RVAD EXPERIMENTS

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1. Introduction

In today's automobile development process, wind tunnel measurements are used to optimise a wide variety of vehicle characteristics, such as aerodynamic, acoustic and thermodynamic behaviour. Thus, there are not only the classical aerodynamicists and designers who strive for sleek vehicle shapes in order to diminish aerodynamic drag. For decades, wind tunnels have become a versatile tool for automotive engineers of very different disciplines [1,2,3]. Not all of them can be discussed herein.

Yet a uniformity of vehicle shapes - supposed or actual - is lamented in the increasingly individualistic society encountered in a great many of today's prosperous western democracies. This individualism is expressed for example in the growing trend towards niche products such as off-road vehicles etc. If distinctive, typical brand design features, and hence visual differentiation from competitors, are to be maintained and heightened, it may be necessary to introduce measures which do not always have a positive effect on aerodynamic properties, in other words on the drag coefficient. On the other hand, no manufacturer can afford to "regress" here. Energy prices will continue to rise in the long term, and the demand for improved environmental compatibility will affect all aspects of car development, including aerodynamics.

One possible solution to these problems might be to exploit new potentials, e.g. at the car under body or in the cooling-air flow duct. These areas however, require innovative experimental techniques as well as parallel use of CFD. With so called conventional wind tunnel technology, i. e. stationary ground and standing wheels, even contradictory results may be obtained [4,5,6,7,8,9,10,11]. This means possible “potentials” for aerodynamic drag reduction may be identified using such techniques. But road tests may prove in some cases that the measures introduced even increased the aerodynamic drag and thus fuel consumption. Therefore, correct road simulation is required in the wind tunnel to make sure that time-consuming development work and financial resources are exclusively dedicated to such components, which will definitely work on the road and help to improve the vehicle’s fuel efficiency.

The advent of road simulation technology as well as other novel wind tunnel techniques, like wake surveys, non-intrusive measurement techniques, e. g. Laser-Doppler-Anemometry (LDA) or Particle-Image-Velocimetry (PIV), acoustic and vibration techniques, e. g. acoustic holography (STSF) and laser vibrometry, turbulence and gust simulation and many other sophisticated experimental methods clearly indicates, that the wind tunnel will remain to be

THE major institution for RVAD. The computer (CFD) will increasingly support the wind tunnel, especially with its ability to instantaneously yield large quantities of flow-field data, which – in the tunnel – may only be measured at the expense of long wind tunnel occupation time and thus at high costs and time delay for vehicle development. However, the accuracy of CFD, especially if details are to be optimized, or if the vehicle contour is complex and thus Reynolds-number dependent, is still subject of ongoing research. Therefore, for the time being, CFD will supplement but not replace experimental techniques in RVAD. The believe in the future of automotive wind tunnels becomes obvious, when looking at the investments made in wind tunnels in recent years. The new Audi Wind Tunnel Center [12], the upgrading of IVK Wind Tunnel [10,11] and Pininfarina Wind Tunnel [13], the new tunnels of Chrysler [14], Hyundai [15] and the French GIE S2A [16], a considerable number of recent wind tunnels for formula 1 teams and upcoming wind tunnel projects by BMW and the Tongji-University Shanghai demonstrate the ongoing importance of experimental RVAD.

Nevertheless, each test, may it be for wind noise, for engine cooling, for dust and dirt ingress or under body aerodynamics has a special scope. Certain questions have to be answered, like "do the side windows produce unacceptable wind noise", "does the radiator still suffice if the engine power is increased by so and so many per cent" or "how will the newly developed rear diffuser affect drag and stability at high speed driving"? However, one has to keep in mind that the wind tunnel, like many other test rigs used in industry and research, does not perfectly reproduce a complete real-life-situation of the test object under consideration. In most cases this is not necessary and by far too elaborate to aim for, because some parameters may be of minor importance for the problem to be solved and therefore may be neglected. It is the art of engineering and the skill of engineers, which have to provide the appropriate test stand for the questions to be answered. A rig which controls as precisely as necessary (not as possible) the relevant physical quantities and boundary conditions of the current test, like for instance air speed, boundary-layer thickness, wheel rotation and flow angularity. Whereas on the other hand, additional properties like, sound-pressure level and turbulence level may not be influential in this special case. From this it appears more than evident that generally, a single wind-tunnel facility does not suffice to cover the full range of automotive development associated with all sorts of airflows.

A "universal wind tunnel", which correctly controls every single parameter which may be important in a certain situation, can hardly ever exist, because too many of the engineering demands are contradictory, as can be depicted from figure 1.1 taken from Honcho [3]. Simulation of rain and optimisation of dirt deposit may add damage to acoustic lining necessary for low noise level in the plenum hall. Extreme temperatures, which are common practice in tests associated with cooling and heating components of the vehicle, may be fatal for the external balance required for aerodynamic force measurements. Even if such a facility could ever be designed, it would be not desirable from an economic standpoint. Because of the different experimental environments discussed so far, the requirements with respect to the boundary conditions vary. This affects the size of a wind tunnel and therefore its costs. Whereas for cooling tests, an open-jet nozzle size between 2 m^2 and 10 m^2 is usually sufficient, this would cause problems in aerodynamic tests, where the prevailing nozzle size of today's full-scale automotive facilities is between 10 m^2 and 30 m^2. Thus, a thermo tunnel may be build more cost-efficiently, if its size is optimised only with respect to the scope of its tests. Therefore, like in other branches of automotive engineering, also in aerodynamics there are special wind tunnels for special demands. Especially climatic wind tunnels (CWT) have been put into operation in considerable numbers in recent years. [17,18] may just serve as examples. CWT serve completely different needs compared to aerodynamic wind tunnels or