Steps towards a real time solution of fire in tunnels

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The availability of an efficient tool for simulation of a fire scenario in a tunnel is of paramount importance for fire safety management in emergency situations, for training of fire brigades prior to emergency cases in order to be able take the right decisions when needed and to evaluate measures geared to increase the resistance of existing tunnel vaults against spalling. We have developed such a tool which takes the thermal fluid-structural coupling in a tunnel fire fully into account [1]. It appears as one of the largest coupled problems actually solved in the community of computational interaction problems. The simulation of a realistic fire scenario is still a time consuming task and the tool is not yet completely ready for the first of the above mentioned three goals. One of the bottlenecks is the heavy computational burden linked with the three fluids model for concrete. It is not possible to disregard the enormous heat sink the tunnel vault represents with the phase changes and chemical reactions going on in heated concrete. Such an omission can yield temperature fields also some 300°C above measured ones in an experiment. On the other hand simplifications of these phenomena are not possible as highlighted in two recent companion papers [2,3]. In the existing model we have chosen a 3D-2D coupling strategy where the thermally driven CFD part is solved in a three dimensional cavity i.e. the tunnel, and the concrete part is solved on 2D sections normal to the tunnel axis, at appropriate intervals. The heat flux and temperature values between the sections which serve as coupling terms between the fluid and the structural problem are interpolated. With such an approximation the heat transfer in the tunnel vault in the direction of the tunnel axis is disregarded. As an example, with such an approach the fully coupled simulation on a realistic tunnel for a fire of 20 MW of the duration of one hour lasts some 24 hours on a PC.
The aim of our current research effort is twofold: realize a true 3D-3D coupling on one hand and reduce drastically the computing time on the other hand. The way for achieving this is through adoption of an extremely fast equation solver which can achieve a speed-up of up to 3600 times [4] and the adoption of the Proper Generalized Decomposition PDG [5,6] for a fast 3D solution of the problem of heated concrete. Steps in this direction as well as the general model will be shown.

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