Participating media에서 열전달 계수의 추정방법

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An inverse radiation problem of estimation heat-transfer coefficient in participating media

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1. Introduction

In the pulverized coal combustor, gasifier or solid waste incinerator, the outlet temperature is determined by the amount of heat removed in the radiant cooler for steam generation. The control of the outlet temperature from the furnace is an important factor for a smooth operation of the plant. If the outlet temperature is kept too low, the required quality of steam is not generated. On the other hand under a higher outlet temperature than the optimum, the fly ash becomes liquid state and can easily stick on the heat transfer surface. Consequently the heat removal rate is retarded, increasing the outlet temperature further which enhances deposition of fly ash on heat transfer surface. In the worst case, the radiant cooler is clogged by ash. Therefore, we must adjust appropriately the water flow rate through the steam generator so that an optimal outlet temperature is maintained always. For this purpose, it is necessary to estimate heat transfer coefficient from temperature measurement in the radiant cooler, where heat is removed from hot gas to generate steam, since heat transfer coefficient changes slowly due to the deposition of fly ash.

In the present investigation, we consider an inverse heat transfer problem of estimating wall heat transfer coefficient $h(z)$ from temperature measurements in the radiant cooler. Since the temperature of the system is very high, the main mechanism of heat transfer is radiation attenuated not only by absorbing gases such as water vapor and carbon dioxide, but also by suspended particulates such as coal, char, ash and soot. Accurate simulation of the radiative process requires analysis of the combined absorption and scattering of radiant energy employing the radiative transfer equation [1, 2].

2. Theory

Figure 1 shows the radiant cooler which is a cylindrical channel of radius $R(=0.5m)$ and length $H(=5m)$ with opaque and diffusively reflecting sidewall, through which hot gas with particulates flows while heat is exchanged through the sidewall, and governing equation may written by

$$\rho C_p \mathbf{v} \cdot \nabla T = \nabla \cdot k \nabla T - \nabla \cdot \mathbf{q}_r \quad (1)$$

$$\nabla \cdot (\hat{s} I) + (\kappa + \sigma) I = \kappa I_b + \frac{\sigma}{4\pi} \int_{4\pi} I(r, \hat{s}') d\Omega \quad (2)$$

$$\nabla \cdot \mathbf{q}_r = 4\pi\kappa (I_b - \frac{1}{4\pi} \int_{4\pi} I d\Omega \quad (3)$$

$$I_b = \sigma T^4 / \pi \quad (4)$$

· at the side wall($r=R$)

$$-\kappa \frac{\partial T}{\partial r} = h(z)(T - T_c)$$

$$I(\mathbf{r}, \hat{\mathbf{s}}) = \varepsilon I_b + \frac{1-\varepsilon}{\pi} \int_{\hat{n} \cdot \hat{s}' < 0} |\hat{n} \cdot \hat{s}| I(\mathbf{r}, \hat{\mathbf{s}}) d\Omega \qquad (\hat{n} \cdot \hat{s} > 0) \quad (5)$$

and equation (1)-(5) solved by following procedure

1. Assume the temperature field.
2. Calculate I_b using Equation (4).
3. Solve the radiative transfer equation (2), using the S_4 method [1].
4. The divergence of the radiative heat flux, $\nabla \cdot \mathbf{q}_r$ is determined by equation (3).
5. Solve equation. (1) using a finite volume method [9] to obtain the temperature field.
6. Repeat the above procedure until the converged temperature and radiation intensity fields are obtained.

3. Result

Figures 2- a, b show the estimated profiles of heat transfer coefficient for the two cases of Fig. 2 when the improved adjoint variable method is employed. In the same figure, the required iteration numbers and the estimation errors are also indicated. Contrary to the results of the adjoint variable method, the improved adjoint variable method is shown to yield satisfactory results. Figures 3-a ~c are the plots for the adjoint variable $P(r,z)$ at several iteration stages for the case of Fig. 2-a when the improved adjoint variable method is used. At the initial stage of the iteration the effect of the singular source appears apparently, but it diminishes as the iteration proceeds. In the case of the improved adjoint variable method, effect of the singular source is smoothed out in the evaluation of $\frac{\partial F}{\partial \mathbf{h}}$ through integration over the basis functions $\psi_m(z)$, resulting in non-oscillatory accurate estimation of . In this case, the predicted temperature $T(r,z)$ coincides with the temperature field obtained by using the exact $h(z)$, $T^*(r,z)$, not only at the measurement points but also at other locations at the final stage of iteration as shown in Fig. 4.

4. Conclusion

An inverse radiation problem is investigated where the wall heat transfer coefficient is estimated from temperature measurements in the radiant cooler. By employing the improved adjoint variable method [8], the numerical difficulty associated with the singularity of the adjoint equation is removed. The present technique is found to identify the heat transfer coefficient $h(z)$ accurately and can be used for an efficient operation of radiant coolers.

5. Reference

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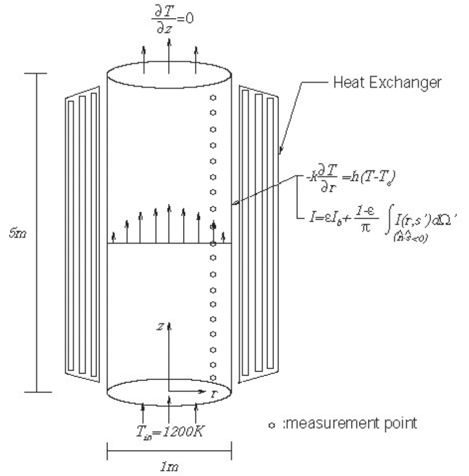

Figure 1. The system and measurement locations.

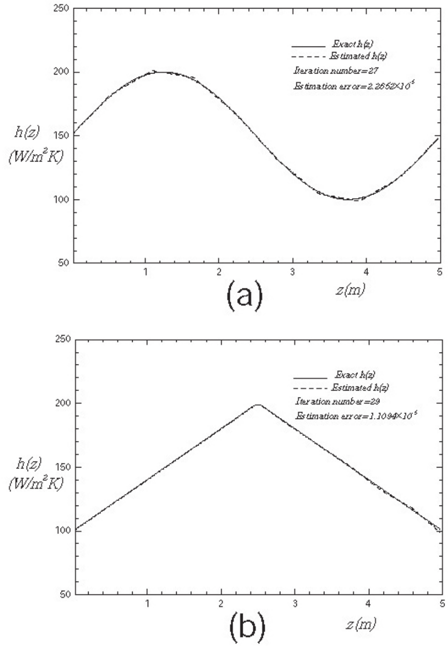

Figure 2. The estimated profiles of heat transfer coefficient for the two cases of coefficient in the present work

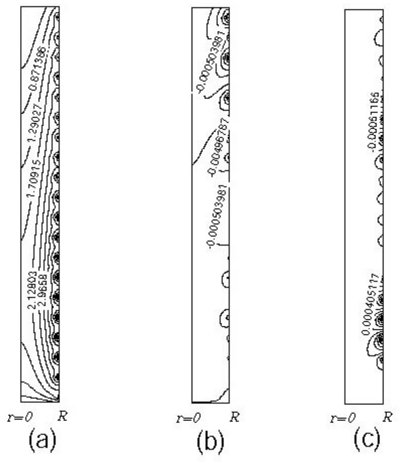

Figure 3. The adjoint variable $P(r,z)$ at several iteration stages for the case (a) of Fig. 2 when the improved adjoint variable method is employed.

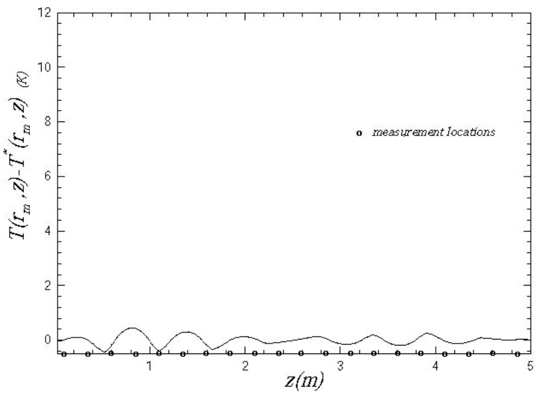

Figure 4. The difference between the predicted temperature $T(r_m,z)$ and the exact temperature $T^*(r_m,z)$ at the final stage of iteration (improved adjoint variable method).