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Thermal Properties and Smoke Diffusion of Oil Pool Fires in Engine Room for Fire Safety Design

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A fundamental study is carried out regarding the heat and mass transfer characteristics of an engine room fire. At first, an oil burning experiment in a box-type compartment, which is a simplified engine room fire model, is conducted under a limited ventilation condition to understand the nature of engine room fires and investigate smoke production and movement. From the experiments, several types of quantitative relation between the oil burning rate and the smoke generating rate are obtained. Then an experiment and a 3-dimensional CFD numerical simulation of smoke movement in a realistic engine room model are performed to investigate the smoke characteristics in a compartment with complicated geometry. Quantitative and qualitative comparisons are made between the measurements and the numerical predictions.

INTRODUCTION

Many fire accidents in the engine rooms of ships and marine structures come into existence worldwide, and the unexpected burning of hydrocarbon liquid, such as fuel oil and lubrication oil, tends to be the primary cause. However, the nature of an engine room fire is still not well understood due to the extreme complexity of the physical and chemical mechanisms. Accordingly, for a safe design in the matter of oil pool fire phenomena, an analysis is necessary that takes thorough account of the governing factors and the characteristics of the flammability of liquid fire. Further, the emission and movement of the smoke during oil burning are very important phenomena for a successful fire-safe design such as setting up escape routes and installing fire detectors.

In this study, 2 experiments are carried out: an oil burning experiment in a box-type compartment and a smoke diffusion experiment in an engine room model. As most engine room fires are caused by the burning of leaked oils, the oil burning experiment, which is carried out under well-ventilated conditions, will help us understand the basic features of smoke production and movement. So it is very important for us to develop a numerical simulation method of predicting an engine room fire for fire safety design. From the experiments, several types of quantitative relation are obtained, such as the smoke weight density vs. the smoke volume release rate and the smoke weight density vs. smoke extinction coefficient. In the experiment with an engine room model, a smoke generating apparatus is used to produce hot smoke constantly from the fire spot on the floor. The smoke density is measured at several points inside the engine room. In this case, a 3-dimensional numerical simulation is also carried out. The numerical method, which is a 3-D field model in which the k-ε model is applied, will be briefly described in this paper. Reasonably good agreement is obtained for both quantitative and qualitative comparisons between the measurements and the numerical predictions.

A number of studies have attempted to simulate fire phenomena, and the most recent review is provided by Tieszen (2001). The zone models, in which room-averaged quantities are predicted for multi-room problems, have been used extensively for engineering applications. Recently, field models, which make simulation possible in much finer spatial and temporal resolution, are used in the study of fires. In case of a field model approach, the Boussinesq approximation that is generally used is not suitable for the fire problem (Gray and Giorgini, 1976), but this difficulty has been settled by Erlebachar and Hussaini (1992). The smoke flow model is required to account for the effect of unresolved small-scale movements. The most common turbulence model for the simulation of a realistic fire problem is the k-ε model. The weak point of this model is its low temporal resolution due to the time average process. The large eddy simulation (LES) approach, in which spatial filters are used to derive the governing equations for state variables, is a very promising model that can obtain time-accurate field information and overcome the weak point of the k-ε model. The usefulness of the LES method has been demonstrated in fire simulations (McGrattan et al., 1998; DesJardin and Frankel, 1998; Hu and Fukuchi, 2002). However, the k-ε model is chosen as the turbulence model for the present computation, because the speed of the smoke flow induced by that release is much slower than that of the propagation of acoustic waves, and a huge number of lattice meshes is not required by dealing simply with the boundary condition.

OIL POOL FIRE PHENOMENON

Accidental spills of liquid fuels in the engine room of ships and marine structures can pose a serious fire hazard. Some hydrocarbon liquids are highly volatile at ambient temperatures, and other liquids have a high flashpoint and require localized heating to achieve ignition. However, a very rapid flame spread will occur over the liquid spill surface igniting at once. In free burn

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