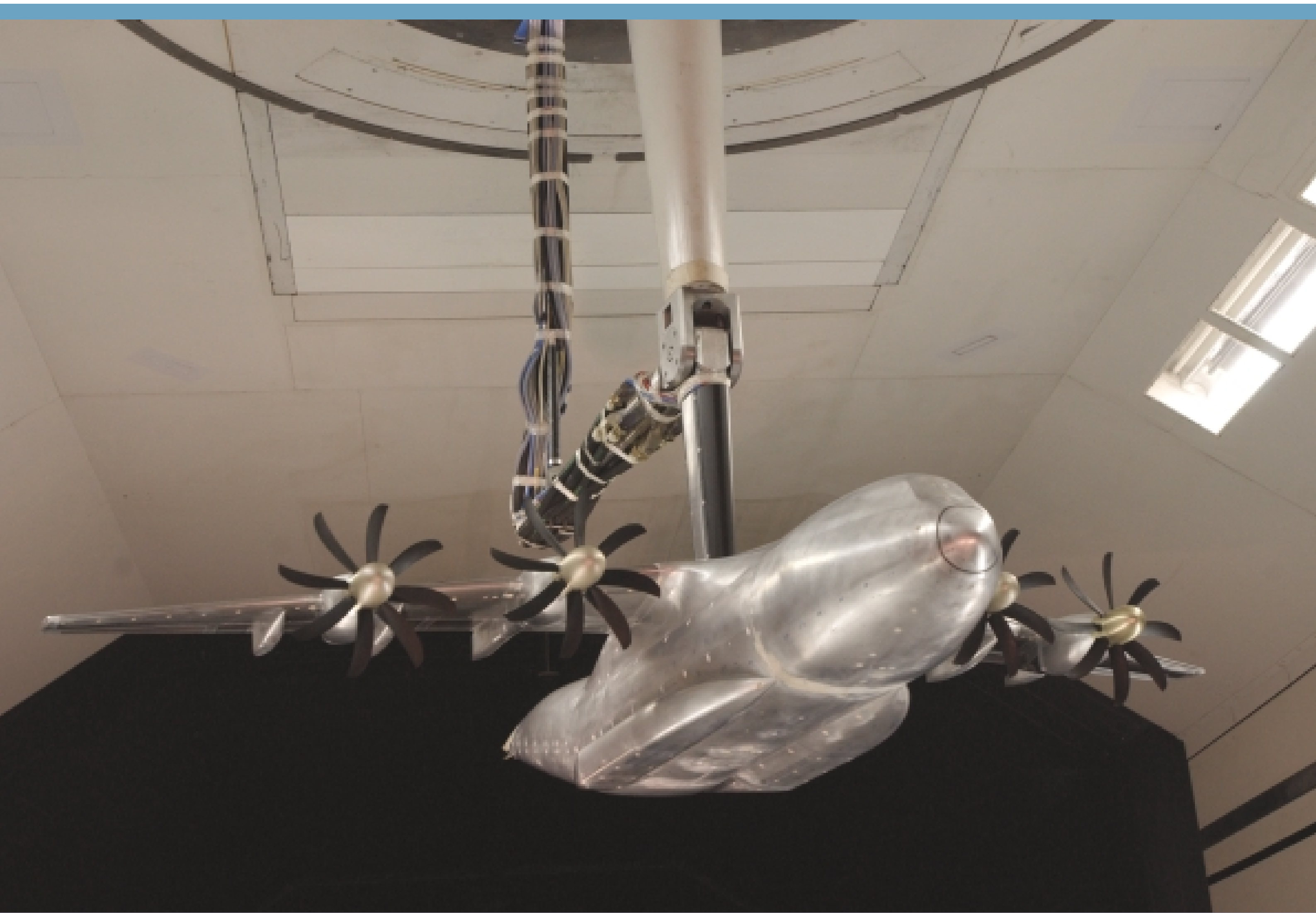
RUAG

Aerospace Defence Technology

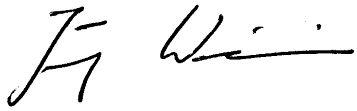


Center Aerodynamics – Newsletter 9 – Fall 2004

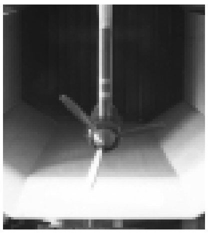
Tradition – Experience - Innovation

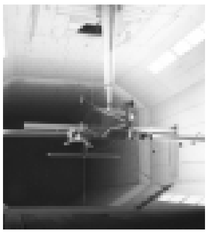
Wind tunnel tests with propeller aircraft have a long history in the Emmen wind tunnels. The facilities were built in 1946. The first test campaigns dealt with the powerful propeller fighter-aircraft of that time. Since those early beginnings, the main challenge of propeller propulsion simulation in wind tunnel tests has remained the same: provide model engines of high shaft power and high RPM, which are compact enough to fit within the geometrical dimensions of the model. Electrical, air or hydraulic motors are commonly used for this purpose.
With the increasing power to size ratio of modern aircraft turbines, the practicality of electrical motors to power the propellers of wind tunnel models becomes limited, especially for the simulation of take-off and climb configurations. RUAG preferred alternative is the use of hydraulic engines. Our latest development in this field culminated in the routine operation of a four engine simulation system consisting of very compact high performance hydraulic engines, their oil supply, the engine control unit, the balance crossing system and a powerful and fast data acquisition and evaluation system. The core elements of the system are developed in-house and tailor-made to the specific customer needs. Our summer 2004 newsletter provides a deeper insight in the systems and procedures used to test the powered model of the Airbus A400M transport aircraft in our large subsonic wind tunnel.

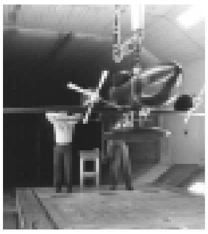
The experience of our staff – engineers, mechanics and IT experts – our innovative thinking and efficient work completion are the fundamental elements of our competitiveness and customer satisfaction. We look forward to collaborate with you in solving your specific wind tunnel requirements for aerospace and automotive test work.

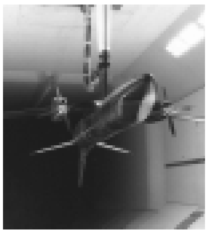


Juerg Wildi









High Thrust Propeller Wind Tunnel Testing

Minimum Body Engine and Propeller Test

Introduction

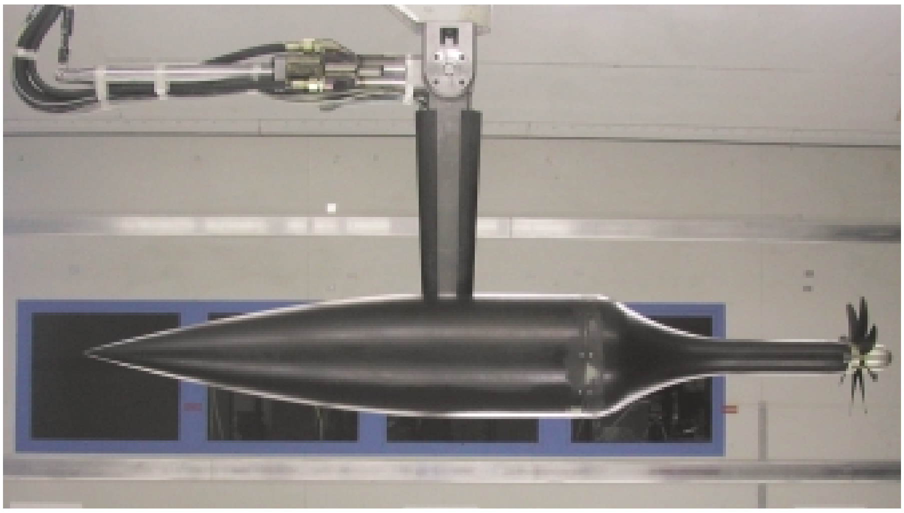
During the development of heavy propeller aircraft such as the Airbus A400M, a large amount of wind tunnel testing is performed. Part of this work is used to investigate the effect of the propeller on the airframe and the stability of the aircraft. These influences are usually difficult to predict with sufficient accuracy with theoretical methods alone.

Wind tunnel tests with powered models are thus required to provide the necessary data. To help with the interpretation of the results, the aerodynamicist is often also interested in knowing the performance of the propeller alone, that is without interference from the airplane flow field itself. The special wind tunnel configuration used to obtain this data is known as a «Minimum Body» setup.

Description

The Minimum Body test setup as installed in the Large Wind Tunnel Emmen (LWTE) consists of an aerodynamically shaped body, which contains the engine, the balance and other instrumentation. An extension shaft puts the propeller sufficiently far upstream of the body so that aerodynamic interference from the body is reduced to a minimum. The whole setup can be pitched and yawed and allows the determination of the propeller characteristics under various power and flow conditions.

The propeller is powered by a hydraulic engine with the same design as those used in the wind tunnel model itself. The forces and moments on the propeller are measured by the main balance with its integrated hydraulic crossing system. A multi-channel slipring assembly for the transmission of propeller data, a rotary shaft balance, a fast data acquisition system and an engine control system complete the Minimum Body setup. The modular size of the Minimum Body allows it to be adapted to a large range of propeller sizes and power requirements. In the following, the system as used for the Minimum Body testing for the A400M model is described in more detail.



Minimum Body test setup in the wind tunnel

Subsystems

Hydraulic engine

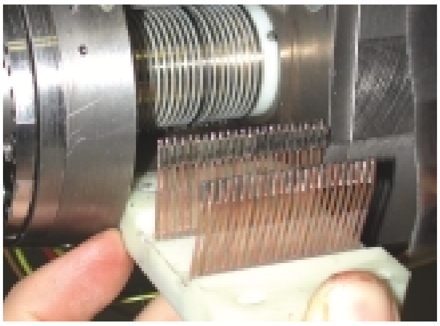
Engine

The engines are based on commercial axial piston hydraulic motors, which are driven by high hydraulic fluid fed from a tunnel external source. The current engine, developed for the A400M model, delivers up to 37 kW (50 hp) shaft power at a rotational speed of 12’000 rpm in a package of approximately 100 mm in diameter and 150 mm in length. Low motor temperatures of below 90°C are achieved by cooling part of the hydraulic return flow. Thus, the need of additional cooling lines is avoided, which reduces the number of hydraulic installations in the model.

The engines have proven to be very reliable and basically, unlimited operation is possible, even at high power. The engines are capable to run clockwise and counterclockwise with only minor modifications. The concept is scalable and currently a 100kW engine with a maximum speed of 9’000 rpm is being considered for another application.

Slipring

Mecanex, a company of the RUAG Holding, specifically developed a slipring with two carbon brush blocks for the present application. The available 23 channels are used to supply the power and transmit back the measured signals for the instrumentation located in the rotating propeller hub. In the present application, the instrumentation consists of a 6-component rotary shaft balance and strain gauges in two of the propeller blades. A small flow of pressurized air is used to cool the slipring and the brushes for reduced wear.



23-channel slipring assembly

Rotary Shaft Balance

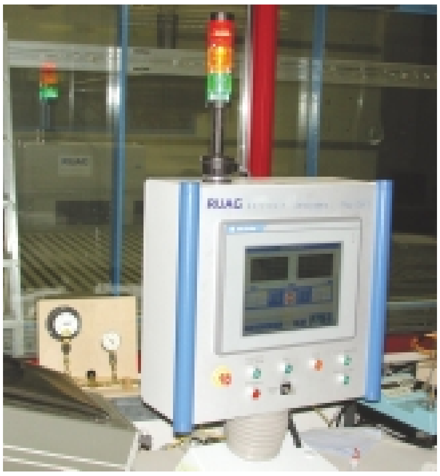
A rotary shaft balance is mounted between the engine shaft and the metric propeller-spinner assembly. The balance rotates at a maximum of 12’000 rpm. The gauge signals are averaged and processed in the fast data acquisition system to obtain the body fixed forces and moments.

Fast Data Acquisition

The propeller data is acquired through a dedicated high-speed data acquisition system, which allows the simultaneous measurement of multiple 16 bit channels at 12 kHz.

Balance Crossing System

In parallel to the rotary balance located in the spinner of the propeller, an internal 6-component block balance is installed in the Minimum Body. The main balance either provides a cross-check for the data obtained from the rotary balance or alternatively allows a simplified test setup without the complexity of the rotary balance. The supply lines containing the pressurized hydraulic fluid (over 300 bar, 4500 psi), which power the engine and the return lines have to cross the balance from the tunnel fixed to the metric side of the model without inducing excessive and uncorrectable forces and moments on the balance. This requirement was achieved with the current design, which is also used for the wind tunnel model itself.



Control system

Engine Control System

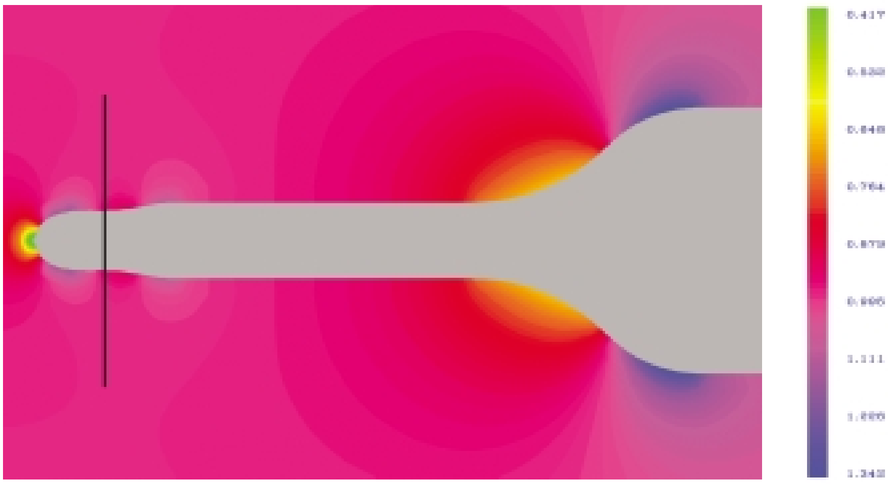
The engine control system is designed to handle up to four individual engine-propeller assemblies. In the present case, for the Minimum Body test, only the rpm of one engine needs to be monitored. With the current engine, the rpm is maintained to an accuracy better than ±20 rpm at high speed (12’000 rpm) or even ±10 rpm at medium speed (6’000 rpm). Additionally, the engine control system constantly checks important and critical parameters and even sets off an alarm or initiates a safe shut down if any of the parameters exceeds pre-set values.

Measured Values

Although specific measurement requirements may vary from customer to customer, most of the instrumentation is common for all the tests. The main interest lies in the forces and moments induced by the propeller, measured either with a rotary shaft balance or the main balance inside the Minimum Body. For detailed propeller blade analysis, the customer may equip certain blades with strain gauges to measure their dynamic bending and torsion behavior. Pressure information may be acquired on the non-rotating surfaces of the Minimum Body, for example pressure information in the propeller wake or inside the gap between the engine and the rotating propeller hub. Vibration levels may also be of interest and are often measured with accelerometers on the engine itself. Other data, also necessary for the engine control system and the data processing, are the accurate engine rotation speed, propeller position (rotation angle), engine pressure and various temperature data.

Flow Quality

The shape of the Minimum Body was designed so that the velocity disturbance of the main body in the propeller plane is less that 2% of the free stream velocity for an incoming flow perpendicular to the propeller plane. This while keeping a rigid, mechanically stable and accurate system.



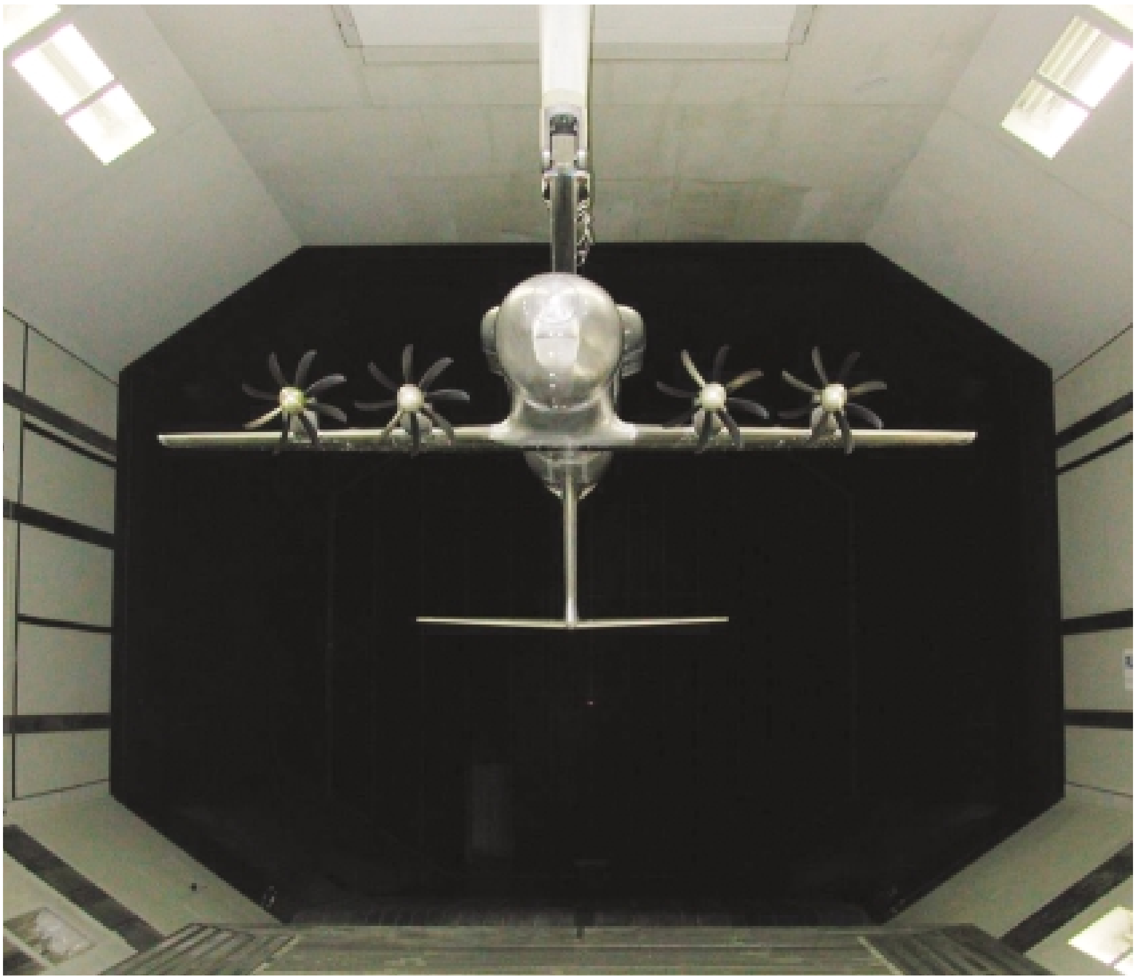
Velocity distribution along minimum body

The Minimum Body test setup available at LWTE is an ideal tool for manufacturers of aircraft, engines and propellers to investigate and optimize the performance of their product in a well-controlled wind tunnel environment.

Powered Wind Tunnel Tests for the A400M

The A400M is the new military airlifter currently being developed in a joint effort by 5 European consortium partners. RUAG Aerospace is working closely with its customer EADS-CASA, who is responsible for the investigation of the aerodynamic characteristics of the airplane in the low speed range. Since 1997, different models of the A400M have been tested in RUAG Aerospace's Large Subsonic Wind Tunnel Emmen (LWTE). The exploration of the high-thrust effects of the propellers on the aerodynamic characteristics of the airplane are an important part of the test requirements.

The 1:15 scale model is equipped with 4 hydraulic engines to power the propellers. These engines, developed by RUAG Aerospace, are capable of delivering up to 37 kW each at a rotational speed of 12'000 rpm without run-time limitations. The propeller are equipped with rotary balances provided by ONERA to measure the 6 force and moment components. The crossing system around the internal main balance assures the supply of high pressure oil to the engines with minimal interference on the balance measurements.

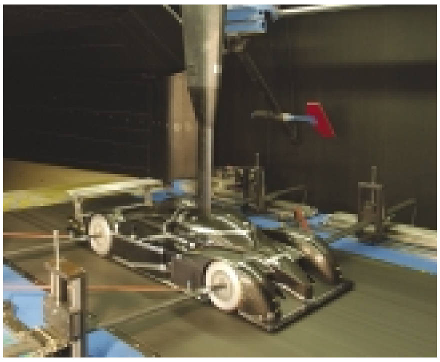


A400M, 1:15 scale wind tunnel model

Recent Activities

Team Bentley

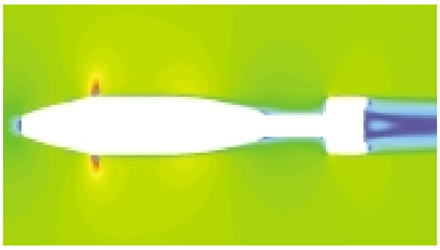
In 2003, Team Bentley achieved a remarkable score in the world famous Le Mans 24 Hour Race. A double victory, new distance and lap-time records highlighted the excellent performance of both the team and its two «Bentley Speed 8» cars.



Racing Technologies Norfolk Limited (RTN) was responsible for the development of the car, with Chief Designer Peter Elleray spending many hours in the Automotive Wind Tunnel Emmen (AWTE) optimizing the car aerodynamic shape. The 40% model was extensively tested at different attitudes to simulate the effects of accelerations, decelerations and cornering. The results obtained on the moving ground facility at speeds up to 210 km/h were later fully confirmed by tests on the track and during the race.

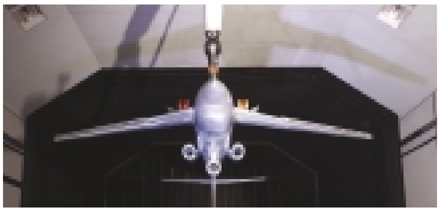
MAPAM Wind Tunnel Tests and CFD

MAPAM stands for Mortar Anti Personnel Anti Material. It is a highly effective 60mm mortar round for light infantry troops. In order to achieve a maximum operation range of 3500 meters and guarantee a stable flight with different fuze shapes, several wind tunnel tests and Navier-Stokes flow calculations in high subsonic speeds were performed. Today, the MAPAM round has successfully passed qualification and type classification for the Swiss Army and is currently undergoing a full-scale program qualification for the US Army. The MAPAM is a product of RUAG Munition.



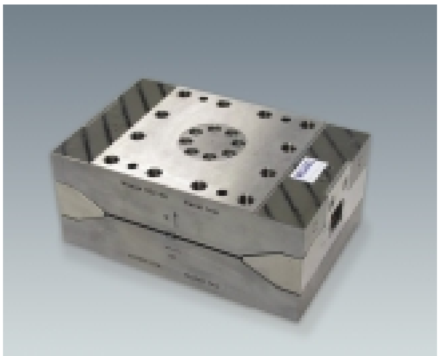
Dassault

Dassault is developing a new business jet: the Falcon F7X. The aerodynamic definition of the new airplane has been completed and an aerodynamic database has been generated. For the low speed segment of the flight envelope, the necessary aerodynamic data was obtained from wind tunnel tests performed in the LWTE facility. The campaign with the specifically built model included various support setups and model configurations.



New 6-component balance for high loads

With its brand new design, the latest RUAG Aerospace 6-component balance offers similar external dimensions and interfaces as the base models used so far. But a gain in the measurable load range of up to four times was achieved to respond to the most demanding test conditions, for example the use in pressurized wind tunnels.



In contrast to the current balances where strain gauge beam arrangements were used as metric elements, the new balance, extensively optimized through finite element analysis, is based on a mono-bloc structure and incorporates a newly designed, trapezoidal metric element. In addition, special material treatment increases the allowable stress by a factor of two.

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