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3. Overview

3.1 Research on Hinge Moment Balance

3.2 Hinge Moment Balances Used in High Speed Aerodynamics Institute of CARDC

3.3 Recent Investments in the National Force Measurement Technology Capability

3.4 A Review of Wind Tunnel Balance Technologies with a Look towards the Future

3.5 Design, Calibration and Commissioning of a Small Cryogenic High


4. Others

4.1 Developing of the Five-Component Load Cell for the Test Rig for Mass, Mass Center Coordinates and Inertia Moments Determination of Objects

4.2 The influence of assembly stress of a cassette balance on the measuring results in half-model test

4.3 The Research of the Deployment Parachute Dynamometry for Emergency Escape Parachute based on the Six Components Balances

4.4 Experimental Research on Symmetrical Temperature Compensation of Small Size Bar-shaped Fiber Optic Balance

4.5 Development of Thrust Vectoring Test Balance Measurement System for 2.4m×2.4m Transonic Wind Tunnel

4.6 The Influence of Measurement Range and Loads on the Accuracy of Sting Balance

4.7 A Study of the Long-Time Stability of the Cryogenic Six-Component Balances of DNW-KKK

4.8 Compact air-line bridge system for propulsion integration in DNW-LLF

4.9 Effect of Boundary Layer of Balance Platform on an Under Floor External Balance Data of a Half Model
1. Design
TsAGI develops and tests new counter rotating propellers for prospective aircrafts. Thereto we use plant equipped with 2-component measurement system, which allows to measure: drag and torque. For new blades certifying, existing 2-component measurement system is enough but for complete investigation of process physics required 6-components. It is necessitate development of novel measurement system for existing plant. 

The novel measurement system based on two integral units consisting of 6-component rotating shaft balances (RSB), the blade hubs mounted to the leading side of the balance, and the telemetry transmitters connected the external ring of the balances for acquisition the signals from the rotating system.

Spatial limitation within the nacelle of existing test equipment in radial as well as in axial direction leads to the decision to develop a fully symmetric spoke-type balance with two transversal planes each with 6 spokes. The spoke has non-prismatic geometry with fillet stress concentrator, which raises Y and Z components signal stress. This scheme provides reduction of centrifugal effects and the influence of X, MX, MY, MZ components on in-plane forces (Y, Z).

In addition, the design has specific cutouts and uncouplers for reduction of temperature and stress influence on spokes of the RSB.

Developed RSB have following loadings on components:

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</thead>
<tbody>
<tr>
<td>X, kN</td>
<td>Z, kN</td>
<td>Y, kN</td>
<td>Mx, kN-m</td>
<td>Mz, kN-m</td>
<td>My, kN-m</td>
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<tr>
<td>2,5</td>
<td>0,6</td>
<td></td>
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Currently, the RSB is in manufacturing and methodology of calibration is in process.
TBULAR STRAIN-GAUGE BALANCES – NEW GENERATION

Lagutin V.I.
TsNIImash, Korolev, Moscow reg., Russia

Abstract
Tubular type strain-gauge balances (SGB) have a body as a tube, in walls of which measuring springy elements are implemented. This type of the SGB widely uses in TsNIImash practice since 90-th for solving various tasks of experimental aerodynamics. Due to a lot of evident merits (compact axisymmetric structure of the balance body which provides high metrological characteristics, manufacturability and applicability) tubular SGB in many cases can be used as conventional «rod type» SGB. Besides, in several cases specific necessity for usage space of SGB inner canal (space for cables, pipes of compressed air supply and so on) takes place. These circumstances explain interest to further development of SB tubular type.
The presentation gives examples of new generation tubular type strain-gauge balances which creation was based on contemporary technologies of mathematical simulation and new technical solutions concern design of separate dynamometric elements and their optimal assemble in SGB structure. The SGB of new generation were successfully used for solving various tasks of aerodynamic forces and moments measurements in TsNIImash aerodynamic facilities.
Technique investigation on force test with different forms of hinge moment balances in subsonic and supersonic wind tunnel

Yuan Jianan¹, Zhao Changhui², Li Yong¹, Yang Zhuang⁴

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Abstract
In the same set of models by installing many sets of hinge moment balances in an experiment to measure aerodynamic load, multiple control surfaces can get data more detailed aerodynamic characteristics, and it will helps to raise efficiency. The model with the control surface of symmetrical airfoil can use two kinds of structure forms of hinge moment balances, you can get more reference significance to contrast data. This paper introduces the flying around flaps were obtained by single component and three-component hinge balance aerodynamic characteristics of the measured data, and the results of the normal force coefficient, hinge moment coefficient and pressure center of the other control flaps at Mach number of 0.6--4.0.
A Six-Component Cartridge Strain-Gage Balances for Shock Tunnel

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An internal six component strain gage balance has been designed and developed for a long test duration shock tunnel. This balance is built for accurate measurements of normal force up to 30000N. In hypersonic shock tunnel, the inertial forces lead to low frequency vibrations of the model and sting. The test time is so short that the mechanical vibration of the model-balance-sting system cannot be damped during a shock tunnel run specially. In order to reduce the length of sting with the objective of reduce the natural frequencies of the system, we developed a cartridge strain gage balance with side sting instead of rear sting. The optimised design configuration of the axial force element comprises two beams, and the normal force element comprises enhance beams. Finite element analysis was carried out for detailed stress distributions and vibration characteristic of the model-balance-sting system.

References

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Development of measuring technology of airship propeller pull force and torque

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Abstract

Two-component balances and data acquisition systems were developed in CAAA in early time to measure pull force and torque of airship propellers. During the development and application, some problems appeared. At first, the measuring system and safeguard devices made the weight of whole system increase significantly. Secondly, the number of failure modes increased, so the reliability of the system was reduced. In addition, the rigidity of the system was lowered, and the structure was more easily to vibrate. Therefore, CAAA and the Academy of Opto-Electronics, Chinese Academy of Science(AOECAS) developed a new technology, use the propeller supporting rack as a spring element, attach strain gages onto it, sum up as a generalized six-component balance. And new math models, calibration methods and loads determining methods were developed.
The Development of
A New Type of Six-component Optical Fiber Balance

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Abstract
Optical fiber sensing technology is developing rapidly in recent decades, which has been applied widely. The paper developed a new type of six-component optical fiber balance. Firstly, on the principle of optic fiber strain gauge, the paper designed a suitable fiber optic strain gauge for six-component optical fiber balance, then the paper analyzed and put forward the layout program of optical fiber strain gauge, and the method of optic fiber strain gauge’s combination bridge way; secondly, the paper analyzed two main demodulation methods, then the suitable demodulation method and the program of static calibration has been proposed for the six-component optical fiber balance; finally, in application of the balance, HB-2 standard model has been used to conduct the wind tunnel experiment in the ultra sonic speed wind tunnel called NHW of Nanjing University of Aeronautics and Astronautics. Did test and analysis of the the balance’s performance, the results showed that the six-component optical fiber balance meets the design requirements, at the same time with a small temperature drift, strong anti-interference ability and high stability.

Key Words: Optical fiber strain gauge, Six-component optical fiber balance, Method of demodulation, Calibration
Strain Gauge Balance Design and Optimization Platform Based on Process Encapsulation and Web Service

XIANG Guangwei¹, SHI Yujie², YI Guoqing³, MI Peng⁴, LIU Wei⁵

China Aerodynamics Research & Development Center, Mianyang, Sichuan 621000, China

Abstract

A distributed strain gauge balance design and optimization platform (BDOP) based on C/S and B/S architecture are developed to meet the increasingly urgent needs of balance design. It can be carried out efficiently by multi-user for high quality online design and optimization of rear sting balances, ring type balances and block balances and also for verification calculation. BDOP integrates modeling, simulation and optimization software tools as well as the design experience so that parametric models can be automatically created and associated with a combination of a variety of structural design and optimization automation process. Through the secondary development of the software, packaged easy-to-use standardized applications for balance designers have a friendly graphic user interface (GUI). Resources for design and optimization are utilized on the server side. A lot of numerical simulation and optimization calculations of the hardware demanding using parallel computing are completed by the server. Client uses lightweight GUI and local browser as a user input/output interface to call design resources remotely to achieve the balance of the design optimization through web service. More than ten balances have been completed the design and verification of remote computing by BDOP, which significantly improves the simulation and optimization of design and collaborative design capabilities. Practice indicates that the scientific and flexible design mode reduces the tedious work of calculating and evaluating by hand. Moreover, further integration of design resources promotes the balance design concepts and enhances the overall quality and efficiency of balance design.

Key Words: Optimization platform, Strain gauge balance, Automatic design and optimization, Process encapsulation, Web service
Development on car balance in 8m×6m low speed wind tunnel

XUE WEI
China Aerodynamics Research & Development Center, Mianyang 621000, China

Abstract

Car balance is an important equipment in wind tunnel test, which can influence the result of the test directly. According to the calibration data of the car balance, this paper gives the problems during the development of the car balance with finite element analysis and provides a three-dimensional force sensor element instead of the old one. It shows that the element type, arrangement and joint interface are reasonable when contracting the FEA and the calibration result, which supply the accuracy data for the car test in 8m×6m low speed wind tunnel.

Key words: 8m×6m low speed wind tunnel; Car balance; Finite Element Analysis(FEA); Three-dimensional force sensor
Development of Strain Gauge Balance for the JF12 Shock Tunnel
Yunpeng Wang¹, Yunfeng Liu², and Zonglin Jiang³

Institute of Mechanics, Chinese Academy of Sciences (CAS), Beijing 100190, China

Force tests were recently conducted at JF12 long-test duration shock tunnel, which has been designed and built in Institute of Mechanics, CAS. The performance tests demonstrated that this facility is capable of reproducing the pure airflow with Mach numbers from 5-9 at altitude of 25-50km with at least 100ms test duration. Therefore, a stiff construction balance, that is the traditional internal strain-gaged balance, was considered to use in this long-test duration impulse facility due to its mature technology, simple structure and low cost. However, when the force test is carried out in shock tunnel, the inertial forces lead to low frequency vibrations of the model and its motion cannot be addressed through digital filtering since enough cycles cannot be found during a shock tunnel run. This implies restriction on the model’s size and mass as its natural frequencies are inversely proportional the length scale of the model. Therefore, there are still many problems for the force measurement in a shock tunnel, especially for the large and heavy model. In order to overcome the technical difficulties, JF12 series SGBs were designed and fabricated. The maximum loads are from 1000N to 30000N for the test models with different scale. The different structures were proposed and optimized for two types of balance, i.e., the sting and cassette balances. The finite element method was employed for the analyses of vibration characteristic of the model-balance-support system (MBSS) in order to ensure high enough vibration frequency of MBSS, especially axial force signal during 100 ms test duration. In addition, the force tests were carried out using several large-scale test models. JF12 series pulse-type SGBs show good performances and the frequency of the model-balance-support system increases due to the stiff construction of the SGB.
Application of Wind Tunnel Strain-gauge Balance for Flying-Wing UAV

LI Yong¹, WANG Shi-hong², ZHAO Chang-hui³

AVIC Aerodynamics Research Institute, Shenyang 110034, China

Abstract

A six-component balance is designed for a flying-wing configuration aircraft model to research its aerodynamic characteristics in wind-tunnel force test. The difficulty is the unmatching of loads. The ratio of longitudinal and the side loads, the lift to drag ratio are much stronger. Considering the aerodynamic characteristics of a flying-wing aircraft, a sheet-beams side-force component and a big eccentricity ‘π’-shape drag-force component is used to effectively solve the problem of measurement of minor drag-force and side force. The test result is ideal. The design, calibration and application of this balance is introduced.

Key Words: flying-wing configuration, wind-tunnel test, force measurement balance
Development of six component digital balance

Zhao Liangliang¹, Hu Guofeng², Liu Litao³, Li Fuhua⁴

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Abstract

The output signal of conventional wind tunnel balance is an analogy signal, which has a magnitude of mv level. Then the transmitted measuring signal data from the balance is post processed by measurement and control system in the wind tunnel. Because of the remote transmission distance and complex electromagnetic environment, (for example, the signal line from balance body to data acquisition terminal is about 50 meters long in 8 meters ×6 meters wind tunnel and in order to decreasing interference the line is wrapped and shielded by wire netting when performing the propeller power tests), the balance data accuracy is seriously being interfered. Therefore, the concept of digital balance is promoted. The analogy signal is converted into digital signal directly when collected from the balance before it is processed in the backstage of the wind tunnel. The balance calibration is executed with TJZ-1 Rig, showing that the indicators of zero drift, component sensitivity coefficient, precision and accuracy conform with the data achieved by traditional methods. Meanwhile, the test results conducted in the 1.8 meters ×1.4 meters wind tunnel indicate that the precision of lift force, literal force, rolling moment, yaw moment components reach advanced indicators, while the drag force and pitching moment components approach the advanced indicators.

Key Words: digital balance; wind tunnel balance; electromagnetic interference; micro scale
The Development Technique of Thin Slab Strain Gauge Balance Based on Beams

SHI Yu-Jie¹, WANG Yu-Hua²

China Aerodynamics Research and Development Center, Mianyang, Sichuan 621000, China

Abstract

Sheet strain gauge balance is used to measure the hinge moment which applies on the control surfaces or the all moving airfoil of an aircraft, the force and the moment which apply on the aircraft parts are also measured by using the balance. Limited by the structure of aircraft, connection stiffness of thin slab strain gauge balance is insufficient compared with elements, so the accuracy and the precision of the balance is low. The whole thin slab is separated into multiple beams, because the single beam is successfully used on strain gauge balance. The new slab strain gauge balance based on multi-beam can improve the accuracy and the precision. The conventional approach, the FEA, and the result of test balances show that the technique is feasible. Now the development technique has been used on several tests in wind tunnel.

Key words: thin slab balance; thin slab; beam; development; accurate; high accuracy
Design Concepts of Fatigue Tolerant Wind Tunnel Balances

Author: Henry Bennett

The wind tunnel strain gage balance has been in use for over 60 years. They are designed to measure the three orthogonal forces and three orthogonal moments on a wind tunnel model. These balances are typically attached via their non-metric end to a support system such as a sting whilst the wind tunnel model is attached to the metric side of the balance. The operational wind tunnel with a scaled model installed is a very harsh environment. Models can subject balances to high steady state loads with very large dynamics. As a result, numerous balance failures have occurred in the last 60 years. Designing for fatigue must be an important consideration in the design of the wind tunnel balance. This paper will explore past deficiencies and some design concepts that will make for a more fatigue tolerant wind tunnel balance.
An Experimental Six Component Wind Tunnel Block Balance Using Optical Fibre Sensors

J.D. de Ponte\textsuperscript{1}, F.F. Pieterse\textsuperscript{2}  
\textsuperscript{1,2}University of Johannesburg, Auckland Park, 2006, South Africa  
\textsuperscript{3}P.M. Bidgood\textsuperscript{3}  
\textsuperscript{3}CSIR, Pretoria, 0001, South Africa

In order to meet the increasingly stringent requirements for wind tunnel balances, as expressed by the wind tunnel testing community, balance design philosophy needs to be further expanded to include alternative sensor, material, design and manufacturing technologies. These are required to not only improve performance, but also to reduce production costs and lead times. This paper outlines the design, manufacture and calibration of a six component block balance that uses Optical Fibre Bragg Grating (OFBG) sensors. The six component block balance uses the “\textit{two-groove}” optical fibre method of strain measurement. The two-groove method offers a simplified balance design with enhanced sensitivity, and/or higher stiffness, as well as low component interactions and total electromagnetic interference (EMI) immunity. The conceptual balance design was analyzed using the finite element method, after which a prototype was manufactured and then calibrated in order to evaluate the design. A major design driver was the minimization of component interactions.
Challenges on auxiliary balances for a 1-22 scale wind tunnel model design, manufacturing and measurement

Jan Schutten (NLR)
Ruben Nahuis (NLR)
Jason Barros (EMBRAER)

Abstract
A complete model of a commercial airliner was designed and manufactured by NLR for transonic wind tunnel testing. The 1:22 model houses several auxiliary balances measuring at least two local force components per balance. Mechanical design of some of the balance hardware proved challenging due to the small scale of the model. Furthermore, model deformations (e.g. wing twist) that occur in the tunnel can interfere with balance readings. Some balances are equipped with additional channels for measuring these interfering inputs. By applying interfering inputs in calibration and determining cross-terms, the interference is kept to a minimum.
Design, manufacture and commissioning of a new NLR 6-component rotating shaft balance for propeller tests at Delft University of Technology

Ruben Nahuis (NLR)
Jan Schutten (NLR)
Tomas Sinnige (TUD)

Abstract
A new 6-component rotating shaft balance was designed and manufactured by the Netherlands Aerospace Centre (NLR) for propeller tests at Delft University of Technology (TUD). The balance was designed according to the new NLR four spoke type standards and is equipped with a PCB to amplify the bridge signals before conversion from the rotating to the stationary domain. A unique feature of the balance is that it can be used in two orientations with two different propeller hubs, thereby maximizing its operational flexibility.

One of the core research activities of the Flight Performance and Propulsion group at TUD focuses on propeller – airframe integration. Experimental work is performed in-house using a dedicated propeller test rig in an open jet wind tunnel with a maximum flow velocity of 30 m/s. To provide reliable measurements of the propeller performance, rotating shaft balances are used. Compared to the previous rotating shaft balance used at TUD, the bridge outputs of the new balance should have a better signal-to-noise ratio.

The rotating shaft balance was statically calibrated by NLR, and has been used for a first reference test at TUD in the beginning of 2015. During this test, several vibrations were observed in the recorded bridge signals, superimposed on the expected outputs. Research in the electrical and mechanical domains on the complete system of balance, (air) motor and data acquisition followed. Static test results of the isolated balance and current status of this research on vibrations are presented in this paper.
Hollow 6-component balance for stator measurements

René Bosman, Jocco Dekker, Maritime Research Institute Netherlands (MARIN)

Maritime model testing increasingly involves detailed measurements on appendages and propulsors of ship models. In many test cases 2, 3 and 4 component balances are sufficient. However, a new hollow 6 component balance was needed to measure forces and moments on a stator in front of a propeller. Following requirements were taken as design challenges for the new balance:

- Capable to measure the maximum loads as shown in Table 1.
- No disturbance of the water flow around and before the stator
- Drive shaft of the propeller must be able to go through the balance.

A hollow balance as shown in figure 1 was designed and manufactured at MARIN. The balance is build up with 6 single MARIN miniature force transducers, a measuring ring for the stator and a mounting ring for attachment to the bearing housing of the propeller shaft. The balance was calibrated in MARIN’s calibration rig with 87 different load cases and 335 calibration steps. Force transducers in the balance are oriented like in a hexapod resulting in a dependent system in which all force transducers are loaded in case the balance is subjected to single force components like $F_x$, $F_y$, $F_z$, $M_x$, $M_y$ and $M_z$. A geometry matrix was used to translate the forces of the individual load cells into 6 independent variables describing the 6 components. A 6x27 calibration matrix is determined with multi-variable regression to correlate the 6 independent variables (calculated with the geometry matrix) with the applied loads.

After calibration, several check loads were applied. These check loads where all combinations of several components. The nature and magnitude of the applied check loads were based on expected loads during model testing. Both the errors of the back-calculated loads of the calibration and the errors of the check loads were determined and they appeared to be very similar. This gave sufficient confidence that the obtained uncertainties in the calibration were representative for this balance design.

The balance production process and calibration analysis will be described in the paper.

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<th>Component</th>
<th>Maximum load</th>
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<tr>
<td>$F_x$</td>
<td>15 N</td>
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<tr>
<td>$F_y$</td>
<td>60 N</td>
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<tr>
<td>$F_z$</td>
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<td>5 Nm</td>
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<td>2.5 Nm</td>
</tr>
<tr>
<td>$M_z$</td>
<td>2.5 Nm</td>
</tr>
</tbody>
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Table 1. Maximum loads

Figure 1. Hollow 6 component balance for stator measurements
Development of Micro Rolling Moment Air Bearing Balance

Xingju Xiang ¹, Hongqiang Ma ², Peng Liu ³

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Rolling moment measurement at micro level is important for small unsymmetrical model in wind tunnel test. Compared to conventional force tests, it is characterized by micro rolling moment load whose level is on the order of g.cm. In order to measure the micro rolling moment of small unsymmetrical model, the air bearing is used for model support and the balance is used for the rolling moment measurement of the model. Two different configuration of balance are designed and tested, which can measure maximal rolling moment of 0.1 N·m. Finite element analysis software ANSYS was used to calculate the stress and strain on balance. The pressurized air flowing support the air bearing and other five component loads on model. The air bearing, the balance and static calibration are described.

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2. Calibration
Application of High Precision and Large Range Load Adapter of Wind Tunnel Strain-gauge Balance Calibration System

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Abstract

This article expatiates on the design of high precision and large range load adapter for BACS5000 Balance Calibration System, and expatiates on some ways to optimize the structure, analyse structural stiffness by establishing a finite element model in the ANSYS WORKBENCH software. Using the Load Adapter accomplished the balance static calibration and got a favourable result.
Development of Fully Automatic Balance Calibration System

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This paper introduces the development of the automatic balance calibration system from three aspects. First, this paper expounds the overall scheme of the system, and the scheme of reset, loading, measuring subsystem in detail; Secondly, this paper introduces the installation process and debugging results in detail.; Finally, this paper sums up the key technologies in the process of the development of the automatic balance calibration system.
Research on the method of improving the accuracy of airfoil balance based on simulation calibration

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During the use of the balance, two additional components are generated in the 4-component airfoil balance due to the design and installation errors. These lead to the effect on the measurement accuracy. In this paper, a new solution is proposed. The accurate balance finite element model was established, the reasonable boundary and the load condition were set, and the grid was divided precisely using finite element simulation calibration method. Then the original components and the additional ones of the balance were simulated. So the unmeasured component coefficient and its influence on the other components were obtained. The simulation calibration formulas of the balance were compared with the experimental formulas. This method can provide more accurate formulas of balances. Finally, it is verified by the wind tunnel test. This method provides a new idea for the accurate measurement of the non six-component balance.
An Application of Balance Calibration Uncertainty Assessment Methodology

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Abstract

With the effort into standardization of balance calibration uncertainty assessment, a complete methodology is developed: firstly the uncertainty from calibration rig is assessed individually, then the uncertainty from other error sources is divided into bias limit and precision limit, and the residuals of checking loads is used to estimate them respectively. Finally the total uncertainty value is obtained with the combination of them. This methodology is also applicable to other calibration systems. At BCS-100 calibration system, balance TG624C has been calibrated seven times in repeat to apply this methodology, the uncertainty result from calibration rig shows the uncertainty components from all the inputs respectively, also the total uncertainty of every component load is obtained in the result and the regularity is demonstrated.
The Calibration Research of Series Skin Friction Balance

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Abstract

The calibration research of series piezoelectric skin friction balances is introduced in this paper. The series skin friction balances includes: the integrated cantilever beam skin friction balance, shear stress skin friction balance, the fit together skin friction balance, the under embedded skin friction balance, the upper embedded skin friction balance, and the improved shear stress skin friction balance. The precision requests for the calibration load mass and the direction of load are researched also. In order to compare the calibration result, a new bias limit calculation method is proposed. In this method, the bias limit was obtained by least square method line fit error with a contain factor, and the precision limit was obtained by the calibration precision with a contain factor. In the end, the uncertainty was obtained by square root of the bias limit and precision limit. The calibration results of the skin balance series are analyzed by this method. The calibration results showed that, the calibration uncertainty decreased gradually with the research course, suitable for the skin friction measurement with the hypervelocity vehicle in shock tunnel. In the uncertainty simple calculation, some error sources with unimportance are ignored, so the calculation time reduced, and the efficiency improved and the cost reduced. This method is applicable for uncertainty calculation of other types balance calibrations also.

Key words: skin friction balance; calibration; data processing; uncertainty
Development of high precision balance based on virtual calibration technology

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Abstract

In this paper, the concept of virtual calibration of wind tunnel balance is established. Based on finite element analysis software called Solidworks simulation, virtual calibration plug-in is developed. The plug-in unit integrates the function of strain output calculation, signal output calculation, first-order interference calculation, which improves the efficiency of balance design optimization greatly. In the development of balance for high aspect ratio aircraft aerodynamic force calibration model, various design schemes are fast calculated and analyzed by using this technology, and the optimization of the size and structure of balance is completed by repeated iteration. Using the virtual calibration, the first-order interference output of various components compared to main output is no more than 5.5%, and the actual static calibration is no more than 6.8%. Based on static calibration, accuracy of each balance component is 0.1%. So virtual calibration technology is successfully applied in the development of high precision balance.

Key words: Virtual calibration; Calculation and analysis; First-order interference; High precision
Error Analysis On Low-speed Wind Tunnel Strain-gauge Balance Automatic Calibration System

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Abstract

Wind tunnel strain-gauge balance is the key measuring device in the aerodynamic force-measuring test of aircraft in wind tunnel. Static calibration equipment is a special standard metering device for strain-gauge balance calibration. The performance of static calibration equipment effects the performance of balance, and then the accuracy of the test result. Error analysis is the key link when we evaluate the performance of the calibration system, which is also an important part of balance calibration uncertainty evaluation. This paper will mainly introduce the error of low speed wind tunnel Strain-gauge Balance Automatic Calibration System, including loading system error, balance installing error on load adapter, resetting system error, balance signal measuring system error.

Key words: Wind tunnel strain-gauge balance; calibration system; error analysis; uncertainty
The research on calibration and test with different condition in box-type balance

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Abstract

This paper gives the emulation strain outputs about box-type balance in different calibration state with finite element analysis (FEA) method. Through simulating calibration and test condition in different balance assemble requirement, we find the phenomenon about the rigidity of the balance's connection to measurement. Investigation were also carried out on the balance design, calibration and usage in low speed wind tunnel.

Key words: Finite Element Analysis (FEA); Box-type Balance; Typical Structure; Test
6-component strain-gauge balance calibration methods on 2-DOF deformation restore calibration device

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Abstract

2-DOF deformation restore balance calibration devices (2-DOF BCD) are still utilized in the calibration of wind tunnel balances in some wind tunnels of China at present. With those 2-DOF BCD, the cross-interaction coefficient between longitudinal and lateral components of balances could not be obtained by conventional calibration methods, because it’s impossible to simulate the longitudinal and lateral aerodynamic loads on balance at the same time during calibration. A special multi-component balance calibration method had been studied, in which the longitudinal and lateral loads are simulated simultaneously by alternate the rolling-angel of balance. A 6-component balance was calibrated with this method on a 2-DOF BCD of 1m wind tunnel of CARDC, and the calibration coefficients, including longitudinal/lateral cross-interaction coefficient, had been obtained. The preliminary analysis indicates that the calibration method is practical and results are reliable.

Key words: strain-gauge balance, balance calibration device, static calibration, calibration method
The TsAGI 6GS-40M automated balance calibration machine is intended for calibrating external and internal six-component strain-gauge balances designed for a maximum normal force of 40 kN. The rig was designed with the focus on calibrating the external balances of the T-128 transonic wind tunnel. It has a fitting rigidly attaching the balance to the rig’s mounting base. The loads applied to balances are specified in a normal-fixed axis system. As a result, the measurement coordinate system of the balance coincides with the normal system, and thus with the rear end of the balance. When applying loads balance deformation changes the angular and linear position of the calibration body relative to the rig, which leads to appearance of systematic errors.

Paper is devoted to the investigation of those systematic errors. The layout of the automated balance calibration machine 6GS-40M is presented and the main specific features of its design are described. The main sources of the systematic errors are considered. The design procedure of the deflection of the balance reference center during the calibration is given. Corrections to forces and moments due to the systematic errors are derived based on the analysis of rig and calibration body design. Estimation of the influence of systematic errors on calibration accuracy of the balance has been also done.

In addition, the calibration of the external balance has been carried out and the calculated corrections to the loads applied are represented in this paper. It is shown that the magnitude of these errors depends on the deflection of the strain-gauge balance being tested and the values of applied loads.
Wind Tunnel Balance Calibration: Are 1,000,000 Data Points Enough?

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Abstract
Measurement systems are typically calibrated based on standard practices established by a metrology standards laboratory, for example the National Institute for Standards and Technology (NIST), or dictated by an organization’s metrology manual. Therefore, the calibration is designed and executed according to an established procedure.

However, for many aerodynamic research measurement systems there is not a universally accepted standard, traceable approach. Therefore, a strategy for how to develop a calibration protocol is left to the developer or user to define based on experience and recommended practice in their respective industry. Wind tunnel balances are one such measurement system. Many different calibration systems, load schedules and procedures have been developed to address balances with little consensus on a recommended approach especially the number of calibration data points needed. Regrettably, the number of data points tends to be correlated with the perceived quality and often it is associated with ones ability to generate the data rather than by a defined need in support of measurement objectives. Hence the title of the paper was conceived to challenge recent observations in the wind tunnel balance community that shows an ever increasing desire for more data points per calibration that appears absent of rigorous methods to determine when there are enough.

This paper presents fundamental concepts and theory to aid in the development of calibration procedures for wind tunnel balances and provides a framework that is generally applicable to the characterization and calibration of other measurement systems. Questions that need to be answered are for example: What constitutes an adequate calibration? How much data are needed in the calibration? How good is the calibration? This paper will assist a practitioner in answering these questions by presenting an underlying theory on how to evaluate a calibration based on objective measures. This will enable the developer and user to design calibrations with quantified performance in terms of their capability to meet the user’s objectives and a basis for comparing existing calibrations that may have been developed in an ad-hoc manner.
Abstract:

Together with several companies the Technische Universität Darmstadt (TUD) formed a consortium to fabricate and sell automatic calibration machines for internal wind tunnel balances using the so called “TUD inverse principle”. This consortium up to now sold two calibration machines to research institutes in Russia. These machines are further developed versions of the TUD machine. A new control system for the pneumatic force generators is implemented and the master calibration setup is optimized for higher stiffness and better repeatability. For the master calibration a realignment system based on position sensitive devices has been developed to maintain exact direction of the horizontal calibration loads. The technological upgrades and some aspects of initial alignment are presented in this paper.
APPLICATION OF A GENERAL TARE PROCEDURE TO CALIBRATION OF INTERNAL WIND TUNNEL BALANCES

Borđe Vuković, Marija Samardžić, Dragan Marinovski

Abstract

In the process of calibration, internal wind tunnel balances sense not only the applied reference loads but also the tare loads due to the weights of the parts of the calibration equipment and weights of the parts of the balance body. Some of the contributions to tare loads, such as the weights of balance parts, can not always be determined by simple measurements. Moreover, the zeros of output signals of a balance usually do not correspond to zero loads, and, unfortunately, the ‘true’ zero-load offsets cannot be easily measured in a terrestrial environment, especially if a balance has pronounced nonlinearity, because it always senses at least its own weight.

It was suggested that measurements by the balance itself could be used to determine the ‘tare’ effects i.e. the tare loads and the zero offsets. Several balance-calibration algorithms were developed to exploit this concept. One of them, proposed by Galway and advocated in the AIAA Recommended Practice For Calibration and Use of Internal Wind Tunnel Balances requires zero offsets to be determined before the calibration, by averaging a series of measurements at symmetrical balance roll angles. Tare loads are thereafter assumed to be constant within each loading series in a calibration campaign, but varying from loading series to loading series in the calibration load set. In an iterative procedure, calibration matrix is computed by global regression and the back-calculated error residuals for the zero-reference-loads datapoints in each loading series are attributed to tare loads and added to applied loads for that loading series. The iterations continue, computing, in each pass, updated calibration matrix and tare-corrected loads, until a convergence to constant values occurs.

Another procedure, implemented in the software used at the authors’ wind tunnel site, was in some aspects similar to the Galway’s algorithm but, opposite to it, assumed that tare loads could be determined a-priori by measurement, while zero offsets could not and, besides, assumed that zero offsets were variable from loading series to loading series due to uncontrollable variations in environmental conditions and imperfections of the data-acquisition systems. Like the Galway’s algorithm, the author’s procedure computed the calibration matrix iteratively, using global regression over the complete calibration data set. However, the algorithm computed separate zero offsets for each loading series on the basis of zero-intercept terms computed in the least-squares fitting (Fig. 1).

Upon closer examination, both algorithms have deficiencies. Galway’s algorithm somewhat indiscriminately assigns part of the back-calculated error residuals to tare loads, while the author’s initial algorithm, equally indiscriminately, assigned part of the error residuals to variations of zero offsets. Both algorithms may thus achieve unrealistically good apparent ‘accuracy’ of calibration. Also, the author’s algorithm was at fault in ignoring the tare loads caused by the weight of the balance body, while the Galway’s algorithm optimistically assumes constant zero offsets and requires special measurements to determine them. These measurements can be impractical and disturbing for the process of calibration.

In order to overcome the observed deficiencies, a new variant of balance-calibration algorithm with tare-prediction capabilities was developed. It combines the iterative method of determining per-load-series zero offsets from the author’s old algorithm with a modified variant of the Galway’s general tare-prediction method that is used to determine zero offsets and tare loads in the pre-wind-on phases of wind tunnel tests. It is convenient for single-vector calibration setups in which the orientation of the balance relative to earth varies during the calibration, such as the recently upgraded rig at the authors’ site (Fig. 2) in which a single-force load is always applied vertically and the balance is rotated in pitch and roll in order to obtain the desired distribution of loads on balance components. Instead of indiscriminately attributing back-calculated error residuals during the iterative calculations of the calibration matrix to either the tare loads or the zero offsets (as previous algorithms do), the new procedure filters the tare loads from the back-calculated error residuals from all datapoints by the least-squares method, allowing only those variations that change with the sines and cosines of the pitch and roll angles of the balance. Zero offsets are then determined from the
parts of error residuals that can not be attributed to filtered tare loads. Allowing for slow drifts of zero offsets due to changes in the environment, separate zero offsets are computed for each loading series on the basis of zero-intercept terms from least-squares fitting. Special tare recordings for determining zero offsets are not needed during the calibration, so that the process of calibration is simplified. The algorithm also produces a ‘gravity matrix’ which can be used to simply determine tare loads in balance checkouts with load configurations and balance orientations that differ from those used in the calibration.

The new calibration algorithm is implemented as an option in the latest version of the balance-calibration software used at the site. Capability of the algorithm to capture both the tare loads and the zero offsets while computing a nonlinear calibration matrix was successfully demonstrated both on a simulated balance-calibration dataset and on several actual balance-calibration data sets.

In the tests with the simulated dataset a pronouncedly nonlinear calibration matrix for an existing direct-read balance was used to compute simulated balance signals from a set of values of ‘applied’ reference loads and tare loads due to the weight of the calibration body. Normally-distributed pseudo-random ‘noise’ was added to simulated signals to simulate the experimental errors and run-to-run variations of zero offsets. The software was then let to compute the calibration matrix and the tare effects. Computed per-run zero offsets were compared with the simulated values and were found to agree well within the measurement uncertainty of the balance which was declared as two standard deviations of the simulated datapoint-to-datapoint ‘noise’. Tare loads were deducted from the computed gravity matrix and were found to agree with the simulated tare weight. A predicted sensitivity of the computation of zero offsets to lack-of-fit errors with an unsuitable mathematical model was confirmed and the effectiveness of provisions to be applied in such case was tested and confirmed. Computation of tare loads was found to be insensitive to lack-of-fit.

In one of the tests with real data, a moment-type six-component balance were used. Zero offsets were determined both by the conventional a-priori no-loads measurements at symmetric roll angles and through the new algorithm. Tare loads due to the weight of the calibration body were determined by measurement of the body weight. Tare loads due to weight of balance itself were estimated through CAD software as, for a moment-type balance, it was clear which parts of balance-body weight were sensed by which component. Zero offsets and tare loads computed by the new algorithm were found to be in very good agreement with values obtained by separate a-priori measurements and CAD estimates, typically within 0.02 - 0.03% of full-scale range of balance components, i.e. well within the measurement accuracy of the balance.

On the basis of test results, the new algorithm was deemed to be suitable for application in the calibration of internal wind tunnel balances at the site and was put into routine use.

![Diagram 1](image1.png)  ![Diagram 2](image2.png)

**Fig.1** Different concept of determining zero offsets: a-priori, tare-loads-only measurement vs. least-squares-fit intercept (errors exaggerated for clarity)

**Fig.2** Concept of the balance-calibration rig at the authors’ site, with pitch-and-roll balance rotation and vertical single-force-vector loading

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A Study on Single-Vector Calibration Method of Wind Tunnel Balance

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Abstract: In order to improve the accuracy and efficiency of Wind Tunnel Balance calibration, a research on single-vector calibration method of wind tunnel balance was carried out. A single gravity vector is applied for generating six component loads on the balance. And by shifting the space attitude of balance and the load point position, incalculable combined loads are achieved. With the simple-loading method, the error sources of calibration system are fundamentally reduced. For satisfying the constraint conditions, the loads distribution has been optimized based on randomness and symmetry. The test results of the No.8 standard model indicate that the single-vector calibration is feasible and well meets the requirements of wind tunnel experiment.
3. Overview
Research on Hinge Moment Balance

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Abstract
This paper introduces a chip hinge moment balance with flat structure. It's suitable for installation in the control surface such as ailerons, elevator, rudder and so on. It's widely used in hinge moment test in low speed wind tunnel. Because of the limitations of the load and size boundary, the design, glues of strain gauge, calibration and application is much more difficult compared to conventional balance. Combined with the experiences of author, this paper mainly discusses the following problems:(1) Determination of balance component,(2) Choice of balance fixed end or floating end,(3) Selection of balance strain mode,(4) Virtual calibration and interference analysis,(5) Applicability of the results of the static calibration.

Key words: chip hinge moment balance; balance component; strain mode; virtual calibration; static calibration
Hinge Moment Balances Used in High Speed Aerodynamics Institute of CARDC

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Abstract

Hinge moment test is one of the most primary wind tunnel project, and the hinge moment balance is the core for measuring the aerodynamic forces and moments. There are many difficulties in hinge moment design, such as the balance configuration is not consistent by restricted model installation space, have stronger strike force in high speed intermittent wind tunnel test, and asymmetric balance temperature distribution, etc. The paper briefly describes the hinge moment strain gauge balances used in High Speed Aerodynamics institute of CARDC recent years, including horizontal axis shaft balance and vertical axis shaft balance, subsection micro-hinge-moment balance, three-component sheet balances and four-component sheet balances, and single-component balances, the balance structure, design point, results of the static calibration and the test, advantage and disadvantage are also may be found in this paper, in the form of descriptions, diagrams and photographs.

Key Words: wind tunnel test; strain gauge balance; hinge moment; development
Recent Investments in the National Force measurement technology capability

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Abstract:
The National Force Measurement Technology Capability (NFMTC) is a nationwide partnership established in 2009 sponsored by NASA’s Aeronautics Evaluation and Test Capabilities (AETC) project to maintain and further develop force measurement capabilities. The NFMTC focuses on force measurement in wind tunnels and provides operational support in addition to conducting balance research. Based on force measurement capability challenges, strategic investments into research tasks are made that are designed to meet the requirements of current and future programs and projects. This paper highlights recent and ongoing force measurement investments into several areas including recapitalizing the strain-gage balance inventory, developing balance best practices, improving calibration and facility capabilities, and researching potential technologies to advance balance capabilities.
A REVIEW OF WIND TUNNEL BALANCE TECHNOLOGIES WITH A LOOK TOWARDS THE FUTURE

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Wind tunnel balances have a rich history of development and innovation. Modern balances routinely meet the diverse requirements of aeronautic researchers. However, future aeronautical research is expected to challenge the capabilities of force balances when it comes to higher load ratios, harsh environments, cost, production time, and lifecycle management. In this work, we will review the materials, design concepts, sensors, and data acquisition systems used to develop wind tunnel balances. Recent advances and opportunities in each of these fields will be highlighted to provide perspective on how new technologies could impact future design, manufacture, and operation.
DESIGN, CALIBRATION AND COMMISSIONING OF A SMALL CRYOGENIC HIGH LOAD BALANCE FOR ETW

The European Transonic Windtunnel (ETW) is a pressurized cryogenic facility for high Reynolds number testing, enabling aircraft manufactures to test their designs at real flight Reynolds and Mach numbers under defined aeroelastic conditions. A high stability of test conditions, excellent repeatability and a wide test envelope of Mach and Reynolds numbers (Figure 1) are some of the main criteria for numerous customers for using ETW. The cryogenic environment combined with increased tunnel pressure at ETW is very challenging for all instrumentation equipment, but especially for the internal balances, which have to guarantee the excellent accuracy of measurement under various environmental effects.

Figure 1: Performance Envelope of ETW

The present paper presents the development and commissioning steps of a small cryogenic high load balance for ETW. Starting from the design goal through to the build of a high load performance balance to fit into slender fuselages of business jet type aircraft models, the paper briefly describes the design challenges, the precautions and checks which were done to verify the design before manufacturing. It will then focus on the steps necessary to convert an “instrumented piece of metal” into a fully functional six component balance for productive client test campaigns. The balance calibration in ETW’s automated balance calibration machine is covered as well as the loading checks, the commissioning wind tunnel entry and finally a first productive client test campaign.

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Review of wind tunnel balance calibration systems
Force Measurement Systems (FMS) division of
Triumph Aerospace Systems

Authors: Ryan Kew, Dennis Booth, Colin Harris

The various calibration procedures in use at our San Diego facility rely on hydraulic and manual loading calibration systems. The Automatic Balance Calibration System, (ABCS) Large Load Rig (LLR), and various manual load stands will be discussed as will a new pneumatic lifting system that was recently added for manual loading of weights.

has always done what many refer to as Dead Weight Loading to complete the calibration procedure for internal strain gage balances. Typically after a balance is hydraulically loaded in the Automatic Balance Calibration System (ABCS), the calibration is verified by manually loading with steel weights. This is a necessary but labor intensive process to confirm the data reduction matrix generated by the ABCS is valid.

In early 2014, FMS commissioned an Indeva Industrial Manipulator Liftronic® Air system featuring pneumatic lifting force and electronic control. This lifting device has been optimized to pneumatically engage / disengage industrial strength magnets that lift the weights. The stabilization and lifting assist aspects of this system now makes lifting and maneuvering weights a one man job. The weights are easily positioned with minimal operator input and the need to bend at the waist to pick up the weights has been eliminated.
4. Others
Developing of the Five-Component Load Cell for the Test Rig for Mass, Mass Center Coordinates and Inertia Moments Determination of Objects

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The focus of this abstract is the design and the principle of operation of the novel five-component load cell for determination of vector components Mx, My, Mz and force components. Because of choosing the design scheme and strain gauge bond points reference point of load cell transferred to design point on OX axis.

Application of such load cell in test rigs for mass, mass center coordinates and inertia moments determination of objects increase the measurement accuracy in comparison with previous engineering solutions at the expense of transferred reference point of load cell to the mass center of object and measurement in addition to side forces.

In addition, the original combination of design and positioning of strain gauges led to reduction of inaccuracy provided by fluctuations of object around the mass center.

The measurement of side forces and is the important feature of load cell. Consequently, the equations of mass coordinates measurement become invariant to the inclination angle of object. It is reducing the inaccuracy provided by deformations of beams of load cell and initial adjustment of object.
The influence of assembly stress of a cassette balance on the measuring results in half-model test

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If the designing sizes of element and joint are improper, the assembly stress which is produced during installing process of cassette balance, will interfere the outputting value of measuring element, and then affects the accuracy of result. Aiming at the wild range half-model cassette balance, on the premise of the overall of balance with no changing, by altering the different conditions of bolt which are distributed on the float box and the thickness of the float box for simulation and analysis with finite element while installing cassette balance. The results show that both the assembly stress and the thickness of the float box will impact the measuring results. Therefore, we should try to balance the assembly stress of wind tunnel balance, and choose the suitable thickness of the floating frame to improve the accuracy of measuring result in the test.
The Research of the Deployment Parachute Dynamometry for Emergency Escape Parachute based on the Six Components Balances

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The purpose of this paper is devoted to research the stick six component balance in the emergency escape parachute airdrop test. According to the low speed and high speed airdrop experiment, we find the obvious difference of the two experiments. Later on, the six components balance is designed to install in the chest of dummy, which can measure the force and torque in three directions. Lastly, an airdrop experiment is conducted to investigate the effectiveness of our proposed balance. And the analysis of comparison between six components balance and centroid overload sensor or drawing force sensor has been exhibited. All the experiments are presented to demonstrate the six component balance can veritably reflect the performance of the emergency escape parachute.
Experimental Research on Symmetrical Temperature Compensation of Small Size Bar-shaped Fiber Optic Balance

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Abstract

The experimental research on symmetrical temperature compensation of small size bar-shaped fiber optic balance has been carried out in the paper. Combined with the characteristics of fiber optic strain gage and three-component balance, a symmetrical temperature compensation is proposed. Then, the theoretical derivation of symmetrical compensation algorithm is carried out, and the effect of compensation is checked by static experiment. The finite element analysis and theoretical derivation prove the rationality of symmetrical temperature compensation; and the static experiment result indicates that the compensation is obviously effective, since the heat output of fiber optic strain gauge is only 0.62% of the output without compensation.

Key words: fiber optic balance, symmetrical temperature compensation, simulation, static experiment
The thrust vectoring control (TVC) technology makes the aircraft possess the ability to fly in post-stall maneuver. It is very important to break through the aircraft's obstacle stall, to enhance the aircraft's mobility and to improve the aircraft's take-off/landing, cruise performance. In 2.4mx2.4m transonic wind tunnel TVC test, a kind of wind tunnel balance measurement system is developed and applied. In the system, three six-component strain-gauge balances and two separate air systems are applied to measure the performance of the whole model and nozzles. The maximal normal force of the balance used to measure the whole model’s load is 15000N. The maximal normal force of the balance used to measure the nozzle’s load is 1200N and the maximal axial force is 800N. In air system the maximal pressure that the bellow need is 2MPa. During the course of design, the strains of balances and balance with air system in various conditions are generated by finite element simulation method in ANSYS software. Both calibration results and wind tunnel test results demonstrate that the balance meets all requirements of thrust vectoring Test.
The Influence of Measurement Range and Loads on the Accuracy of Sting Balance

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Abstract

In several wind-tunnel experiments, we found that there exist errors when measuring small loads using balance with large measurement range. To investigate this problem, a six-component sting balance is loaded with both large and small loads in static calibration. It is found that the magnitude of loads in static calibration has no significant effects on the accuracy of balance. There exists nonlinear interference when measuring small loads, however, its magnitude can be neglected.
A Study of the Long-Time Stability of the Cryogenic Six-Component Balances of DNW-KKK

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To ensure the test quality, a wind tunnel balance should be calibrated regularly. Though the measurement properties of the balance body gets better with the time, ageing of the adhesive and carrier materials of strain gages occurs also. In order to determine a proper calibration interval, it is necessary to investigate the long-time stability of balances. In this paper the stability of the balance was analysed based on the three cryogenic wind tunnel balances of DNW-KKK.

The first cryogenic balance was manufactured by Airbus Bremen. It was manually calibrated in 1988. Eight years later it was calibrated using the ETW automatic calibration machine. The change of the direct factor is shown in Fig. 1. Though different method and facility were used, the maximum difference is less than 1%.

The second balance was first manually calibrated by the Modern Machine and Tools in USA. Almost 20 years later it was calibrated using the ETW automatic calibration machine. The change of the direct factor is shown in Fig. 2. The maximum difference is less than 0.4%.

The third balance was used most frequently. It was calibrated four times. The first calibration was performed manually at TU Darmstadt in 1993. The rest three calibrations were done using the ETW automatic calibration machine. The change of the direct factor is shown in Fig. 3. The maximum difference is less than 0.8%. When using the same facility, the maximum difference is less than 0.1%.

![Fig. 1 Change of the direct factors of the balance W609 in 1996 to the first calibration in 1988](image-url)
Fig. 2 Change of the direct factors of the balance W612 in 2009 to the first calibration in 1990.

Fig. 3 Change of the direct factors of the balance W614 to the first calibration in 1993.
Compact air-line bridge system for propulsion intergration in DNW-LLF

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Nomenclature

\begin{itemize}
  \item \textit{DNW} = German Dutch Wind tunnels
  \item \textit{\textit{C}_D} = Drag coefficient (in wind axis system)
  \item \textit{NLR} = Netherlands Aerospace Centre
  \item \textit{LLF} = Large Low speed Facility
  \item \textit{AoA} = Angle of Attack
  \item \textit{RALD} = Air-line bridge
  \item \textit{TPS} = Turbofan Propulsion Simulator
\end{itemize}

I. Abstract

PROPULSION integration is one of the key assets of the German Dutch Wind Tunnels (DNW) in its high-speed and low-speed facilities. DNW has not only specialized in Turbofan Propulsion Simulators (TPS), also propeller simulation has been applied for multiple aircraft development programs in the last decade. A variety of test setups and techniques has been regularly applied to investigate the influence of propellers and their downstream on the performance of aircraft. At DNW's large low speed facility (DNW-LLF) multiple test campaigns were conducted including A400M, E-2D Advanced Hawkeye, Clean Sky L-CER (Large Counter Rotating Open Rotor), NICEFTRIP and MA700. Driven by model size limitations a more compact air-line bridge system has been developed along the route.

Simulating modern propellers requires a relatively high torque to achieve the necessary advance ratios. Given the typical model scales and testing conditions at DNW-LLF until today only air motors can provide sufficient power. To get the compressed air to the motors the air-supply lines have to cross the internal balance. This necessitates an air-supply technique that minimizes parasitic forces and moments introduced by bridging the balance and by the momentum of the compressed air flow.

The exhaust of the air motor does not scale appropriately with the exhaust flow of the full scale engine. Exhausting the air directly after passing the air motor would mostly result in a too large model engine exhaust flow and momentum. This would cause interaction effects on the wing and high lift devices that are not similar to full scale. The simulation is improved by returning the exhaust flow of the air motor through the model and the model support. Returning the exhaust air through the model implies that a mass flow needs to pass the internal balance again. Therefore also an air return line is needed.

The required air-line bridge concept to supply and return compressed air to a model engine has been developed at DNW/NLR and is presented in ref \cite{1}. This system is designated RALD 2000 (air-supply line bridge) and RALD 2001 (air-return line bridge). The new air-line bridge system reported in this paper elaborates on the existing concept with increased compactness. The new system is named RALD 2007 and RALD 2008 for the air-supply and air-return line bridge respectively. Figure 1 shows both systems illustrating the attained size reduction. Most recently the compact system has been applied for the Chinese MA700 aircraft development program.

The paper shows the minimized parasitic influence of the new air-line bridge system on the main internal balance applied in the MA700 model. The different steps to correct the remaining parasitic effects are presented including an uncertainty analysis of the applied corrections. Since the compact air-line bridge system was applied in combination with the same balance for multiple test campaigns it is possible to investigate the “long-term” behavior of the system. Figure 2 shows the error in \textit{C}_D as a function of the angle of attack for different mass flows through the system during two test campaigns. The error bands indicate the error propagation in \textit{C}_D of the 3\% uncertainty of the main balance calibration. A direct repeat of the reference measurement of the second test is included to indicate the repeatability for a measurement without mass flow through the air-line bridge system.

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References:

Figure 1: The compact air-line bridge system concept (right) side-by-side with the original air-line bridge system.

Figure 2: Error in $C_D$ for an operational air-line bridge system.
Effect of Boundary Layer of Balance Platform on an Under Floor External Balance Data of a Half Model

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While using an under floor external balance to measure the forces acting on a semi span wing model, there is always a requirement to keep some gap between the model and the balance platform of subsonic wind tunnel. There seems to be no universal school of thought to define that gap/spacer height for half models attached with the external balance's platform. Moreover, no hypothesis is there which drives the difference in the results obtained from the balance. Moreover, the balance measurement data at low speed is missing for semi span model of a wing in which the said gap is equal to average value of the estimated boundary layer thickness. The present study focuses on the quantitative comparison of the balance data by defining physical gap between the model and the balance platform. Based on this comparison study at different Reynolds numbers for an array of positive as well as negative angle of attacks, it was found that the said gap has a significant effect on the balance data at moderate and high angle of attacks; specially on the windward side of the wing. It has also been found that the change in velocity has also significant contribution towards overall change in the aerodynamic and static longitudinal stability coefficient.