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Force measurement technique for the ¾-open measurement test section of the RWT (Regensburg Wind Tunnel)

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Introduction

The RWT (=Regensburg Wind Tunnel) has got a bigger airflow cross section (0,5 x 0,6 m) than the old wind tunnel. This circumstance makes it possible to measure larger models. This is good in view of the Reynolds' number. The maximum speed of the airflow (almost 50 m/s for the open test section) is higher, too. The bigger model scales (up to M1:8) and the higher speeds produce both higher aerodynamic forces.

By an airflow about a car there are areas with laminar and turbulent boundary layer and areas with detached airflow. Every car has got its own velocity profile and according to this its own pressure distribution on its surface (Fig. 1). Airflow, which has got an angle of attack different from zero, makes the pressure distribution in the horizontal cut of a car asymmetric (Fig. 2).

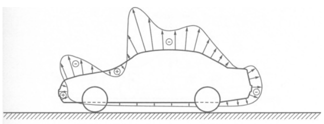

Fig. 1 Pressure distribution in the mid cut of a car [PAP06]

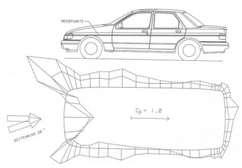

Fig. 2 Pressure distribution in the horizontal cut of a car with an angle of incidence of 0 and 20° [ADA94]

The pressure distribution causes at most 3 forces (drag, lift und a force from the side) and up to 3 torques (pitch, yaw and rolling moments). The amount, the direction and the point of attack of the force are depending on the pressure distribution.

A big pitch moment can lead to a negative lift at the front axle and a positive lift at the rear axle. A lift force, which is nearer to the rear than to the front axle, causes a bigger unloading of the rear axle. Both can lead to over steering in curves at high speed.

For reasons of safety and comfort the lift should be distributed equally between both axles and positive lift should be as small as possible. Competition cars have mostly downforce (negative lift) but the aerodynamic balance is very important, too.

concept study, design and realization of a 6-compoment-balance including measurement value logging

The sensors for force and torque measurement

The forces are measured with platform load cells (Fig. 3). Active principle: double bending beam

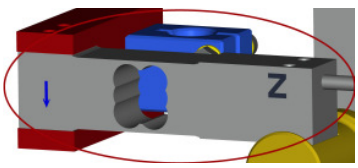

Fig. 3: Platform load cell

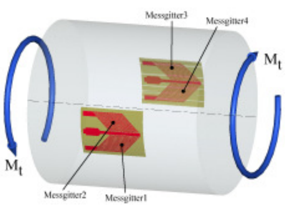

Fig. 4: Measuring of torques with a torsion bar

The fastening elements between the load cells are pasted up with strain gages such as pictured in Fig. 4. Thus they grow to sensors for torques. Tension/pressure and bending are compensated by the orientation and the wiring of the measuring grids (2 per strain gage). These loads haven't a effect on the measurement signal.

Set-up

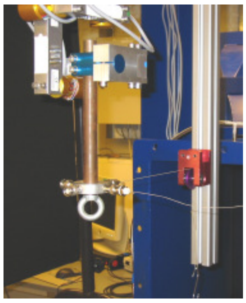

Fig. 6: calibration with guide rollers and weight forces

Fig. 5: the 6-component-balance in the measuring cabin of the RWT

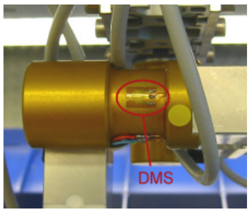

Fig. 7: the strain gages were clued in the LWS-laboratory

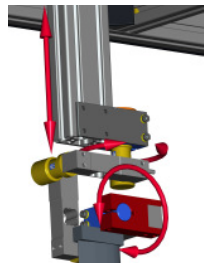

Fig. 8: the altitude and the angles of yaw and pitch of the model are adjustable

Results of the calibration

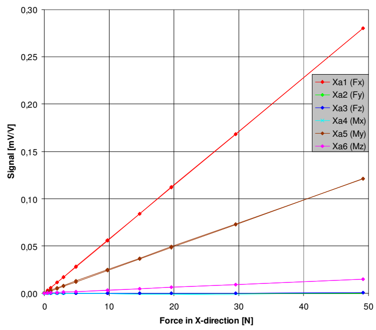

Fig. 9: All signals plotted over the calibration load in X direction

Fig. 9 shows clearly the connection between the force in X direction and the torques about the Y and Z coordinate axis. The torque M_y is bigger than M_z because of the bigger lever arm of the force relative to the Y axis.
The other sensors aren't allowed to have a signal for this load and fig. 9 shows that the compensation works very good.

In Fig. 10 you can see a little hysteresis, which is probably provoked by friction in the bearing of the guide roller.

After a residence time of 3 minutes at maximum load there is no drift discoveralbe. The characteristic line is practically linear. With the reciprocal of the gradient of the curve we get the following equation:

$$M_y = 95{,}79\left[\frac{Nm}{mV/V}\right]\cdot Xa5$$

With the Spider8 we get a resolution of

$$0{,}0096\frac{Nm}{Digit}$$

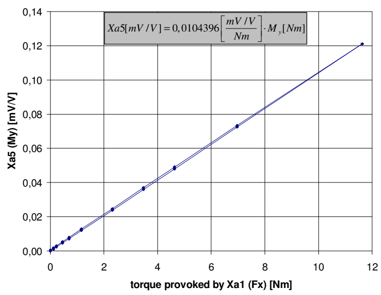

Fig. 10: the signal of the torsion bar for M_y (Xa5) plotted over the calibration load in X direction

References:
- [ADA94] HUCHO, W.-H.: Aerodynamik des Automobils. Düsseldorf: Vieweg 1994
- [PAP06] PAPENFUß, H.-D.: Skript Aerodynamik des Automobils. Ruhr-Universität Bochum 2006