ICE in the wind tunnel

Determination of aerodynamic loads in a wind tunnel

Dr. Claus Zimmermann and Werner Häberli, RUAG Aerospace, Emmen, Switzerland
Daniel Franck and Peter Deeg, Deutsche Bahn AG, DB Systemtechnik, Munich, Germany

In general, force and torque balances with strain gages (SG) are used to determine aerodynamic loads that act on test objects in a wind tunnel test. The measurement engineer often wishes for an autonomous, flexible and mobile measuring system with which they can acquire, record and display the balance forces.

Safety test for rail vehicles

The determination of aerodynamic vehicle parameters in a wind tunnel test is required for the safety evidence for rail vehicles in side winds. Requirements for the model, measurement technology and implementation are specified in a regulation. The measured data are valid as a component of the vehicle licence. In order to implement such tests with high precision, reproducibly and essentially independently of the measurement technology used by the wind tunnel operator, RUAG Aerospace, Emmen, Switzerland developed a system consisting of a SG balance, signal processing, data acquisition and measured value analysis on behalf of Deutsche Bahn AG, Munich, Germany. This system can be configured with various models outside of and independently of the wind tunnel. The balance is installed in the model, which means that shorter lever arms and therefore more precise determination of the torque can be ensured. On the wind tunnel side, only the main operating and set-up parameters (pressure, temperature, humidity, pushing angle) must be provided to determine the required aerodynamic parameters.

Principle of measurement

SG's are installed in a Wheatstone bridge circuit on the measuring elements of the wind tunnel balance used. Under the action of the aerodynamic loads, the components with measurement point deform in the elastic region causing the measuring bridges to emit a voltage signal proportional to the force applied. Depending on the balance type, up to 6 load components in space can be determined (force F_X, F_Y, F_Z and torque M_X, M_Y and M_Z). In general, these balances are also called multi-component balances. The relationship between the electric output signal and the loads applied is determined by calibrating the balance.

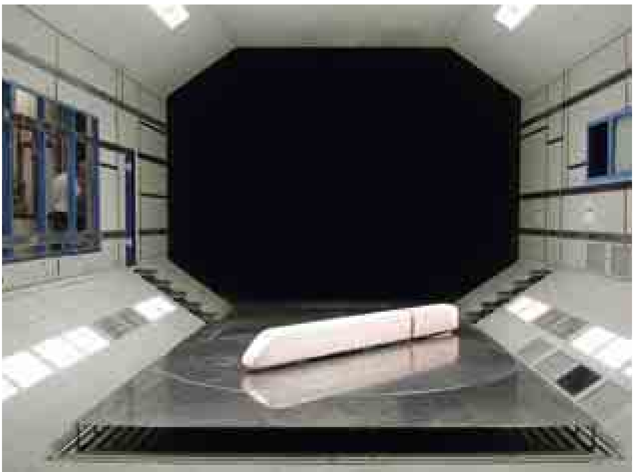

Fig. 1: Train model in subsonic wind tunnel at RUAG Aerospace

The complete system (Fig. 2)

The following functional requirements are placed on the complete system:

- Independent measuring system consisting of sensors, signal processing and measured value analysis
- High accuracy, resolution and reproducibility
- Modular construction
- Simple operation

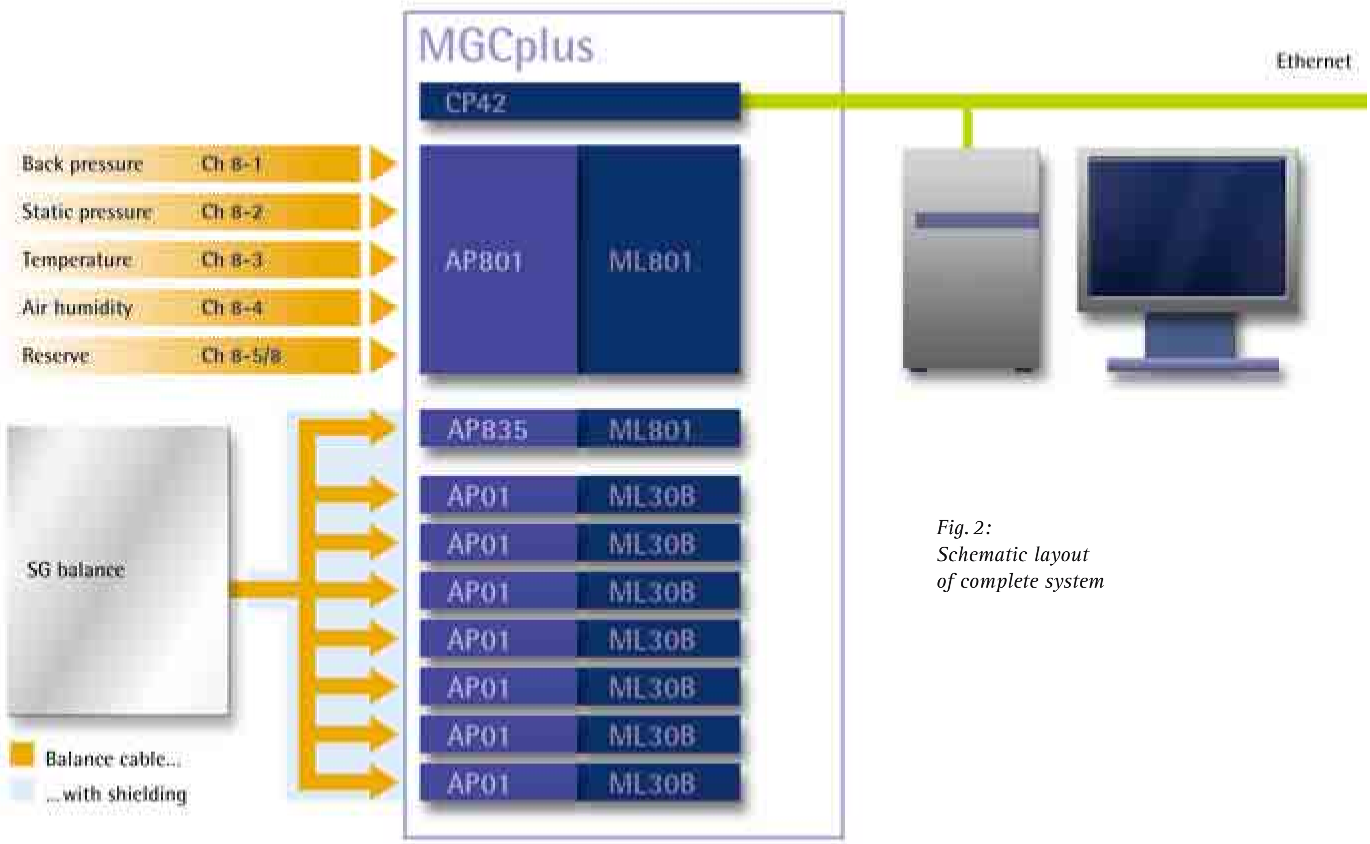

Fig. 2:
Schematic layout
of complete system

RUAG Aerospace block balances

A whole family of block balances have been developed over the years at RUAG Aerospace. They cover a wide diversity of application cases with regards to geometry and load requirements. The balances are characterized by their robustness, high measuring sensitivity and long-term stability.

The block balance type consists of a wind tunnel-side load-bearing plate with 7 beam spring elements that are connected to their model-side counterparts with articulated rods. These articulated rods have the task of transmitting forces without interference where possible. The balance therefore does not have moving parts that could generate friction-based hysteresis effects (Fig. 3).

Measuring amplifier

The tasks of sensor supply, signal amplification and conditioning, as well as communication with the PC, are implemented by the measuring amplifier system MGCplus. The defined linearity deviation of the ML30B amplifier rack means that the expected signals can be measured in the design range with the required balance accuracy of < 0.3 %.

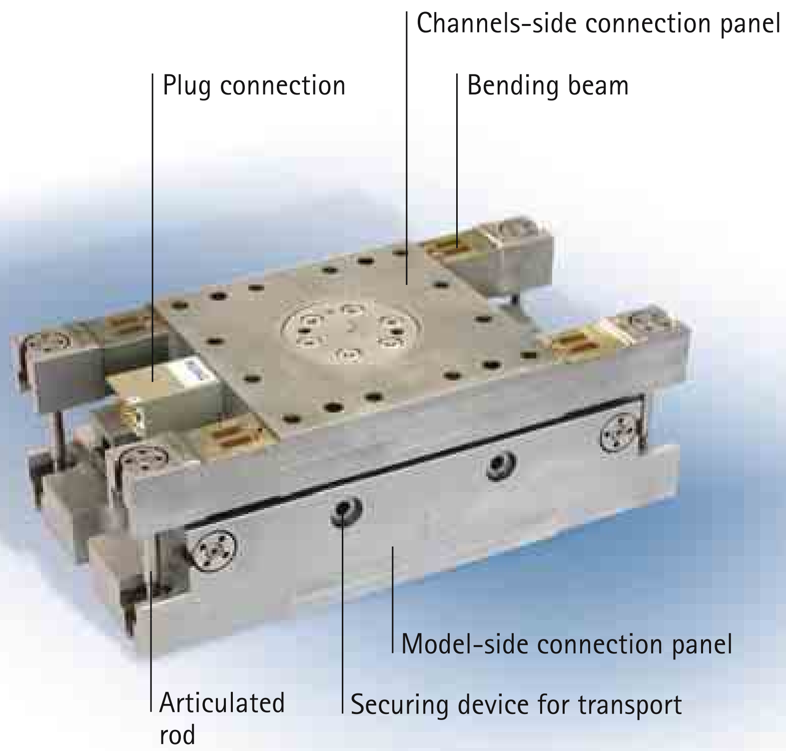

Fig. 3:
RUAG Aerospace block balance

Continuation →

ICE in the wind tunnel

Cont'd:

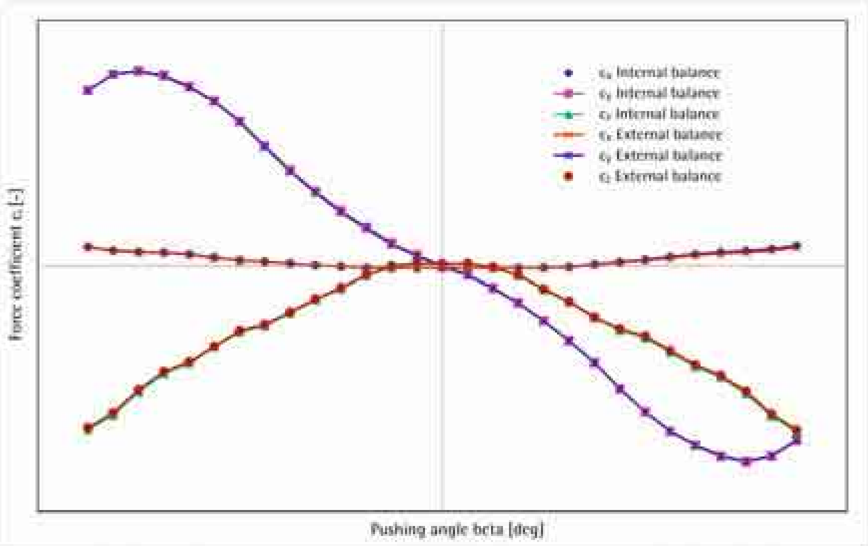

Fig. 4:
Force coefficients of train model with parallel measurement using internal and external balances

The measuring bridges on the SG block balance are connected to the carrier frequency amplifier with electrically insulated 6-wire circuitry. To avoid a ground loop, the cable shielding must not have any connection to the balance. An optical and acoustic balance overload control is also implemented. A limit value of 80% of the balance measuring point design value is set for every SG signal.

Software

The developed application uses the software DIAdem from National Instruments as the measuring and evaluation program. The data connection to the measuring amplifier system MGCplus is provided via Ethernet using the appropriate HBM driver. Alternatively, other products can be used.

Software requirements:

- Sequence control for data acquisition and processing
- Acquisition of measuring signals
- Acoustic and optical monitoring of the SG balance
- Statistic evaluation of individual values
- Processing of measuring signals
- Visualisation and saving of data
- Modular construction

The MGCplus assistant is used to set and parameterize the measurement channels. This assistant is part of the MGCplus package and can be started directly in DIAdem. The scaling of all sensors, including the balance, is implemented with the DIAdem macros. Only the limit values for the balance monitoring are set in the MGCplus assistant.

Wind tunnel test

Figure 1 (at the beginning of this article) shows the test layout in the flow direction within the RUAG Aerospace subsonic wind tunnel. The model based on the ICE with the internal SG balance is fixed to a rotating floor with two struts in the area of the undercarriage in order to implement the side flows. The measuring cables of the balance are fed through the hollow struts to the measuring amplifier in the measuring cabin.

Measurement results

The qualification of the new measuring system is implemented by comparison with the measured values of an external balance which have been externally acquired. Figure 4 shows an example of force coefficients over the travelled pushing angle at constant wind speed. The differences in both systems lie within the required tolerances. Very good results were also obtained regarding hysteresis and symmetry of flow.

Conclusion

The measuring system presented here, consisting of a RUAG Aerospace multi-component balance, a HBM measuring amplifier unit and appropriate software, permits very precise determination of forces and torques that occur in a wind tunnel test. Further advantages are the overload and frictional connection monitors integrated in the system and the short set-up time in the wind tunnel. This measuring system is also suitable for other applications, in which dynamic or even intermittent loads must be determined. ■