Quality assurance in the wind tunnel

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Initial situation

Experimental measurement investigations in the wind tunnel provide aerodynamacists with the data they require to assess the aerodynamic properties of a test object (aircraft, vehicle, athlete, building, etc.). To this end, the RUAG Aerospace Aerodynamics Center in Emmen (Switzerland) operates several wind tunnels, in which measurement data is acquired, conditioned and evaluated on an industrial scale (see Fig. 1). To meet current requirements, the hardware and software for acquiring the measurement data has been replaced and HBM's modern MGCplus technology has been introduced.

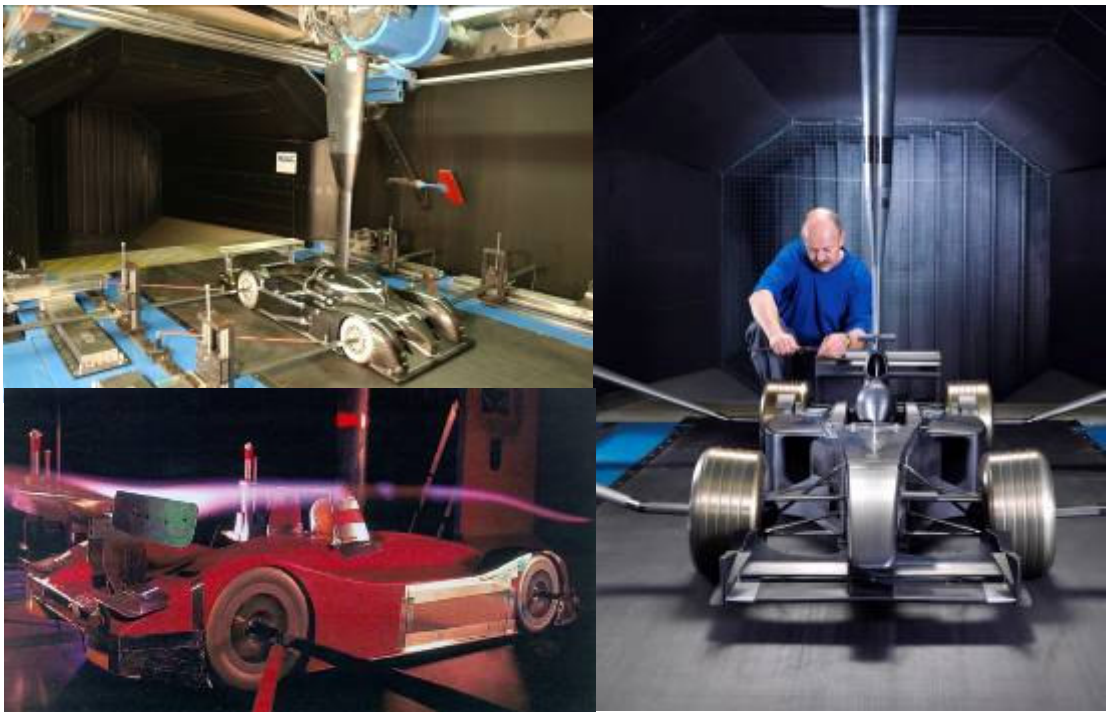

Fig. 1: *Industrial measurement technology in the wind tunnel*

Test sequences per the ISO 9001 standard require measuring chains to be calibrated periodically and proof of traceability to national standards. As operation of the wind tunnel in the Aerodynamics Center requires a very high level of flexibility and availability, RUAG Aerospace decided to set up an on-site calibration option so that they could intervene both periodically, in accordance with the utilization of the wind tunnel and also spontaneously, should there be any malfunctions (uncertainties in measurement quality), thus performing the necessary work efficiently and cost-effectively.

Calibration concept

A vast number and variety of amplifier modules, in combination with different connection boards, are used in the wind tunnel's measurement data acquisition systems. This allows forces and moments, pressures, temperatures, accelerations, frequencies, angles and lengths to be measured (see Fig. 2). In addition to this, the use of different amplifier types and qualities enables the stringent demands the measurement task makes on accuracy and repeatability to be met. Although as far as quality assurance is concerned, this complex situation does pose the problem that the calibration procedure defined for every option has to be as efficient as possible and also guarantee traceability. This traceability comes from the step-specific deployment of various calibration tools and the use of relevantly certified calibration facilities. All the calibration and measuring tools mentioned are always calibrated every year. Table 1 provides a general overview of the existing equipment types, measurands and accuracies, as well as step-by-step traceability.

Fig. 2: *Data acquisition systems in wind tunnels at RUAG Aerospace, with MGCplus technology: Front (on the left) and back with connection boards (on the right)*

The overview can be summarized as follows:

a. Bridge standard BN100A Q-27866 from HBM is used to calibrate the bridge amplifier [mV/V] and calibration takes place at the German manufacturer's premises in a certified German Calibration Service (DKD) laboratory.
b. MGCplus amplifiers for connecting Wheatstone bridges are calibrated using the BN100A calibration unit in the calibration laboratory at the Aerodynamics Center.
c. The MGCplus amplifiers are calibrated for all the other existing electrical quantities by suitable calibrators, also in the calibration laboratory at the Aerodynamics Center. The calibrators themselves are calibrated in turn by the relevantly certified RUAG Aerospace

calibration facility.

HBM «SwiftCal» software is used to control and record the calibration. The software was developed for HBM measuring instruments and has the following features:

- automatic detection of virtually all HBM amplifier/connection board combinations
- fully-automatic calibration with a controllable calibration unit
- user-driven manual calibration - automatic preparation of calibration certificates as an EXCEL sheet and in a PDF
- format – calibration certificates with a conformity statement – the opportunity to integrate third-party calibration units – error evaluation and identification with regard to the permissible error limits (mpe)

Implementation

The various calibration tools are made into a complete system in a standard modular enclosure (see Fig. 3). Making the mounting as simple as possible is a consideration, as the various calibration tools, as previously described, have to be periodically sent to the primary calibration facilities.

A further important aspect covers documentation of the calibration process and archiving. The documentation initially includes all the necessary hardware and software descriptions, including error tolerances. The instructions for the calibration sequence of the different amplifier types also have to be prepared in detail, as these will ultimately produce a calibration report for each individual measurement channel. The procedure must also be defined for verifying the measuring chain made up of the hardware and software used when starting up the system or for any modifications that may be necessary.

Fig. 3: *Calibration tower at RUAG Aerospace for wind tunnel data acquisition systems*

The calibration process requires the primary calibration facility at RUAG Aerospace to permanently monitor the measuring and calibration tools, as well as the calibration intervals. The calibration facility at the Aerodynamics Center schedules the individual procedures in accordance with the availability of the measuring instruments, based on the utilization of the wind tunnel, making sure that all the calibration and measuring equipment is ready and ready for operation in the air-conditioned calibration chamber at least 4 hours beforehand.

Experiences during initial operation

The new calibration system for measurement data acquisition systems in RUAG wind tunnels is ready for operation and initial calibrations have been performed. As far as the accuracy requirements are concerned, the target values on startup have been verified. Operational experience with the system shows that periodic calibrations are scheduled very flexibly with ongoing wind tunnel operation and can be performed on-site by the calibration facility of the Aerodynamics Center.

Conclusion

The calibration system that has been set up in the Aerodynamics Center at RUAG Aerospace is capable of calibrating a vast number of HBM MGCplus amplifier types. The step-specific design and the integration of external calibration facilities allows traceability to national standards. In consequence, measurement results are of a high quality and the users of the wind tunnel (the customers) are satisfied.

With the implementation of this project, the Aerodynamics Center could put their decades of experience in electrical measurement technology and systems engineering to the test. We are also making this knowledge available to other interested parties outside the company, from other sectors of industry.

Amplifier type	Connection board	Measurand	Measuring range	Accuracy of test specimen	Calibration unit	Accuracy of calibration unit	Traceability
Bridge standard BN100A	-	Voltage ratio	-100 = +100 mV/V	0.0005 %	HBM Equipment in Darmstadt > DKD certificate[1]	-	PTB2 national standard
Calibration unit K3608	-	Voltage ratio	+/-100 mV/V	0.0025 %	via with BN100A calibrated ML38B		HBM DKD certificate (transfer cal.)
ML38B	AP01 – carrier-frequency bridge amplifier	Voltage ratio	+/-2…10 mV/V	0.0025 %	Bridge standard BN100A	0.0005 %	HBM DKD certificate
ML01B	AP01	Voltage	+/-10 V	0.03 %	Digistant 4462 from Burster	0.01 %	RA calibration laboratory[3]
		Voltage	+/-76 mV	0.03 %	Digistant 4462 from Burster	0.01 %	RA calibration laboratory
		Current	-50..+50 mA	0.03 %	Digistant 4462 from Burster	0.01 %	RA calibration laboratory
ML460B (4CH)	AP460	Frequencies	0.0001...500 KHz	0.01% (0.05 % PWM)	Agilent 33220A Function/Arbitrary Waveform Generator	0.002 %	RA calibration laboratory
ML801B (4CH)	AP418	Current source	4.0 mA		Agilent 34401A	0.005 %	RA calibration laboratory
		Voltage	+/-0.05..5 V DC..1000 Hz	0.05 %	Agilent 33220A Function/Arbitrary Waveform Generator	0.01 %	RA calibration laboratory
ML801B (8CH)	AP801	Voltage	+/-10 V	0.05 %	Digistant 4462 from Burster	0.01 %	RA calibration laboratory
	AP809	Thermo-couple	ca. -200 °C … +1500 °C	<0.30 °C lin. >0.06 °C	Digistant 4462 from Burster	0.01 %	RA calibration laboratory
	AP815 full bridge	Voltage ratio	+/-8…80 mV/V	0.10 %	HBM-K148 350 Ω (1)	0.01 %	RA calibration laboratory
	AP815 quarter bridge	Voltage ratio	+/-8…80	0.10 %	HBM-K800 350 Ω (2)	0.03 %	RA calibration laboratory
	AP835	RTD PT100	-200.+848 °C	+/-0.1 °C lin.<0.02 °C	PT100 Simulator 4506 from Burster	0.08 °C (2 ppm)	RA calibration laboratory
	AP836	Potentiometer	190..5000 Ω	0.1 % lin.0.05 %	Agilent 34401A	0.005 %	RA calibration laboratory

Tab. 1: *Amplifiers, measurands, accuracy requirements and traceability to be calibrated for RUAG wind tunnel measuring systems*

(1) DKD .. German calibration service
(2) PTB … German National Metrology Institute
(3) RA calibration laboratory … central calibration facility at RUAG Aerospace, Emmen (Switzerland)