Heat and Air Flow Analysis Laboratory

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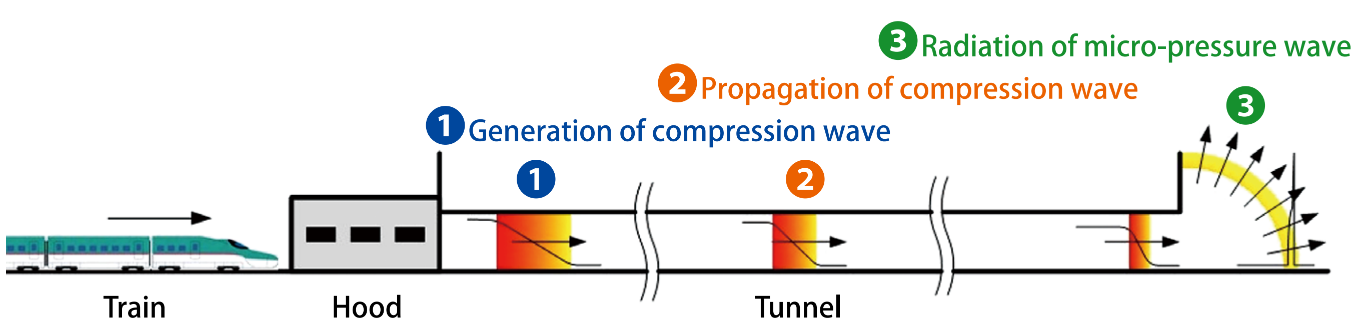
Heat & Air Flow Analysis

The Heat and Air Flow Analysis Laboratory deals with various aerodynamic phenomena in a tunnel. Our current main research subjects include those related to compressible fluids (e.g., micro-pressure waves radiated from the tunnel exit to the outside when the train enters the tunnel, and train draft and pressure fluctuation in the tunnel) and those related to heat and fluids (e.g., temperature rise in the tunnel due to train running, and understanding the flow behavior of hot gas in a tunnel fire). The following introduces research activities concerning micro-pressure waves and hot gas flow in tunnel fires.

Micro-pressure wave

When a train enters a tunnel at high speed, a compression wave is generated in the tunnel. This wave propagates through the tunnel at the speed of sound, resulting in a radiation of pulsed pressure waves from the other portal of the tunnel (Generating mechanism of micro-pressure waves). These pressure waves, called micro-pressure waves, generate blasting noise and shake houses near tunnel portals; therefore, we should take measures to reduce them.

The magnitude of micro-pressure wave is proportional to the maximum value of the pressure gradient of the compression wave in the tunnel (time derivative of pressure). Therefore, the basic principle for the measures is to reduce the maximum pressure gradient of the compression



Generating mechanism of micro-pressure waves wave in the tunnel, that is to lengthen the formation time of the compression wave. The main measures implemented under this principle include a hood installed at the tunnel entrance (Tunnel entrance hood), and a train nose lengthened and optimized (Lengthened and optimized train nose).

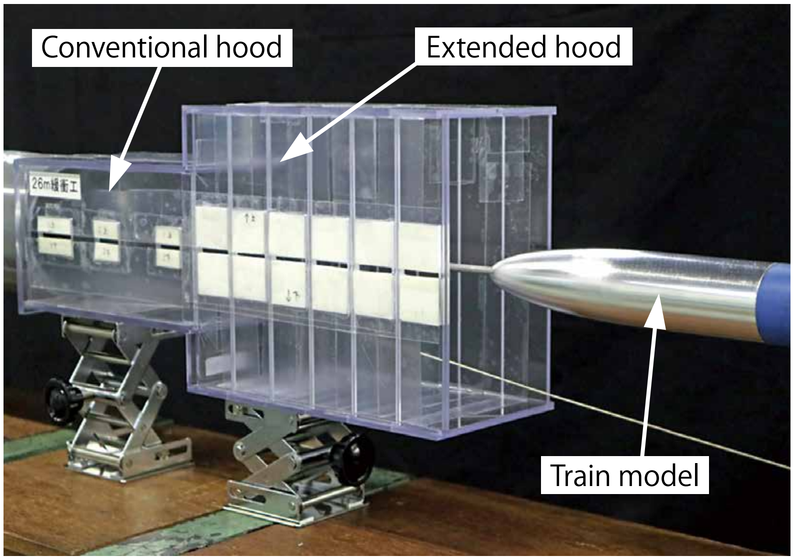
The tunnel entrance hood is the most important measure to reduce the micro-pressure wave. However, the construction cost can be very high because the total length is required to be several tens of meters or more for vehicle speeds of 300 km/h or more. As such, we are currently researching ways to shorten the length of the entrance hood to reduce the cost. Model experiment of two-step entrance hood shows an example of the achievements, which is a two-step entrance hood with a larger cross-sectional area at its forefront than the conventional one. We determined the optimal cross-sectional area and length of the forefront by numerical calculation and model experiment and verified that it has the same performance as the conventional hood with a shorter length than the conventional one.

Tunnel fire

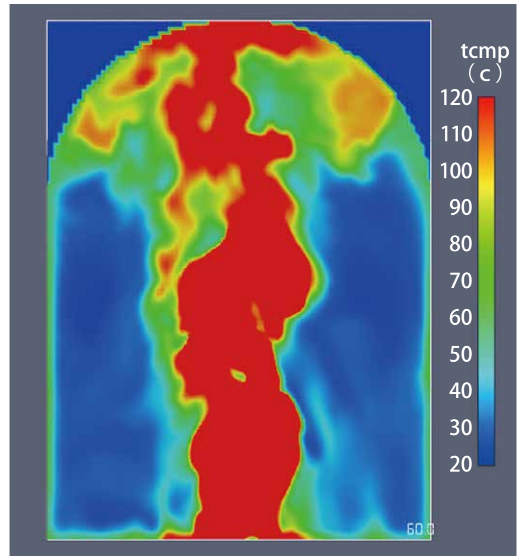
Although there are few cases of fires in railway tunnels, they can be hazardous situations because railway tunnels are very narrow and easily filled with smoke. Furthermore, unlike road and subway (urban) tunnels, railway mountain tunnels are not equipped with ventilation for smoke exhaust, making it difficult to predict the flow of smoke. Thus, we are studying smoke flow (i.e., hot airflow) prediction by numerical simulation.

When a fire occurs in a tunnel, the hot gas impinges on the ceiling due to its buoyancy, then travels toward the tunnel

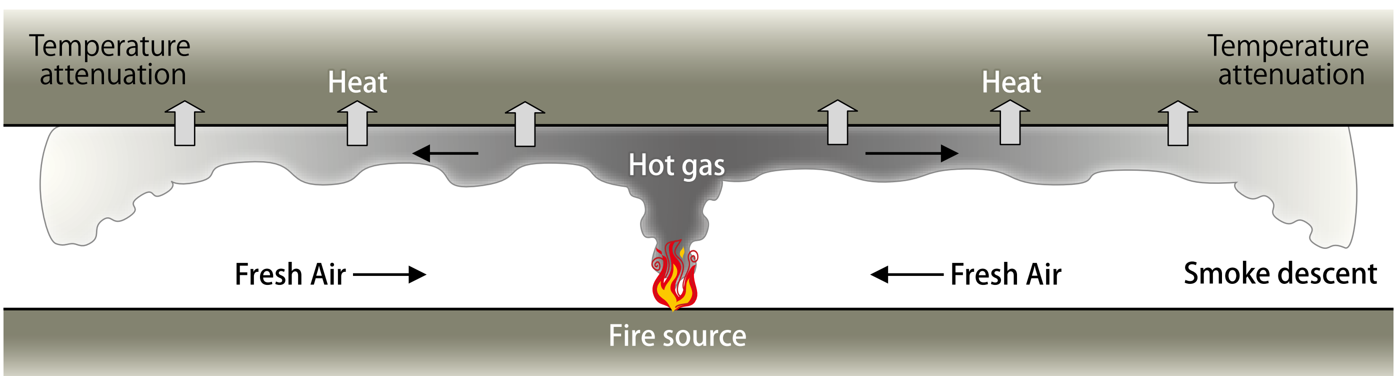
Upper row: Tunnel entrance hood
Lower row: Lengthened and optimized train nose



Model experiment of two-step entrance hood



Example of simulation of hot gas



Schematic diagram of hot gas in a tunnel fire

portals beneath the ceiling, and fresh air flows under it from the portals entrance toward the fire source (Schematic diagram of hot gas in a tunnel fire). The hot gas traveling beneath the ceiling is cooled by the ceiling wall and the fresh air flowing under the hot gas, and it gradually descends to the ground due to the decrease in its buoyancy. The numerical simulation, therefore, requires that not only flow field but also the heat transfer be accurately solved, making it difficult to assure calculation accuracy. Thus, we have also conducted model experiments and have verified the validity of the calculation model by comparing the experimental results with the calculation results. As an example, Example of simulation of hot gas shows a result of calculating the temperature distribution near the fire source installed on the tunnel floor.

The above is an introduction of research activities that the Heat and Air Flow Analysis Laboratory has conducted recently. We will continue to research the aerodynamic phenomena in a tunnel through theoretical analysis, numerical analysis, model experiments, and other means.