CFD Modelling Of Urban Road Tunnels

Marjan Demuynck[1], Siegfried Denys[1]

[1]University of Antwerp, Antwerp, Belgium

Abstract

Urban road tunnels offer a promising solution to extend existing road infrastructure while mitigating air pollution and nuisances affecting nearby residential areas. By diverting traffic underground, valuable surface space becomes available to address other urban challenges. However, road traffic within tunnels still contributes to atmospheric pollution, necessitating effective management measures both inside the tunnels for user safety and well-being, and at tunnel outlets to limit environmental impacts.

This research project focuses on evaluating the environmental impact of road tunnel infrastructure, specifically air quality, and explores air purification techniques and design modifications to minimize these effects. To accomplish this, a comprehensive computational model is developed using the COMSOL Multiphysics® Model Builder. Computational fluid dynamics (CFD), with the implementation of the RANS k-e turbulent model, plays a central role in characterizing the flow dynamics in various scenarios. Longitudinal ventilation inside the tunnel is modeled using the Interior Fan feature in COMSOL Multiphysics®. A preliminary study is conducted to efficiently incorporate the influence of traffic and the piston effect, with the direct modeling of vehicles using the moving wall and moving reference frame methods. Indirect modelling through the inclusion of source terms in the defining equations is also explored. Additional factors such as external wind, tunnel exits and ventilation shafts are accounted for by adapting the geometry and boundary conditions. Furthermore, the heat transfer module is coupled to consider the shaft effect, while the transport of diluted species aids in calculating concentrations of particulate matter, NO, and CO within the computational domain.

Initial results include successful simulations of basic tunnel geometries, traffic, and ventilation options, serving as fundamental building blocks for larger infrastructure projects and guiding future research endeavors. Subsequent simulations will incorporate innovative air purification techniques (both passive and active), complex geometries, and a validation of the model through a comprehensive measurement campaign.

Figures used in the abstract

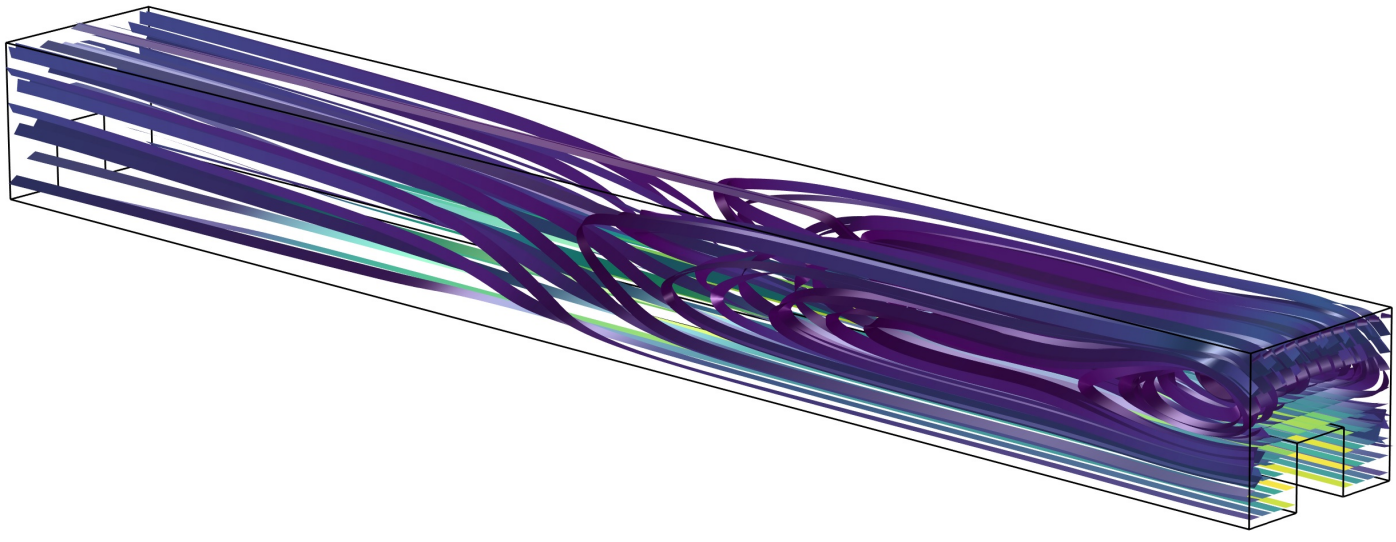

Figure 1 : Airflow due to moving cars, modelled as a moving block in the tunnel.

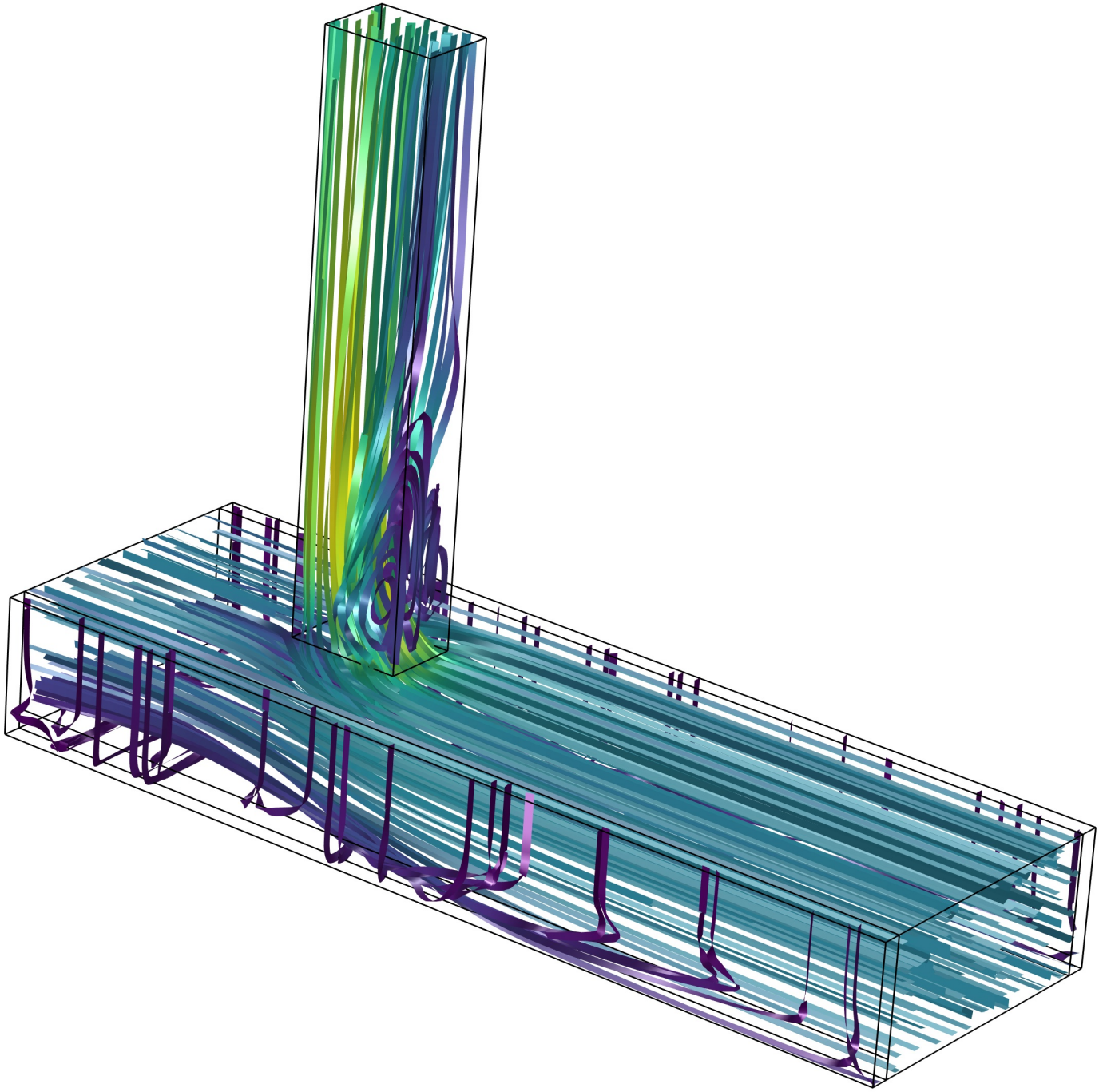

Figure 2 : Airflow in a tunnel when an active extraction shaft and a passive injection shell is present.