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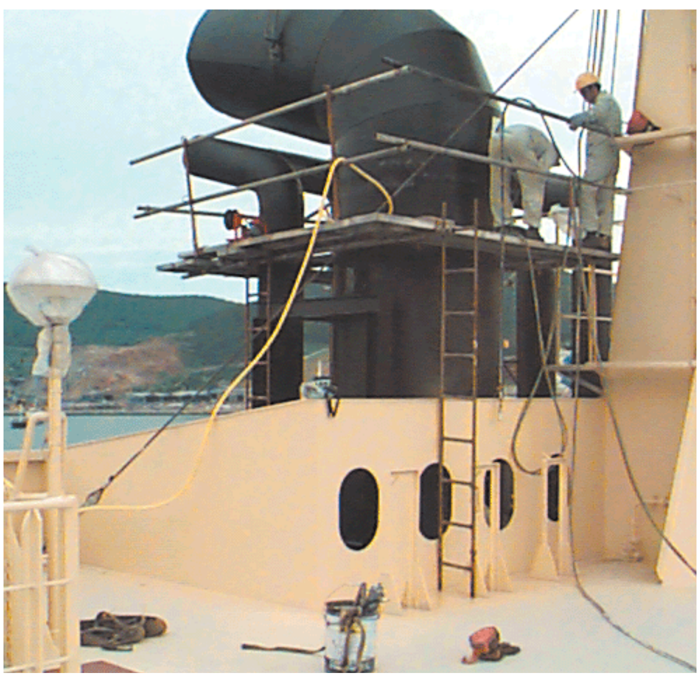
Improving Air Quality on Cargo Vessels

Courtesy of Daewoo Shipbuilding and Marine Engineering Co., Ltd.

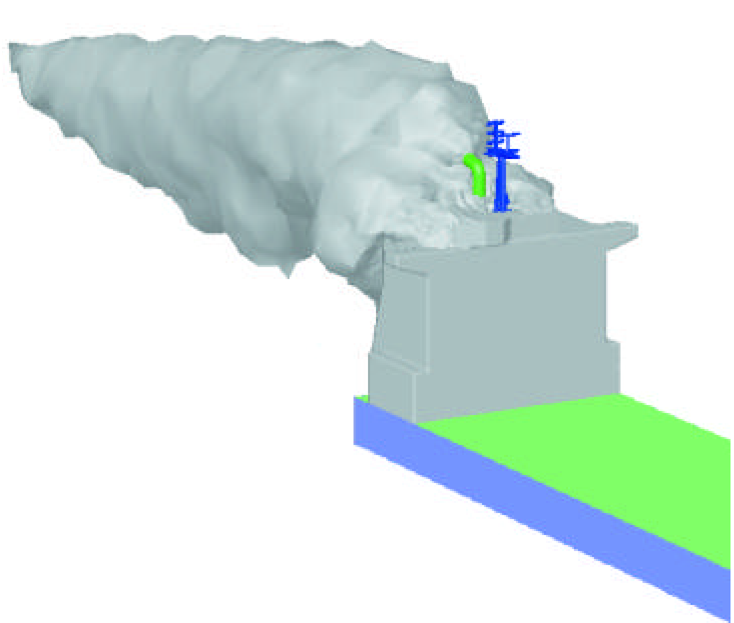
Air pollution is a health hazard and can threaten the integrity of structures not only in the city but also at sea. A sea-going vessel has its own propulsion system, which is usually an exhaust-emitting internal combustion engine. The exhaust can cause serious problems for the on-board air quality and result in irreversible damage to the ship. To prevent this from happening, the exhaust must leave the vessel immediately after being emitted from the funnel, rather than linger in the vicinity of the vessel. Simulations of the exhaust plume are a key factor in the design of funnel placement and size. Previously, simulations were done solely by wind tunnel tests on scaled models. Recently, however, DSME (Daewoo Shipbuilding and Marine Engineering Co., Ltd.) in Seoul, Korea has successfully used FLUENT for this purpose.

A typical arrangement of a cargo vessel has the funnel just behind the accommodation, a huge block that creates turbulence, a considerable pressure drop, and a large re-circulation zone behind it. Unless the funnel is tall enough, the exhaust can get trapped in this re-circulation zone, causing it to engulf the stern area of the vessel and perhaps the accommodation as well.

While an easy solution to this dilemma would be to make the funnel taller, doing so is not feasible. Many design constraints exist that act to confine the funnel height. One is that a tall funnel interferes with navigation and communication devices such as signal lights, radar, satellite dishes, and antenna that are usually installed on top of the accommodation. Because the funnel is a cantilever, a larger height can lead to increased vibration levels. Last but not least the air-draft, or maximum allowed height of a vessel, imposes a severe restriction on the funnel height. Taking these factors into consideration, the goal of the accommodation design engineers is to determine the optimum location for the smallest possible funnel so that serious on-board pollution will not occur. By using FLUENT for this task, DSME engineers could avoid performing time-consuming and costly wind tunnel tests.

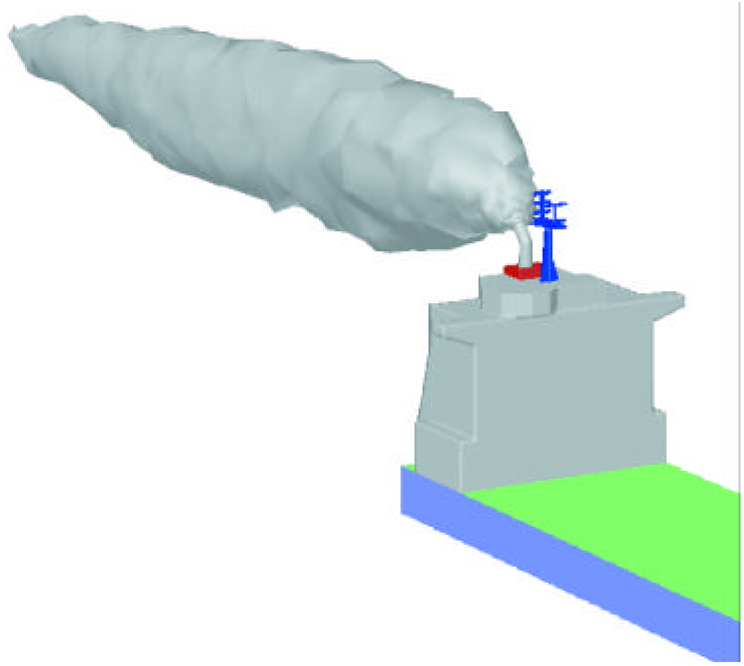


The original funnel design



Exhaust plumes from the original design engulfed the rear of the ship

A modified funnel design



Exhaust plumes from the modified design are carried away from the ship

In the simulation, the exhaust was modeled as a mixture of air and pollutants such as NO_2 and SO_2 using the species transport model. The temperature of the exhaust was also modeled, as it reached as high as 300°C. The parametric modeling capability of GAMBIT saved much time and effort in modeling the various wind conditions (speed and direction) to account for a wide range of travel velocities for the vessel.

The level of the pollution was evaluated by pollutant concentrations and ash trajectories. To check if the concentration level was acceptable or not, OEL2000 (Occupational Exposure Limit 2000), which is published and updated annually by HSE (Health and Safety Executive, UK), was used as a reference. The ash was incorporated using the discrete phase model with a Rosin-Rammler particle size distribution, and tracked from the exhaust release at the top of the funnel. Several designs were proposed and simulated. Based on the resulting pollution levels, the designs were modified and simulated again. The process was repeated until the pollution levels became satisfactory.

The simulation of exhaust plumes using FLUENT is now a part of the regular design cycle at DSME for those vessels with dubious exhaust emission performance. It also plays an important role in the imperative troubleshooting between the launch and delivery of a vessel when it happens to have on-board air pollution problems. FLUENT enabled DSME to have a quick and economical way of keeping its vessels immaculate, while avoiding time-consuming and costly tests to improve their performance.