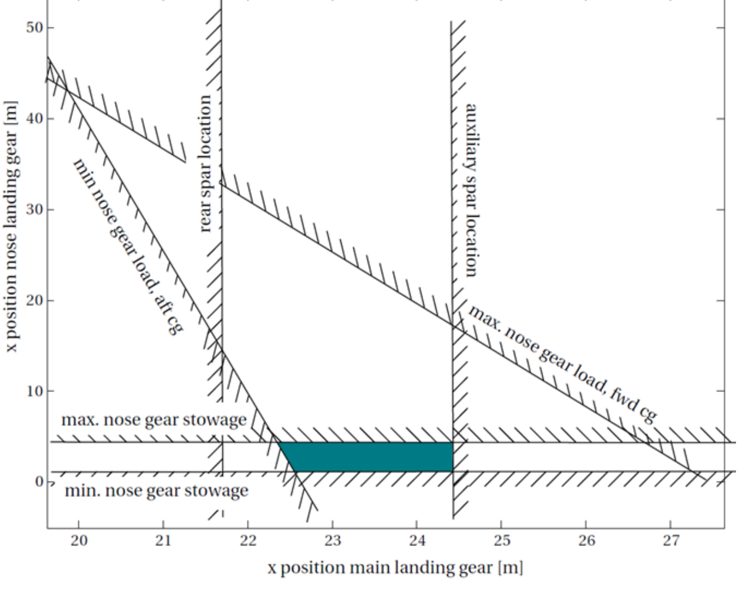

Fig. 3 Nose and main landing gear longitudinal positions limited by nose gear loading limits and stowage limits. Green indicates viable gear longitudinal locations [3]

The maximum load on the nose landing gear can be estimated, in a first iteration, to be 15% of the maximum weight of the aircraft. The minimum load on the nose landing gear can be estimated, in a first iteration, to be 8% of the maximum weight of the aircraft. Both estimated loads have a great influence on the positioning of the aircraft landing gears [3, 5]. The solution l_n from equation (3) results in a maximum limit of the nose landing gear, which is a function of the longitudinal position of the main gear. This limit is the maximum load limit of the landing gear in figure 3. Similarly, the solution for l_l in equation (1) provides the minimum nose landing gear limit, which is also shown in figure 3 [3, 5].

The longitudinal position of the main landing gear and the nose landing gear is also limited by the storage constraints and by the wing spar existing constraints. All these constraints together leave open only a small design space for the longitudinal positions of the nose and the main landing gear [3, 5].

2.2 Take-off and landing stability of the aircraft

When the aircraft is on the ground as shown in figure 4, during take-off and during landing it should be capable of safely pitch up or pitch down without striking the ground or having a predisposition to turn on its side. To check if this is happening or not the coupling of the gear position with the take-off and landing performance and the aircraft center of gravity gamut needs to be considered [3].

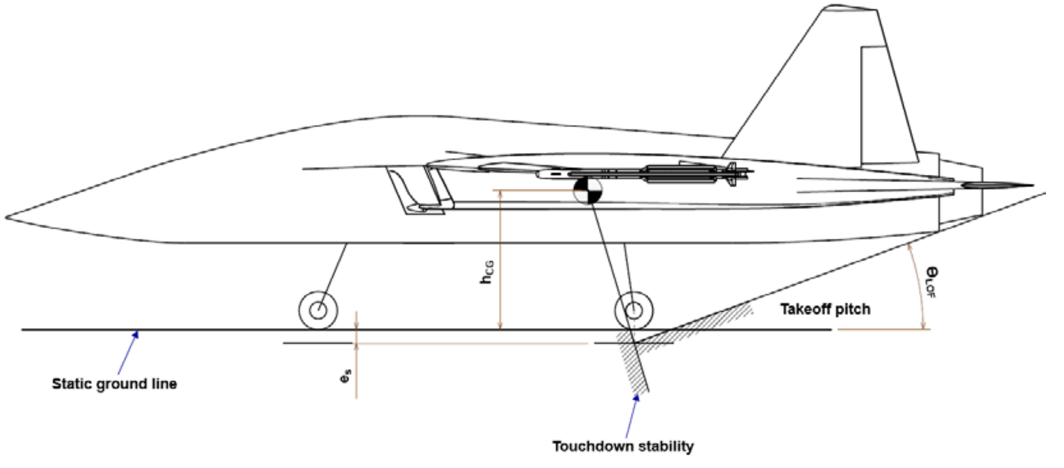

Fig. 4 Limits for positioning of the gears

The necessary pitch angle when the aircraft is taking off with all landing gears fully extended is calculated using the next equation [1, 2, 3, 5]:

$$\theta_{LOF} = \alpha_{LOF} + \frac{d\theta}{dt}\left(\frac{2l_l}{V_{LOF}} + \sqrt{\frac{l_2 C_{L\,LOF}}{g C_{L\alpha}}}\right) \tag{4}$$

The above equation takes into account the dynamics of the aircraft motion at take-off. At the beginning of the design stage when more accurate information is not available the lift curve slant is calculated with the next equation [3, 5]:

$$C_{L\alpha} = \frac{dC_L}{d\alpha} = \frac{2\pi cos\Lambda_{0.25}}{1 + 2/A} \tag{5}$$

and the angle at lift-off [3, 5]:

$$\alpha_{LOF} = \frac{1}{2\pi}\left[\left(1+\frac{2}{A}\right)\left(\frac{(C_{L\,max})\delta_{f=0}}{cos\Lambda_{0.25}} - p\frac{(C_{L\,max})_{to}}{cos\Lambda_{0.25}} - \frac{C_{L\,cr}}{cos\Lambda_{0.25}}\right) - \frac{1}{A}\right]\frac{180}{\pi} \tag{6}$$

where p takes values in the range 0.15 - 0.20, dependent on aircraft aerodynamics. Equation (6) takes into account the ground effect, flap deflection at take-off is assumed to have reduced effect on the critical lift coefficient and it is assumed that the fuselage is horizontal during cruise [3, 5].

When the aircraft is landing the maximum pitch-angle reached must be lower than for the take-off. The worst-case landing is a landing when both CG_{aft} and the h_{CG} have the highest position. When there are no other loads influencing the pitch down tendency the main landing gear should be minimally behind the CG_{aft} by a distance of l_m [3, 5]:

$$l_m \geq (h_{CG} + e_s)tan\theta_{TD} \tag{7}$$

where e_s is the static deflection of the shock absorber and tire in static condition and h_{CG} is the height from the ground of the CG while taxiing.

2.3 Sideways turnover and ground stability limits

Forces acting sideways on the airplane in cross-wind landing condition or a high-speed turn during taxiing could cause the aircraft to turnover on its side. The sideways turnover angle Ψ, is calculated [3, 5] as shown in figure 5:

$$\tan\Psi = \frac{h_{CG}}{l_n sin\delta} \tag{8}$$

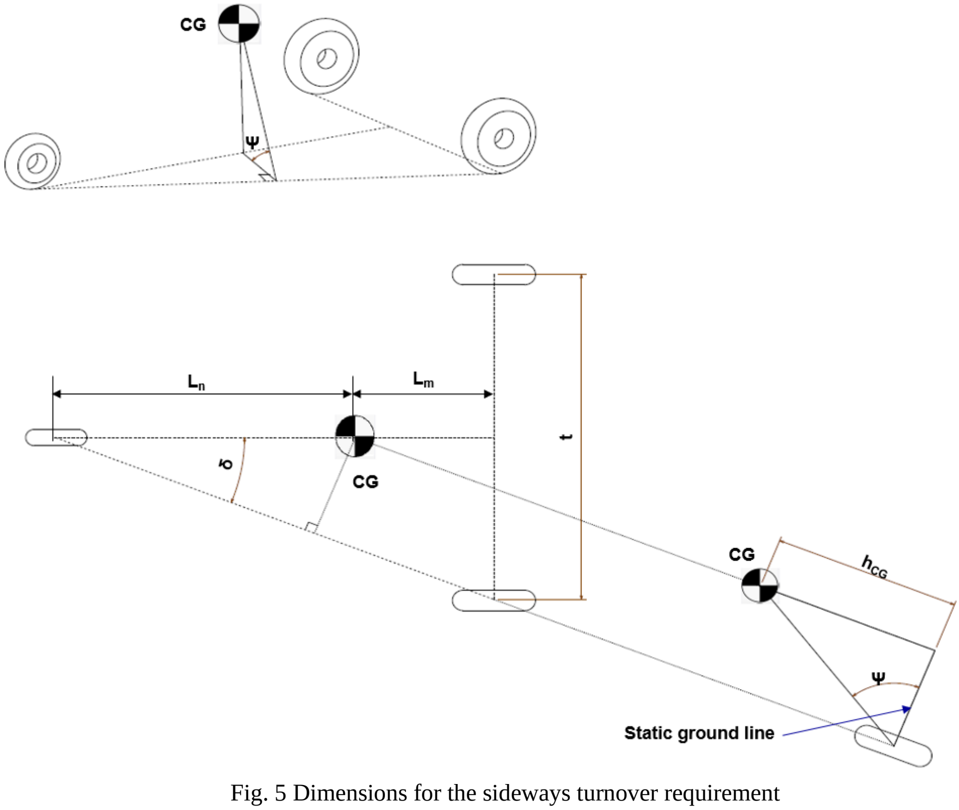

Fig. 5 Dimensions for the sideways turnover requirement

where δ is calculated with the next equation:

$$\tan\delta = \frac{t}{2(l_m + l_n)} \tag{9}$$

The nose wheel track is presumed to be of slight significance. Using equations (7) and (8) the minimum necessary track (t) can be calculated in order to prevent the turnover [3, 5].

To ensure that the aircraft remains stable during taxiing and touchdown, another limit should be taken into account.

When assuming that the nose wheel location is fixed, a circle is drawn with a radius of $0.54h_{CG}$ centered in the center of gravity CG as shown in figure 6 [1, 2, 3, 5].

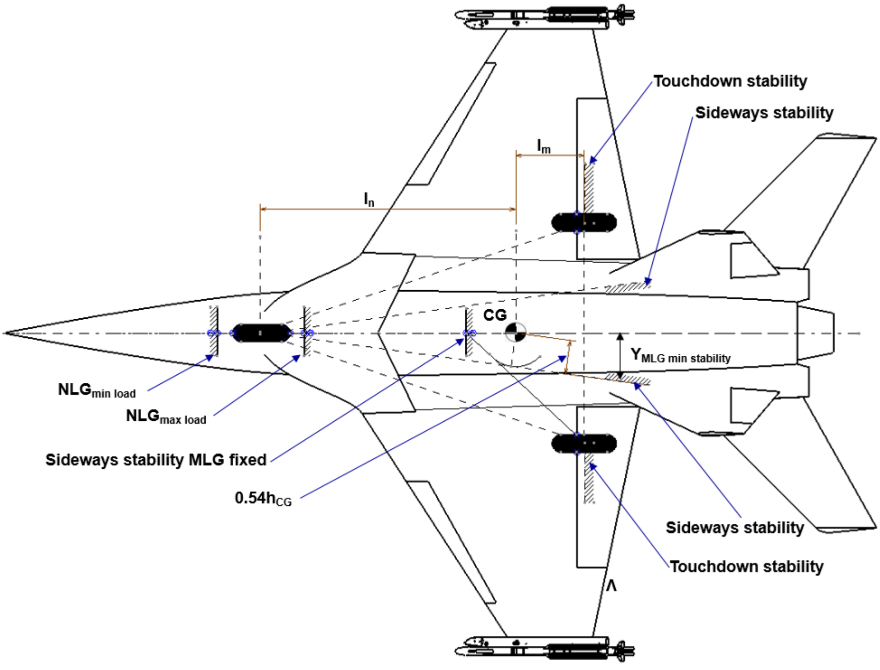

Fig. 6 Dimensions for the sideways turnover requirement

Then the line drawn from the nose wheel position to the tangent of the circle determines the minimum lateral position of the main gear: $Y_{MLG\ min\ stability}$. This can also be calculated using the next equation [3, 5]:

$$Y_{MLG\ min\ stability} = tan\left(sin^{-1}\left(\frac{0.54h_{CG}}{l_n}\right)\right)(l_n + l_m) \tag{10}$$

Supposing the main landing gear location is fixed, a limit on the nose gear position can be found by drawing a line from the fixed main gear position to the tangent of a circle with a radius of $0.54h_{CG}$, as shown in figure 6, this resulting in [3, 5]:

$$\Delta = tan^{-1}\left(\frac{l_m}{t/2}\right) \tag{11}$$

$$l_{n\ min} = tan\left(sin^{-1}\left(\frac{0.54h_{CG}}{l_m sin(\Delta)}\right) + \Delta\right)t/2 - l_m \tag{12}$$

3. CONCLUSIONS

The paper presents a preliminary calculation method, which is easy to apply for pre-dimensioning the landing gear. The landing gear of a military training aircraft is to provide a support and running system during taxi, take-off and landing operations. In all military training aircraft, the landing gear is designed to be retractable to minimize the aerodynamic drag of the aircraft during flight.

The preliminary calculation includes estimating the loads on landing and determining the position of the nose landing gear and the main landing gear. Another purpose of the preliminary calculation is to ensure the stability of a military training aircraft on landing and take-off, as well as to ensure the lateral stability of the aircraft during ground operations such as taxiing, landing or take-off.

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