Pre-flight Calibration of Air Data Sensors of a Fighter Aircraft

Defence Research &
Development Organisation
Ministry of Defence, India

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Ministry of Defence, New Delhi – 110 011
2014

DRDO MONOGRAPHS/SPECIAL PUBLICATIONS SERIES

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Cataloguing-in-Publication

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Pre-flight Calibration of Air Data Sensors of a Fighter Aircraft

DRDO Monographs/Special Publications Series

1. Air Data Sensors 2. Fighter Aircraft 3. Calibration

I. Title II. Series

629.73:533.6.052

ISBN 978-81-86514-53-5

Printing
SK Gupta

Marketing
Rajpal Singh

Published by Director, DESIDOC, Metcalfe House, Delhi – 110 054.

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Preface

Air data is very important for completing an aircraft mission successfully. The air data, which includes indicated and true air speed, pressure altitude, ambient air temperature, Mach number, and angles of attack are measured using pitot and static probes and angles of attack (AOA) vanes mounted generally on the front fuselage. These measured quantities are supplied to the air data computer for necessary correction before using the data by the aircraft flight control system.

The pre-flight calibration of air data sensors of a fighter aircraft is vital to provide effect of aircraft geometry on the calibration of air data system (SADP, AOAV, and NADP), which is achieved through CFD/wind tunnel techniques. The work for air data system design and development of the Indian combat aircraft started about two decades ago. A large amount of data had been generated initially using CFD tools/ wind tunnel tests and finally from flight tests. The main motivation of writing this monograph is to document the procedure and archive the results.

This monograph describes the procedure for pre-flight calibration of air data sensors of a fighter aircraft and finding a suitable location of the probe and estimating the position error corrections for an Indian combat aircraft. Though the procedure of pre-flight calibration outlined in this monograph is specific to an Indian combat aircraft, yet, it is general enough to be adopted for any other aircraft programme. However, post-flight calibration, which includes the procedure to obtain data from flight and subsequently update the air data is not discussed here.

The Monograph is divided into the following chapters:

Chapter 1 deals with an overview of air data sensors and its important role for the combat aircraft flight.

Chapter 2 describes air data sensors of an Indian Combat aircraft which includes six air data sensors: one NADP, two SADP, two AOA vanes, and one β vane.

Chapter 3 is devoted to the CFD tools and methods used for generation of flow field data over the aircraft.

Chapter 4 deals with the selection of suitable location for SADP and AOA vanes. The various parameters which affect the optimal location are highlighted.

Chapter 5 deals with the CFD data generation at selected locations of air data probe and parametric study to find the effect of location and Mach number. Preliminary validation with wind tunnel data is also shown.

Chapter 6 contains the procedure used to estimate the position error correction in static and total pressure for SADP and NADP. The effect of the aircraft configuration is assessed using the CFD tool at various Mach numbers, angles of attack, and side slip angles. The probe alone error is derived from vendor's supplied data to evaluate the position error in static and total pressure measurement.

Chapter 7 highlights in detail the validation of the CFD predicted data with the data obtained from wind tunnel measurement. It was necessary to have this validation to gain confidence in CFD data before providing the data to the CLAW team.

Chapter 8 addresses the validation of data with the flight data. The flow angularity data, total and static pressure measured during flight by NADP, SADP, AOAV and β vane are compared with the CFD and flight data.

Chapter 9 summarizes the methods and techniques and calibration results of the monograph.

Bengaluru

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Acknowledgements

I am very grateful to Shri PS Subramanyam, Distinguished Scientist, Programme Director (Combat Aircraft) & Director, Aeronautical Development Agency (ADA), Bengaluru for encouraging me to write this monograph. My sincere thanks are due to Shri SK Jindal, Director, Defence Scientific Information & Documentation Centre (DESIDOC), Delhi for providing me an opportunity to write this monograph.

I would like to sincerely thank Dr Girish S Deodhare, Outstanding Scientist, ADA and Dr Amitabh Saraf, Sc 'G', ADA for reviewing the monograph critically and providing valuable suggestions. My thanks are due to Shri Satya Prakash, Sc 'F', ADA for discussion and valuable inputs for improving the manuscript.

I must particularly thank Smt Anitha Saravanan, Head Monographs Division, DESIDOC for providing excellent support and closely monitoring the progress. The efforts of Editorial Board are also gratefully acknowledged.

I would like to thank Shri Alex Nazerene and Shri Venkatnarayan T for their assistance in preparing the manuscript.

During the course of preparation of this monograph, I have cherished the memories of all my colleagues who have worked for decades to make the calibration process of air data sensors a matured technology.

I write this monograph with the memories of all my colleagues who worked for calibration of air data sensors for decades to make the process at ADA matured.

I finally thank my entire family, especially my wife Mrs Jayakumari, for their patience and cooperation while writing this monograph.

Dr KP Singh

List of Acronyms

ADA	Aeronautical Development Agency
ADC	Air data computers
ADE	Aeronautical Development Establishment
AOA	Angle of attack
AOAV	AOA vane
AOSS	Angle of side slip
CAS	Calibrated air speed
CFD	Computational fluid dynamics
CLAW	Control laws
CSCI	Computer software configuration item
DCSU	De-icing current sensing unit
DFCC	Digital flight control computer
DGPS	Differential global positioning system
DICU	De-icing current unit
DRU	Data recording unit
FCS	Flight control system
FPR	Flight path reconstruction
FRL	Flight refuelling limited
GHU	Get-U-Home
HAL	Hindustan Aeronautics Limited
HWCI	Hardware configuration item
LRU	Line replacement unit
MMCS	Martin Marietta Control System
MMOC	Martin Marietta Overseas Corporation
MMR	Multi mode radar
NADP	Nose air data probe
NAL	National Aerospace Laboratories
PEC	Position error correction
RVDT	Rotary variable differential transformers
SADP	Side air data probes
SSA	Side slip angle
TAS	True air speed
TATP	Total air temperature probe

Chapter 1

Overview

1.1 INTRODUCTION

Air data is very important to successfully complete an aircraft mission and it is derived from the air surrounding the aircraft. The information regarding air data measurement and calibration is given in detail in various reports[1-7]. Air data includes the indicated and true air speed, pressure, altitude, ambient air temperature, angle of attack (AOA), side slip angle (SSA), and Mach number. Typically, these quantities are measured using pitot and static probes, and AOA vanes, mounted generally on the front fuselage (Fig. 1.1). These measured parameters are commonly input to air data computer, which usually with appropriate algorithm and corrector factors (or calibrations), provides other parameters, such as true air speed (TAS), AOA, pressure, and altitude required by the aircraft flight control system.

The pitot-static probes and AOA vanes are generally calibrated by vendors, and calibration curves are provided, which are used internally to give the free-stream pressure, air speed, and value of AOA. However, since these devices are mounted on the aircraft geometry (generally on front fuselage), the presence of the aircraft in the air stream causes input errors to the measuring instruments. As these devices can be used for any aircraft, the vendors in general provide calibration of the instrument in the absence of aircraft body. The effect of aircraft geometry needs to be accounted by designers. Figure 1.2 shows an air flow around the air plane geometry. As a result of flow disturbance by aircraft geometry, the static/total pressures and also local flow angles differ from the free-stream flow values. In fact, these air data probes measure the local pressure and local angles at the location where these probes are mounted. However, the designer's interest is to get free-stream static pressure, free-stream air speed, and AOA. The effects of the aircraft geometry on the measurement and air data can be studied using wind-tunnel test and theoretical simulation based on computational fluid dynamics (CFD). A typical effect of aircraft geometry on air data measurement is shown in Fig. 1.3.

Accurate air data is required for many purposes and it has many applications. Obviously, the pilot cannot fly the aircraft safely without the knowledge of aircraft speed and altitude of the aircraft. In civil aviation, the small vertical separation between two aircraft assigned by air traffic controller is based on accurate measurement of

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About the Book

This monograph presents the latest tools and methods for pre-flight calibration of air data sensors of a fighter aircraft. A generic fighter aircraft that was designed and developed at Aeronautical Development Agency (ADA), Bengaluru is used as a typical case in the study. The procedure of selection of optimal choice of locations of air data sensors is presented in detail. CFD methods have been extensively used to generate flow angularity and position error correction data tables for air data sensors for an extensive range of angles of attack, angles of side slip, and Mach numbers. Data from CFD tables are compared with the data from wind tunnel tests and a close match obtained proving the adequacy of CFD methods for pre-flight calibration. Validation results with the flight tests have also been presented. Though the procedure highlighted here in this monograph is for a generic fighter aircraft of ADA, it is highly applicable and adaptable for any fighter aircraft programme and will also serve as a guideline for future engineers and scientists for pre-flight calibration of air data sensors.

About the Author

Dr KP Singh obtained BE in Mechanical Engineering from the Institute of Technology, BHU, Varanasi in 1971; ME in Aeronautical Engineering from IIT, Kanpur in 1973; and PhD in Aeronautics from Indian Institute of Science, Bengaluru in 1988. He worked as a Senior Aerodynamicist at the Vikram Sarabhai Space Centre, Thiruvananthapuram, during 1973–1988. In 1988, he joined Aeronautical Development Agency (ADA), Bengaluru, to lead the CFD group. His responsibility involved making ADA self-sufficient in the application of CFD tools for design and development of combat aircraft. He worked in many areas of aircraft configuration design and development, aerodynamic loads, store separation studies, and pre-flight calibration of air data sensors, where he spent major part of time of his career. After superannuating as an Outstanding Scientist from ADA, Bengaluru in 2009, he continued as an Emeritus Scientist. He also served as Chairman, CFD Division, Aeronautical Society of India for nine years.

Price: ₹325
US: $35
UK: £25

9 788186 514535

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Ministry of Defence, Metcalfe House, Delhi – 110 054, India