APPLICATION OF VARIOUS METHODS OF MODELLING RADIATIVE HEAT TRANSFER FOR CONTINUOUS INDUSTRIAL FURNACES WITH FLAT FLAME BURNERS.

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The main objective of researches was the application and comparison of the most popular available methods of solving heat radiation problems. Stress has been laid on the application of these methods to analyse heat transfer in continuous industrial furnaces. In this article three different methods have been considered : brightness and configuration factor method, Hottel's zoning method and irradiation factor method supported by Monte Carlo technique. Additionally, grey and wide band models of emission have been examined.

METHODS

Brightness and view factor method[4] — an improved version of very well-known method previously applied to enclosures filled with isothermal and absorbing-emitting gas. In the method presented here the enclosure was filled with nonisothermal gas. The walls of the enclosure and the gas were divided into surface and volume elements.The discretization is relative thin. The time consumption for the calculation is low but the accuracy is also poor. It is difficult to apply advanced fluid dynamics without a large complication of model. Despite this, it seems to be a good method for control systems because the result can be achieved in a real time.

Hottel's zoning method[1-2] – the most frequently used engineering technique of solving heat radiation problems with active gases. The enclosure is divided into number of surface and volume elements. The direct exchange surfaces are achieved by numerical multidimensional integration over each surface and each volume element. The method of putting out the emission of the isothermal elements of the enclosure has been applied to obtain the tatal exchange surfaces. Unfortunately, in many cases a singularity of integrands was observed. It is possible to achieve a good accuracy but at a significant numerical cost.

Irradiation factor method[4-5] – a kind of Monte Carlo technique. Irradiation factors are defined as:

$$\Psi_{i \to j} = \frac{\dot{E}_{i \to j}}{\dot{E}_i} \qquad (1)$$

where: $\dot{E}_{i \to j}$ -radiant energy originated from the *i-th* element and in a direct way or after reflection or partial absorption in gas is absorbed by the *j-th* element. $\dot{E}_i$ -total radiant energy emitted from this element. Probabilistic tools have been used to obtain direct irradiation factors, and then the method of putting out the emission as in Hottel's method has been applied. The discretization technique is similar to Hottel's method. There are no problems with solving the multidimensional integrals of the singular functions. Additionally, the time consumption is much lower than in the case of the classical Monte Carlo method.

OBJECT

In the first stage of the work the fragment of a pusher type furnace with flat flame burners has been considered (Fig.1). Steady state has been assumed. Two flat flame burners fed with natural gas (94% of CH_4) are mounted on the furnace roof. Flue gases contain 12% of CO_2 and 20% of H_2O (vapour). Turbulent (standard k-ε model) flow has been considered. The charge in form of slabs with dimensions of 160mmx140mmx6000mm covers the whole bottom surface of the furnace.

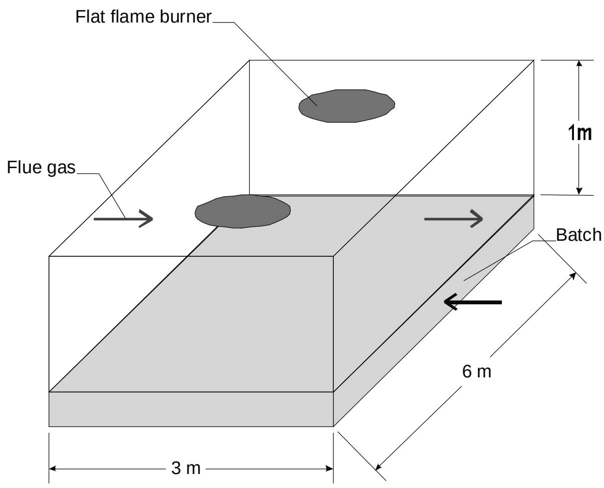

Fig. 1.

SOLUTION METHODS

Modelling the fluid flow, grid preparation, gas combustion, energy balances and postprocesing have been performed by CFD package Fluent.The described methods of radiative heat transfer have been programmed in Fortran90 language outside the comercial package. The energy equation takes the form:

$$\frac{\partial}{\partial t}(\rho E) + \nabla(u(\rho E + p)) = \nabla(k_{eff}\nabla T - \sum_i h_i J_i) + q_V \qquad \textbf{(2)}$$

where q_V has been defined as the volumetric source of radiation expressed by the equation:

$$q_V = \dot{E}_{ai} - \dot{E}_i \qquad \textbf{(3)}$$

where: $\dot{E}_{ai}$ -radiant energy flux absorbed in the surface or volume elemenyt, $\dot{E}_i$-radiant energy flux emitted by the surface or volume element.
The main aim of this work was to examine the effectivnees of various methods of calculating the term $\dot{E}_{ai}$ in equation (3).
The solution concerns the grey and wide-band models[3].

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