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Elementary approach to monitoring and evaluation of aerodynamics simulations of moving parts in computational domain

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This paper is generally focused on modelling of aerodynamics with motion in computational domain. Basic approach to modelling of domain zones motion using so called "sliding-mesh" method and setting relevant boundary conditions for simulate calculations are described. These engineering cases were selected: CFD simulations of the hydrodynamic situation around the model of moving control rods and CFD simulations of the aerodynamic situation in the tunnel through which a train pass. Results of simple case studies of trains riding through a tunnel are showed. Relationship between the resulting values of CFD calculations and values mentioned in standards and other rules determining the operating condition in tunnels are discussed.

Modelling of aerodynamics with a motion in the computational domain is a problem where separate domain parts move relatively to each other. The relative motion of stationary and moving components of domain generates transient interactions and time dependent aerodynamic load. This motion can be translational or rotational.

One possible approach how to simulate "motion in domain" is the method of "sliding-mesh" which is often used in CFD simulation of aerodynamics [1]. This method is based on the motion of one or more moving zones relatively to stationary non-moving zones. 3D-case domain includes moving/stationary zones as volumes with "unchanging shape and size" and non-deforming computational mesh in domain.

The "sliding-mesh" modelling is used in many applications of engineering praxis:

- rotating machines, turbines, compressors, fans,
- control valves,
- control and nuclear fuel rods,
- moving and passing vehicles.

Important part of the "sliding-mesh" setup model is the "interface-zone". Each domain cell zone is bounded by at least one "interface zone". These cell zones slide (rotate or translate) relatively to each other along the mesh interface in discrete steps during the calculation.

Basic setup of "sliding-mesh" models is common and consists of several main steps (moving/stationary zones, interfaces, time-dependent solvers, etc.). Each "sliding-mesh" model application is different in many details corresponding to the particular engineering case. Size and dimensions of domain, types of mesh elements, boundary layer requirements, boundary conditions, medium materials (aero/hydro) or time background of model play important role and have significant influence on other parameters of the calculation setup. Time management of calculation is often crucial because choice of time-step size, number of time steps or number of iterations per time-step affect the process of convergence of the calculation. Of course, set-up parameters of currently solved task are always very different from others cases.

Simulation of the slow motion of a control rod in channel was chosen as the first illustrating case from engineering praxis. Small cylindrical rod was shifted in shaped channel. Domain dimensions size were several millimetres, high-pressure water was used as the surrounding medium, rod shifts several millimetres. The pressure load of the rod was investigated as the main result of simulation.

The simulation of train aerodynamics in tunnels was chosen as the second illustrative example from the engineering praxis. [2]. This category of tasks contains wide variety of ride regimes to simulate: the train enters the tunnel, the train rides through the tunnel and passing and crossing trains in the tunnel (at various speed, various shape of tunnel, various types of trains – loco, electric/motor-unit, etc). Results of simulations allowed us to judge the aerodynamic influence of moving vehicles or influence of a moving vehicle to the surroundings and then to examine:

- the design of a train shape,
- the aerodynamic load of a train body or its parts,
- the influence of the riding train to the surroundings,
- the design of the tunnel and tunnel portals.

The setup, post processing and the result analysis of these tasks correspond to the requirements given by standards or ride regulations (e.g. maximal running speed, line speed) of pressure strain of train parts, tunnel and surroundings. The graph of the time-dependant value of pressure on front part of the moving locomotive or the graph of the time-dependant value of pressure in fixed point along the railway tracks are often used as relevant results.

It should be noted that other approaches to model a “motion in domain” is to use the method of “dynamic-mesh” with deforming meshes of moving zones [1]. The “dynamic-mesh” model allows us to move the boundaries of a cell zone relatively to other boundaries of the zone. Simulations of aero/hydrodynamic situation in the model as “moving piston in cylinder” are typical engineering cases for this method.

Conclusion of this extended abstract is simple: CFD simulations allow us to model engineering cases with “complicated” aerodynamics when one or more parts of computational domain are in motion. The methodology of the simulation itself is clear, but it should be noted that the approach how to compare the results to the requirements of standards is not. It should be clearly defined what monitoring is required, which aerodynamic loads should be studied and how and where they act.

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References

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