Research on the Effects of Aircraft Mass and Wind on the Landing Performance of the L-39NG Aircraft

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Abstract —

The landing process is complex and influenced by many factors. Any small error during landing can pose a significant risk to flight safety in both operations and training. This study provides the theoretical basis and calculations on the effects of mass and wind on the landing characteristics of the L-39NG aircraft, contributing to safe and efficient aerospace engineering operations.

Keywords* — *Landing, Aircraft mass, wind, L-39NG aircraft.

I. INTRODUCTION

Landing is one of the critical and complex phases of flight, directly impacting the safety of operations and training. Operational factors such as aircraft mass and wind conditions significantly affect landing speed, deceleration distance, and landing distance. Therefore, studying and quantitatively assessing the effects of mass and wind on the landing performance of the L-39NG aircraft is necessary. This clarifies the variation patterns of landing parameters and provides a scientific basis for calculation, forecasting, and selecting appropriate operational conditions, thereby enhancing training effectiveness and ensuring flight safety.

II. METHODOLOGY

Landing is the decelerating motion of an aircraft, beginning when the aircraft starts its descent from a specified altitude and ending when the braking run is completed.

Landing is divided into five stages: descent, flare, hold-off, touchdown, and braking run.

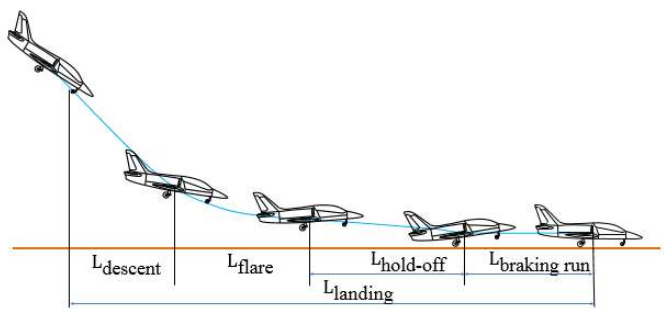

Figure 1. Landing profile

2.1. Aircraft Landing Performance

Landing speed

The landing speed V_{hc} is the aircraft speed at the moment the aircraft initially touches down on the two main landing gears.

The landing speed is calculated using the following formula:

$$V_{hc} = \sqrt{\frac{2G}{C_{yhc}\rho S}}$$

Braking run distance

The aircraft braking run distance $L_{hđ}$ is the distance traveled by the aircraft from touchdown until the braking run is completed.

The braking run distance $L_{hđ}$ is calculated using the following formula:

$$L_{hđ} = \frac{V_{hc}^2}{2|J_{xtb}|}$$

Landing distance

The landing distance L_{hc} is the ground distance measured from the point where the aircraft begins its descent from the specified altitude until the braking run is completed.

The landing distance is calculated as follows:

$$L_{hc} = L_o + L_{hđ} \text{ or } L_{hc} = (2.2 \div 2.4)L_{hđ}$$

where L_o is the airborne distance, including the pre-landing descent distance (from H = 15 m), flare distance, and hold-off distance;

2.2. Effects of Aircraft Mass and Wind on Landing Performance

Aircraft mass m

Aircraft mass directly affects landing speed and landing distance. As mass increases, the landing speed must increase to maintain the lift-equals-weight condition. Since the braking run distance is proportional to the square of the landing speed, an increase in aircraft mass results in increases in both the braking run distance and the landing distance. When the aircraft mass increases by an amount Δm, the braking run distance increases by an amount $L_{hđ}$. Their relationship is expressed by the following formula:

$$\frac{\Delta L_{hđ}}{L_{hđ}} = \frac{\Delta m}{m}$$

Wind

When wind with velocity U blows along the runway axis, the braking run distance can be calculated using the following formula:

$$L_{hđ} = \frac{(V_{hc} \pm u)^2}{2|J_{xtb}|}$$

Where "+" corresponds to tailwind and "–" to headwind.

2.3. L-39NG Parameters and Calculation Conditions

The parameters used for the calculations are summarized as follows:

Parameter	Value	Unit
Empty mass	3280	kg
Maximum landing mass	5320	kg
Maximum speed with the flaps in the landing position	93	m/s
Landing speed without external pylons	66	m/s
Reference braking run distance	600–700	m
Maximum crosswind speed for takeoff and landing	10,3	m/s
Maximum headwind speed for takeoff and landing	20,6	m/s

For an aircraft in a clean configuration, without external stores or equipment, at a reference weight of 4100 kg under MSA conditions, landing on a paved, dry runway at mean sea level 0 ft (MSL), the landing ground-roll and landing distance are as follows:

Parameter	Value
Braking run distance	520 m
Total landing distance from a height of 15 m	960 m

For an aircraft in a clean configuration, without external stores or equipment, at a Basic Take-off Weight (BTOW) of 4580 kg, with the engines operating at the appropriate power setting (take-off or idle thrust) and under Minimum Safe Altitude (MSA) conditions, the following landing speed is obtained, Landing speed with landing gear extended and flaps deployed to the landing position (44°) 59,7 m/s.

To separately evaluate the effects of runway-axis wind and aircraft mass, the study investigates wind velocities u = −5, 0, 5, 10, 15, and 20 m/s, where u = −5 m/s represents a tailwind and u > 0 represents a headwind. The landing mass is investigated at m = 3000, 3500, 4000, 4500, 5000, and 5500 kg.

Based on the calculated results, graphs can be constructed to show the dependence of landing speed, braking run distance, and landing distance on wind velocity for the investigated mass levels. These graphs are used to illustrate the trends in the variation of the parameters and to support a rapid assessment of the landing conditions of the L-39NG aircraft.

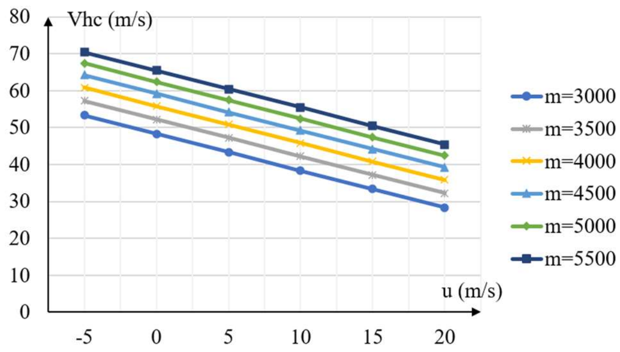

Figure 2. Effect of Aircraft Mass and Wind on landing speed

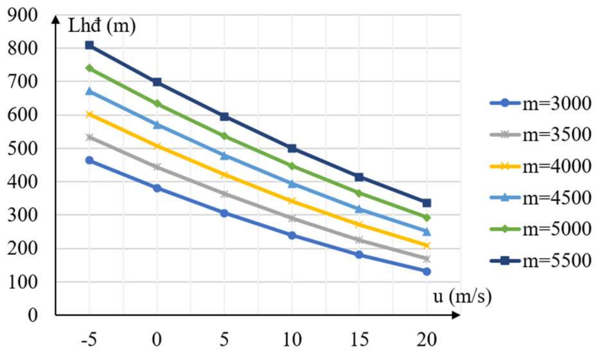

Figure 3. Effect of Aircraft Mass and Wind on braking run distance

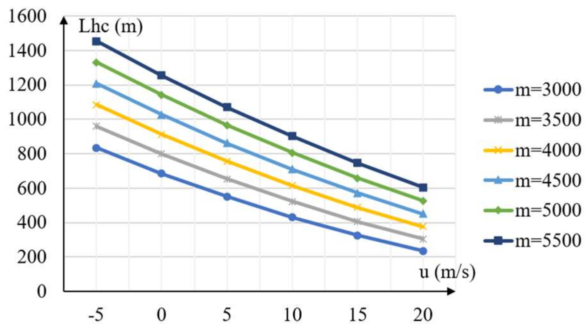

Figure 4. Effect of Aircraft Mass and Wind on landing distance

2.4. Analysis of Calculated Results

Analysis of the calculated results shows that the variation of the landing performance parameters is consistent with the theoretical basis. As the headwind velocity increases from 0 to 20 m/s, the aircraft ground speed decreases by 5 m/s for each 5 m/s increment in wind velocity, resulting in a marked reduction in both braking run distance and landing distance. Conversely, at u = −5 m/s, corresponding to a tailwind condition, all landing distances increase compared with the no-wind condition.

The effect of aircraft mass is clearly reflected in the simultaneous increases in landing speed, braking run distance, and landing distance. For example, under no-wind conditions, increasing the mass from 3000 to 5500 kg increases the landing speed from 48.34 to 65.45 m/s, the braking run distance from 380.49 to 697.56 m, and the landing distance from 684.88 to 1255.61 m. Thus, a high aircraft mass combined with a tailwind represents an unfavorable condition, whereas a low mass combined with a headwind significantly reduces the landing distance.

The results show that the effect of wind on landing distance follows a systematic trend and becomes significantly greater at higher aircraft mass. Therefore, landing operations should take into account both the actual aircraft mass and the runway-axis wind component, particularly under high-mass or tailwind conditions. These results can serve as a basis for calculation, prediction, and selection of appropriate landing procedures in the operation and training of the L-39NG aircraft.

III. CONCLUSIONS

This study clarifies the effects of aircraft mass and wind on the landing performance of the L-39NG aircraft based on theoretical analysis and calculations. The results show that an increase in aircraft mass increases landing speed and landing distance; a headwind reduces, whereas a tailwind increases, the landing distance. Among the investigated factors, changes in aircraft mass have a pronounced effect on landing speed and distance, while wind conditions directly affect the actual landing distance on the runway. The obtained results provide a scientific basis for assessing landing performance, selecting appropriate operating conditions, and improving safety in the training and operation of the L-39NG aircraft.

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