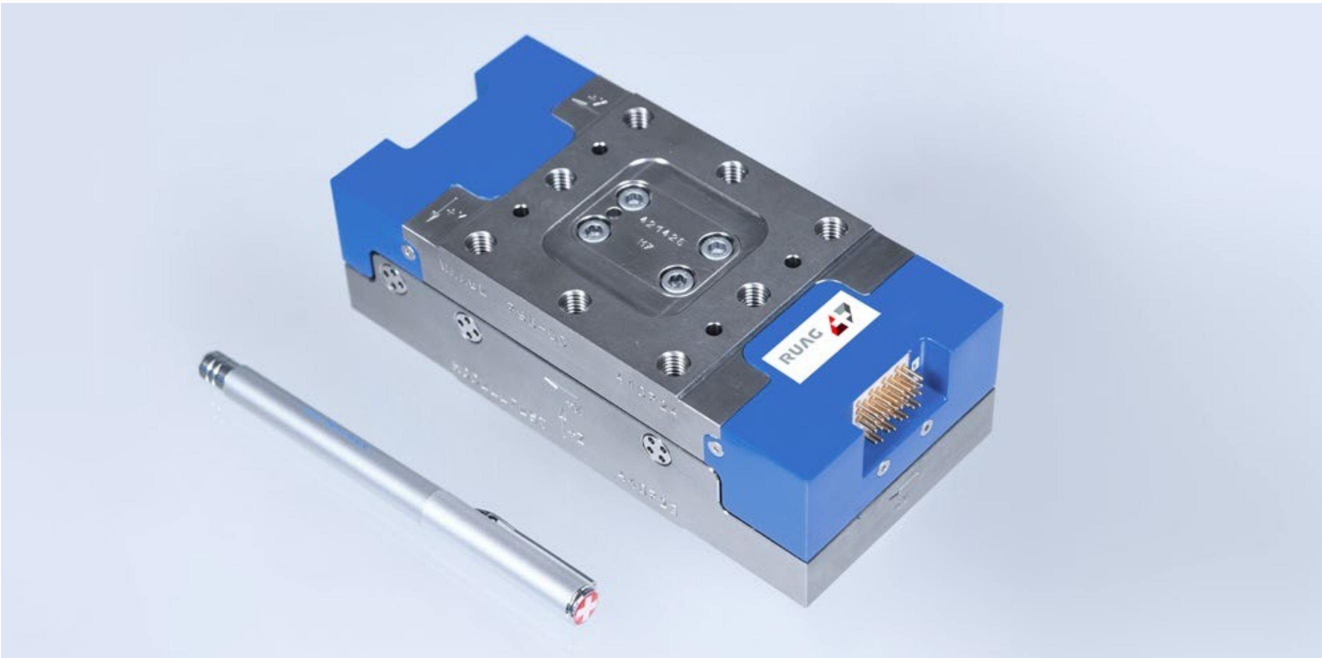
AERODYNAMICS

Strain gauge balances for high loads: Precise – stiff – reliable



↗ Using the latest technology available the well-known family of RUAG block-type balances has been optimized for precision, stiffness and high loading.

BALANCE FAMILY OPTIMIZED FOR PRECISION, STIFFNESS AND HIGH LOADING

Compared to the previous generation of balances with which they essentially share the external dimensions, the load ranges are now about two to four times higher. Even though the stiffness in both the translational and the rotational directions has been further increased the balance family has been optimized to be more precise and accurate.

The Aerodynamics Department of RUAG can look back on many decades of experience in designing, manufacturing, and operating strain gauge balances. These balances are primarily used in RUAG's own wind tunnels but are also well received by customers in wind tunnels and other test facilities all around the world for applications as diverse as aerospace, automotive, civil engineering, education, and others.

DESIGN, CALIBRATION AND PRECISION

The principal and well-proven design concept has been much refined using today's available tools for design optimization.

Strain gauges at carefully selected and designed locations on the balance measure the strain produced e.g. by aerodynamic loads and the model weight on the metric side of the balance. The gauges are arranged in seven Wheatstone bridges with integrated temperature compensation. Thus, seven data acquisition channels are required to determine the unknown six loads (three forces and three moments); four channels are dedicated to the vertical loads (normal force or lift, pitch and roll moment), two to the lateral loads (side force and yaw moment), and one to the axial load (axial force or drag).

Extensive theoretical, computational, and experimental analyses led to design features which reduce the interferences between the load components, diminish local and overall deformations, and increase the safety factor by limiting local stress concentrations in the critical areas. The material of the balance, its conditioning, and the strain gauges are chosen to minimize hysteresis and creeping behaviour and thus to further reduce error sources. In addition, all balances are equipped with very precise temperature sensors on both the metric and the non-metric parts. Since the balance is also suited for measurements with highly dynamic loads, extensive fatigue analyses and testing were performed for the most critical elements to determine the admissible number of load cycles.

The relation between the electrical output signals of the strain gauges and the applied loads is determined by a balance calibration. About 400 precisely defined and distributed load combinations are applied to the balance and the signals of the gauges are measured with a high precision data acquisition system. The calibration and many tests in wind tunnels confirm

the design goals: small interferences, high linearity and an accuracy in the order of less than 0.05% for combined load cases[1]. The highly linear characteristic of the balance allows the use of a linear calibration matrix which considerably simplifies data processing and thus improves test performance. The accuracy can be further improved (better than 0.03 %) by using a second order nonlinear matrix which additionally considers statistic criteria to eliminate linear dependencies and insignificant terms.

[1] The relative accuracies are referred to design loads.

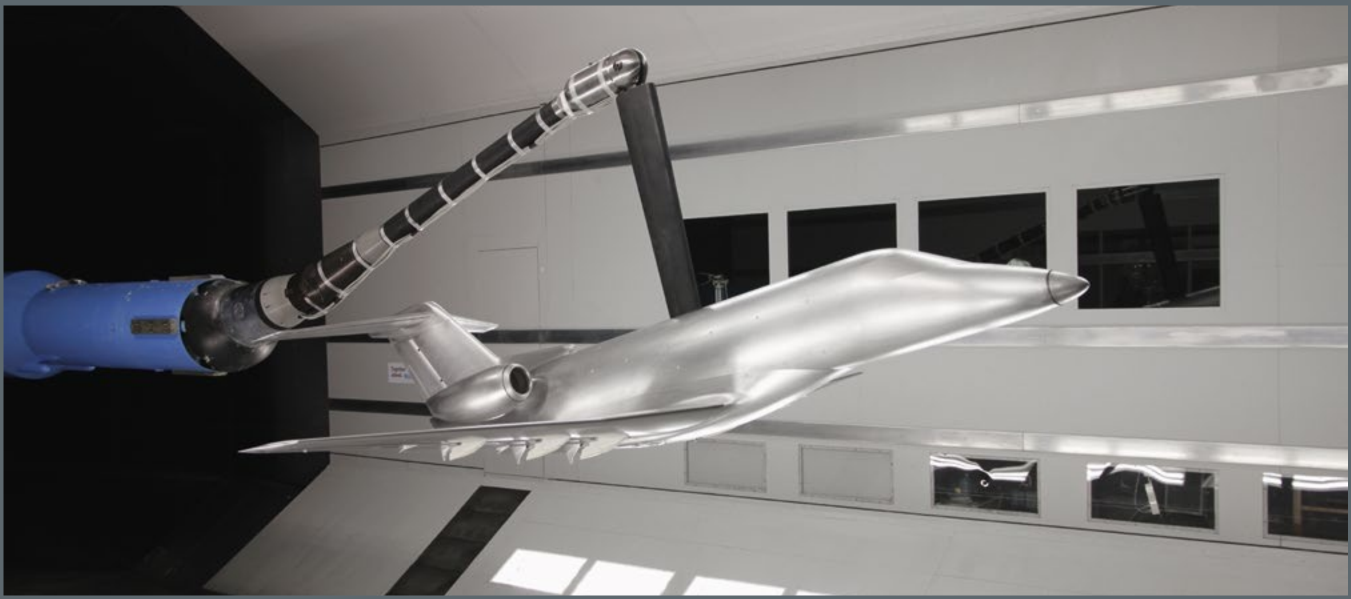
FURTHER READING MATERIAL

Case Study (HBM):
https://www.hbm.com/en/9242/wind-tunnel-testing-at-ruag/

Application site (HBM):
https://www.hbm.com/en/4686/wind-tunnel-testing/

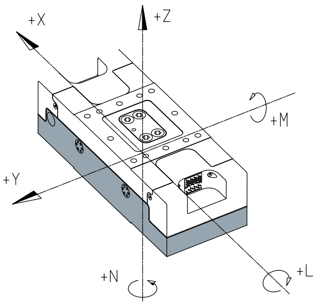
Article (Cosworth):
https://www.cosworth.com/news/electronic-news/wind-beneath-motorsports-wings/

Case Study (Cosworth):
https://www.cosworth.com/electronics/case-study-ruag/



BALANCE SELECTION

Balance selection is a decisive step during the definition of an experiment, be it in the wind tunnel or any other test facility. An inappropriate balance selection either causes overload conditions possibly resulting in damages to the precious balance or the absolute measurement precision is unnecessarily reduced as the balance range is not utilized optimally.



X = Axial force
Z = Normal force
Y = Lateral force
L = Rolling moment
N = Yawing moment
M = Pitching moment

■ = Metric part
□ = Non-metric part

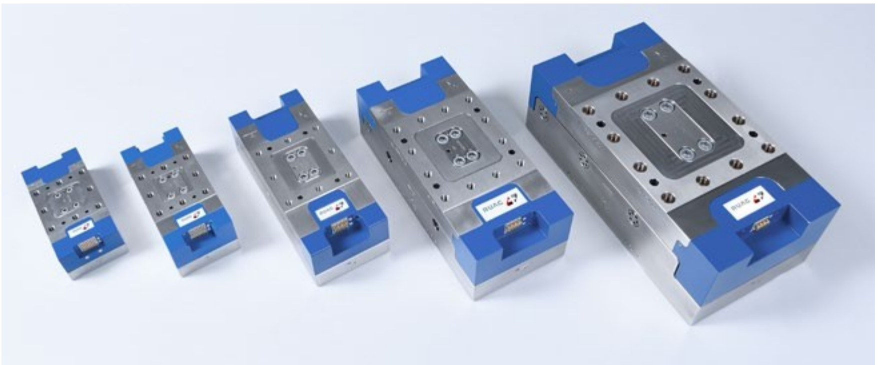
A balance is suitable if the following criteria are fulfilled:

$$\left|\frac{X}{X'}\right| \leq 1.0, \qquad \left|\frac{Y}{Y'}\right| + \left|\frac{N}{N'}\right| \leq 1.0, \qquad \left|\frac{Z}{Z'}\right| + \left|\frac{L}{L'}\right| + \left|\frac{M}{M'}\right| \leq 1.0,$$

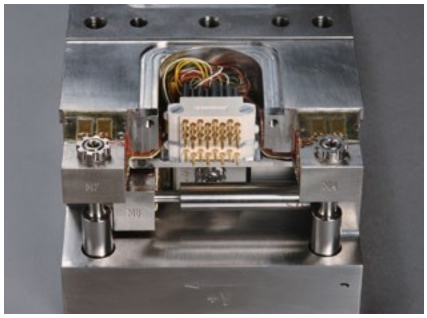
X, Y, Z, L, M, N: maximally expected measurement loads defined by the application
X', Y', Z', L', M', N': limit loads defined by the balance (see table below).

To get best measurement accuracy the values defined above should be close to one but must never exceed one. In order to simplify the critical selection process RUAG provides a selection tool on an EXCEL spreadsheet. The customer then only needs to enter the maximum measurement loads and a suitable selection is shown. Either visit our website (https://ruag-ch.picturepark.com/v/VX3ULDIm) for a download or send us a request by mail.

↗ MAIN CHARACTERISTICS
High specific load range
Extreme stiffness
Accuracy, repeatability and linearity
Dynamic measurement capability
Long-term stability and reliability
Minimal temperature sensitivity
Protective cover



DOCUMENTATION

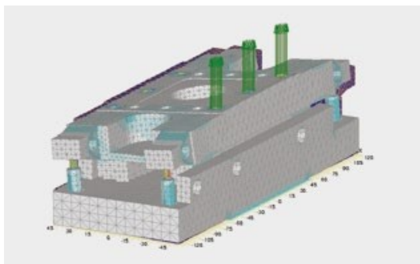


A comprehensive calibration report, containing the complete technical information, handling and installation instructions as well as an extensive error analysis is delivered together with the balance.

STANDARDS

Development, fabrication, and test procedures conform to ISO9001-2015.

BALANCE RENTAL



For your convenience, all RUAG balances are also available for rental – a possible option for short projects within a tight timescale. The rental of a balance consists of a flat rate and a daily rate for the period of rental.

Main characteristics of Family 7xx

↗ DESIGN LOADS

Balance	798	796	788	776	777	767
X [N]	500	1'000	4'000	1'500	3'000	13'000
Y [N]	400	800	600	5'500	4'000	10'000
Z [N]	2'000	3'500	8'000	5'625	8'500	30'000
L [Nm]	130	350	300	350	1'100	2'300
M [Nm]	200	350	1'100	1'300	2'500	3'800
N [Nm]	150	350	1'000	650	1'300	3'100

Design loads refer to combined loading, i.e. all loads are simultaneously acting on the balance.

↗ LIMIT LOADS

Balance	798	796	788	776	777	767
X* [N]	500	1'000	4'000	1'500	3'000	13'000
Y* [N]	3'000	5'500	10'000	11'000	16'000	32'000
Z* [N]	10'000	19'000	25'000	22'500	50'000	88'000
L* [Nm]	250	550	1'000	1'100	2'375	6'000
M* [Nm]	700	1'520	3'000	3'000	6'850	14'000
N* [Nm]	170	385	1'100	1'300	1'750	4'500

Limit loads refer to single loading, i.e. only a single load is acting on the balance.

↗ DIMENSIONS

Balance	798	796	788	776	777	767
Length [mm]	160	180	250	300	300	350
Width [mm]	75	80	100	130	130	180
Height [mm]	50	60	70	90	90	120
Mass [kg]	3.8	5.0	10.3	21	21.5	50.0

↗ DEFORMATIONS

Balance	798	796	788	776	777	767
δx/δX [m/N]	$4.8*10^{-8}$	$5.0*10^{-8}$	$2.0*10^{-8}$	$3.0*10^{-8}$	$2.8*10^{-8}$	$1.5*10^{-8}$
δy/δY [m/N]	$2.5*10^{-8}$	$1.5*10^{-8}$	$6.0*10^{-9}$	$1.5*10^{-9}$	$1.0*10^{-9}$	$5.0*10^{-9}$
δz/δZ [m/N]	$9.9*10^{-9}$	$6.3*10^{-9}$	$5.0*10^{-9}$	$5.5*10^{-9}$	$5.1*10^{-9}$	$3.0*10^{-9}$
δφ/δL [°/Nm]	$8.3*10^{-4}$	$4.0*10^{-4}$	$1.4*10^{-4}$	$1.2*10^{-4}$	$9.4*10^{-5}$	$3.6*10^{-5}$
δα/δM [°/Nm]	$1.2*10^{-4}$	$8.0*10^{-5}$	$2.8*10^{-5}$	$3.3*10^{-5}$	$1.2*10^{-5}$	$6.5*10^{-6}$
δβ/δN [°/Nm]	$3.8*10^{-4}$	$2.0*10^{-4}$	$3.4*10^{-5}$	$4.2*10^{-5}$	$3.0*10^{-5}$	$1.5*10^{-5}$

Typical values

All balances	nominal excitation	7 V
	nominal output	14 mV or 2 mV/V
	No. of channels	7 × strain gauge bridges, 2 × PT100
	electrical connector	Souriau (standard) or D-Sub Micro (optional)
	Eigenfrequencies	>900 Hz
	Temperature zero shift	<0.004 %/K (referred to the nominal electrical signal)

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