INVESTIGATION OF GAS DISTRIBUTION DUE TO CIRCULATION FANS IN STRUCTURAL FUMIGATION

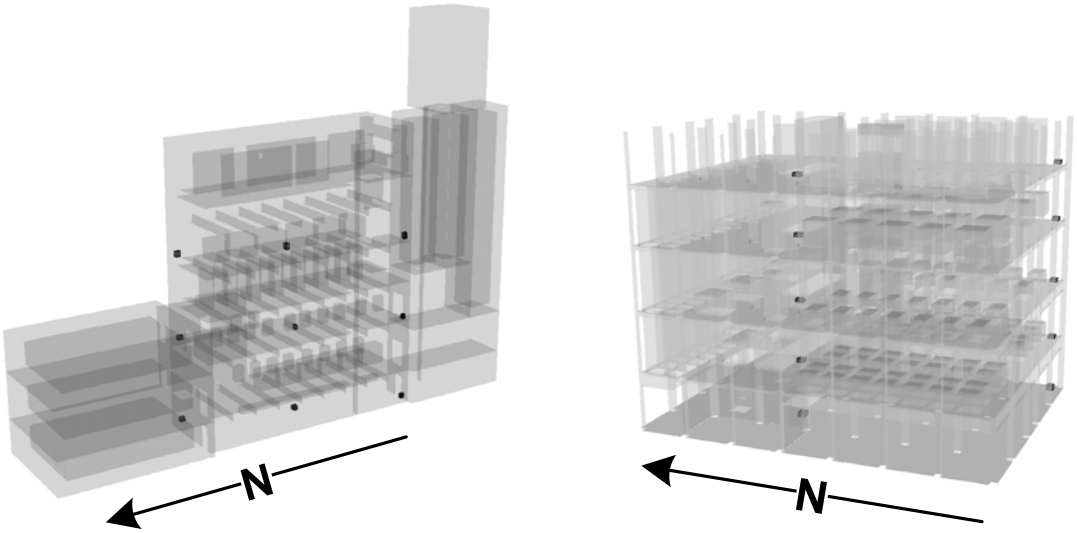
Watcharapol Chayaprasert[1], Dirk E. Maier*[1], Klein E. Ileleji[1], and Jayathi Y. Murthy[2]
[1]Agricultural and Biological Engineering Department, [2]Mechanical Engineering Department, Purdue University, West Lafayette, IN 47907

Achieving uniform gas distribution is one of the key elements to the success of a structural fumigation job. In order to thoroughly disinfest the fumigated structure of insect pests, the target dosage (i.e., concentration×time or Ct product) must be reached throughout the structure. However, because it is not possible to completely seal a structure, there will always be areas of low fumigant concentrations. This is especially true for large structures such as flour mills or food-processing plants. Insufficient fumigant distribution could result in one of the following worst-case scenarios:

- If the monitoring point was located in a low concentration region, for the most part the fumigated volume would experience fumigant overdosing, resulting in inefficient fumigation.
- If the monitoring point was located in a high concentration region, insect pests in low concentration regions could potentially survive due to under-exposure, resulting in a fumigation failure.

Although it is a standard practice to use circulation fans to ensure uniform gas distribution, proper selection and utilization of circulation fans (including number, location, flow capacity, orientation, and operating time) is subject to the fumigator's experience and understanding of the fumigation process. The objective of this study was to use available computational fluid dynamics (CFD) models developed in our previous study to quantitatively evaluate the effectiveness of circulation fans on gas distribution during fumigation.

Two CFD models developed based on two reference flour mills, Mills A and B, were used in this study (Figure 1). For each model, several fumigations were simulated. Each simulation was performed with various circulation fan numbers, locations, orientations and flow capacities. In addition, fumigant introduction locations were also varied. In the Mill A model, possible fan locations were at the north-east or south-west corners, or in the middle of the basement and the second and fourth floors of the flour mill (Figure 1a). In the Mill B model, possible fan locations were at the south-east or in the middle of every floor of the mill (Figure 1b). All fans were located on the floor levels. Except for the configuration of circulation fans and fumigant introduction locations, the other parameters were assumed the same for all simulations of each respective model. The gas fumigant used for both models was sulfuryl fluoride (SF). The release of fumigant was made in one application starting at the beginning (i.e., exposure time = 0 hour) of each simulated fumigation and no follow-up releases were made. For both models, fumigant concentrations were monitored at the four corners and in the middle of each floor of the flour mills.



(a) (b)

Figure 1. Simulation flow domains of (a) Mill A and (b) Mill B.

The simulation results yielded the following conclusions:

- Configuration of circulation fans has significant impacts on gas distribution.
- In general, the more circulation fans, the better the gas distribution. However, excessive use of circulation fans is not necessary. Given the same total flow capacity (e.g., cfm), a circulation fan layout with fewer fans can out perform one with more fans if the fans are well placed.
- Circulation fans have a more significant effect than fumigant injection locations with regard to fumigant distribution. With the same fan layout, different injection locations would present the same distribution pattern except for the transient phase during the fumigant injection period.
- For good fumigant distribution, circulation fans should be placed in such a way that the flow path in front of it is as long as possible.
- Circulation fans have almost no operating cost. Leaving them on during the entire exposure period will benefit fumigant distribution without adding costs to the fumigation. The optimum gas distribution can be achieved by proper sizing and placement of circulation fans.