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FLUID DYNAMIC LIFT. CONTENT SUMMARY

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The background and methods used in preparing and completing the remaining chapters for the book "Fluid Dynamic Lift" are discussed. This book, started by Dr. Hoerner, is a logical follow-on to the book "Fluid-Dynamic Drag" and covers the factors involving lift in the same manner as was done in the drag book. The chapters completed are discussed and major topics covered are given.

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PREFACE

The work summarized in this report is a continuation of the work done by the late Dr. S.F. Hoerner under Office of Naval Research Contract Nonr-3196(00).

INTRODUCTION

In 1958 Dr. Hoerner completed and published the book "Fluid-Dynamic Drag". This book filled an important need as it provided an understanding and basic data on the subject "drag". The drag book is far more than just a collection of data on the subject as it gives specific data, references and statistical analysis on the subject. Also, a very complete coverage of the subject with many unusual sets of data are collected, analyzed and compared with the available theories. As a result the original drag book and its revised editions have become a standard reference volume.

With the wide acceptance of the drag book, it was considered desirable to prepare a book on lift. This work was started in 1961 with the support of the U.S. Navy Office of Naval Research, Contract Nonr-3196(00). Under this contract approximately one half of the book was completed at least in rough draft form by the late Dr. Hoerner as of 1971. The work on the book "Fluid Dynamic Lift" was again started by the writer in June of 1973 under contracts with Mrs. Hoerner and the Office of Naval Research. The contract with ONR was for the purpose of finishing the chapters identified but not necessarily started by Dr. Hoerner. In addition, support was granted by ONR to completely revise one chapter that was considered obsolete.

DISCUSSION

To complete the unfinished chapters for the book "Fluid Dynamic Lift" to obtain a well integrated body required a thorough review of the chapters completed in final and rough draft form. This was necessary as many of these original chapters contained material and statements referring to what would be in the uncompleted chapters. This, then, provided an insight into what was expected in the new chapters and the overall intent of Dr. Hoerner on the book. This intent was then to present engineering information on lift to be taken from wherever it is available: theory, experiments, statistics or a combination of all three. In evaluating the available information on lift the search was always for the truth of the situation. In this respect, Dr. Hoerner would never accept what the theory says it "must" be. He felt that emphasis should be placed upon the deviations for the theoretical predictions, although any theoretical analysis was greatly accepted as soon as it agreed with theoretical results. In particular, theory is used where

experimental results are not available or where extrapolations of the available statistical data are required. Thus, Dr. Hoerner did not reject theory but recognized its limitations and used it wherever it was supported by proper experimental justification.

In completing the remaining chapters of the book "Fluid Dynamic Lift" we agreed with the use of the best data possible for presenting the facts, recognizing that the theory must be supported by test correlation if it is to be used in lieu of experimental or statistical data. Because of the availability of high speed computers which can rapidly solve highly complex equations, better theoretical experimental correlation is being developed all the time. However, before this is possible good experimental data is needed to provide a base for the development of the theory. Thus, it was considered desirable to present both theoretical and experimental data where possible with sufficient explanation of the results to provide an understanding of the interpretation and application of the data. Where possible, statistical data was developed for presenting engineering data, as many different sets of test data generally improve the confidence in the results. However, when this was not possible the available material is presented even if it is a single source. This makes possible future correlation and theoretical checks.

Dr. Hoerner collected and reviewed a considerable amount of technical material on the subject of lift as well as drag. These technical data and notes covered material from a great number of sources both in this country and abroad. With these technical reports and new information made available by NASA and other sources, as well as the writer's own files, the coverage of the engineering data and material was considered nearly complete.

In preparing the new chapters it was the writer's intent to present the information and material in much the same form as if Dr. Hoerner were doing it. Thus, notes and analysis were used wherever available. However, these were always reviewed and analyzed in light of the current technology and modified whenever later data proved the results to be wrong. Also, if the existing material was made obsolete by new data it was replaced. This was done in the case of one chapter completed by Dr. Hoerner that was suitable for inclusion in the book when completed in 1964, but which would now be obsolete in 1975. This chapter originally entitled "Influence of Propulsion on Stability" was mainly concerned with propellers, which today are used only on the smaller aircraft and are considered to be obsolete by many. This chapter was completely revised and is now entitled "Propulsion Lift". The revised chapter contains the essentials of the original material plus the available data on ducted fans, turbo fan engines and turbo jet engines.

RESULTS

The book "Fluid Dynamic Lift" will cover the material as indicated in the following table of contents:

Table of Contents
Fluid Dynamic Lift

A summary of the objectives and material covered by each of the chapters written under this contract and delivered to the Office of Naval Research are given in the following paragraphs:

Chapter IV Maximum Lift and Stalling

The objective of this chapter was to provide data and an understanding of the stalling characteristics of airfoils and straight wings. In particular the three types of stall are discussed and data are given for determining the maximum lift coefficient as a function of section type and operating condition. The detailed material covered in the chapter is given in the following table:

1. Theoretical and Demonstrated Levels of Maximum Lift
2. The Physical Mechanism of Stalling
3. Correlation Procedures of Test Data
4. Maximum Lift as a Function of Shape and Reynolds Number
5. Influence on Surface Roughness

6. Airfoil Characteristics Above Stall
7. Dynamic Effects
8. Stalling of Straight Wings

Chapter X Roll Control of Airplanes

In this chapter the roll characteristics of straight and swept wings induced by various aileron types are considered. These include the Frise, balanced, sealed and spoiler types as well as many other. Effect of span covered sweep back and coupling into yaw are discussed. The headings covered are:

1. Characteristics in Roll
2. Characteristics of Spoilers
3. Influence of Compressibility Upon Lateral Control

Chapter XII Propulsion Lift and Stability

The lift characteristics of the propulsion systems generated by the unit itself, as well as the increase in lift due to the interaction on the airplane, are discussed. All different combinations of systems including propellers, ducted fans, turbofan engines and jet engines are considered. The effects of the propulsion system on the longitudinal and directional stability of the airplane are given. The detailed contents of this chapter are:

1. Lift of Propulsion Systems
2. Influence of Propeller Slipstream on Wings
3. Slipstream Effects of Ducted Propeller and Fan Engine on Wings
4. Slipstream Effects on Tail Surfaces

Chapter XIV Lateral Stability Characteristics of Airplanes

Lateral stability is a function of the yawing and rolling moments, the lateral force and their associated cross coupling. The stability of the airplane from these forces and moments must be determined by a dynamic analysis as the motion is time dependent. However, the most important contribution to such a dynamic stability analysis comes from so-called "static" stability derivatives, i.e. from the derivatives of forces and moments with angles of roll, yaw and pitch. Static stability is, therefore, considered first; while principles, derivatives, theory and practical results of dynamic lateral stability are presented in the last part of this chapter. The following give the important major topics covered in this chapter:

1. Forces and Moments of Straight Wings
2. Lateral Characteristics Due to Dihedral
3. Lateral Characteristics of Swept Wing
4. Influence of Fuselage on Rolling Moment

5. Theory - Dynamic Lateral Stability
6. Lateral Directional Flying Qualities

Chapter XVI Stalling of Swept Wings

The stalling characteristics of swept wings is very different from those of straight wings, especially when operating at high angles of attack. The stall, maximum lift, moment and drag characteristics of swept wings are generally very unfavorable and,thus, special attention is required in the design to achieve satisfactory flying qualities. These characteristics are covered in detail as well as the following topics:

1. Characteristics at High Angles of Simple Swept Wings
2. Swept Wing Modifications for Stall
3. Compressibility Effects
4. High Lift Devices for Swept Wings
5. Deep Stall

Chapter XVII Characteristics of Small Aspect Ratio Wings

The flow around the tips of low aspect ratio wings has a greater influence on its characteristics compared with wings of A = 5 and above. This makes it necessary to consider low aspect ratio wings separately. Thus, in this chapter low aspect ratio wings with rectangular, tapered and round planforms are considered, including wings with swept leading and trailing edges. Covered are the linear and non-linear slope characteristics of the wings. The important headings of the chapter are as follows:

1. Basic Lift Curve Slope
2. Non-linear Lift Component
3. Characteristic Data
4. Compressibility
5. Maximum Lift

Chapter XVIII Characteristics of Delta Wings

Delta wings are treated separately because of the importance of the flow about the leading edge on the lift characteristics. Although delta wings are primarily designed for use at supersonic speeds, their characteristics are needed at subsonic speeds and so are covered in this chapter. Procedures are given so that the linear and non-linear lift characteristics of any delta type wing can be calculated. The details of the flow and other important characteristics of delta wings are discussed to provide a complete understanding as described by the following topics:

1. Characteristics of Delta Wings
2. Flow Characteristics
3. Analytical Analysis

4. Configuration Variables
5. Vortex Breakdown -- Wing Stall
6. High Lift and Control Devices
7. Compressibility Effects -- Delta Wings
8. Parawings

Chapter XX Lift of Airplane Configurations

The characteristics of typical aircraft are covered in this chapter to bring out the important points discussed in the remainder of the book. In addition, the effect of unusual wing placements are covered along with mutual interference effects between the wing and fuselage. The details of this chapter are:

1. Configuration Types
2. Various Wing Arrangements
3. Lift of Wing-Body Combinations
4. Interruptions of Span
5. Total Aircraft Lift

Chapter XXI Lift of Blunt Bodies

Lift can be developed on bodies with blunt shapes that have no resemblance to wings. In this case the lift on the bodies is defined as that force acting normal to the direction of the relative wind motion. Any lateral force may then be considered to be a lift force, although in the strict sense the force is side force. Since these forces are of interest in the design of land vehicles, they are included in this chapter. The contents of this chapter are:

1. In Two-Dimensional Flow
2. Three-Dimensional Drag Bodies
3. Lift in Ground Vehicles
4. Lift Forces on Structures.