Master Van Huy Khuat, 2026, 14:2
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Aircraft Wing Flatter Phenomenon Using Matlab Simulink Software

Master Van Huy Khuat [1], Master Le Phan [2]

Abstract- This paper presents the results of a study investigating the flutter phenomenon of aircraft wings using MATLAB/Simulink. Flutter is a self-excited oscillation of an aircraft wing that occurs when its airspeed exceeds a critical limit. The wing oscillation model was developed within the MATLAB/Simulink environment. The paper details the simulation results and compares them with experimental data found in the aircraft technical manuals from the Air Force Officer School. This method enables the determination of the critical flutter velocity and analyzes how variations in wing parameters affect this threshold. Keywords: Flutter; Air plane wings; Calculate on Matlab.

Keywords— Flutter, Aircraft Wings, MATLAB/Simulink, Critical Flutter Velocity, Aeroelasticity, Oscillation Analysis, Simulation, Wing Parameters.

I. INTRODUCTION

Flutter is a self-excited oscillation phenomenon affecting aerodynamic surfaces in general and aircraft wings in particular. When flutter occurs, the oscillation amplitude can increase exponentially, potentially leading to catastrophic structural failure. This phenomenon became a critical focus for researchers and designers in the early 1930s as flight speeds surged due to the transition to monoplane configurations and increased engine thrust. Since then, mitigating flutter has been a fundamental requirement in the design and manufacturing of high-speed aircraft. The specific airspeed at which these oscillations begin, denoted as VF, is defined as the critical flutter speed. According to structural integrity standards, we have: VF > k.Vmax ,

Where Vmax is the speed corresponding to qmax;
k is a coefficient specified by durability standards; for aircraft, k = 1.2.

Among the various types of aircraft wing flutter, the most common is the torsional flutter. To study this phenomenon, we can use Matlab Simulink software to build a model of the aircraft wing's oscillations during air movement, and then examine and compare it with real-world parameters.

II. METHODOLOGY

The choice of survey calculation method for a specific problem depends on the required accuracy, simplicity and consistency of the method, economic requirements, available resources, and controllability. Verify the results obtained.

We chose a method of surveying the oscillation process of aircraft wings in motion, based on a mathematical model built using Matlab Simulink software. This method provides quick calculation results and allows for easy modification of system parameters to conduct surveys while maintaining accuracy. However, this is only an initial survey method based on mathematical models built on software. Therefore, the survey results need to be re-tested on real-world models.

We will consider the rectangular wing diagram, in which the centroid line T, the stiffness axis ж, and the focal line ϕ are straight lines perpendicular to the wing's cross-section (Figure 1).

© 2026 Master Van Huy Khuat, This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly credited.

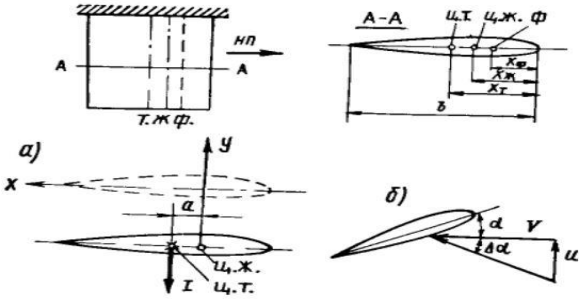

Figure 1: Deformation of a rectangular wing during flutter
a – inertial force I; b – change in the angle of attack of the wing Δα

Typically, in the cross-section of the wing, the center of gravity of the structure is located at 43-50% of the chord length, the center of stiffness is at approximately 30-36% of the chord length, and the focal point is usually considered to be at 25% of the chord length. It is assumed that the aerodynamic forces acting on the wing can be represented by the aerodynamic characteristics of a given element AA of the wing. The displacement of this element from its equilibrium position (displacement y and twist angle φ) will characterize the oscillation process of the wing. In the mechanism of formation and generation of self-oscillation of the wing's bending and twisting motion, there always exists a relationship between the bending and twisting motion of the wing, which will lead to simultaneous bending and twisting oscillation of this wing element. Usually, with the arrangement of the rigid axis and the center of gravity of the wing, pure bending or pure twisting oscillation cannot exist independently on the aircraft wing, even if the initial impulse causing the motion is purely bending or purely twisting. In both cases, the oscillations will necessarily combine, meaning the initial bending will lead to a twisting of the wing and vice versa.

Let's consider the most important aerodynamic forces arising from the oscillation of the wing, as shown in Figure 1.

Besides the elastic force of the wing during deformation, inertial forces are generated when wing elements move with acceleration. Bending oscillations in the airflow, at angles of attack of the wing far from the critical angle, always create drag. Suppose the wing moves downward in the incoming airflow with velocity $u = \| \frac{dy}{dt}$. The relative air velocity is upward and equal to the total flow velocity V. With velocity u, we obtain a resulting velocity deflected by an angle $\Delta\alpha \approx (u/V)$ see Figure 1, b).

Therefore, when the aircraft wing moves downward, the angle of attack will increase and the lift will increase, in the opposite direction to the movement — upward, i.e., an aerodynamic force Pd will appear, reducing the oscillation. When the aircraft wing moves upward, the situation is reversed: a downward drag force appears. The aerodynamic drag force Pd is proportional to the velocity V.

$$P_d = \Delta C_y \frac{\rho V^2}{2} S = \frac{dC_y}{d\alpha} \Delta\alpha \frac{\rho V^2}{2} S = \frac{dC_y}{d\alpha} \frac{u}{V} \frac{\rho V^2}{2} S = K_1 uV$$

Furthermore, the change in the angle of attack during torsional oscillation leads to the creation of an aerodynamic force proportional to the angle of torsion φ and the square of the flight speed V:

$$P_B = \frac{dC_y}{d\alpha} \varphi \frac{\rho V^2}{2} S = K_2 V^2$$

Both the aerodynamic forces Pd and PB, which are the increases in lift, are caused by the change in the angle of attack of the wing acting at the wing's focal point.

By analyzing the forces acting on this aircraft wing element, we can construct a system of differential equations that describe the oscillation of the wing in the air:

$$m\frac{d_y^2}{dt} = F_{dhu} + F_{qtX} + F_D + F_B$$

$$I\frac{d_\varphi^2}{dt} = M_dh_x + M_qt_u + e.F_D + e.F\ B$$

In which: $P_d = \Delta C_y \frac{\rho V^2}{2} S = \frac{dC_y}{d\alpha} \Delta\alpha \frac{\rho V^2}{2} S = \frac{dC_y}{d\alpha} \frac{u}{v} \frac{\rho V^2}{2} S = K_1 uV$

$$P_B = \frac{dC_y}{d\alpha} \varphi \frac{\rho V^2}{2} S = K_2 V^2$$

$$F_{qtX} = \frac{I}{e} \frac{d_y^2}{dt}$$

$$M_{qtu} = me\frac{d_y^2}{dt}$$

$$E = X_t - X_m$$

Based on these differential equations, a mathematical model was developed using MATLAB/Simulink to simulate the free vibration of the aircraft wing in an airflow. The model utilizes the geometric and structural properties of the wing element as input parameters. The outputs consist of time-history data for the bending displacement and twist angle. By leveraging Simulink's graphical interface, these results are visualized as waveforms, illustrating the dynamic response of the system. Following rigorous research and development, the resulting model effectively captures the evolution of wing parameters during the flutter phenomenon, as demonstrated below:

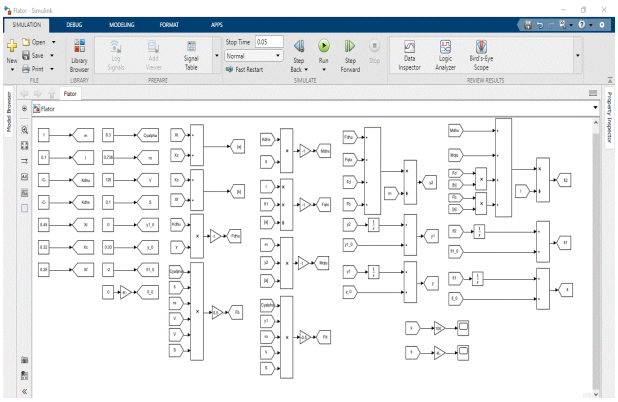

Figure 2: Model illustrating the oscillation of an aircraft wing during a plane crash.

III. RESULTS AND DISCUSSION

To conduct the survey, we input the parameters of a specific wing element into the model. We vary the flight velocity from small to large to determine the velocity at which the flattening phenomenon occurs.

At low speeds, before flattening occurs, the bending and torsional oscillations of the blade will gradually decrease over time.

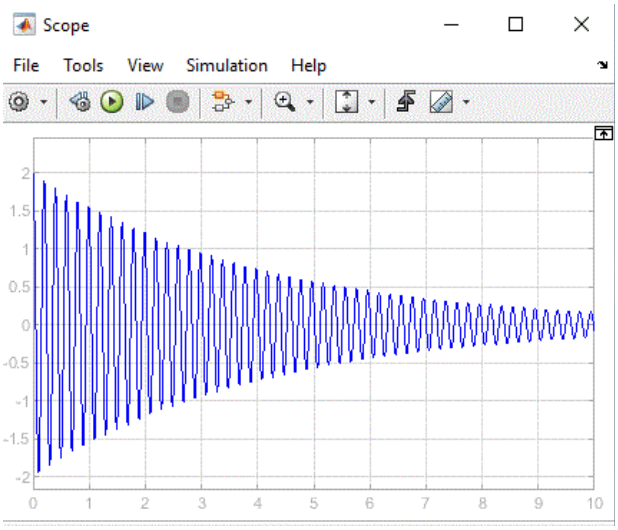

Figure 3: Results of the survey on the change in bending of the wing element at low velocity value V1
As velocity increases, the process of velocity decreasing over time slows down:

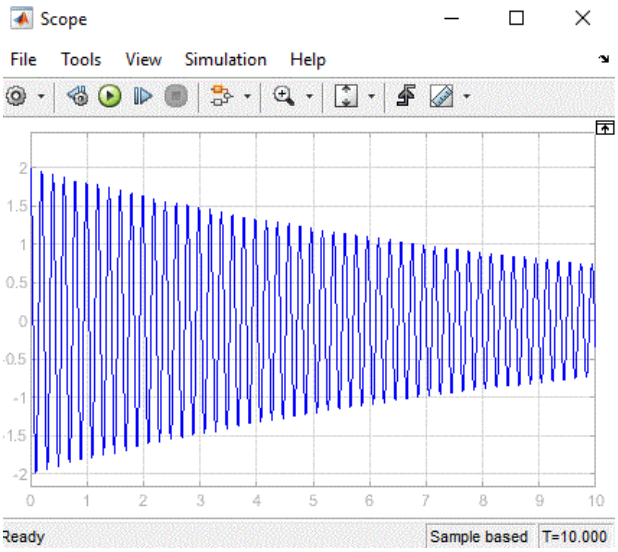

Figure 4: Results of the survey on the change in bending of the wing element at velocity value V2 > V1
Once the velocity value at which Flatter occurs is reached, the oscillation of the wing is maintained over time.

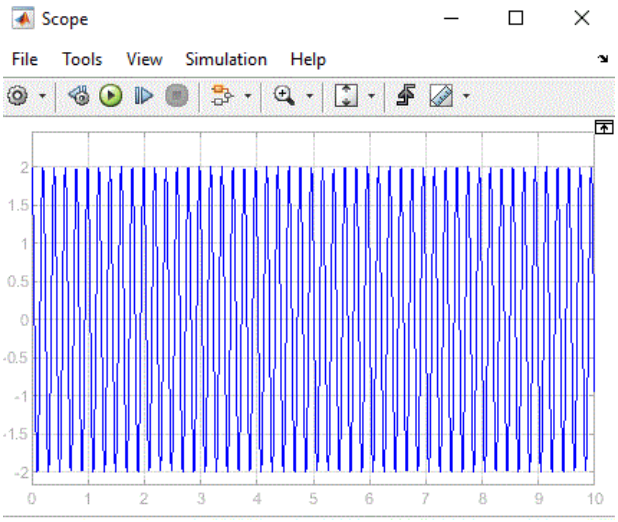

Figure 5: Results of the survey on the change in bending of the wing element when the velocity value V3 is equal to the flat value.

According to the survey results, when the velocity value is small, the effect of increasing the oscillation of the P component is Pb =(dC_y)/dα φ (ρV^2)/2 S= K2 V2 will be smaller than the component hindering the movement of the wing element Pd = ΔCy (ρV^2)/2 S= (dC_y)/dαΔα (ρV^2)/2 S=(dC_y)/dα u/V (ρV^2)/2 S= K1uV. This causes the oscillation of the wing to gradually dampen over time. As the velocity increases, the difference between these two elements decreases, and the oscillation of the wing continues to decrease over time, but at a slower rate. Once the velocity reaches the point where flattening occurs, the oscillation will continue to be sustained over time.

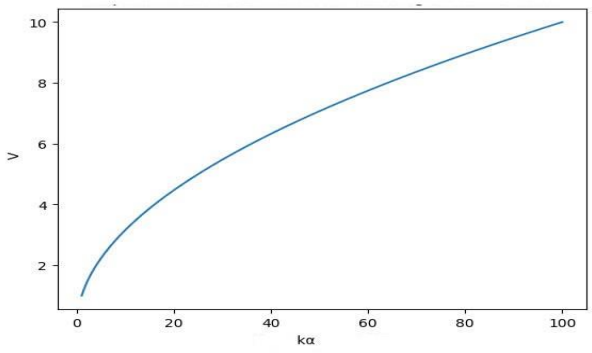

Figure 6: Results of surveying the change in planar velocity with torsional stiffness of the wing element.

The investigation can be continued by changing other parameters of the aircraft wing element, for example, changing the torsional stiffness of the wing element, the position of the center of gravity of the wing element, and continuing the investigation in the same way to find the velocity of the plane. We obtain the graph of the dependence of the plane velocity on stiffness as shown in Figure 6.

The graph showing the dependence of the plane velocity on the position of the centroid of the wing element is determined in Figure 7.

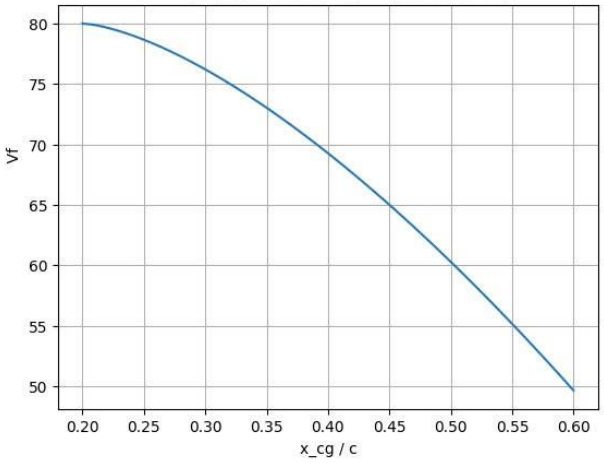

Figure 7: Results of surveying the change in planar velocity with the position of the center of gravity of the wing element.

IV. CONCLUSION

Through the computational results of the developed model, the critical velocity at which the flutter phenomenon occurs for a specific wing type has been successfully determined. Furthermore, by performing a parametric study, the dependence of the flutter velocity on various structural characteristics of the wing element was established. The results demonstrate that MATLAB/Simulink is an effective tool for modeling and simulating the oscillation process of aircraft wings in an airflow.

By incrementally increasing the flow velocity, the threshold for the onset of flutter was identified. Subsequent investigations into parameters such as stiffness and center of gravity position revealed

critical trends: specifically, increasing the torsional stiffness of the wing leads to a higher flutter velocity, meaning a stiffer wing structure is more resistant to flutter. Conversely, shifting the center of gravity toward the trailing edge (further back) decreases the flutter velocity, increasing the risk of instability. Therefore, to mitigate flutter, design measures should focus on shifting the wing's center of gravity forward. These findings provide a valuable reference for the design, manufacturing, and safety-limit parameterization of various aircraft types in practical applications.

Acknowledgements

The authors would like to express their sincere gratitude to the agencies, organizations, and individuals who supported and encouraged this research. Special thanks are extended to the faculty of the Air Force Officer School for their invaluable cooperation, as well as to colleagues and friends for their consistent assistance.

We are particularly grateful to the Board of Directors of the Air Force Officer School and the lecturers of the Department of Aircraft and Engines for their dedication in providing the specialized knowledge and technical guidance throughout the research process. While every effort has been made to ensure the rigor of this study, some limitations may remain. The authors welcome constructive feedback and contributions from experts and colleagues to further refine and improve this work.

REFERENCES

1. Д. С. Фролов (2024), Основы конструкции и прочности летательных аппаратов: Учебное пособие.
2. Э. И. Григолюп, В ведение в теорию аэроупругости
3. К. Д. Миртова и Ж. С. Черненк Конструкция и прочность самолетов и вертолетов
4. G. Adroher (2023), Aeroelastic study of the flutter conditions of an aircraft wing. UPCommons.

Author information

1. MSc Van Huy Khuat, Faculty of Aircraft – Engines, Air Force Officer's College, Khanh Hoa, Viet Nam, khuathuy88@gmail.com
2. MSc Le Phan, Faculty of Aircraft – Engines, Air Force Officer's College, Khanh Hoa, Vietnam, phl39.info@gmail.com