

Progress in Vehicle Aerodynamics III

Unsteady Flow Effects

Edited by

Prof. Dr.-Ing. Jochen Wiedemann

Dr.-Ing. Wolf-Heinrich Hucho

Authors

Stefan Becker

Johannes Bosbach

Antonello Cogotti

Brendan Gilhome

Jeff Howell

Wolf-Heinrich Hucho

Moni Islam

Ulrich Knörnschild

Jürgen Kompenhans

Hermann Lienhart

Angus Lock

Sigfried Loose

Matthias Marquardt

Markus Raffel

Edmond Széchényi

Cameron Tropea

Andreas Wagner

Christian Willert

With 191 figures, 7 tables
and 248 references

expert  verlag®

Table of Contents

1	Unsteady Flow Effects in Vehicle Aerodynamics – Occasional Observations and Distinction of the Phenomena	1
	<i>Wolf-Heinrich Hucho</i>	
2	Characterisation of Unsteady Flows	19
	<i>Cameron Tropea</i>	
3	Large Scale Fluctuations and Turbulence in the Wake of a Generic Car Model	45
	<i>Hermann Lienhart and Stefan Becker</i>	
4	Unsteady Flow Structures and Forces Over/On the Rear Window and Boot Lid of Sedan Automobiles	57
	<i>Brendan Gilhome</i>	
5	A Comparison of Unsteady Forces on Passenger Cars	71
	<i>Matthias Marquardt</i>	
6	The Overtaking Process of Vehicles	80
	<i>Edmond Széchényi</i>	
7	Unsteady Aerodynamics – Its Simulation, Measurement and Effect on the Driver	89
	<i>Angus Lock</i>	
8	An Approach to Predict and Evaluate the Driver's Response to Crosswind	107
	<i>Andreas Wagner</i>	
9	Influence of Unsteady Pitch Angle Changes on a Race Car	121
	<i>Ulrich Knörnschild</i>	
10	Unsteady Aerodynamic Loads on a Road Vehicle in Windy Conditions	133
	<i>Jeff Howell</i>	
11	Generation of a Controlled Turbulent Flow in an Automotive Wind Tunnel and its Effect on Car Aerodynamics and Aeroacoustics	150
	<i>Antonello Cogotti</i>	

- 12 **Measurement of Unsteady Flow Fields**
*Markus Raffel, Christinan Willert, Jürgen Kompenhans,
Sigfried Loose and Johannes Bosbach*
- 13 **Simulation of Unsteady Flows**
Moni Islam

177

192

The Authors

**1 Unsteady Flow Effects in Vehicle
Occasional Observations and**

Wolf-Heinrich Hucho

Abstract

Unsteady flows effects observed on a vehicle character of the oncoming flow. This flow can be calm weather – or in a wind tunnel. Unsteady effects occur at otherwise steady conditions or from an unsteady boundary layer velocity profile. Up to quite recently only with the latter two phenomena, if at all. In the following chapters, it is the aim of this chapter to describe effects which are still widely overlooked. These are the moments which are stochastic and, in some cases, have a content close to the natural frequency of the vehicle.

1.1 Occasional Observations

The vehicle aerodynamicist is used to think in terms of "time" does not exist, and spectra analysis and aero acoustics being the only exception. However, it can be verified by observation that the flow past a bluff body is not else but steady state. Here are some examples.

- Right after his start in vehicle aerodynamics, the author experienced an exciting event: In the course of measuring the aerodynamic characteristics of a back saloon, a Reynolds-number series was conducted. As standard practise in this wind tunnel, the shock absorbers were unlocked. Already at a low speed, the vehicle got "nervous". At a speed, which was not specified, it started to oscillate like a pendulum, the contact point of the rear wheel motion. The edge of the trunk went up and down, the oscillation growing with increasing wind speed. At a certain speed, a resonance, the car jumped from the back of the test cell. The "experiment" had to be terminated. Later, it was observed with other cars. This was noticed by the force beam and moving weight at that time – did