Investigation Into Wind Influence on the Landing Performance of the C-212 Platform

Van Viet Vo[#1], Duc Dung Nguyen [#2], Le Thanh Nguyen [#3]

[#] *Faculty of Aircraft - Engines, Air Force Officer's College, Khanh Hoa, Viet Nam*

[1]teivuc@gmail.com

Abstract—

Landing is a critical flight phase that requires precise energy dissipation. This paper utilizes the 4th-order Runge-Kutta method and MATLAB software to evaluate the touchdown performance profiles of the C-212 platform under standard, headwind, and tailwind conditions. The computational results indicate a nominal ground roll distance of exactly 598.97 meters. Under the influence of a headwind at -6m/s, the distance decreases significantly to 454.65 meters. Conversely, a tailwind at +6 m/s substantially extends the necessary stopping distance to 770.99 meters. Ultimately, these specific quantitative results serve as a crucial theoretical foundation for future pilot training.

Keywords— C-212 aircraft; landing characteristics; ground roll; headwind; tailwind; Runge-Kutta.

I. INTRODUCTION

Landing is a highly complex dynamic phase, associated with the relative transformation designed to completely dissipate the aircraft's kinetic and potential energy from a state of relatively high speed and altitude in the air to touchdown, braking, and coming to a complete stop.

The C-212 aircraft utilizes a braking landing method, employing reverse thrust by changing the propeller blade pitch to increase negative deceleration while diminishing the vehicle's forward velocity throughout the ground roll. Subdividing the landing process into multiple stages simplifies the research, the establishment of the force equations, along with the formulation of analytical expressions to compute the touchdown dynamics of the C-212 platform.

Therefore, this study constructs a mathematical model and calculates aerodynamic parameters for the landing phase to investigate the landing characteristics under standard conditions and evaluate variations under the influence of headwinds and tailwinds.

II. METHODOLOGY

To simplify the problem, the following simplifications are established: The aircraft is modeled as an absolute rigid body and a point mass with mass m; the acceleration due to gravity is defined as $g = 10\ m/s^2$; while the vehicle maintains moment equilibrium ($\Sigma M = 0$).

Establishment of Basic Equations

According to Newton's Second Law, the equations of motion of the aircraft in the vertical plane are determined as follows:

Along the Ox axis:

$$m.\frac{dV}{dt} = P.\cos\alpha - X + G.\sin\theta$$

Along the Oy axis:

$$m.V.\frac{d\theta}{dt} = P.\sin\alpha + Y - G.\cos\theta$$

Where:

- m: Aircraft mass;
- V: Velocity vector;
- P: Propeller thrust;
- α: Angle of attack;
- X: Aerodynamic drag;
- G: Aircraft weight;
- θ: Flight path angle;
- Y: Lift force.

The landing process with ground roll is divided into four stages:

- **Descent phase:** Straight flight with decreasing altitude (flight path angle $\theta = const < 0$).
- **Flare phase:** The pilot pulls the control stick to curve the flight path, reducing the vertical velocity V_y.
- **Hold-off phase:** The aircraft moves from an altitude of $H = 0.5 \div 1$ m until touchdown.
- **Ground roll phase:** Subdivided into four minor stages:

Stage I: Rolling on two main wheels;

Stage II: Lowering the nose gear;

Stage III: Rolling on three wheels while simultaneously using reverse thrust (negative thrust $P_r = -7{,}500$ N);

Stage IV: Rolling on three wheels applying wheel brakes (tyre-to-ground friction $f_b = 0.33$) until completely stopped.

Initialization of Boundary Conditions and Aerodynamic Coefficients

The gross landing weight is designated as $G_L = 50{,}000$ N; the entry velocity at the onset of the touchdown sequence (calculated at an altitude of H = 25 m): V = 49.8 m/s. Through computational procedures, the basic aerodynamic parameters of the C-212 aircraft associated with the touchdown phase include:

- Critical Mach number: $M_{cr} = 0.8$

- Derivative of the lift coefficient with respect to the angle of attack: $C_y^{\alpha} = 6.27$

- Zero-lift drag coefficient: $C_{x0} = 0.0325$.

Computational Algorithm

Since the equations of motion for the landing stages are differential equations, the 4th-order Runge-Kutta method is employed using MATLAB software to solve them. The computational procedure is illustrated via the flowchart of the parameter calculation algorithm.

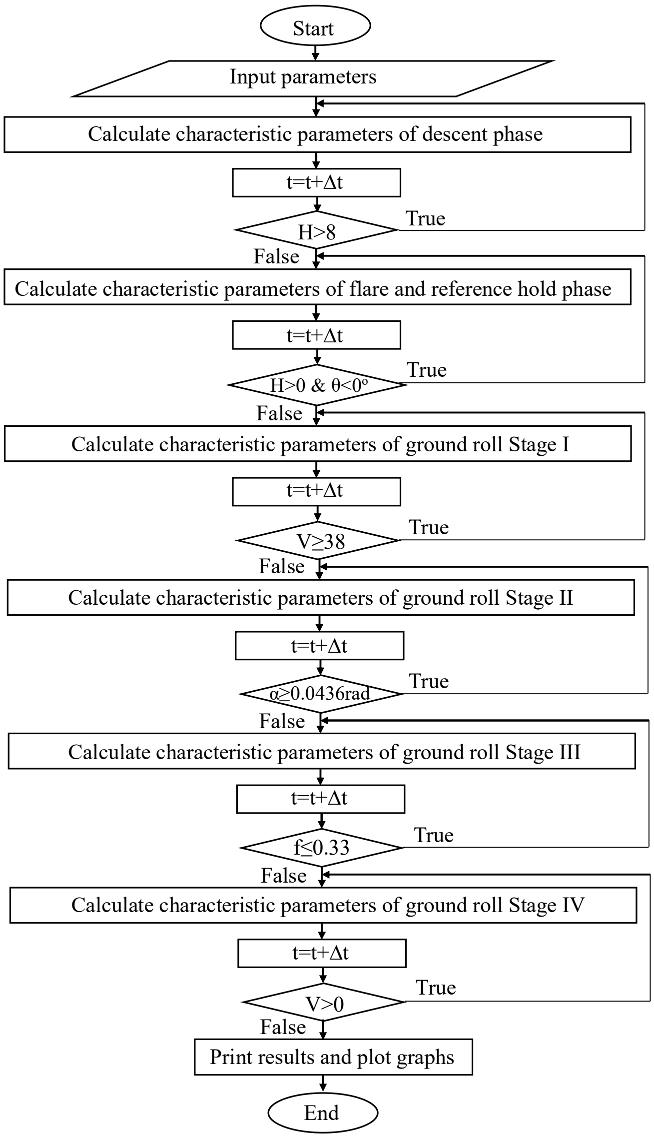

Fig. 1. Flowchart for computing landing characteristic parameters

III. RESULTS AND DISCUSSION

Landing Characteristics under Standard Conditions

Under standard ground conditions (ignoring the influence of crosswinds), the aircraft's landing process occurs over a relatively short time of 18.7 s; with a landing distance of 598.97 m.

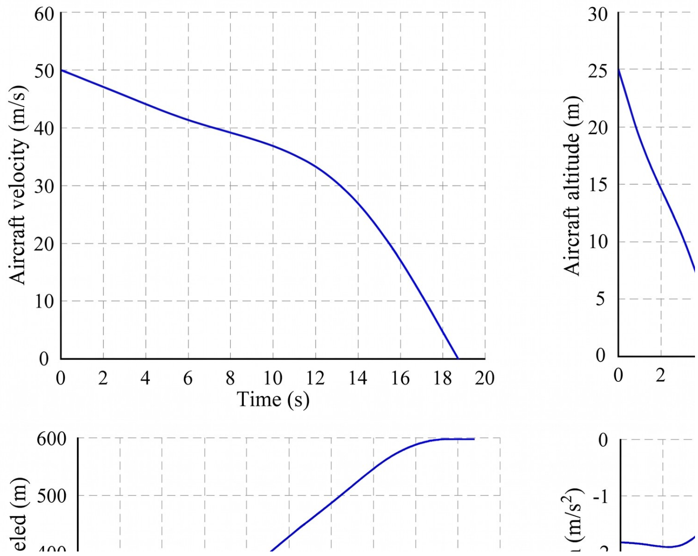

Fig. 2. Time-history curves of forward velocity, flight altitude, longitudinal displacement, and acceleration beneath standard conditions

The aircraft's velocity continuously decreases over time, while the traveled distance increases throughout the landing process. The calculated variations in the aircraft's characteristic parameters align perfectly with the physical rules governing the landing process.

Influence of Headwind Components on Landing Performance

With a headwind of 6 m/s opposite to the landing direction and parallel to the runway axis, the absolute initial ground speed of the vehicle relative to the runway is V_0 = 43.8 m/s. Under the influence of a headwind, the aircraft's landing process is completed within a compressed duration of 16.4 s, curtailing the overall landing distance to 454.65 m.

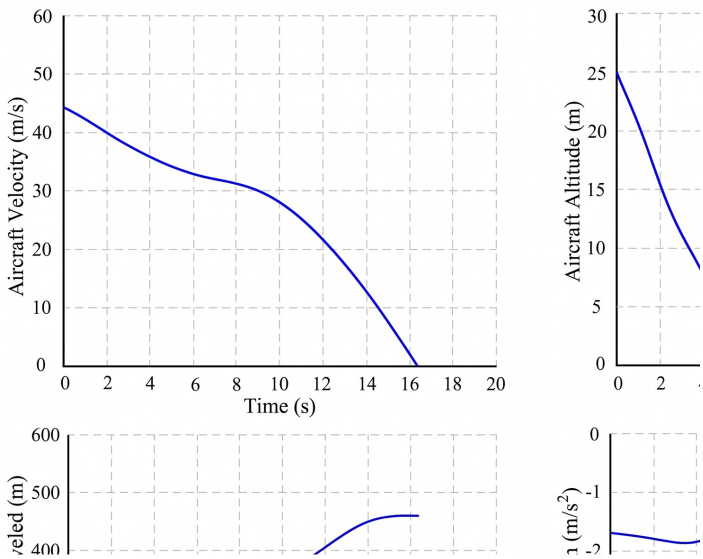

Fig. 3. Parametric plots of touchdown parameters under headwind conditions

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Influence of Tailwind Components on Landing Performance

With a tailwind of 6m/s, aligned with the landing direction and collinear with the airstrip axis, the absolute initial velocity of the aircraft relative to the runway is V_0= 55.8 m/s. Under the influence of a tailwind, the landing process prolongs to a total duration of 21.1 s, concurrently expanding the final ground roll to 770.99 m.

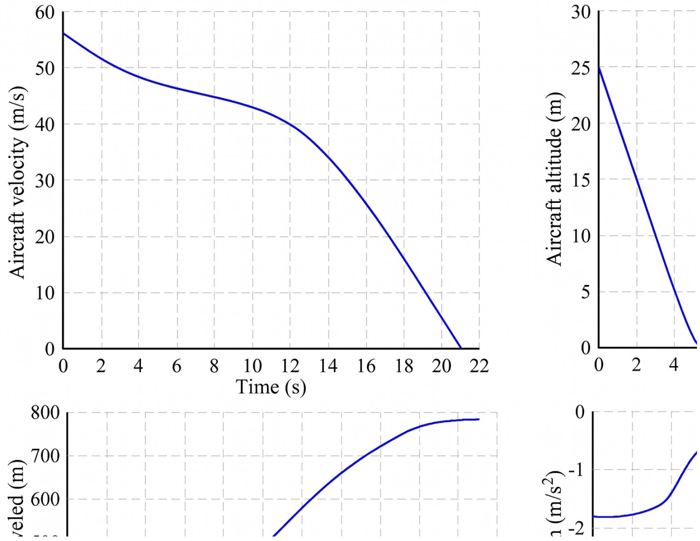

Fig. 4. Parametric plots of touchdown parameters under tailwind conditions

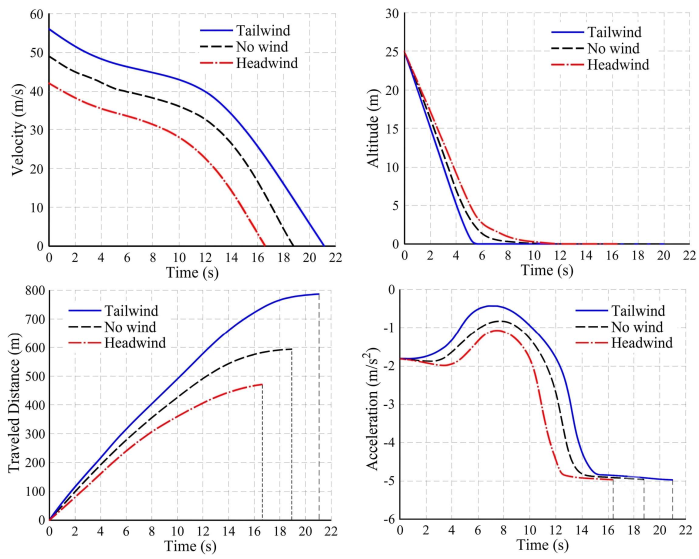

Fig. 5. Comprehensive comparison graphs of landing characteristics

IV. CONCLUSIONS

This study computed the aerodynamic parameters for the landing phase and subsequently evaluated the landing characteristics of the C-212 aircraft under standard, headwind, and tailwind conditions using the 4th-order Runge-Kutta method.

The numerical findings demonstrate that wind perturbations exert a critical impact on the aircraft's touchdown sequence. Specifically, the discrepancy in landing time and distance between tailwind and headwind scenarios is substantial. Encountering a headwind component curtails the ground roll to 454.65 m, whereas a tailwind condition conversely amplifies the deceleration distance to 770.99 m.

The obtained computational results can serve as a theoretical basis for pilot training, assisting pilots in monitoring the dynamic state variables of the vehicle throughout operation and landing.

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