Recent Development of Aerodynamic Design Methodologies

Edited by
Kozo Fujii and
George S. Dulikravich

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– Inverse Design and Optimization –

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Susumu Takanashi

Dedication

Dr. Susumu Takanashi, the former Computational Fluid Dynamics (CFD) researcher at the National Aerospace Laboratory (NAL) in Japan, passed away on October 28, 1995, at the age of 56. He was engaged in developing CFD design methods at the NAL for many years. The aerodynamic shape inverse design method that he developed has been and still is used by many researchers and practicing engineers in the world.

Dr. Takanashi's results were used in the aerodynamic design process of the YXX aircraft and others in the 1980's. Recently, the design method was used for the modification of the National Space Development Agency (NASDA) HOPE-X space vehicle configuration that may fly early in the year 2000. In addition, his inverse design method is a main aerodynamic tool for the experimental supersonic transport (SST) aircraft, planned to fly early in 20002 by the NAL.

Dr. Takanashi contributed significantly to the development of the CFD analysis software at the NAL. His contribution was not restricted to the development of CFD design methods. He led the group of CFD analysis code developers for three-dimensional Navier-Stokes flow-field simulations over wings, wing-fuselage combinations, and full aircraft configurations. At the same time, he developed a three-dimensional block-structured computational grid generation code based on his own idea. The code became an important part of the simulation of the transonic flow fields around aircraft configurations. He also contributed to the introduction of the Numerical Wind Tunnel (NWT) at the NAL, still the largest practical supercomputer system in the world with more than 220 GFLOPS peak performance. The NWT is now playing the key role in the aerodynamic analysis and design of the HOPE-X and NAL's SST supersonic experimental research vehicle.

Dr. Takanashi worked together with many CFD researchers as shown by his technical publication list. He influenced his co-workers profoundly, not only from the point of view of how to do the advanced research, but also with his attitude toward the research. We all miss him and will remember him as our teacher, fellow researcher, and a friend that could have offered many more new exciting contributions to the profession.

As a humble token of our deep appreciation and respect for the memory of Dr. Susumu Takanashi, we prepared this volume on Aerodynamic Shape Inverse Design and Optimization, and would like to dedicate it to him. Listed below are his resume and a list of technical papers memorizing his contribution.

K. F.
G. S. D.

Susumu Takanashi

1939 Born on March 6th, in Chiba, Japan
1958 Employee of Muromachi-Kaiun
1960 Technical Assistant, National Aerospace Laboratory
1962 Research Scientist, National Aerospace Laboratory
1963 Graduated from University of Electro-Communications, Junior College, March 1963
1968 Graduated from Science University of Tokyo, Department of Physics, March 1968
1975 Received ph. D. from University of Tokyo, December 1975
1977 Principal Research Scientist1985 Section Chief, Aircraft Performance Research Section
1988 Section Chief, Computational Aerodynamics Research Section
1995 Died October 28th at the age of 56

Representative Research Papers

Takanashi, S., "A Method of Obtaining Transonic Shock-Free Flow around Lifting Aerofoils", Transactions of the Japan Society for Aeronautical and Space Sciences, Vol. 16, No. 34, pp. 246-263, Dec. 1973.

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Preface

Computational Fluid Dynamics (CFD) has made remarkable progress in the last two decades and is becoming an important, if not inevitable, analytical tool for both fundamental and practical fluid dynamics research. The analysis of flow fields is important in the sense that it improves the researcher's understanding of the flow features. CFD analysis also indirectly helps the design of new aircraft and/or spacecraft. However, design methodologies are the real need for the development of aircraft or spacecraft. They directly contribute to the design process and can significantly shorten the design cycle. Although quite a few publications have been written on this subject, most of the methods proposed were not used in practice in the past due to an immature research level and restrictions due to the inadequate computing capabilities.

With the progress of high-speed computers, the time has come for such methods to be used practically. There is strong evidence of a growing interest in the development and use of aerodynamic inverse design and optimization techniques. This is true, not only for aerospace industries, but also for any industries requiring fluid dynamic design. This clearly shows the matured engineering need for optimum aerodynamic shape design methodologies. Therefore, it seems timely to publish a book in which eminent researchers in this area can elaborate on their research efforts and discuss it in conjunction with other efforts.

With this as a background, we have decided to prepare this book entitled "Recent Development of Aerodynamic Design Methodologies – Inverse Design and Optimization -". All the contributing authors are well-recognized researchers in this field. A different author covering another aerodynamic shape design methodology writes each chapter.

Three categories of design methodology are considered: Genetic Algorithms, Inverse Design, and Optimization. "Genetic Algorithms (GA)" are rapidly gaining popularity and may become the methods of choice for multi-objective and interdisciplinary optimization. "Optimization" can be considered as generalized design, which introduces integral target properties and constraints. "Inverse Design" describes methods to find a configuration that realizes, for instance, the target pressure distribution. Although this approach has some drawbacks, such as the difficulty of finding good target

pressure distribution, it has been accepted and is practically used by industry.

In addition, two short contributions are added from Japanese industries. These contributions describe how they used Dr. Takanashi's inverse design method in their practical applications.

As editors of this book, we would like to acknowledge all the contributing authors for their effort and patience in the process of preparing this publication. We also would like to thank Prof. Ernst H. Hirschel, the general editor of the series of Notes on Numerical Fluid Mechanics, as well as the Vieweg Verlag, for giving us the opportunity to publish this book.

Kozo Fujii and George S. Dulikravich August, 1998

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