CFD METHODS IN INDUSTRIAL APPLICATIONS – VEHICLE EXTERNAL AERODYNAMICS AND AERODYNAMIC INTERACTION OF MOVING VEHICLES

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Summary The paper deals with the properties of 3-D flow around a moving vehicle during the aerodynamic interaction with its environs. The models of rail vehicles intended for the public mass transport (fast trains, sub-urban trains units, underground and municipal railways trains) are simulated. Driving speeds of those vehicles are supposed in the range of 80 – 220 km/h. The computer simulations contribute to understanding and summarising the complex description of aerodynamic load of rail vehicles during various running regimes and situations, important aerodynamic effects occur during the passing of vehicles and/or under side wind. Simulations are carried out by means of commercial CFD code. Aerodynamic load is modelled as a special boundary condition in form of aerodynamic effect models. Those models describe (and to calculate) aerodynamic and interaction effects onto vehicles during passing and under side-wind and include time-dependent and space-dependent values of load. The studies allow to increase efficiency and accuracy of computer simulations.

EXTERNAL AERODYNAMICS OF TRAINS

Development of public transport is of a great priority in nowadays Europe. A great effort is done in the field of developing effective and rapid surface which should ensure ability to compete and meet requirements for comfort and safety of passengers with adequate driving time, availability and roads´ network density. When considering environmental demands those services can be ensured by railway transport with driving speed in the range of 150 - 250 km/h. When projecting both rail lines and trains under those driving conditions aerodynamic effects of running rail vehicles and interaction vehicles-environs is considered to be useful to investigate deeper. The situation is similar at long distance bus traffic, only a greater role is played by the influence of side-wind on the course stability of the vehicle on the road. Aerodynamic influence of interaction comes to light in the form of supplementary loading of vehicles and environments and buildings. Aerodynamic forces influence the output of driving units, vehicle stability, added loading, generation of aerodynamic noise etc.
The computer simulation is aimed at the research into external aerodynamics and interaction between running rail vehicles of public transport and environs, which is surrounding mass of air, other means of transport and various buildings in the vicinity of the line of running (tunnels, terrain corridors, wind barriers etc.). Aerodynamic interaction is mediated or caused by flowing air, important aerodynamic effects on vehicles occur during the passing of vehicles, under side wind and during the propagation of pressure waves and pulses in tunnels.

COMPUTER SIMULATION

Computer simulation is aimed at 3-D flow in the vicinity of moving vehicle during the aerodynamic interaction with its environs. The main aim is:
- simulation of drive regimes using the commercial CFD program,
- preparation of the methodology for the evaluation of the way of loading and the magnitude of values of added aerodynamic loading of the vehicles surface during the typical regimes of the drive and ranges of flow rate,
- creation of user models of aerodynamic effects as a special boundary condition setup.

Systematic steps of simulation are:
- modelling of physical properties of flow around vehicles,
- modelling of motion of vehicles in computational domain.

Vehicle motion is modelled in two ways:
- relative motion – relative velocity between train surface and surrounding air is presented as velocity in inlet plane to computational domain, the train geometry is non-moved, (see Fig. 1 and 2),
- real motion – geometries of passing trains are moving, in this case we can use interface, sliding mesh or deforming grids tools of CFD codes (see Fig. 3 – there is 2D-train models' passing).

The subject of simulations is to analyse the physical relations between moving vehicle and environs, to classify important parameters and to include these parameters into the computational CFD programs for the purposes of technical simulations. The task is to prepare the model of aerodynamic effects and the interaction (passing, side-wind). These models are expected as:
- special function as a similar polynom will be include into CFD code (UDF – user-defined function),
- complicated mathematical terms and polynoms as external codes will be implemented into CFD code (data file),
- external code, which will compute the most complicated load parameters.

The goals and tasks of computer simulation in this period:

- creation of aerodynamic effect models as an in-house code or UDF-functions (various structure of codes corresponding with load conditions),
- implementation and test of models in commercial CFD code as special boundary conditions,
- verification calculation and simulation of typical running regimes of vehicles,
- test of capabilities and cooperation between CFD (computational fluid dynamics) code and MBS (multibody simulation) code to solve vehicle dynamic response and course stability during aerodynamic load regimes.

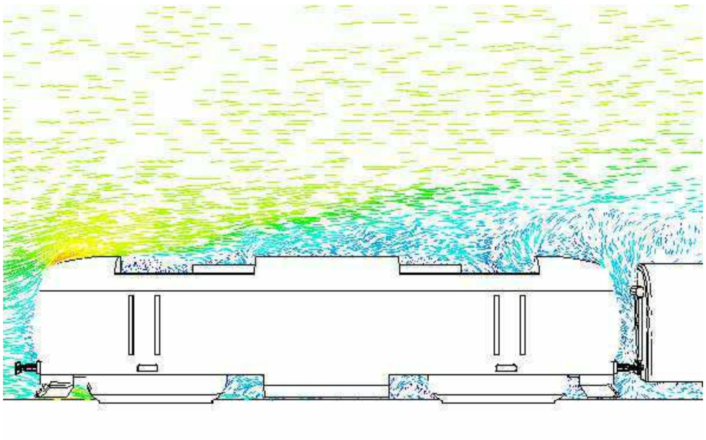

Fig. **1**

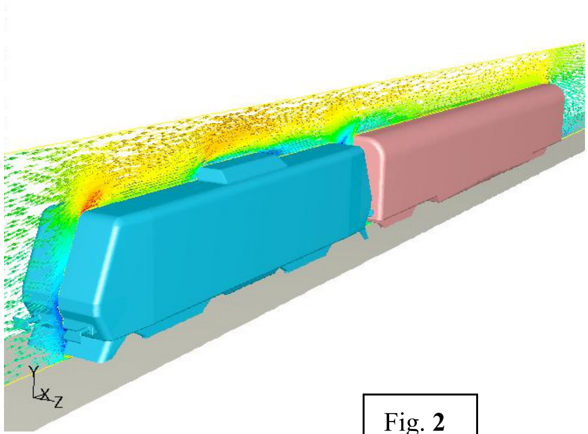

Fig. **2**

Simulation of non-moving train and velocity vectors in symmetry plane, Fig. **1** is train in the open air going at speed 200km/h, Fig. **2** is train in tunnel (train relative motion speed is 100km/h).

Fig. **3** - simulation of passing 2D- train models, there is pressure map of one time step of unsteady calculation only.

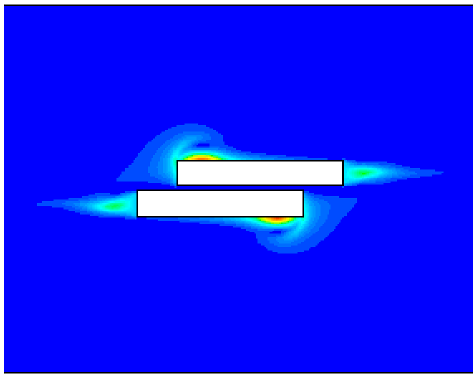

Fig. **3**.

GRID COMPUTING PROJECT

The external aerodynamics and interaction flow simulation tasks need big capacity of computing resources. The EU-funded project IST-2001-38433 “Flow simulations on-demand using grid computing” (acronym FlowGrid) creates a virtual organisation of Europe CFD centres to develop and validate software and knowledge for grid-based CFD computations. Developing and sharing CFD software and computing resources will enable this. FlowGrid system will control and manage computer grid and computing resources making to possible to increase power of CFD analyses. Several tasks from vehicle external aerodynamics are used for FlowGrid testing.

CONCLUSIONS

Computer simulations of rail vehicle external aerodynamics are described in the paper. Possibilities of CFD analyses by commercial CFD code are discussed. CFD grid computing is briefly meant.