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ENGINEERING SCIENCE

Decembr 14, 1982

NASA Scientific and Technical
Information Facility
P.O. Box 8757
Baltimore-Washington International Airport
Maryland 21240

Dear Sirs:

Please find enclosed two copies of the final report of cooperative grant NCC2-23 entitled "The Investigation of the Flow About General Fuselage Shapes at High Angles of Attack".

Also enclosed are two copies of AIAA paper no. 82-0056.

Sincerely,

M. H. Clarkson

M. H. Clarkson
Principal Investigator

enclosures

MHC:mld

(NASA-CR-169611) THE INVESTIGATION OF THE FLOW ABOUT GENERAL FUSELAGE SHAPES AT HIGH ANGLES OF ATTACK Final Report, 1 Nov. 1979 - 31 Oct. 1982 (Florida Univ.) 8 p HC A02/MF A01 CSCL 01A G3/02

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THE INVESTIGATION OF THE FLOW ABOUT GENERAL FUSELAGE SHAPES AT HIGH ANGLES OF ATTACK

Final Report for the Period

November 1, 1979 to October 31, 1982

by

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Cooperative Agreement Number is NCC2-23

Date: December 1982

I. HISTORY

The writer was a Senior NRC Associate at the Ames Research Center from September, 1973 through August, 1974. It was proposed, originally, to develop parameter identification methods for use in deducing aerodynamic data from flight tests conducted on full-scale aircraft and on scaled instrumented models during spin entry and the ensuing spin. However, it became apparent early in the tenure of the associateship that the parameter identification problem for the spinning aircraft was too unwieldy to use brute force methods and that a better knowledge of the aerodynamics of spinning bodies at high angles of attack was needed, not only for parameter identification work, but for design purposes as well.

It was known that aircraft spin producing moments are highly dependent on fuselage shape and on Reynolds number for the case of the flat spin. However, as no rotary aerodynamic data were known to exist over the wide range of Reynolds numbers achievable in the Ames 12-foot pressure tunnel, it was decided to conduct an exploratory investigation of rotary characteristics of some fuselage-like shapes in the 12-foot tunnel using a modified existing rotary rig and existing TASK 6-component internal strain gage balance. These tests were carried out during the summer of 1974 and the results were reported at the 1975 annual Technical Meeting of the AIAA. These results were also published in the AIAA Journal of Aircraft.[1] Much of the analysis was done at the University of Florida by the writer under a consortium agreement with the Ames Research Center.

Although the results of this investigation were quite informative, the sensitivity of the balance at the lower range of Reynolds numbers was quite low in the side force direction. For this reason, it was decided to repeat portions of the rotary tests with balances designed for the purpose, i.e., strong in the axial and normal force directions but more sensitive in the side force direction. These tests were carried out in the summer of 1975 with the writer serving as a co-prinicpal investigator with Mr. Gerald N. Malcolm of ARC. A portion of the results of these tests were reported on at the AIAA Aerodynamics Testing Conference in Arlington, Texas in June 1976. In addition to the rotary tests, force measurements were made in the non-rotating mode at quite close spacing of the Reynolds number at angles of attack of 45, 60, 75 and 90 degrees. These tests showed a strong dependence on Reynolds number and angle of attack in a rather unexpected way. To pursue this, oil flow, pressure distribution and sublimation tests were run. The sublimation tests indicated that some of the observed behavior was due to inflexional instability in the laminar boundary layer. This work was presented at the AIAA 15th Aerospace Sciences Meeting held in Los Angles in January 1977, AIAA paper 77-180. A slightly shortened version of this paper was published in the December 1978 issue of the AIAA Journal.[2]

A transparent hemisphere cyclinder model was constructed at the University of Florida with an 8 mm camera located inside the model on a traversing mechanism. Some interesting footage of boundary layer flow was obtained by mounting the model on a pontoon boat and testing in a clear water lake in Florida. However, it wasn't clear whether the observed flow was related to the inflexional instabilities mentioned above so it was decided to perform a rotating disk experiment in water. This experiment was performed in air by Newell H. Smith (NACA TN 1227, May 1947), and by Gregory, Stuart and Walker (Philosophical Transactions of the Royal Soc. of London, July 1955); and in water by Faller and Kaylor (Dynamics of Fluids and Plasmas, Edited by S. I. Pai, Academic Press, 1966). However, the experimental set-up of Faller and Kaylor differed in substantial respects from our experiment. Our rotating disk experiment proved that the vortices would be observed provided care was taken with injection of the dye. We also noted secondary instabilities that appear to be different than those reported by Faller and Kaylor.

These tests were repeated during the fall of 1979 using a disk with carefully scribed concentric circles and radial lines on the upper surface of the transparent disk. Thus, quantitative measurements could be readily carried out. The number of vortices with axes fixed with respect to the plate ranged from 29 to 40. Stuart, Gregory and Walker reported between 25 and 34 using a boundary layer probe and 28 to 31 using the china clay technique. The angle of the axis of the vortex was about 11° compared to 13° of the above referenced work. In addition it was found that the spiral flow about the fixed vortex axis lagged behind the disk being only about 30% of the disk velocity at a given radius. This corresponds roughly to the tangential velocity at the point of inflexion of the radial profile.

The secondary instabilities mentioned above were also examined in detail. The lifespan of these were about .020 seconds.

Two undergraduate students who assisted the principal investigator wrote-up the experiment and presented the results at the Southeastern AIAA Student Paper Competition in Atlanta, Georgia on April 5, 1979. Their paper won third place. An expanded version of the paper was presented at the annual AIAA meeting in January 1980, and also was published.[3]

An extension of the above work to paraboloids was supported by NASA Langley under grant NAG-1-104. Additional work on flat disks under this grant showed that the vortex angle was a function of radius.

II. SUMMARY OF WORK UNDER NCC2-23

Work under this grant was pursued both at Ames Research Center and at the University of Florida. Water tunnel visualization of the flow about bodies at high angles of attack was done at the University of Florida. Results of some of this work are summarized in a Master's thesis by Victoria Brittain.[4] Miss Brittain also was awarded second place in the Graduate Division of the Southeastern AIAA Student Paper Competition in 1980. A paper was also given by the principal investigator at the "High Angle of Attack Missile Aerodynamics Working Group Meeting" held October 14-16, 1981 at Singer Island, Florida.

The flow visualization work on bodies with non-circular cross sections led to a contract with the U.S. Air Force Armament Laboratory under contract no. F08635-81-K-0281. Some of this work will be reported on at the January 1983 Aerospace Sciences Meeting in Reno, Nevada in a paper co-authored by the principal investigator and Dr. Gary Chapman of the Ames Research Center.

The work performed at Ames consisted of wind tunnel tests in the Ames' 12-foot pressure tunnel on a series of models with non-circular cross sections and the analysis of the data. A portion of this work was reported on at the 1982 Aerospace Sciences Meeting.[6]

A data report was prepared in the summer of 1982 summarizing the results of the tests in the 12-foot tunnel on the bodies with non-circular cross sections. The number of this report[7] is not available at this writing but will be published by NASA ARC.

III. ACCOMPLISHMENTS

A. Wind Tunnel Tests

1. The rotary tests were the first ever performed over a wide range of Reynolds numbers at constant Mach number.
2. Hysteresis effects at high angles of attack were documented.
3. Effect of inflexional instabilities on aerodynamic characteristics of bodies at high angles of attack determined for several bodies.

4. Important effects of nose shape on aerodynamic characteristics of bodies with non-circular cross sections determined over a wide range of angles of attack and Reynolds numbers.

5. Reasonable explanations provided for most of the complex flow patterns observed.

B. Flow Visualization

1. The method of a continuous distribution of dye sources was developed for flow visualization under this grant. Tests using this technique proved, experimentally, the existence of an "open" type of separation and helped to interpret, generally, separated flows.

C. Student Involvement

This work has been very instrumental in providing support and motivation to a number of undergraduates as well as graduate students. As a result of this program, five papers have been entered in the AIAA student paper competition resulting in two awards. Three Master's theses were supported by this work. In all, four graduate students and six undergraduates have participated. One of the graduate students is now working for NASA, and the rest of the students are employed in the aerospace industry.

IV. SUGGESTIONS FOR FUTURE WORK

A. The present sublimation methods of detecting the presence of inflexional instabilities in the boundary layer are not very satisfactory and need improving.

B. The research bodies used in the last series of tests should be tested to determine the boundaries of inflexional instabilities.

C. The same research bodies should be tested for roughness effects which are known to be substantial.

D. The applicability of the impulsive flow analogy should be thoroughly investigated.

E. Flow visualization techniques for determining the flow patterns in cross-flow planes should be developed further.

F. Flow visualization techniques for use at higher Reynolds numbers should be developed.

V. ACKNOWLEDGEMENTS

The author would like to express his appreciation to members of the Aerodynamic Research Branch for their efforts in making this cooperative grant both technically rewarding and intellectually stimulating. In particular, I would like to thank Jerry Malcolm and Gary Chapman who made the word "cooperative" in cooperative grant have real meaning. This work would not have been possible without them.

Thanks are also due to Murray Tobak who provided insight and help on numerous occasions during the course of the work.

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4. Brittain, V. A., "A Study of Flow Separation Using a Continuous Distribution of Dye Sources," Master Thesis, University of Florida, June 1981.

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7. Clarkson, M. H., Malcolm, G. N., Brittain, V. A. and Intemann, P. A., "Aerodynamic Characteristics of Bodies with Noncircular Cross Sections at High Angles of Attack," Data Report to be published by NASA ARC.