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Helicopter Aerodynamics Volume II Progress in Rotor-blade Aerodynamics Integrated Aerodynamic/Dynamic Optimization of Helicopter Rotor Blades **Helicopter Aerodynamics Volume I Basic Helicopter Aerodynamics** Unsteady Rotor Blade Aerodynamics of Wind Turbines **Airplane Flying Handbook (FAA-H-8083-3A)** HELICOPTER AERODYNAMICS **An Examination of the Aerodynamic Moment on Rotor Blade Tips Using Flight Test Data and Analysis Analytical Evaluation of Aerodynamic Characteristics of Turbines with Nontwisted Rotor Blades** *Aerodynamics of the Helicopter* Aerodynamics of Helicopter Rotor Blade Tips **Zinnenverzinzin Kinderboekenweek 2008** *Structural Optimization of Rotor Blades with Integrated Dynamics and Aerodynamics* **Aerodynamic Study of Helicopter Main Rotor Blade in Hovering Flight** Control of Helicopter Rotorblade Aerodynamics **NREL Advanced Research Turbine (ART) Aerodynamic Design of ART-2B Rotor Blades Aerodynamic Loads on a Rotorcraft Main Rotor Blade** *Flapping Inertia for Selected Rotor Blades* **Aerodynamics of Wind Turbines Vibratory Loads Data from a Wind-Tunnel Test of Structurally Tailored Model Helicopter Rotors** *Principles of Helicopter Aerodynamics* **Aerodynamics and Multibody Dynamics of Helicopter Rotors in Icing Conditions** Computation of Rotor Aerodynamic Loads in Forward Flight Using a Full-Span Free Wake Analysis **Rotorcraft Aeromechanics A Flight Investigation of Blade-section Aerodynamics for a Helicopter Main Rotor Having RC-SC2 Airfoil Sections Elements of Propeller and Helicopter Aerodynamics Blade Element Rotor Theory** *Rotary-Wing Aerodynamics Aerodynamics of Wind Turbines* **Advanced UAV Aerodynamics, Flight Stability and Control Aerodynamics and Acoustics of Rotor Blade-vortex Interactions** *Aerodynamics of Wind Turbines* Unsteady Aerodynamics in Transonic Compressor Rotor Blade Passages **Rotorcraft Aeromechanics Flapping Inertia for Selected Rotor Blades Principles of Helicopter Aerodynamics with CD Extra** Aerodynamic Problems Associated with V/STOL Aircraft: Propeller and rotor aerodynamics **Vibratory Loads Data from a Wind-tunnel Test of Structurally Tailored Model Helicopter Rotors** *Aerodynamics of Wind Turbines, 2nd edition*

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Written by an internationally recognized teacher and researcher, this book provides a thorough, modern treatment of the aerodynamic principles of helicopters and other rotating-wing vertical lift aircraft such as tilt rotors and autogiros. The text begins with a unique technical history of helicopter flight, and then covers basic methods of rotor aerodynamic analysis, and related issues associated with the performance of the helicopter and its aerodynamic design. It goes on to cover more advanced topics in helicopter aerodynamics, including airfoil flows, unsteady aerodynamics, dynamic stall, and rotor wakes, and rotor-airframe aerodynamic interactions, with final chapters on autogiros and advanced methods of helicopter aerodynamic analysis. Extensively illustrated throughout, each chapter includes a set of homework problems. Advanced undergraduate and graduate students, practising engineers, and researchers will welcome this thoroughly revised and updated text on rotating-wing aerodynamics. This is a collection of the Ray Prouty's columns in Rotor and Wing and American Helicopter Society's Vertiflite magazine from 1992 to 2004. A rotorcraft is a class of aircraft that uses large-diameter rotating wings to accomplish efficient vertical take-off and landing. The class encompasses helicopters of numerous configurations (single main rotor and tail rotor, tandem rotors, coaxial rotors), tilting proprotor aircraft, compound helicopters, and many other innovative configuration concepts. Aeromechanics covers much of what the rotorcraft engineer needs: performance, loads, vibration, stability, flight dynamics, and noise. These topics include many of the key performance attributes and the often-encountered problems in rotorcraft designs. This comprehensive book presents, in depth, what engineers need to know about modelling rotorcraft aeromechanics. The focus is on analysis, and calculated results are presented to illustrate analysis characteristics and rotor behaviour. The first third of the book is an introduction to rotorcraft aerodynamics, blade motion, and performance. The remainder of the book covers advanced topics in rotary wing aerodynamics and dynamics. This book is developed to serve as a concise text for a course on helicopter aerodynamics at the introductory level. It introduces to the rotary-wing aerodynamics, with applications to helicopters, and application of the relevant principles to the aerodynamic design of a helicopter rotor and its blades. The basic aim of this book is to make a complete text covering both the basic and applied aspects of theory of rotary wing flying machine for students, engineers, and applied physicists. The philosophy followed in this book is that the subject of helicopter aerodynamics is covered combining the theoretical analysis, physical features and the application aspects. Considerable number of solved examples and exercise problems with answers are coined for this book. This book will cater to the requirement of numerical problems on helicopter flight performance, which is required for the students of aeronautical/aerospace engineering.. SALIENT FEATURES • To provide an introductory treatment of the aerodynamic theory of rotary-wing aircraft • To study the fundamentals of rotor aerodynamics for rotorcraft in hovering flight, axial flight, and forward flight modes • To perform blade element analysis, investigate rotating blade motion, and quantify basic helicopter performance The development of an advanced computational analysis of unsteady aerodynamic loads on isolated helicopter rotors in forward flight is described. The primary technical focus of the development was the implementation of a freely distorting filamentary wake model composed of curved vortex elements laid out along contours of constant vortex sheet strength in the wake. This model captures the wake generated by the full span of each rotor blade and makes possible a unified treatment of the shed and trailed vorticity in the wake. This wake model was coupled to a modal analysis of the rotor blade dynamics and a vortex lattice treatment of the aerodynamic loads to produce a comprehensive model for rotor performance and air loads in forward flight dubbed RotorCRAFT (Computation of Rotor Aerodynamics in Forward Flight). The technical background on the major components of this analysis are discussed and the correlation of predictions of performance, trim, and unsteady air loads with experimental data from several representative rotor configurations is examined. The primary conclusions of this study are that the RotorCRAFT analysis correlates well with measured loads on a variety of configurations and that application of the full span free wake model is required to capture several important features of the vibratory loading on rotor blades in forward flight. Quackenbush, Todd R. and Bliss, Donald B. and Wachspress, Daniel A. and Boschitsch, Alexander H. and Chua, Kiat Unspecified Center AERODYNAMIC LOADS; COMPUTATIONAL FLUID DYNAMICS; HELICOPTERS; HORIZONTAL FLIGHT; ROTARY WINGS; ROTOR AERODYNAMICS; ROTOR DYNAMICS; WAKES; UNSTEADY AERODYNAMICS; VIBRATORY LOADS; VORTEX SHEETS; VORTICES... This comprehensive book presents, in depth, what engineers need to know about modeling rotorcraft aeromechanics. The focus is on analysis, and calculated results are presented to illustrate analysis characteristics and rotor behavior. The book begins with an introduction to rotorcraft aerodynamics, blade motion, and performance and then covers advanced topics in rotary wing aerodynamics and dynamics. An experimental study was conducted in the Langley Transonic Dynamics Tunnel to investigate the use of a Bell Helicopter Textron rotor structural tailoring concept, known as rotor nodalization, in conjunction with advanced blade aerodynamics, and to evaluate roto-blade aerodynamic design methodologies. A 1/5-size, four-bladed bearingless hub, three sets of Mach scaled model rotor blades, and two sets of Froude scaled model rotor blades were tested in forward flight from transition up to an advanced ratio of 0.35. The data presented pertain only to evaluation of the structural tailoring concept and consist of fixed-system and rotating-system vibratory loads. These data are useful for evaluating the effects of tailoring blade structural properties on fixed-system vibratory loads and for validating analyses used in the design of advanced rotor systems. A vital resource for pilots, instructors, and students, from the most trusted source of aeronautic information. Rotorcraft integrated dynamics analysis is a very difficult task, which showed only partially successful results in current practice. However, the need for reliabletools that couple the structural dynamics and the aerodynamics of rotorcraft is strong, and satisfactory results cannot be obtained with existing software. DIVClear, concise text covers aerodynamic phenomena of the rotor and offers guidelines for helicopter performance evaluation. Originally prepared for NASA. Prefaces. New Indexes. 10 black-and-white photos. 537 figures. /div "Flying into icing conditions remains a problematic scenario for most helicopters. Few rotorcraft are equipped with an icing protection system (IPS) to prevent or remove ice; the result can be a highly dangerous situation that contributes to the deterioration in helicopter performance and agility. Traditionally, numerical approaches have assisted in IPS design, deployment, and certification of fixed-wing aircraft. Similar tools for rotorcraft, however, lag behind in development due to the increased complexity associated with rotor aerodynamics/dynamics. The present work discusses a cost-effective, yet fairly accurate, numerical framework to evaluate in-flight icing on fully-articulated helicopter rotors. The approach assesses the impact of icing on blade aerodynamics, blade dynamics, rotor performance, and hinge/joint mechanical loading. This technique can contribute to the conceptual and preliminary design phases of helicopter rotors and IPS design by providing high-quality results in a rapid iteration cycle. A loose-coupling between the multibody dynamics module MBDyn and the aerodynamic/aeroicing module FENSAP-ICE is adopted. A quasi-3D technique has been developed for aeroicing calculations on rotor blades, determining flow field and droplet calculations in 2D blade sections, and eventually performing ice accretion in 3D. A test case is presented for a model-size rotor in hover flight. When compared to icing calculations on separated 2D sections, the use of the quasi-3D approach displays adjustments to ice geometries when glaze conditions are present. These include a reduction in ice thickness near the stagnation point, and a widening of double-horn ice geometries. Improvements have been observed in predicting rotor torque rise and thrust loss. The quasi-3D approach has caused no additional computational expense when compared to icing on isolated 2D sections. Forward flight has been addressed by imposing the periodically-varying velocity and blade dynamics as sinusoidal functions on 2D blade sections. Unsteady flow field and droplet impingement calculations are performed, while a quasi-unsteady technique is used for ice accretion. The approach is implemented in entirely 2D and quasi-3D calculations. Comparison with a forward flight test case for a model-size rotor in an icing tunnel is made. Improvements due to the unsteady approach are demonstrated in rotor performance degradation ice geometry prediction for regions of the blade encountering glaze icing. " -- Aerodynamics of helicopter rotor systems cannot be investigated without consideration for the dynamics of the rotor. One of the principal properties of the rotor which affects the rotor dynamics is the inertia of the rotor blade about its root attachment. Previous aerodynamic investigation have been performed on rotor blades with a variety of planforms to determine the performance differences due to blade planform. The blades tested for this investigation have been tested on the U.S. Army 2 meter rotor test system (2MRTS) in the NASA Langley 14 by 22 foot subsonic tunnel for hover performance. This investigation was intended to provide fundamental information on the flapping inertia of five rotor blades with differing planforms. The inertia of the bare cuff and the cuff with a blade extension were also measured for comparison with the inertia of the blades. Inertia was determined using a swing testing technique, using the period of oscillation to determine the effective flapping inertia. The effect of damping in the swing test was measured and described. A comparison of the flapping inertials for rectangular and tapered planform blades of approximately the same mass showed the tapered blades to have a lower inertia, as expected. Berry, John D. and May, Matthew J. Langley Research Center... Blade Element Rotor Theory This book presents an extension of the conventional blade element rotor theory to describe the dynamic properties of helicopter rotors. The presented theory focuses on the accurate mathematical determination of the forces and moments by which a rotor affects its rotorcraft at specified flight conditions and control positions. Analyzing the impact of a blade's non-uniform properties, the book covers blade twisting, the non-rectangular planform shape of a blade, and inhomogeneous airfoil along the blade. It discusses inhomogeneous induced airflow around a rotor disc in terms of the blade element rotor theory. This book also considers the impact of flapping hinge offset on the rotor's dynamic properties. Features • Focuses on a comprehensive description and accurate determination of the rotor's aerodynamic properties • Presents precise helicopter rotor properties with inhomogeneous aerodynamic properties of rotor blades • Considers inhomogeneous distribution of induced flow • Discusses a mathematical model of a main helicopter rotor for a helicopter flight simulator This book is intended for graduate students and researchers studying rotor dynamics and helicopter flight dynamics Helicopters are highly capable and useful rotating-wing aircraft with roles that encompass a variety of civilian and military applications. Their usefulness lies in their unique ability to take off and land vertically, to hover stationary relative to the ground, and to fly forward, backward, or sideways. These unique flying qualities, however, come at a high cost including complex aerodynamic problems, significant vibrations, high levels of noise, and relatively large power requirements compared to fixed-wing aircraft. This book, written by an internationally recognized expert, provides a thorough, modern treatment of the aerodynamic principles of helicopters and other rotating-wing vertical lift aircraft. Every chapter is extensively illustrated and concludes with a bibliography and homework problems. Advanced undergraduate and graduate students, practising engineers, and researchers will welcome this thorough and up-to-date text on rotating-wing aerodynamics. The study of rotor blade aerodynamic performances of wind tur- bine has been presented in this thesis. This study was focused on aero- dynamic effects changed by blade surface distribution as well as grid solution along the airfoil. The details of numerical calculation from Fluent were described to help predict accurate blade performance for comparison and discussion with available data. The direct surface curvature distribution blade design method for two-dimensional airfoil sections for wind turbine rotors have been dis- cussed with the attentions to Euler equation, velocity diagram and the factors which affect wind turbine performance and applied to design a blade geometry close to an existing wind turbine blade, Eppler387, in order to argue that the blade surface drawn by direct surface curvature distribution blade design method contributes aerodynamic efficiency. The FLUENT calculation of NACA63-215V showed that the aero- dynamic characteristics agreed well with the available experimental data at lower angles of attack although it was discontinuities in the surface curvature distributions between 0.7 and 0.8 in x/c. The dis- continuities were so small that the blade performance could not be affected. The design of Eppler 387 blade performed to reduce drag force. The discontinuities of surface distributionmatched the curve of the pressure coefficients. It was found in the curvature distribution that the leading edge pressure side had difficulties to connect to Bezier curve and also the trailing edge circle was never be tangent to the lines of trailing edge pressure and suction sides due to programming difficulties. An experimental study was conducted in the Langley Transonic Dynamics Tunnel to investigate the use of a Bell Helicopter Textron (BHT) rotor structural tailoring concept, known as rotor nodalization, in conjunction with advanced blade aerodynamics as well as to evaluate rotor blade aerodynamic design methodologies. A 1/5-size, four-bladed bearingless hub, three sets of Mach-scaled model rotor blades were tested in forward flight from transition up to an advance ratio of 0.35. The data presented pertain only to the evaluation of the structural tailoring concept and consist of fixed-system and rotating system vibratory loads. These data will be useful for evaluating the effects of tailoring blade structural properties on fixed-system vibratory loads, as well as validating analyses used in the design of advanced rotor systems. Yeager, William T., Jr. and Hamouda, M-Nabil H. and Idol, Robert F. and Mirick, Paul H. and Singleton, Jeffrey D. and Wilbur, Matthew L. Langley Research Center BELL AIRCRAFT; DYNAMIC STRUCTURAL ANALYSIS; HELICOPTER DESIGN; HELICOPTERS; ROTARY WINGS; ROTOR AERODYNAMICS; ROTOR BLADES; VIBRATORY LOADS; AIRCRAFT MODELS; HORIZONTAL FLIGHT; SCALE MODELS; TRANSONIC WIND TUNNELS; WIND TUNNEL TESTS... The problem of structural optimization of helicopter rotor blades with integrated dynamic and aerodynamic design considerations is addressed. Results of recent optimization work on rotor blades for minimum weight with constraints on multiple coupled natural flap-lag frequencies, blade autorotational inertia and centrifugal stress has been reviewed. A strategy has been defined for the ongoing activities in the integrated dynamic/aerodynamic optimization of rotor blades. As a first step, the integrated dynamic/airload optimization problem has been formulated. To calculate system sensitivity derivatives necessary for the optimization recently developed, Global Sensitivity Equations (GSE) are being investigated. A need for multiple objective functions for the integrated optimization problem has been demonstrated and various techniques for solving the multiple objective function optimization are being investigated. The method called the Global Criteria Approach has been applied to a test problem with the blade in vacuum and the blade weight and the centrifugal stress as the multiple objectives. The results indicate that the method is quite effective in solving optimization problems with conflicting objective functions. Chattopadhyay, Aditi and Walsh, Joanne L. Langley Research Center RTOP 505-63-51-10... Focusing on Aerodynamics of Wind Turbines with topics ranging from Fundamental to Application of horizontal axis wind turbines, this book presents advanced topics including: Basic Theory for Wind turbine Blade Aerodynamics, Dynamics-Based Health Monitoring and Control of Wind Turbine Rotors, Experimental Testing of Wind Turbines Using Wind Tunnels with an Emphasis on Small-Scale Wind Turbines Under Low-Reynolds Numbers, Computational Methods, Ice Accretion for Wind Turbines and Influence of Some Parameters, and Special Structural Reinforcement Technique for Wind Turbine Blades. Consequently, for these reasons, analysis of wind turbines will attract readers not only from the wind energy community but also in the gas turbines heat transfer and fluid mechanics community. An integrated aerodynamic/dynamic optimization procedure is used to minimize blade weight and 4 per rev vertical hub shear for a rotor blade in forward flight. The coupling of aerodynamics and dynamics is accomplished through the inclusion of airloads which vary with the design variables during the optimization process. Both single and multiple objective functions are used in the optimization formulation. The Global Criteria Approach is used to formulate the multiple objective optimization and results are compared with those obtained by using single objective function formulations. Constraints are imposed on natural frequencies, autorotational inertia, and centrifugal stress. The program CAMRAD is used for the blade aerodynamic and dynamic analyses, and the program CONMIN is used for the optimization. Since the spanwise and the azimuthal variations of loading are responsible for most rotor vibration and noise, the vertical airload distributions on the blade, before and after optimization, are compared. The total power required by the rotor to produce the same amount of thrust for a given area is also calculated before and after optimization. Results indicate that integrated optimization can significantly reduce the blade weight, the hub shear and the amplitude of the vertical airload distributions on the blade and the total power required by the rotor. Chattopadhyay, Aditi and Walsh, Joanne L. and Riley, Michael F. Langley Research Center NASA-TM-101553, NAS 1.15:101553, AIAA PAPER 89-1269 RTOP 505-61-51-10... Wind power is an increasingly significant renewable energy resource, producing no environmentally damaging CO_2 emissions. The efficient production of electricity by wind turbines relies on aerodynamics: Aerodynamics of Wind Turbines provides the fundamental solutions to efficient wind turbine design. Following a historical introduction, Part 1 of Aerodynamics of Wind Turbines is concerned with basic rotor aerodynamics, while Part 2 deals with structural aspects of the wind turbine and calculation of the loads on it. Topics covered include increasing mass flow through the turbine, performance at low and high wind speeds, assessment of the extreme conditions under which the turbine will perform and the theory for calculating the lifetime of the turbine. The classical Blade Element Momentum method is also covered, as are eigenmodes and the dynamic behavior of a turbine. Aerodynamics of Wind Turbines is an essential reference for both engineering students and others with a professional or academic interest in the physics and technologies behind horizontal axis wind turbines. It will provide a sound understanding of the mechanisms behind the generation of forces on a wind turbine. Comprehensively covers emerging aerospace technologies Advanced UAV aerodynamics, flight stability and control: Novel concepts, theory and applications presents emerging aerospace technologies in the rapidly growing field of unmanned aircraft engineering. Leading scientists, researchers and inventors describe the findings and innovations accomplished in current research programs and industry applications throughout the world. Topics included cover a wide range of new aerodynamics concepts and their applications for real world fixed-wing (airplanes), rotary wing (helicopter) and quad-rotor aircraft. The book begins with two introductory chapters that address fundamental principles of aerodynamics and flight stability and form a knowledge base for the student of Aerospace Engineering. The book then covers aerodynamics of fixed wing, rotary wing and hybrid unmanned aircraft, before introducing aspects of aircraft flight stability and control. Key features: Sound technical level and inclusion of high-quality experimental and numerical data. Direct application of the aerodynamic technologies and flight stability and control principles described in the book in the development of real-world novel unmanned aircraft concepts. Written by world-class academics, engineers, researchers and inventors from prestigious institutions and industry. The book provides up-to-date information in the field of Aerospace Engineering for university students and lecturers, aerodynamics researchers, aerospace engineers, aircraft designers and manufacturers. This is a collection of Ray Prouty's columns from Rotor and Wing magazine from 1979 to 1992. The aerodynamic characteristics of nontwisted-rotor-blade turbines are approximately those of free-vortex turbines intended for similar application for values of hub-tip-radius that are used in current turbines. Basic Helicopter Aerodynamics is widely appreciated as an easily accessible, rounded introduction to the first principles of the aerodynamics of helicopter flight. Simon Newman has brought this third edition completely up to date with a full new set of illustrations and imagery. An accompanying website www.wiley.com/go/seddon contains all the calculation files used in the book, problems, solutions, PPT slides and supporting MATLAB® code. Simon Newman addresses the unique considerations applicable to rotor UAVs and MAVs, and coverage of blade dynamics is expanded to include both flapping, lagging and ground resonance. New material is included on blade tip design, flow characteristics surrounding the rotor in forward flight, tail rotors, brown-out, blade sailing and shipborne operations. Concentrating on the well-known Sikorsky configuration of single main rotor with tail rotor, early chapters deal with the aerodynamics of the rotor in hover, vertical flight, forward flight and climb. Analysis of these motions is developed to the stage of obtaining the principal results for thrust, power and associated quantities. Later chapters turn to the characteristics of the overall helicopter, its performance, stability and control, and the important field of aerodynamic research is discussed, with some reference also to aerodynamic design practice. This introductory level treatment to the aerodynamics of helicopter flight will appeal to aircraft design engineers and undergraduate and graduate students in aircraft design, as well as practising engineers looking for an introduction to or refresher course on the subject. Aerodynamics of Wind Turbines is the established essential text for the fundamental solutions to efficient wind turbine design. Now in its second edition, it has been entirely updated and substantially extended to reflect advances in technology, research into rotor aerodynamics and the structural response of the wind turbine structure. Topics covered include increasing mass flow through the turbine, performance at low and high wind speeds, assessment of the extreme conditions under which the turbine will perform and the theory for calculating the lifetime of the turbine. The classical Blade Element Momentum method is also covered, as are eigenmodes and the dynamic behaviour of a turbine. The new material includes a description of the effects of the dynamics and how this can be modelled in an ?aeroelastic code?, which is widely used in the design and verification of modern wind turbines. Further, the description of how to calculate the vibration of the whole construction, as well as the time varying loads, has been substantially updated. The analysis CAMRAD/JA is used to model two aircraft, a Puma with a swept-tip blade and a UH-60A Black Hawk. The accuracy of the analysis in predicting the torsion loads is assessed by comparing the predicted loads with measurements from flight tests. The influence of assumptions in the analytical model is examined by varying model parameters and comparing the predicted results to baseline values for the torsion loads. Flight test data from a research Puma are used to identify the source of torsion loads. These data indicate that the aerodynamic section moment in the region of the blade tip dominates torsion loading in high-speed flight. Both the aerodynamic section moment at the blade tip and the pitch-link loads are characterized by large positive (nose-up) moments in the first quadrant with rapid reversal of load so that the moment is negative in the second quadrant. Both the character and magnitude of this loading are missed by the CAMRAD/JA analysis. Aerodynamics of helicopter rotor systems cannot be investigated without consideration for the dynamics of the rotor. One of the principal properties of the rotor dynamics is the inertia of the rotor blade about its root attachment. Previous aerodynamic investigations have been performed on rotor blades with a variety of planforms to determine the performance differences due to blade planform. The blades tested for this investigation have been tested on the U.S. Army 2-meter rotor test system (2MRTS) in the NASA Langley 14- by 22-Foot Subsonic Tunnel for hover performance. This investigation was intended to provide fundamental information on the flapping inertia of five rotor blades with differing planforms. The inertia of the bare cuff and the cuff with a blade extension were also measured for comparison with the inertia of the blades. Inertia was determined using a swing-tested technique, using the period of oscillation to determine the effective flapping inertia. The effect of damping in the swing-test was measured and accounted for. A comparison of the flapping inertials for rectangular and tapered planform blades of approximately the same mass showed the tapered blades to have a lower inertia as expected.