

Welcome to the “Mastering Aerodynamics” Webinar

The presentation will begin at 10am Central time

All attendees microphones are muted for the entire webinar session. Be sure your speaker is active and join the audio conference.

If you have a question, please send it to the host using the “Q&A” function. Questions will be answered at the end of the presentation.

Organizational Information

- ▲ All participants' **microphones** are **muted** during the webinar.
- ▲ Please do not forget to **activate** your PC **speakers** to enable **audio** or connect **headphones** to your PC. You may have to take the step of joining the audio conference to hear sound.
- ▲ Please type any questions you have into the WebEx Q&A dialog
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- ▲ Today's presentation will be E-mailed to all attendees. The webinar will also be posted on our website: <http://www.hbm.com/en/3157/webinars/>
- ▲ If you have additional technical questions, feel free to contact our technical support team at support@usa.hbm.com

Presenter

Sandro Di Natale

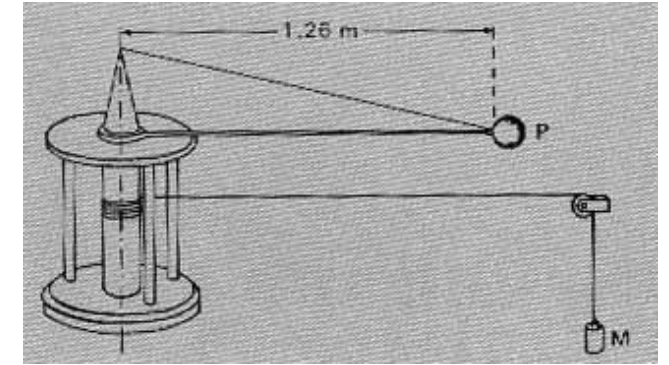
- ▲ Product and Application Manager Test & Measurement at HBK (Hottinger Brüel & Kjær) for > 5 years
- ▲ Graduate physicist
- ▲ Product manager for MGCplus, DMP41
- ▲ Application manager for High Precision Applications
- ▲ E-mail: sandro.dinatale@hbkworld.com or LinkedIn



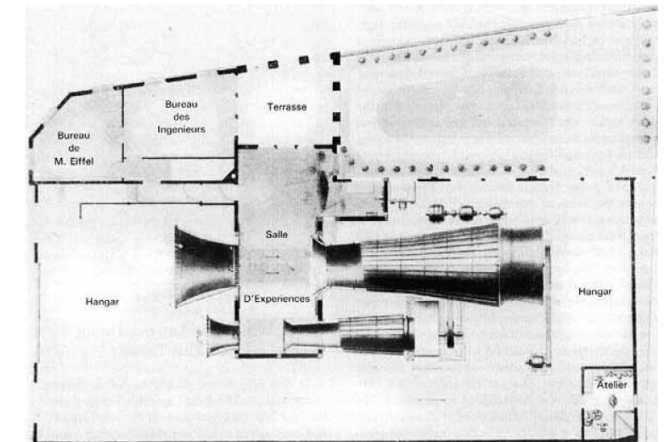
- 1. Introduction**
2. Testing Requirements
3. HBK Solution
4. Reference Story

History

- ▲ 18th/19th century: Whirling or rotating arms constructed by Benjamin Robins, George Cayley and Otto Lilienthal
- ▲ 1871: Francis Herbert Wenham designs and operates the first enclosed wind tunnel
- ▲ Late 19th / early 20th century: Pioneers like the Wright brothers, Gustave Eiffel and Osborne Reynolds perform numerous tests to increase understanding of aerodynamics
- ▲ Until mid of 20th century more and more wind tunnels built in Germany, US, France, etc.
- ▲ After World War II speeds keep increasing beyond the speed of sound
- ▲ In the last years, the influence of CFD (computational fluid dynamics) is increasing.



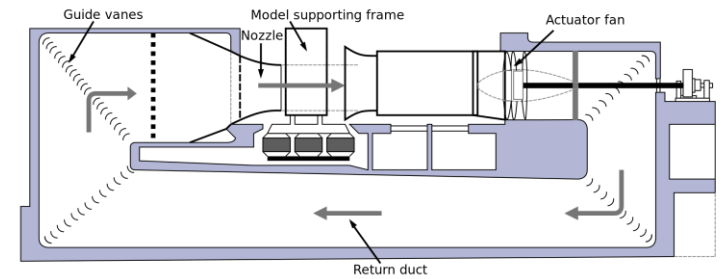
Robins' whirling arm



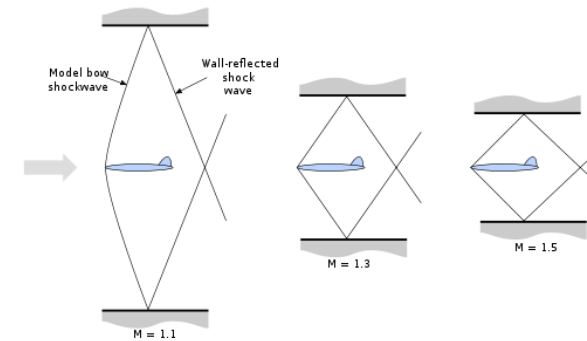
Gustave Eiffel wind tunnel

Wind Tunnel Types – by Speed

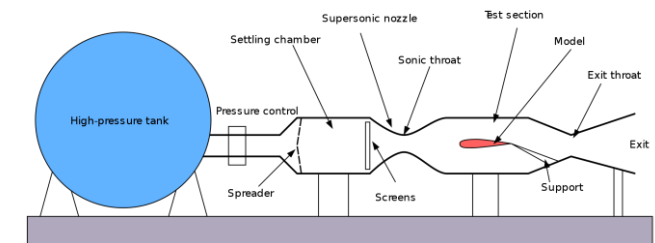
- ▲ Subsonic (Mach (M) $\sim < 0.75$)
Open-return or closed-return type
- ▲ Transonic ($M > 0.75$, $M < 1.2$)
Reflection of shock waves from the walls
Requires large scale and pressurization and cooling
- ▲ Supersonic ($M > 1.2$, $M < 5$)
High pressure ratio is required
Energy stored in high pressure tank
Condensation or even gas liquefaction might occur
Usually not operated continuously
- ▲ Hypersonic ($M > 5$)
 $\sim > 50$ MW power consumption / m^2 of test section
Only seconds of actual testing time
Mostly for space applications



Closed-return wind tunnel



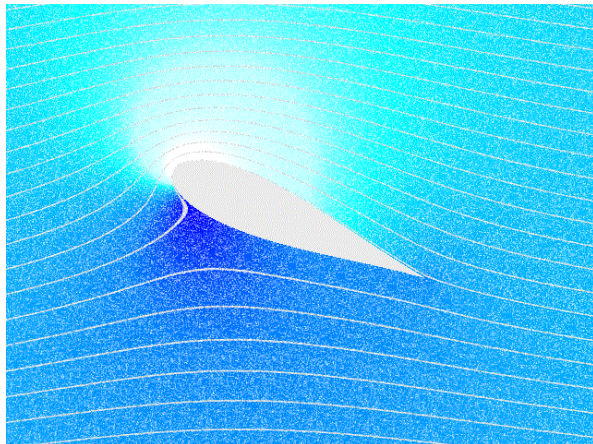
Shockwave reflection



Sketch of supersonic wind tunnel

Aerodynamics and Aeroacoustics

- ▲ Study of airflow and forces involved when an object moves through the air or air moves past an object.
- ▲ Describes behavior of objects in air or compressible gases.
- ▲ Important factor in achieving optimum energy, comfort, acoustics and style.
- ▲ Four major forces affect airflow: lift, gravity, thrust, drag



Flow around a wing

- ▲ Study of noise generation caused by turbulent fluid motion or aerodynamic forces interacting with surfaces
 - Noise source identification
 - Noise characteristics (frequencies)
 - Importance
 - How does it sound?
 - Origin
 - Impact

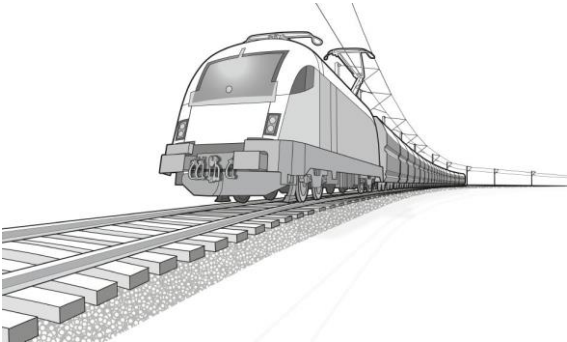


Noise source identification

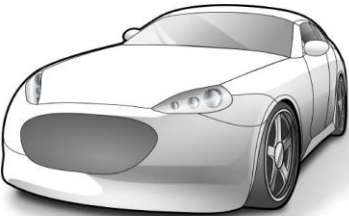
Industries



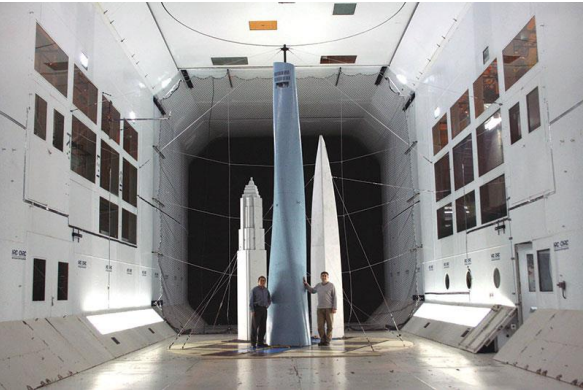
Aerospace



Rail



Automotive



Civil engineering

Sports

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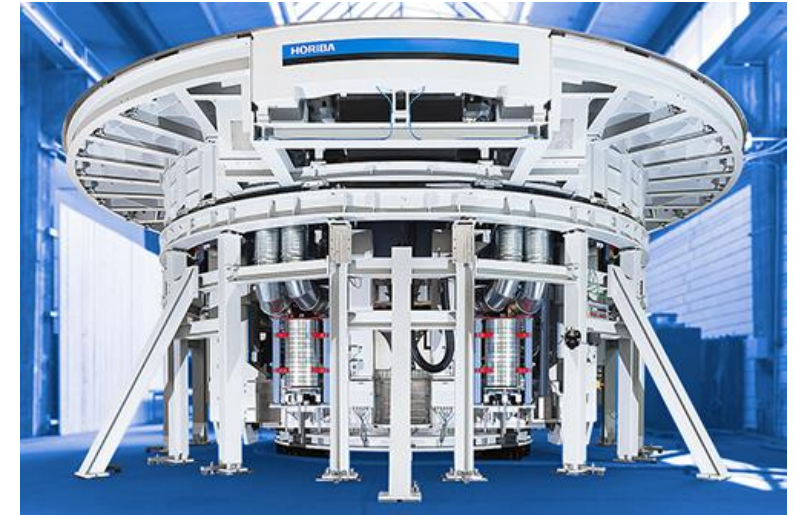
Wind Tunnel Testing

- ▲ Test of aerodynamic, aeroelastic and aeroacoustic behavior
- ▲ Full-scale (preferred) or scaled model
- ▲ Main measurands: **load/force**, velocity, pressure
- ▲ Validation of FVM (finite volume method) models and CFD simulations
- ▲ Validation of stability, performance and efficiency
- ▲ Wind tunnel time is precious and expensive and needs to be used cautiously



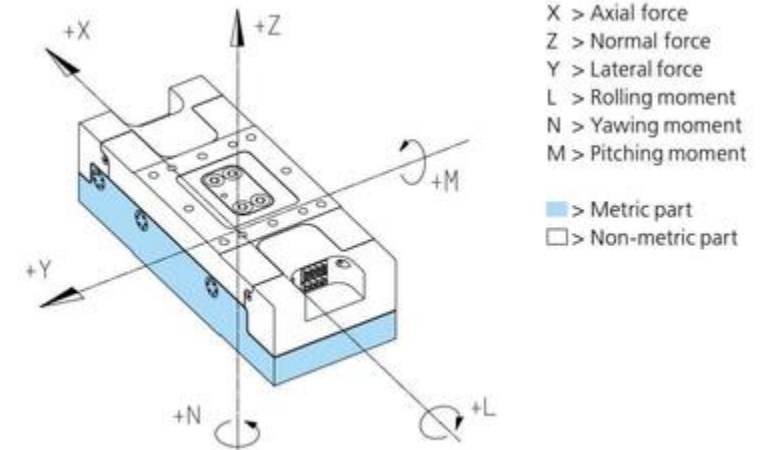
“Rolling” Platform

- ▲ In this setup the test specimen is located on a platform.
- ▲ The platform is rolling to simulate the vehicle on a road as realistic as possible.
- ▲ Used for ground vehicles
- ▲ All six degrees of freedom (3 forces and 3 moments) are calculated from force transducers below the platform.
- ▲ ~10 kN of vertical force can be applied.
- ▲ Speeds in the range of 200-300 km/h

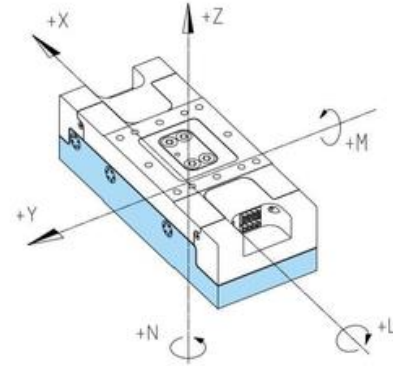
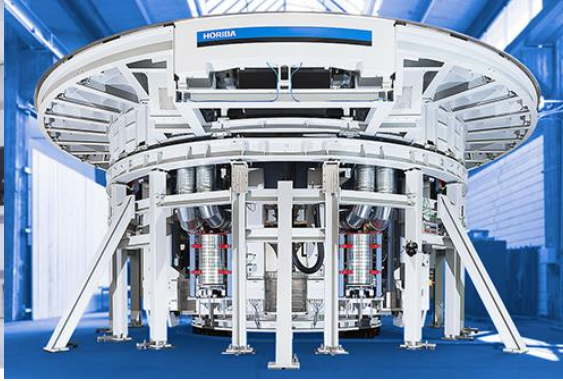


“Hanging” Fixture

- ▲ In this setup the test specimen is mounted on a lever.
- ▲ The fixture’s influence is as low as possible
- ▲ Typically used for flying vehicles (aircraft, spacecraft)
- ▲ Inclination can be changed in all degrees of freedom
- ▲ All six degrees of freedom (3 forces and 3 moments) are measured by balance in fixture.



Wind Tunnel Testing – Full-scale and Scaled Models



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

■ > Metric part
□ > Non-metric part



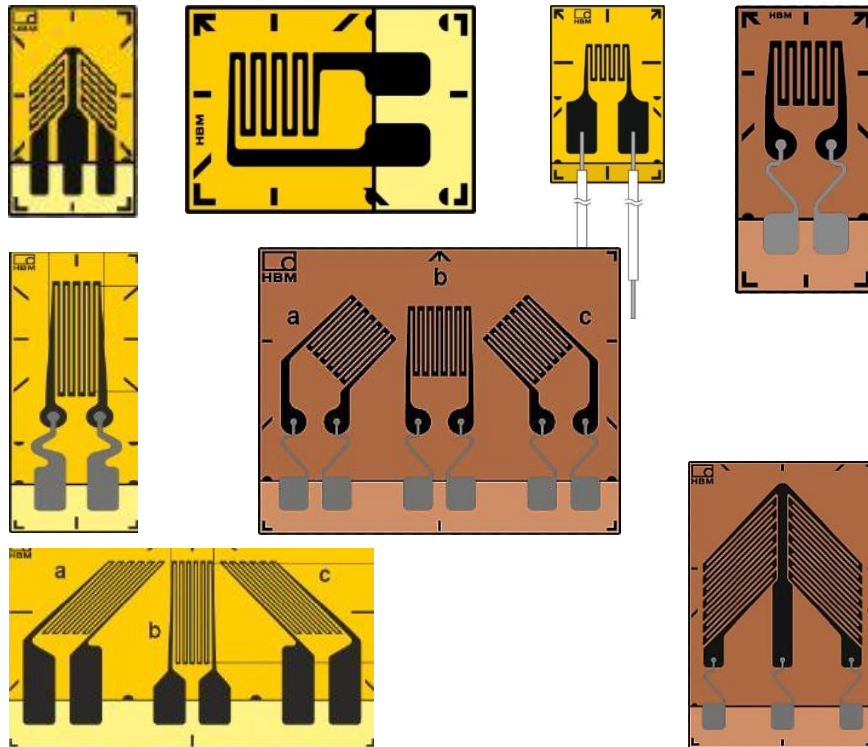
Key features and requirements

- ▲ Sensor flexibility: force/load, pressure, strain, displacement, temperature
- ▲ Scalability in channel number and bandwidth
- ▲ Scalability of accuracy
- ▲ Long-term stability
- ▲ Synchronization with other data sources like high-speed cameras, pressure scanners, etc.
- ▲ Open interfaces

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HBK Solution – Sensors

Strain gauges

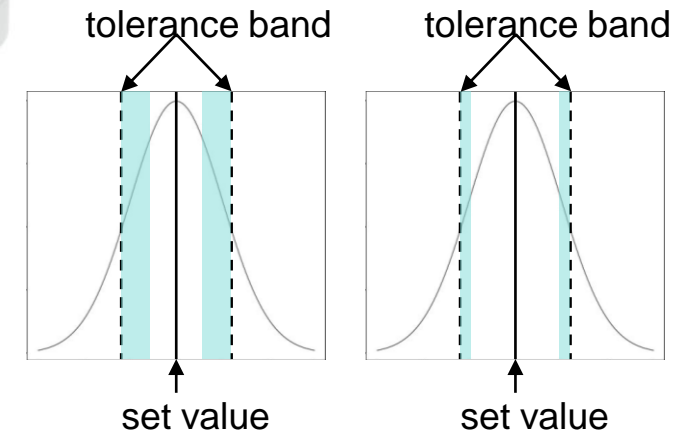


- ▲ Proven in aerospace and automotive applications
- ▲ More than 2,000 variants available
- ▲ Polyimide or glass-fiber reinforced phenolic resin carrier material (with constantan or CrNi grid)
- ▲ High alternating loads, large temperature range

Force transducers



uncertainty



- ▲ Made from stainless steel
- ▲ Hermetically sealed for immunity against humidity
- ▲ Constructed as a real Faraday's cage, tested and optimized in HBK's own EMI lab
- ▲ Vibration and shock tested
- ▲ Measurement range: 2.5 kN...2.5 MN
- ▲ ISO 17025 calibration

HBK Solution – Hardware and Software

Higher channel number →



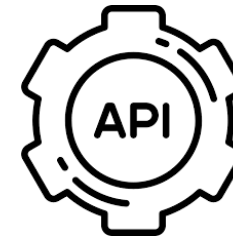
QUANTUM^X MGCplus

- ▲ Wide variety of sensor inputs incl. strain gauges, LVDTs, IEPEs, thermocouples
- ▲ Patented strain gauge circuits
- ▲ Autocalibration and auto adjustment routines to ensure long-term stability
- ▲ Scalable in multiples of 1/2/4/8/16 channels
- ▲ TEDS technology
- ▲ Experienced custom systems department for turn-key solutions



Higher channel number →

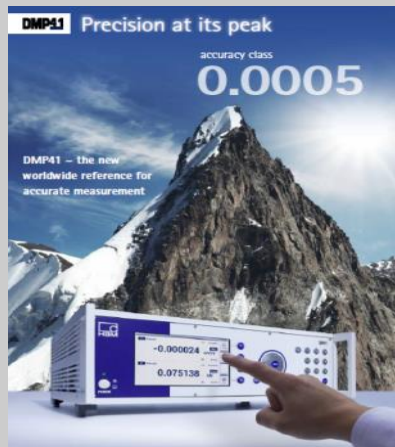
- ▲ Easy left-to-right workflow
- ▲ Synchronized acquisition of data from different sources
- ▲ Intelligent triggering
- ▲ Script-based automation
- ▲ Application-specific visualization objects



- ▲ Integration into Linux, Visual Studio .NET, LabVIEW
- ▲ Integration into automation system via EtherCAT

HBK Solution for High Accuracy Full Bridge Measurement

DMP41 The Reference 5 ppm



Ultra-high Precision
 Claim: **Sensor calibration**
 Amplifier: 225 Hz CF
 Accuracy class: *0.0005*
 Customer / Application:
 National Metrology Institutes
 (PTB, AIST, KRISS, NIST, ..)

MGCplus Instrument 25 ppm



High Precision
 Claim: **Instrument**
 Amplifier: **ML38B** (225Hz CF)
 Accuracy class: *0.0025*
 Customer: all industries

QuantumX Compact 25 ppm



High Precision
 Claim: **Compact Precision**
 Device: **MX238B** (225Hz CF)
 Accuracy class: *0.0025*
 Customer: all industries
 Package includes catmanAP

QuantumX Dynamic 100 ppm



Industrial Precision
 Claim: **Dynamic Accuracy**
 Device: **MX430B**
 (DC or CF 600 Hz)
 Accuracy class: *0.01*
 Customer: all industries



The Full DAQ Solution



GPS-based grandmaster clock
e.g. Omicron Ticro 100



Force/load, temperature, ...



Pressure scanners



Acoustics



High-speed cameras



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Use Case: Wind Tunnel Testing at RUAG



- ▲ Swiss company
- ▲ 70+ years of history
- ▲ Independent full-service provider
- ▲ Leading in civil and military aviation

- ▲ Operating two wind tunnels in Emmen
- ▲ Testing aircraft, race cars, civil engineering, sports, etc.
- ▲ Not only test, but also design, manufacturing and analysis
- ▲ Own calibration laboratory

- ▲ Supplier of high accuracy wind tunnel balances



Use Case: Wind Tunnel Testing at RUAG



RUAG measurement and calibration cabinets

Requirements

- ▲ Static measurement with highest accuracy
- ▲ Dynamic measurement with up to 2 kHz bandwidth
- ▲ Full sync of all measurement channels
- ▲ Wide range of sensor types
- ▲ On-site calibration (traceability)
- ▲ Long-term stability

DAQ Hardware (Solution)

based on MGCplus, DMP and calibration units:

- ▲ ML38B (25 ppm class) for balances
- ▲ DMP40 for balance calibration
- ▲ BN100A, K800, K148 for MGCplus calibration
- ▲ Many more MGCplus amplifiers for voltage, strain, temperature, etc.

Additional equipment:

- ▲ Calibration units from other manufacturers

Questions?

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Thank You