ARL-AERO-TM-400

AR-005-534

AD-A204 086

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Aerodynamics Technical Memorandum 400

MODELLING AIRCRAFT DYNAMICS (U)

DTIC
ELECTE
FEB 1 5 1989
D

by

C.A. Martin

Approved for Public Release

SEPTEMBER 1988

89 2 14 047

AR-005-534

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
AERONAUTICAL RESEARCH LABORATORY

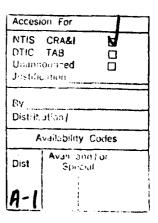Aerodynamics Technical Memorandum 400

MODELLING AIRCRAFT DYNAMICS

by

C.A. Martin

SUMMARY

A review has been made of the approaches currently under development for the modelling of aircraft flight dynamics at high angles-of-attack. The review is based on current research literature and on discussions held during an overseas visit carried out for the purpose of technical updating in the areas of flight dynamic modelling and parameter estimation.

Accesion For		
NTIS CRA&I		☑
DTIC TAB		☐
Unannounced		☐
Justification		
By		
Distribution /		
Availability Codes		
Dist	Avail and / or Special	
A-1		

DSTO
MELBOURNE

CONTENTS

1 INTRODUCTION

An overseas visit was made by the author in August 1986 for the purpose of scientific updating in the areas of modelling aircraft dynamics at high angles-of-attack and on the use of parameter estimation techniques in flight test data analysis. These topics were also covered in a workshop on modelling aircraft dynamics at high angles-of-attack organised by The Technical Cooperation Program - technical panel covering Manoeuvring Aerodynamics (TTCP HTP-5) at NASA Ames Research Center in August 1987. Attendance at this workshop as Australian National Leader provided access to valuable information.

Research into flight dynamic behaviour at high angles-of-attack has been a major activity in research laboratories in the USA and Europe during recent years. This interest is motivated partly by the problems encountered by current combat aircraft and also by the requirements for substantially increased manoeuvre capability from future aircraft. Prior to the visit the Aircraft Behaviour Studies - Fixed Wing (ABS-FW) group at ARL had considerable experience in modelling aircraft dynamic behaviour within the normal flight envelope and had begun to establish a technology base in modelling at high angles-of-attack. Nomination in 1981 to TTCP Technical Panel HTP-5 has enabled much closer interactions with the activities of the TTCP member countries in this area.

Aircraft parameter estimation for the determination of aerodynamic information from flight test measurements has been an important research activity at ARL. Through work at ARL, and via a research agreement with the University of Newcastle, the ABS-FW group has made contributions to this field by developing aircraft flight path reconstruction and data compatibility checking procedures. These procedures are currently being used to analyse flight data from the F111-C aircraft and from helicopter flight trials. The objective of the visit, in relation to parameter estimation, was to obtain information on its application to aircraft with advanced flight control systems and its application to flight at high angles-of-attack.

2   GENERAL BACKGROUND

Models of aircraft flight dynamics are required for a range of applications, for example: for the analysis of aircraft behaviour, for aircraft design and development, for the estimation of aerodynamic parameters,for flight test planning, for use in adaptive control systems, and for driving flight simulators.

The kinematics of aircraft motion are well established and adequate representation of mechanical and electrical aircraft systems can generally be achieved. As noted in Ref. 1 the principal distinguishing feature and particular difficulty of modelling flight dynamics is the prediction and measurement of the aerodynamic forces. It is in this area that significant inadequacies can arise due to the shortcomings in the methods for predicting aerodynamic forces. These limitations constrain the scope of the resulting model.

Fortunately the early formulations of flight dynamic models, which assumed small disturbance motion and linear aerodynamics, have proved satisfactory for a large range of flight conditions. However, combat aircraft are now being designed to fly at large angles-of-attack and at low speeds, including hover, and to achieve these capabilities new design features are being investigated. Modelling of these situations is proving to require more development than a simple extension of current formulations and a clear solution to the problem has not yet emerged.

Operational experience with aircraft such as the F/A-18, research experience with experimental aircraft such as the X-29, and research studies on future designs have highlighted three features which will be important in the flight behaviour of future combat aircraft. These are: (a) controlled vortical flows allowing flight at high angles-of-attack, (b) greater authority and capability of flight control systems and (c), the introduction of effective controls at very low speeds.

These features lead to aerodynamic forces which are more nonlinear, and can exhibit time-dependent behaviour. Furthermore the large rotation rates associated with flight at low speeds and large angles-of-attack lead to large variations in onset flow conditions across the vehicle.

Vortex lift can be sustained on lifting surfaces to much higher angles-of-attack than the lift developed from attached flow. However, within the normal operating range, the associated aerodynamic forces are generally more nonlinear, due in part to the fact that the vortex structures can change their geometry and their position with changes in onset flow. As with the stall of aircraft which generate lift from attached flow, these intense vortical structures can also breakdown leading to additional nonlinear and time-dependent behaviour. This nonlinear behaviour greatly complicates model formulation since the linear properties of homogeneity and additivity no longer apply. Consequently the aerodynamic forces cannot be represented simply as the sum of independent functions of the state and control variables.

Aircraft configurations designed to provide vortex lift are typically slender and often feature canard surfaces. A consequence of this type of layout is that vortices generated near the nose of the aircraft can influence lifting surfaces downstream. This interaction introduces time-dependent effects which need to be measured and modelled. Time-dependent aerodynamic forces are, in the most general sense, functions not only of the current states, but also, of the entire time history of the states. Therefore, the forces associated with any given set of state and control variables can each have a wide range of values. In most applications to-date only the simplest representation of time-dependence has been used in flight dynamic modelling; that is, terms are included in the equations which are a function of the first derivative of the current state only.

For conventional aircraft, very large angular rates and large onset flow variations occur mainly during stalling and spinning manoeuvres. Numerous attempts have been made to model aircraft spin behaviour, and this experience is relevant to the high angle-of-attack manoeuvring situation. In general, extensions of conventional models have had limited success in predicting spin behaviour. One particular difficulty is associated with the nature of the manoeuvre. Transition from level flight to the fully developed spin involves transition from one stable state to another stable state. For conventional aircraft, the motion during transition may contain unstable modes. Furthermore, during this phase the controls may become ineffective due to flow separation. For these reasons, small errors in model prediction at the beginning of the unstable phase can result in large differences at the end. Consequently very accurate modelling is required to achieve good prediction during the unstable part of the transition.

For future combat aircraft employing controlled vortex flows and control systems with increased authority, transition from one flight condition to another at high angles-of-attack can be expected to occur in a more controlled manner. Any destabilising forces will be small compared with the control forces and so better model prediction will be expected.

3   MODEL FORMULATION AND DATA DETERMINATION

The following discussion is restricted to the consideration of a rigid aircraft and will focus attention on the major fundamental problems of firstly, deriving the aerodynamic forces and then of formulating these within a dynamic model. A similar and very useful review of this problem is presented in Ref.2.

3.1   POLYNOMIAL MODEL

The conventional formulation of the aerodynamic forces, using the first derivatives of a Taylor expansion of the force functions about an equilibrium condition, is employed extensively and is documented in standard texts on flight dynamics. The extension of this model to include nonlinear functions using polynomials has frequently been used, the terms of the polynomials having been based on the known characteristics of the forces. An advantage of the polynomial model is that it provides a concise description of the aerodynamic forces and so is suitable for use within parameter estimation flight-test methods.

Recently the polynomial formulation has been used in parameter estimation techniques to determine the aerodynamic characteristics of aircraft at high angles-of-attack from flight measurements.(Refs.3 and 4). Part of this procedure is the determination of an adequate model using the method of stepwise regression. Starting with a postulated set of coefficients for the polynomials any coefficient which produces a statistically insignificant contribution to a least squares cost function is removed from the model. The careful application of this technique in Ref.3 has yielded aerodynamic parameters which compare well with wind-tunnel data for angles-of-attack up to 45 degs.

The approach used in Ref.3 has also been applied to determine aerodynamic data for the modelling activity described in Ref.4. The technique used in these studies appears to be the most effective currently in use for determining nonlinear aerodynamic parameters.

The discussion in Ref.3 concerning model verification illustrates a general problem that frequently occurs when modelling complex dynamic behaviour. The report suggests that a good verification

of model accuracy is to check the prediction capability of the model. In the example, the model derived from specified test manoeuvres gave a poor prediction of a free oscillation manoeuvre. Conversely, when the free oscillation data was used to determine a model, the parameters differed appreciably from those derived from the test manoeuvres. Typically, for complex situations, models can be developed to match specific manoeuvres but these models frequently provide less accurate predictions for substantially different manoeuvres.

3.2   TOBAK AND SCHIFF FORMULATION

A rigorous approach to the development of mathematical models which can represent all types of nonlinear,time-dependent motion is reported in Refs. 5.and 6. The formulation starts from a very general basis using an indicial response formulation, which has been extended to include nonlinear behaviour, and the use of functionals to account for time-dependent effects.

Application of this approach to specific problems is shown in Ref.2 to result in formulations which are consistent with conventional models. The basic approach is very general and provides modelling insight by separating the total motion into certain 'characteristic motions'. However, the approach does not result in a universal model. For each application the model is developed from a general framework and requires the introduction of a number of simplifying assumptions to enable the available aerodynamic information to be utilized.

For flight at high angles-of-attack, the breakdown into 'characteristic motions' emphasises the importance of coning motion. Data for modelling high angle-of-attack situations needs to be obtained from test rigs which can replicate this coning motion; for example rotary balances. Alternatively, for simple configurations, empirical or computational methods could be considered.

3.3   DATA TABLE REPRESENTATION

With the development of computers having large storage capability, aerodynamic data is frequently stored in data tables. This enables the forces to be represented as arbitrary nonlinear functions of a number of independent variables.

This approach is used widely for simulation and is satisfactory providing that the data base can be generated to cover the ranges of state and control variables involved. Current wind-tunnel methods provide only part of the data required to cover the state space spanned by large manoeuvres at high angles-of-attack. Typically, static data can be obtained throughout the

required angle-of-attack and sideslip range. Small disturbance oscillatory data is generally available only for low flow angles, although some data has been measured at large flow angles. However, this data cannot be extrapolated to cover the large arbitrary rotations associated with manoeuvring at high angles-of-attack. Aerodynamic force data for large steady rotation rates can be obtained from rotary balances which replicate the steady spin and the steady coning motion described in section 3.2.

The general empirical approach outlined above has been developed in a more formal way by Hanff (Ref.7). The approach is based on a knowledge of the instantaneous values of airloads as a function of the corresponding instantaneous values of the pertinent motion variables. The formulation is based on the assumption that there is a well defined (although not necessarily single-valued) relationship between any given aerodynamic reaction and the motion variables. This corresponds in a topological sense to the existence of a unique "reaction hypersurface".

Experimental determination of the hypersurface poses a serious practical problem. Ref.7 provides a brief summary of a wind-tunnel technique which should provide more comprehensive aerodynamic data than existing wind-tunnel methods. It is pointed out that some aerodynamic modelling will still be required to provide all the information needed. As with the conventional model, time-dependent effects are included by defining relationships between the aerodynamic forces and the higher order derivatives at each time instant.

3.4   ROTARY BALANCE DATA

Rotary balances have been used in wind-tunnels since the 1930's for the investigation of aircraft spin behaviour. These balances enable the model to be rotated at constant incidence angles to the velocity vector, and over a range of rotation rates. This motion is the same as the coning motion referred to in Section 3.2. With the development of modern instrumentation, fast data acquisition systems and computer analysis, the use of this form of testing has increased significantly. It provides aerodynamic information for determining equilibrium spin conditions and for the study of high angle-of-attack flight behaviour.

In Ref.8 a six degree-of-freedom model of spin behaviour was developed which combined rotary balance data with empirically estimated oscillatory derivatives. The resulting formulation is similar to that which results from the more rigorous approach described in Section 3.2. Unfortunately the associated simulations suffered because of deficiencies and inaccuracies in the rotary balance data. However, the formulation of the aerodynamic forces provides a useful approach to

incorporating rotary balance data into a flight dynamic model. The model is most accurate at steady spin conditions and deteriorates as the manoeuvre departs from this condition. Although comprehensive rotary balance data bases have now been obtained on a number of aircraft, information on the adequacy of this model formulation has not yet been established. Specifically the magnitude of the errors associated with departure from the steady coning motion, and the adequacy of modelling time-dependent effects as functions of the state derivatives has to be established.

Ref.2 describes a number of model formulations which have been developed to investigate particular flight dynamic phenomena. Models for rolling at low speed and for the spin are proposed. The proposed spin model would use data from a rotary balance together with the forces due to perturbations about the given rotary motion. The formulation is similar to that prcposed in Ref.5 .The report notes that complex apparatus would be required to measure the forces due to perturbations about steady rotary motion.

Ref.2 notes that a salient feature of all the formulations for the aerodynamic forces and moments entering into the equations of motion is that the leading terms in all the expressions for the coefficients represent some datum condition closely related to the dynamic problem

3.5   SUMMARY OF MODEL FORMULATIONS

Experience shows that the complexity needed in a flight dynamic model depends upon the nature of the problem and upon the form of the aerodynamic data that can be measured or estimated. For flight at high angles-of-attack, where the aerodynamic forces can be nonlinear and time-dependent, various solutions have been proposed. All these solutions are constrained by limitations in the methods for the estimation of the required data. Currently there are no well-developed wind-tunnel methods for determining the forces due to large arbitrary rotations or due to perturbations about large steady rotations. Ref.9 gives information on a unique facility under development for this purpose.

One approach to the estimation of aerodynamic data for flight dynamic models is to use computational fluid dynamic solutions of the flow equations. This opens up the possibility that an aerodynamic simulation could be used to replace the flight dynamic model. These considerations are discussed in section 4.

4.0   AERODYNAMIC ESTIMATION BY COMPUTATIONAL METHODS

4.1   GENERAL CONSIDERATIONS

Developments in computational fluid dynamics have increased the prospects for estimating numerically the aerodynamic forces needed for flight dynamic studies. The use of this capability was discussed in Refs .10 and 11.

Two approaches are considered. Firstly the equations describing fluid flow can be coupled with the aircraft inertial equations of motion to produce time responses which will include correctly both nonlinear and time-dependent effects. Alternatively, the gasdynamic equations can be used to provide an aerodynamic data base for use within a flight dynamic model. The aerodynamic terms should be formulated so that they represent accurately the aerodynamic forces occurring in all motions of interest. Ideally with a modelling approach, evaluation of the aerodynamic terms would be required only once.

Complete modelling can be envisaged if the solution of the Reynolds-averaged form of the Navier Stokes equations governing the unsteady separated flow field surrounding a complete configuration could be achieved. However this is beyond the computing resources likely to be available for many years. In the meantime accurate solutions can be applied to very simple configurations, while less complete solutions can be used for more complex configurations - with an associated loss in accuracy. In either case, the aerodynamic solutions have to be computed for each time history required, and this represents considerable computing cost.

At present the modelling approach offers the possibility of employing more accurate aerodynamic solutions to provide a data base from which a range of computations can be calculated.

As discussed in Section 3.2 the utility of the aerodynamic modelling approach depends on the ability of the model to encompass the aerodynamic phenomena that occur in flight. The example described in Ref.10 uses a model formulation derived from Ref.5 and defines clearly the restrictions and assumptions for the flight behaviour under consideration. To provide the aerodynamic data for the model, thirty six individual computations were carried out using a Cray-1 computer. The results indicate satisfactory modelling for the range of manoeuvres considered, and demonstrate the validity of this approach.

4.2   AXIOMATIC MODEL

A further effort aimed at understanding the validity of aerodynamic modelling is reported in Ref.12. In this study a computational aerodynamic model of the loading on an aircraft configuration undergoing arbitrary time dependent motion is developed using a vortex lattice representation. The model is intended to be a realistic representation of the main aerodynamic features but is not accurate in detail. It has been termed an axiomatic model since it is assumed that the model applies in all circumstances. Therefore the aerodynamic behaviour will be consistent and compatible in all applications.

The purpose of the study is to use the model to investigate the validity of aerodynamic modelling. For example the conventional aerodynamic derivatives can be obtained from the axiomatic model and used in a standard dynamic model to compute aircraft behaviour. This behaviour can be compared with that obtained using the aerodynamic forces produced by the aerodynamic model directly in the equations of motion.

In Ref.12 the predicted full scale response behaviour based on derivatives is compared with actual full-scale behaviour based on the axiomatic model for various control surface inputs. Differences between the outputs from the two approaches have, in certain cases, been traced to assumptions in the derivative model and demonstrate the nature and accuracy of the assumptions. In other cases the cause of the differences have still to be identified.

The above examples use computational aerodynamic solutions to investigate the validity of aerodynamic modelling methods. These solutions can be used to augment experimental data for cases where experimental techniques are inadequate or not available. They therefore provide an alternative source of aerodynamic data. The accuracy of this data depends on the complexity of the aerodynamic model and this is currently limited by computing capability. However, as noted in Ref.13, it is important that the dynamic model formulation should encompass all the aerodynamic phenomena that occur in flight.

4.3   COMBINING WIND-TUNNEL AND COMPUTATIONAL SOLUTIONS

The aerodynamic data used in flight dynamic models has traditionally been derived from empirical methods which usually have a theoretical base, wind-tunnel or flight test measurements, or from combinations of these. Recent developments in computational methods now provide a further source of data. As noted in Sections 3.2 and 3.4, wind-tunnel techniques capable of providing the forces due to perturbations about steady coning motion

are at an early stage of development. However, a prediction of these terms could be made using computational methods.

Currently a study is being undertaken at ARL in which a simple computational model of the aerodynamic forces on a straight tapered wing is being developed to provide some of the additional aerodynamic information. The model has been developed and validated against measured force data for a Basic Training Aircraft undergoing steady coning motion. Small perturbations are then applied to the model and the associated incremental forces and moments are calculated. These increments are then used in conjunction with the measured steady forces to represent the forces due to the total general motion.

Combining data in this manner has considerable merit since the experimental data can act as a reference from which to extrapolate to conditions which are difficult to measure experimentally.

5 PARAMETER ESTIMATION FROM FLIGHT TEST MEASUREMENTS

In recent years there has been development of dynamic flight measurement techniques which determine the net aerodynamic forces acting on an aircraft indirectly from measurements of non-steady motion. The techniques use flight dynamic models to relate the forces to the motion and employ statistical estimation to determine the aerodynamic parameters which satisfy the model equations.

Parameter estimation has been developed to a successful level for cases where small-disturbance linear models are valid. For cases in which the aerodynamic forces are nonlinear then, in addition to identifying the parameters, it is often necessary to determine the form of the model. In Ref.3 this is achieved by using the physical knowledge of the aerodynamic behaviour to postulate a possible model. Statistical hypothesis testing is then used to decide which terms in the model are significant. For this process an analytical description of the aerodynamic forces is required. The forms used so far include polynomials and spline functions.

Identification of the time-dependent aerodynamic forces has rarely been attempted. In Ref. 14 these forces were modelled in the standard manner as functions of the rate of change of angle-of-attack, and special manoeuvres were flown to determine the associated derivatives. However, little work has been carried out concerning the investigation of time-dependent forces on aircraft manoeuvring at large angles-of-attack.

A number of difficulties arise with the use of parameter estimation for aircraft with advanced flight control systems irrespective of the nature of the aerodynamic forces. Firstly, the unaugmented aircraft may

be unstable in which case the application of
identification techniques is less straightforward.
Ref. 15 outlines a technique for dealing with this
situation.

Secondly, modern control systems may command more
than one control surface in response to the pilots input.
In this situation it can be difficult to identify the
separate control contributions. At the NASA Dryden Flight
Research Center consideration is being given to
generating separate control surface commands for the
identification of the F/A-18 High Alpha Research Vehicle
(HARV) aerodynamic parameters.

Further detailed information on the application of
parameter estimation techniques and other related topics
were obtained during the overseas visit. This information
is available in the Aircraft Behaviour Studies - Fixed
Wing group at ARL.

6   CONCLUDING REMARKS

A review has been made of the approaches currently
under development for the modelling of aircraft flight
dynamic behaviour at high angles-of-attack and with high
rotation rates. Accurate models are required for the
design and development of aircraft which can operate in
this extended flight regime. Greater understanding of the
aerodynamic forces involved in these flight regimes is
required and also improved methods of formulating this
information into flight dynamic models. Four approaches
to the modelling problem have been discussed. The
approaches are dependent on the methods used in the
generation of the aerodynamic data. For manoeuvres at
high angles-of-attack the importance of obtaining data
for steady coning motion is emphasised. The prospect of
using computational methods to generate aerodynamic
information for use in flight dynamic modelling is
discussed and an example under development at ARL is
briefly described. The application of parameter
estimation to determine aerodynamic data for aircraft at
high angles-of-attack and to aircraft with advanced
flight controls is discussed.

REFERENCES

1.   ETKIN, B.E. ; Dynamics of Atmospheric Flight.
 John Wiley and Sons Inc. ,1972.

2.   THOMAS, H.H.B.M. ; Some Thoughts on Mathematical
Models for Flight Dynamics. The Aeronautical Journal.MAY
1984.

3   Klein, V. and Batterson, J.G. ; Aerodynamic
Characteristics of a Fighter Airplane Determined from
Flight and Wind Tunnel Data. NASA TP 2483 SEPTEMBER 1985.

4.   Ross, A.J. ,Edwards, G.F. ,Klein, V.,Batterson, J.G.
Validation of Aerodynamic Parameters at High Angles of
Attack for RAE High Incidence Research Models RAE Tech
Memo Aero 2100. JUNE 1987.

5.   Tobak, H. and Schiff, L. ; Aerodynamic Mathematical
Modelling - Basic Concepts AGARD Lecture Series No 114,
1981.

6.   Schiff, L.B. ; A Study of the Nonlinear Aerodynamics
of Bodies in Nonplanar Motion NASA TR R-421 JAN. 1974.

7.   HANFF, E.S. ; Dynamics Nonlinear Airloads -
Representation and Measurement. AGARD-CP-386 MAY 1985.

8.   Scher, S.H. ; An Analytical Investigation of
Airplane Spin-Recovery Motion by use of Rotary Balance
Aerodynamic Data. NACA TN 3188 ,1954.

9.   Tristant,D. and Renier,O. Recent Developpements Des
Techniques De Simulation Dynamique Appliquees A
L'Identification Des Parametes De Stabilite. AGARD-CPP-
386 1985

10. Schiff, L.B. and Katz, J. ; Application of CFD
Techniques Towards The Validation of Nonlinear
Aerodynamic Models. AGARD Lecture Series No 114, 1981.

11. Katz, J. and Schiff, L. ; Modelling Aerodynamic
Responses to Aircraft Maneuvres - A Numerical Validation.
 Journal of Aircraft Vol. 25 No 1 JAN 1987.

12.   Hancock, G.J. and Lam, J.S.Y. ; On the Application
of Axiomatic Modelling to Aircraft Dynamics. Parts 1,2,3
Aeronautical Journal JAN. 1987.

13.   Katz, J. and Maskew, B. ; Unsteady Low-Speed
Aerodynamic Model for Complete Aircraft Configurations.
AIAA Atmospheric flight Mechanics Conference Paper 86-
2180 Williamsburgh AUG. 1986.

14.   Maine, R.E. and Iliff, W. ; Maximum Liklihood
Estimation of Translational Acceleration
Derivatives from Flight Data.
Journal of Aircraft Vol 16 No 10 OCT 1979.

15.   Maine. R.E and Murray, J.E. ; Application of
Parameter Estimation to Highly Unstable Aircraft AAIA
Paper 862020 Atmospheric Flight Mechanics Conference
Williamsburgh AUG.1986.

Statutory and State Authorities and Industry
    Aero-Space Technologies Australia, Manager/Librarian (2 copies)
    Hawker de Havilland Aust Pty Ltd, Bankstown, Library

Universities and Colleges

    Adelaide
        Barr Smith Library

    Flinders
        Library

    LaTrobe
        Library

    Melbourne
        Engineering Library

    Monash
        Hargrave Library
        Professor I.J. Polmear, Materials Engineering

    Newcastle
        Library
        P.W. Gibbens, Department of Electrical and Computer Engineering

    New England
        Library

    Sydney
        Engineering Library
        Head, School of Civil Engineering

    NSW
        Physical Sciences Library
        Professor R.A. Bryans, Mechanical Engineering

    Queensland
        Library

    Tasmania
        Engineering Library

    Western Australia
        Library
        Professor B.J. Stone, Head Mechanical Engineering

    RMIT
        Library

    University College of the Northern Territory
        Library

SPARES (10 copies)
TOTAL (80 copies)

AL 149

DEPARTMENT OF DEFENCE

DOCUMENT CONTROL DATA

PAGE CLASSIFICATION
UNCLASSIFIED

PRIVACY MARKING

1a. AR NUMBER AR-005-534	1b. ESTABLISHMENT NUMBER ARL-AERO-TM-400	2. DOCUMENT DATE SEPTEMBER 1988	3. TASK NUMBER DST 86/052

4. TITLE	5. SECURITY CLASSIFICATION	6. NO. PAGES

4. TITLE
MODELLING AIRCRAFT
DYNAMICS

5. SECURITY CLASSIFICATION
(PLACE APPROPRIATE CLASSIFICATION
IN BOX(S) IE. SECRET (S), CONF.(C)
RESTRICTED (R), UNCLASSIFIED (U)).

6. NO. PAGES
16

U	U	U
DOCUMENT	TITLE	ABSTRACT

7. NO. REFS.
15

8. AUTHOR(S)

C.A. Martin

9. DOWNGRADING/DELIMITING INSTRUCTIONS

Not applicable

10. CORPORATE AUTHOR AND ADDRESS

AERONAUTICAL RESEARCH LABORATORY
P.O. BOX 4331, MELBOURNE VIC 3001

11. OFFICE/POSITION RESPONSIBLE FOR:

SPONSOR _____ DSTO _____

SECURITY _____

DOWNGRADING _____

APPROVAL _____ CAAD _____

12. SECONDARY DISTRIBUTION (OF THIS DOCUMENT)
Approved for public release.

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE CENTRE, DEFENCE INFORMATION SERVICES BRANCH, DEPARTMENT OF DEFENCE, CAMPBELL PARK, CANBERRA, ACT 2601

13a. THIS DOCUMENT MAY BE ANNOUNCED IN CATALOGUES AND AWARENESS SERVICES AVAILABLE TO....

No limitations.

13b. CITATION FOR OTHER PURPOSES (IE. CASUAL ANNOUNCEMENT) MAY BE   [X] UNRESTRICTED OR   [ ] AS FOR 13a.

14. DESCRIPTORS		15. DRDA SUBJECT CATEGORIES
Flight dynamics, High angle of attack, Mathematical models, Flight tests,	Parameters, Data reduction, Australia . (Driving)	0051A

16. ABSTRACT   A review has been made of the approaches currently under development for the modelling of aircraft flight dynamics at high angles-of-attack. The review is based on current research literature and on discussions held during an overseas visit carried out for the purpose of technical updating in the areas of flight dynamic modelling and parameter estimation. Keywords:

THIS PAGE IS TO BE USED TO RECORD INFORMATION WHICH IS REQUIRED BY THE ESTABLISHMENT FOR
ITS OWN USE BUT WHICH WILL NOT BE ADDED TO THE DISTIS DATA UNLESS SPECIFICALLY REQUESTED.

16. ABSTRACT (CONT.)

17. IMPRINT

AERONAUTICAL RESEARCH LABORATORY, MELBOURNE

18. DOCUMENT SERIES AND NUMBER	19. COST CODE	20. TYPE OF REPORT AND PERIOD COVERED
Aerodynamics Technical Memorandum 400	52 5026	

21. COMPUTER PROGRAMS USED

22. ESTABLISHMENT FILE REF.(S)

23. ADDITIONAL INFORMATION (AS REQUIRED)