Process Exhaust Duct System Design in a Semiconductor Factory Using Feedback Simulation Method

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Abstract

achieve pressure balance and ignore energy conservation in the actual running process. A feedback simulation method that contains system simulation and correction procedure is proposed. An acidity gas exhaust system in a semiconductor factory is presented in this study to understand the characteristics of the proposed method. The results demonstrate that the feedback simulation method improves efficiency of duct system design and facilitates the pressure balance of an exhaust duct system. It also provides the energy conservation strategies for the actual operating condition during the design stage.

Keywords: duct design, feedback simulation method

I. INTRODUCTION

At present, most conventional HVAC duct designs use the equal friction method [1], which fail to achieve a pressure balance system. After construction of factory is complete, system pressure has to be on-site balanced by adjusting the fan speeds and the branch dampers to meet the designed flow rate. However, the pressure balancing procedures for air distribution systems is rather complicated [2]. It usually takes long time to proportional adjust branch dampers until each terminal has the proper air volume. If the factory is expanded or the duct layout is changed, the pressure balance needs to be readjusted in order for the system to reach equilibrium. In some cases, overly large fans must be installed to make up for poor design, which add to the extra costs.

Tsai et al. [3] introduced a design that eliminates the disadvantages of conventional designs. With its exact mathematical model and iterative method, the duct system is optimized. Meanwhile, it has the advantages of minimum life cycle cost and system pressure balance. However, T-method offers poor control of flow velocity or duct diameter. When there are too many limitations, Mathews and Claassen [4] indicated that it is difficult to obtain the satisfactory optimal solution from T-method. Shiu et al. [5] proposed dynamic programming method for the exhaust duct system design. Although dynamic programming method enables the system to achieve system pressure balance with the life cycle cost taken into account, it fails to give method for flexible design and an insight into the actual operating condition during the design stage. Moreover, they cannot conduct the design in case of expansion of the factory or change of duct lay out. Thus, it is necessary to search for an efficient design method that considers the pressure equilibrium under certain limits on space or flow velocity and provides the energy conservation strategies for the actual running conditions.

II. FEEDBACK SIMULATION METHOD

Figure 1 shows the design flowchart for duct design, which includes four major steps: inputting given system dimensions and constraints, initial duct design, system simulation and correction procedures [6, 7]. Initial design method can adopt one of the conventional duct design methods with designating given system conditions and limitations. In this paper we use equal friction method as the initial design method. System simulation and the correction procedure can be described as follows.

The system simulation adopts the simulation method introduced by Tsai et al. [8]. It comprises three major expansion. First, the total friction loss from the Darcy-Weisbach equation for round duct is:

$$\Delta P = \frac{fL}{D} + \sum C \frac{8 \rho}{\pi^2} Q^2 D^{-4}$$

(1)

If $\mu$ is defined as $\mu = \frac{fL}{D} + \sum C \cdot D$, the volume flow rate can be identified in terms of diameter and pressure loss as

$$Q = \frac{\pi}{\sqrt{8}} \left( \frac{D}{\mu} \right)^{0.5} \sqrt{\Delta P}$$

(2)

By introducing the duct section characteristic, $K_s$, as

$$K_s = \frac{\pi}{\sqrt{8}} \left( \frac{D}{\mu} \right)^{0.5}$$

(3)

Then, the flow rate at a duct section becomes

$$Q = K_s \sqrt{\Delta P}$$

(4)

This step determines system flow rate and total pressure by locating the intersection of the system curve and fan performance curve. When the system condensing is completed, the duct system arrives at only one fan and one imaginary duct section. Therefore, from Eq. (4) we