

# MECHANICS OF FLIGHT

A. C. KERMODE

11th Edition



Revised by  
**R.H. BARNARD & D.R. PHILPOTT**



# Mechanics Of Flight

**Yijin Wang**



## Mechanics Of Flight:

**Basic Flight Mechanics** Ashish Tewari, 2016-04-22 This book presents flight mechanics of aircraft spacecraft and rockets to technical and non technical readers in simple terms and based purely on physical principles Adapting an accessible and lucid writing style the book retains the scientific authority and conceptual substance of an engineering textbook without requiring a background in physics or engineering mathematics Professor Tewari explains relevant physical principles of flight by straightforward examples and meticulous diagrams and figures Important aspects of both atmospheric and space flight mechanics are covered including performance stability and control aeroelasticity orbital mechanics and altitude control The book describes airplanes gliders rotary wing and flapping wing flight vehicles rockets and spacecraft and visualizes the essential principles using detailed illustration It is an ideal resource for managers and technicians in the aerospace industry without engineering degrees pilots and anyone interested in the mechanics of flight Mechanics of Flight Alfred Cotterill Kermode, 2012 Mechanics of Flight is an ideal introduction to the basic principles of flight for students embarking on courses in aerospace engineering student pilots apprentices in the industry and anyone who is simply interested in aircraft and space flight Written in a straightforward and jargon free style this popular classic text makes the fascinating topic of aircraft flight engaging and easy to understand Starting with an overview of the relevant aspects of mechanics the book goes on to cover topics such as air and airflow aerofoils thrust level flight gliding landing performance manoeuvre *Flight mechanics and flight control for a multibody aircraft* Köthe, Alexander, 2019-06-26 Aircraft operating as so called High Altitude Platform Systems HAPS have been considered as a complementary technology to satellites since several years These aircraft can be used for similar communication and monitoring tasks while operating at a fraction of the cost Such concepts have been successfully tested Those include the AeroVironment Helios and the Airbus Zephyr with an endurance of nearly 624 hours 26 days All these HAPS aircraft have a high aspect ratio wing using lightweight construction In gusty atmosphere this results in high bending moments and high structural loads which can lead to overloads Aircraft crashes for example from Google's Solara 50 or Facebook's Aquila give proof of that fact Especially in the troposphere where the active weather takes place gust loads occur which can lead to the destruction of the structure The Airbus Zephyr the only HAPS aircraft without flight accidents provides only a very small payload Thus it does not fully comply with the requirements for future HAPS aircraft To overcome the shortcomings of such single wing aircraft so called multibody aircraft are considered to be an alternative The concept assumes multiple aircraft connected to each other at their wingtips It goes back to the German engineer Dr Vogt In the United States shortly after the end of World War II he experimented with the coupling of manned aircraft This resulted in a high aspect ratio wing for the aircraft formation The range of the formation could be increased correspondingly The engineer Geoffrey S Sommer took up Vogt's idea and patented an aircraft configuration consisting of several unmanned aerial vehicles coupled at their wingtips However the patent does not provide any insight

into the flight performance the flight mechanical modeling or the control of such an aircraft. Single publications exist that deal with the performance of coupled aircraft. A profound complete analysis however is missing so far. This is where the present work starts. For the first time a flying vehicle based on the concept of the multibody aircraft will be analyzed in terms of flight mechanics and flight control. In a performance analysis the aircraft concept is analyzed in detail and the benefits in terms of bending moments and flight performance are clearly highlighted. Limits for operation in flight are shown considering aerodynamic optimal points. The joints at the wingtips allow a roll and pitch motion of the individual aircraft. This results in additional degrees of freedom for the design through the implementation of different relative pitch and bank angles. For example using individual pitch angles for individual aircraft further decreases the induced drag and increases flight performance. Because the lift is distributed symmetrically but not homogeneously along the wingspan a lateral trim of the individual aircraft in formation flight becomes necessary. The thesis presents a new method to implement this trim by moving the battery mass along half the wingspan which avoids additional parasite drag. Further a complete flight dynamics model is provided and analyzed for aircraft that are mechanically connected at their wingtips. To study this model in detail a hypothetical torsional and bending spring between the aircraft is introduced. If the spring constants are very high the flight dynamics model has properties similar to those of an elastic aircraft. Rigid body and formation eigenmotions can be clearly distinguished. If the spring constants are reduced towards zero which represents the case of the multibody aircraft classical flight mechanics eigenmotions and modes resulting from the additional degrees of freedom are coupled. This affects the eigenstructure of the aircraft. Hence normal motions with respect to the inertial space as known from a rigid aircraft cannot be observed anymore. The plant also reveals unstable behavior. Using the non linear flight dynamics model flight controllers are designed to stabilize the plant and provide the aircraft with an eigenstructure similar to conventional aircraft. Different controller design methods are used. The flight controller shall further maintain a determined shape of the flight formation. It shall control flight bank and pitch angles and it shall suppress disturbances. Flight control theories in the time domain. Eigenstructure assignment and in the frequency domain  $H_\infty$  loop shaping are considered. The resulting inner control loops yield a multibody aircraft behavior that is similar to the one of a rigid aircraft. For the outer control loops classical autopilot concepts are applied. Overall the flight trajectory of the multibody aircraft above ground is controlled and thus an actual operation as HAPS is possible. In the last step the flight controller is successfully validated in non linear simulations with complete flight dynamics. Flugzeuge in der Form von sogenannten Hohenplattformen engl. High Altitude Platform Systems (HAPS) werden seit einigen Jahren als kostengünstige Ergänzung zu teuren Satelliten betrachtet. Diese Flugzeuge können für ähnliche Kommunikations- und Überwachungsaufgaben eingesetzt werden. Zu den gegenwärtigen Konzepten solcher Fluggeräte, die bereits erfolgreich im Flugversuch eingesetzt wurden, zählen der Helios von AeroVironment und der Airbus Zephyr, der eine Flugdauer von fast 624 Stunden (26 Tagen) erreicht hat. Alle diese HAPS-Flugzeuge besitzen einen Fl

langer Streckung der in Leichtbauweise konstruiert ist. Hieraus resultieren in großer Atmosphäre hohe Biegemomente und starke strukturelle Belastungen die zu Überbelastungen führen können. Flugunfälle beispielsweise von Googles Solara 50 oder Facebooks Aquila belegen dies. Insbesondere in der Troposphäre in der das aktive Wetter stattfindet treten Belastungen auf die die Struktur zerstören können. Der Airbus Zephyr der bisher als einziger HAPS Flugzeug frei von Flugunfällen ist besitzt nur eine sehr geringe Nutzlast. Daher kann er die Anforderungen an zukünftige HAPS Flugzeuge nicht vollständig erfüllen. Um die Schwachstellen solcher Einflügel Konzepte zu überwinden wird in dieser Arbeit ein alternatives Flugzeugkonzept betrachtet das als Mehrkörperflugzeug bezeichnet wird. Das Konzept geht von mehreren an den Flügelspitzen miteinander verbundenen Flugzeugen aus und beruht auf Ideen des deutschen Ingenieurs Dr. Vogt. Dieser hatte in den USA kurz nach Ende des Zweiten Weltkrieges bemannte Flugzeuge aneinanderkoppeln lassen. Hierdurch ergab sich ein Flugzeugverbund mit einem Einflügel langer Streckung. Damit konnte die Reichweite des Verbundes gesteigert werden. Geoffrey S. Sommer griff die Idee von Vogt auf und ließ sich eine Flugzeugkonfiguration patentieren die aus mehreren unbemannten Flugzeugen besteht die an den Enden der Tragflächen miteinander gekoppelt sind. Die Patentschrift gibt jedoch keinen Einblick in die Flugleistungen, die flugmechanische Modellierung oder die Regelung eines solchen Fluggerätes. Vereinzelt existieren Veröffentlichungen die sich mit den Flugleistungen von gekoppelten Luftfahrzeugen beschäftigen. Eine tiefgreifende vollständige flugmechanische Analyse fehlt jedoch bisher. Hier setzt die vorliegende Arbeit an. Ein Fluggerät basierend auf dem Konzept des Mehrkörperflugzeugs wird erstmalig hinsichtlich der Flugmechanik und Flugregelung untersucht. In einer Flugleistungsbetrachtung wird das Flugzeugkonzept genau analysiert und die Vorteile hinsichtlich der Biegemomente und der Flugleistungen klar herausgestellt. Die Grenzen des Einsatzes im Flugbetrieb werden mithilfe aerodynamischer Optimalpunkte aufgezeigt. Bei der Lager an den Flügelspitzen die eine relative Roll- und Nickbewegung der Flugzeuge untereinander ermöglichen ergeben sich durch die Einstellung unterschiedlicher Längslage und Höhenwinkel zusätzliche Freiheitsgrade im Entwurf. Die Verwendung unterschiedlicher Nicklagewinkel der einzelnen Flugzeuge reduziert beispielsweise den induzierten Widerstand weiter und steigert die Flugleistung. Durch die symmetrische entlang der Spannweite jedoch nicht homogene Auftriebsverteilung ist auch eine laterale Trimmung der einzelnen Flugzeuge in der Formation notwendig. Hier stellt die Arbeit eine neuartige Möglichkeit vor um diese Trimmung ohne zusätzlichen parasitären Widerstand mittels Verschiebung der Batteriemasse entlang der Halbspannweite umzusetzen. Weiterhin wird ein vollständiges flugdynamisches Modell für über mechanische Lager verbundene Luftfahrzeuge aufgestellt und analysiert. Für diese Analyse wird eine hypothetische Torsions- und Biegefeder zwischen den Flugzeugen modelliert. Sind die Federsteifigkeiten hinreichend hoch besitzt das flugdynamische Modell Eigenschaften die einem elastischen Flugzeug entsprechen. Starrkörper- und elastische Eigenbewegungsformen sind in diesem Fall klar separiert. Bei immer weiterer Reduzierung bis auf eine Federsteifigkeit von Null kommt es zu Kopplungen zwischen den klassischen flugmechanischen Eigenbewegungsformen und den Moden aus den zusätzlichen Freiheitsgraden. Dies stellt

den Auslegungsfall für das Mehrkörperflugzeug. Dabei verändert sich die Eigenstruktur (engl. eigenstructure) des Flugzeugs und normale bei einem starren Flugzeug beobachtbare Bewegungen gegenüber dem inertialen Raum sind nicht mehr erkennbar. Zusätzlich zeigt die Strecke instabiles Verhalten. Basierend auf dem nichtlinearen flugdynamischen Modell werden mit verschiedenen Methoden Regler entworfen, die die Regelstrecke stabilisieren und dem Flugzeug eine Streckenstruktur zuweisen, die derjenigen klassischer Flugzeuge ähnelt. Zudem soll durch die Regler eine vorgegebene Form des Flugzeugverbundes beibehalten werden. Die Fahrt der Längs- und Rolllagewinkel sollen geregelt und Störungen unterdrückt werden. Als Auslegungsverfahren werden Theorien der Zustandsregelungen im Zeitbereich (Eigenstrukturvorgabe) und Frequenzbereich ( $H_\infty$  loop shaping) verwendet. Hierdurch wird durch die inneren Regelschleifen ein Verhalten des Mehrkörperflugzeugs erzielt, das dem eines starren Flugzeugs entspricht. Für die äußeren Regelschleifen werden anschließend klassische Konzepte von Autopiloten verwendet. Im Ergebnis ist eine Regelung des Flugweges über Grund des Mehrkörperflugzeugs und somit ein tatsächlicher Betrieb als HAPS möglich. Die Funktionalität des Reglers wird abschließend in nichtlinearen Simulationen mit vollständiger Flugdynamik verifiziert.

Mechanics of Flight Warren F. Phillips, 2004-01-29  
This comprehensive volume addresses the mechanics of flight through a combination of theory and applications. Topics are presented in a logical order and coverage within each is extensive, including a detailed discussion on the quaternion formulation for six degree of freedom flight.

**Flight Mechanics Modeling and Analysis** Jitendra R. Raol, Jatinder Singh, 2023-03-31  
Flight Mechanics Modeling and Analysis comprehensively covers flight mechanics and flight dynamics using a systems approach. This book focuses on applied mathematics and control theory in its discussion of flight mechanics to build a strong foundation for solving design and control problems in the areas of flight simulation and flight data analysis. The second edition has been expanded to include two new chapters and coverage of aeroservoelastic topics and engineering mechanics, presenting more concepts of flight control and aircraft parameter estimation. This book is intended for senior undergraduate aerospace students taking Aircraft Mechanics, Flight Dynamics, Controls, and Flight Mechanics courses. It will also be of interest to research students and R & D project scientists of the same disciplines. Including end of chapter exercises and illustrative examples with a MATLAB based approach, this book also includes a Solutions Manual and Figure Slides for adopting instructors.

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Fundamentals of Airplane Flight Mechanics David G. Hull, 2007-01-20  
Flight mechanics is the application of Newton's laws to the study of vehicle trajectories, performance, stability, and aerodynamic control. This text is concerned with the derivation of analytical solutions of airplane flight mechanics problems.

associated with flight in a vertical plane Algorithms are presented for calculating lift drag pitching moment and stability derivatives Flight mechanics is a discipline As such it has equations of motion acceptable approximations and solution techniques for the approximate equations of motion Once an analytical solution has been obtained numbers are calculated in order to compare the answer with the assumptions used to derive it and to acquaint students with the sizes of the numbers A subsonic business jet is used for these calculations *Aerodynamics, Aeronautics and Flight Mechanics* Barnes W.

McCormick,1979-08 A single comprehensive in depth treatment of both basic and applied modern aerodynamics Covers the fluid mechanics and aerodynamics of incompressible and compressible flows with particular attention to the prediction of lift and drag characteristics of airfoils and wings and complete airplane configurations Following an introduction to propellers piston engines and turbojet engines methods are presented for analyzing the performance of an airplane throughout its operating regime Also covers static and dynamic longitudinal and lateral directional stability and control Includes lift drag propulsion and stability and control data numerical methods and working graphs Mechanics of Flight Alfred Cotterill

Kermode,1987 L rebogsagtig beskrivelse af forhold og teknikken i f m flyvning herunder overlyds og rumflyvning

**Mechanics of Flight** Alfred Cotterill Kermode,1952 Flight Mechanics of High-Performance Aircraft Nguyen X.

Vinh,1995-05-04 Covers all aspects of flight performance of modern day high performance aircraft **Introduction to**

**Aircraft Flight Mechanics** Thomas R. Yechout,Steven L. Morris,2003 Annotation A textbook for a two semester course within an undergraduate aeronautical engineering curriculum The course is usually taken after a fundamental course in aeronautics Annotation c 2003 Book News Inc Portland OR booknews com **Introduction to Aircraft Flight Mechanics**

,2003 **Mechanics of flight ... seventh edition** Alfred Cotterill Kermode,1970 *Flight Theory and Aerodynamics*

Joseph R. Badick,Brian A. Johnson,2021-09-30 FLIGHT THEORY AND AERODYNAMICS GET A PILOT S PERSPECTIVE ON FLIGHT AERODYNAMICS FROM THE MOST UP TO DATE EDITION OF A CLASSIC TEXT The newly revised Fourth Edition of Flight Theory and Aerodynamics delivers a pilot oriented approach to flight aerodynamics without assuming an engineering background The book connects the principles of aerodynamics and physics to their practical applications in a flight environment With content that complies with FAA rules and regulations readers will learn about atmosphere altitude airspeed lift drag applications for jet and propeller aircraft stability controls takeoff landing and other maneuvers The latest edition of Flight Theory and Aerodynamics takes the classic textbook first developed by Charles Dole and James Lewis in a more modern direction and includes learning objectives real world vignettes and key idea summaries in each chapter to aid in learning and retention Readers will also benefit from the accompanying online materials like a test bank solutions manual and FAA regulatory references Updated graphics included throughout the book correlate to current government agency standards The book also includes A thorough introduction to basic concepts in physics and mechanics aerodynamic terms and definitions and the primary and secondary flight control systems of flown aircraft An exploration of atmosphere altitude and

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*In-Flight Simulators and Fly-by-Wire/Light Demonstrators* Peter G. Hamel,2017-03-15 This book offers the first complete account of more than sixty years of international research on In Flight Simulation and related development of electronic and electro optic flight control system technologies Fly by Wire and Fly by Light They have provided a versatile and experimental procedure that is of particular importance for verification optimization and evaluation of flying qualities and flight safety of manned or unmanned aircraft systems Extensive coverage is given in the book to both fundamental information related to flight testing and state of the art advances in the design and implementation of electronic and electro optic flight control systems which have made In Flight Simulation possible Written by experts the respective chapters clearly show the interdependence between various aeronautical disciplines and in flight simulation methods Taken together they form a truly multidisciplinary book that addresses the needs of not just flight test engi neers but also other aeronautical scientists engineers and project managers and historians as well Students with a general interest in aeronautics as well as researchers in countries with growing aeronautical ambitions will also find the book useful The omission of mathematical equations and in depth theoretical discussions in favor of fresh discussions on innovative experiments together with the inclusion of anecdotes and fascinating photos make this book not only an enjoyable read but also an important incentive to future research The book translated from the German by Ravindra Jategaonkar is an extended and revised English edition of the



book *Fliegende Simulatoren und Technologietrger* edited by Peter Hamel and published by Appelhans in 2014      *Flight Dynamics Principles* Michael V. Cook, 2012-10-03 The study of flight dynamics requires a thorough understanding of the theory of the stability and control of aircraft an appreciation of flight control systems and a grounding in the theory of automatic control *Flight Dynamics Principles* is a student focused text and provides easy access to all three topics in an integrated modern systems context Written for those coming to the subject for the first time the book provides a secure foundation from which to move on to more advanced topics such as non linear flight dynamics flight simulation handling qualities and advanced flight control Additional examples to illustrate the application of computational procedures using tools such as MATLAB MathCad and Program CC Improved compatibility with and more expansive coverage of the North American notational style Expanded coverage of lateral directional static stability manoeuvrability command augmentation and flight in turbulence An additional coursework study on flight control design for an unmanned air vehicle UAV

Scientific and Technical Aerospace Reports ,1984      Computational Space Flight Mechanics Claus Weiland, 2010-06-29 The mechanics of space flight is an old discipline Its topic originally was the motion of planets moons and other celestial bodies in gravitational fields Kepler's 1571-1630 observations and measurements have led to probably the first mathematical description of planet's motion Newton 1642-1727 gave then with the development of his principles of mechanics the physical explanation of these motions Since then man has started in the second half of the 20th century to capture physically the Space in the sense that he did develop artificial celestial bodies which he brought into Earth's orbits like satellites or space stations or which he did send to planets or moons of our planetary system like probes or by which people were brought to the moon and back like capsules Further he developed an advanced space transportation system the U S Space Shuttle Orbiter which is the only winged space vehicle ever in operation In the last two and a half decades there were several activities in the world in order to succeed the U S Orbiter like the HERMES project in Europe the HOPE project in Japan the X-33 X-34 and X-37 studies and demonstrators in the United States and the joint U S European project X-38 However all these projects were cancelled The motion of these vehicles can be described by Newton's equation of motion      **Lessons with Emphasis on Flight Mechanics from Operating Experience, Incidents and Accidents** North Atlantic Treaty Organization. Advisory Group for Aerospace Research and Development. Flight Mechanics Panel, 1971

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