Melchior Schepers Lund university June 2018
Master 's thesis in fire safety engineering

Multi-scale modelling of fire in accelerator tunnels: a CERN case study

Modern day engineering and architecture push the boundaries of our technical capabilities. As structures become more and more complex a one size fits all approach based on prescriptive regulations is no longer up to the task of ticking all the boxes to ensure a fire safe design. This is where a performance-based approach based on fire modelling comes into the picture. In a performance-based approach the design is not based solely on written regulations, but rather tested by detailed numerical simulations. Running such a simulation however requires huge amounts of computational power, which is costly and often only available at supercomputing centers. To be able to run a large number of different fire scenarios approximating techniques therefore have to be used. An example of one such technique is multi-scale modelling. Multi-scale modelling combines detailed 3D computational fluid dynamics with simplified 1D approximations, in order to reduce the computational cost of the simulation and thus significantly enhance its speed.

The European Organization for Nuclear Research, CERN, located at the Franco-Swiss border is a typical facility housing complex infrastructure, which has to be designed using a performance-based approach. This is in part also due to the fact that the special diplomatic status of the CERN site causes it to fall outside of national regulations. At the CERN site near Geneva, huge particle accelerators are used to collide fundamental particles and investigate their properties. These accelerators are housed in large underground tunnels often spanning many kilometers. The largest accelerator in use is the Large Hadron collider or LHC, located in a 27km long circular tunnel, 100m below the surface. Modelling a fire in the 27km long tunnel completely in 3D would lead to a very slow and computationally expensive model, due to the size of the domain. This is where multi-scale modelling comes in, as it allows for the vast majority of the domain to be represented by a simplified 1D model.

By using the Fire Dynamics Simulator software it was possible to build a representative multi-scale model of a three kilometer long section of the LHC tunnel. The domain was split in a 640m long 3D section and a 2360m long 1D part. This division is the strength, but also the weakness of the multi-scale modelling technique as the coupling implies a sudden loss of information when going from 3D to 1D. Not surprisingly the location of the 1D-3D interface is thus a very important parameter in designing the multi-scale model and was extensively researched in the thesis work.

A question that however comes to mind when using approximating techniques such as multi-scale modelling is how exact the results are? Validation of the results either by experiments or by a full 3D simulation is thus the logical step forward for any future research.