APPLICATION OF A LATTICE-BOLTZMANN CODE IN AUTOMOBILE AND MOTORCYCLE AERODYNAMICS

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1. Introduction

The request for shortening development cycles in the automotive industry enforces the employment of simulation methods, especially in the early phase where no hardware is available yet for physical testing. Analyzing concepts by simulation in the initial phase can avoid errors whose correction will be cost and time intensive in later stages of the development process. But also during serial development, simulation tools provide a deeper understanding of the physics and thus may reduce the number of physical models to be tested for instance in the wind tunnel in case of aerodynamics (Fig. 1, Ref. [1]).

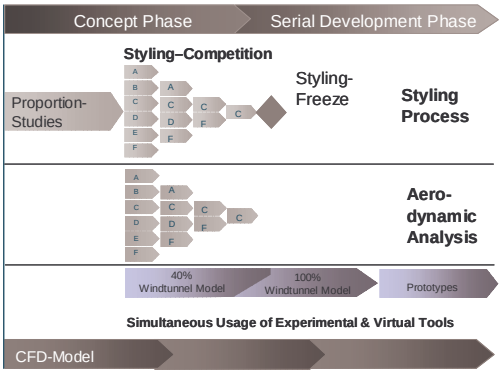

Fig.1: CFD in the aerodynamic development process [1]

At the BMW group wind tunnel and CFD are not considered as competing tools, rather they are utilized in a complementary fashion.

To be accepted as a valuable tool in an industrial environment a CFD code ideally has to

- be accurate ($\Delta C_X < \pm 0.005$, $\Delta C_Z < \pm 0.010$), at least for trend predictions
- require a minimum of geometry input preparation
- be able to handle complex geometries (underhood & underbody details)
- deliver results in a reasonable timeframe (over night)
- be easy to use (by wind tunnel engineers, i.e. non-numerics specialists)

Around 1997 BMW started to validate a Lattice-Boltzmann code (PowerFLOW by EXA Corp.) for aerodynamics [2]. To date the tool has reached a level of maturity which enables its productive use in external aerodynamics. In close cooperation with the code developers we are working to extend the applicabilty to thermal management investigations, where currently still a traditional tool (STAR-CD) is employed.

2. Basics of Lattice-Boltzmann Methods

This chapter only intends to convey the basic ideas of Lattice-Boltzmann methods. Details can be found in [3]-[6].

2.1 Mesoscopic Approach

The macroscopic behaviour of fluids that we observe and which is governed by the Navier-Stokes equations is the consequence of molecular motion, described by kinetic theory. Although molecular dynamics is simpler and more general than the macroscopic approach, the numerical simulation of flows at a microscopic level is still prohibitive for practical problems.

The idea of Lattice methods is to construct a simplified microscopic description at a mesoscopic level between kinetic theory and Navier-Stokes equations that still contains the essentials to produce the correct macroscopic appearance (Fig. 2).

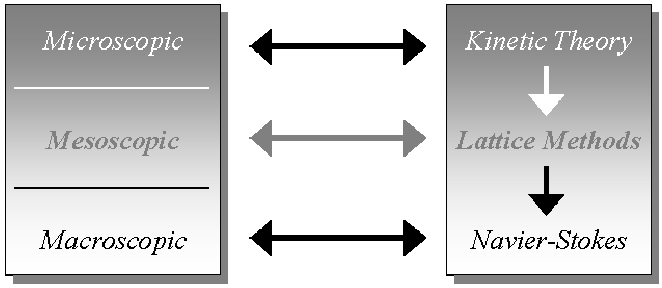

Fig.2: Mesoscopic approach to the simulation of fluid motion

2.2 Kinetic Theory

The interaction of molecules composing a fluid is described by kinetic theory. Unlike the Navier-Stokes equations where macroscopic variables like density, velocity and temperature are used, the fundamental quantity in kinetic theory is a velocity distribution function

Eq. (1) $$f = f(\vec{x}, \vec{c}, t)$$

which gives the number of particles per unit volume at time t in the phase space $\vec{x}$ and $\vec{c}$ (location and particle speed). Macroscopic quantities are obtained by integration (Eq.2-4).