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Numerical Simulation of Dump Combustor with Auxiliary Fuel Injection

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Solutions of the steady, two-dimensional Navier-Stokes, thermal energy, radiation flux, and species conservation equations have been computed for a dump combustor geometry with downstream constriction. The equations are solved in the conservative finite-difference form on a nonuniform rectilinear grid of sufficient resolution to capture the momentum/thermal boundary layers accurately. The numerical procedure, SIMPLEST, which is a variation of SIMPLE, is used to ensure more rapid convergence. A $k-\varepsilon$ model is incorporated for the enclosure of turbulence with a wall function. The combustion model, ESCRS (extended simple chemically-reacting system) with eddy break-up model for the reaction rates of species conservation equation or energy equation is also used. For the good destruction of hazardous waste, it is effective that the waste is injected in the recirculation zone of high temperature with the condition not disturbing the combustion cavity. Excess oxygen from a lean core flame can be effectively utilized for waste destruction with the hydrocarbon waste injection as fuel-rich condition. The core flame has a significant impact on the structure of recirculation cell, in some cases completely changing the nature of the flow within the cavity. The optimum velocity of waste injection exists for the highest temperature at the recirculation zone. A premixed flame type for the auxiliary fuel is good for high temperature and long residence time to be large cavity in the recirculation zone.

Key Words : Dump Combustor, Combustion Cavity, Hazardous Waste, Incineration

1. Introduction

Incineration is an attractive alternative for the treatment of several classes of toxic wastes. In addition to providing a significant reduction in waste volume, incineration allows recovery of a substantial amount of energy. Many metals are rendered less toxic through promotion to higher oxidation states. Recent legislation has largely eliminated such less expensive options as landfills and surface impoundments in favor of source minimization and post-treatment technologies. Of the post-treatment technologies available, incineration is one of the most versatile, and the one for which considerable operational experience exists. Thus, considerable growth in the use of incineration for hazardous waste disposal is expected gradually (Krieger, 1989). Particularly dump combustor located on the same site where the waste is generated usually have been considered as an attractive combustor for the less opposition of public.

Dump combustors are characterized by the sudden expansion of a fuel-air mixture into a combustion cavity formed by a rearward facing step. While a stable combustion configuration can be achieved in which two flames are attached to the rearward-facing steps, combustion instabilities frequently arises in which vortical structures coincident with the flames are periodically shed from the flame-holding dump plane, that is, from the steps at the entrance to the combustion cavity (Logan et al. 1991). The vortices can be shed alternately from either side of the dump plane, exciting transverse modes of acoustic oscillation within the cavity and creating the phenomenon known as screech (Rogers et al. 1956). Longitudi-

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nal mode combustion instabilities, in which the pairs of shed vortices are in phase with each other, have been studied more recently through experimental (Pitz et al., 1983; Pointsot et al. 1987) as well as analytical efforts (Yang et al. 1986).

Most of past studies have been focused on the flame stability and structure. However we are interested in utilizing the large hot recirculation zones in the dump cavity as oxidizing chemical reactors for the destruction of hazardous wastes. We are concerned with the residence time of wastes and rate of entrainment of oxidizing species within the recirculation zone, and with the effects on both of the location and rate of waste injection.

In this paper we present the construction of a steady two-dimensional model of the combustor with combustion models, and its use in characterizing the structure of the flame front and recirculation zone. For the presentation of basic data for the design of dump combustor, parametric screening studies have been done with different conditions.

2. Numerical Models

2.1 Turbulent model

The $k-\varepsilon$ turbulent model (Launder et al. 1972) is used for turbulent flow, where a Prandtl-Kolmogorov relationship is used to correlate the turbulent viscosity μ_t to the turbulent kinetic energy (k) and its dissipation rate (ε).

$$\mu_t = C_\mu \frac{\rho k^2}{\varepsilon} \tag{1}$$

Here C_μ and ρ are empirical constant and density respectively. Thus this model is closed by solving transport equations for k and ε shown in Table 1.

Effective turbulent viscosity (μ_{eff}) is defined as:

$$\mu_{eff} = \mu + \mu_t \tag{2}$$

where μ is the molecular viscosity.

2.2 Wall function

A wall function is used near a wall, since the expression of μ_t given by equation (1) is accurate only at the fully turbulent flow region. For the velocity components parallel to a wall, the diffusion fluxs are calculated by defining an effective turbulent viscosity from the empirical law of the wall[7] as

$$\begin{aligned} \mu_{eff} &= \mu && \text{if } y^+ < 11.5 \\ &= \frac{\mu y}{2.5\ln(9y^+)} && \text{if } y^+ \geq 11.5 \end{aligned} \tag{3}$$

where $y^+ = \rho k^{1/2} C_\mu^{1/4} \frac{y_l}{\mu}$ and y_l is a normal distance from a wall to the corresponding first internal grid point.

2.3 Combustion model

The combustion model used is ESCRS (extended simple chemically- reacting system) which allows for variable specific heats, density, temperature and heats of reaction. the data for which are taken from the CHEMKIN (Kee et al. 1981) thermodynamic data base. The ESCRS model in this study is used by the finite-rate chemistry model of which the chemical reactions are relatively slow like premixed flames.

Two-step three reactions such as the burning of CH_4 with H_2 and CO as intermediates via all three reactions is used as follows

$$\begin{aligned} &2CH_4 + O_2 \rightarrow 2CO + 4H_2 \\ &2CO + O_2 \rightarrow 2CO_2 \\ &2H_2 + O_2 \rightarrow 2H_2O \end{aligned} \tag{4}$$

The chemical reaction rate for each of this reactions ($t = 1, 2, 3$) can be expressed as

$$w_j = -a \times \min(m_i, s \times m_{ox}) \times \frac{\varepsilon}{k} \tag{5}$$

where a is the EBU constant which has a value of 4.0, s stoichiometric requirement, m_{ox} oxidant mass fraction, and m_i the species mass fractions of CH_4, CO and H_2 ($i = 1, 2, 3$, respectively).

2.4 Radiation model

Radiation heat transfer plays a dominant role in most combustor and industrial furnace. The products of gas combustion, such as CO_2 and H_2O, are strong selective adsorbers and emitters. The composite flux model has been widely applied in combustion chambers and furnaces by Gosman et al. (1973) and Khalil (1975).

The assumptions of four flux model used in this study allow the energy transfer in four principal coordinate direction. The RTEs (radiative transfer equations) are given by Spalding (1980) as

$$\frac{d}{dx}\left(\frac{1}{a+s}\frac{dR_x}{dx}\right)=a(R_x-E)+\frac{s}{2}(R_x-R_y)$$
$$\frac{d}{dy}\left(\frac{1}{a+s}\frac{dR_y}{dy}\right)=a(R_y-E)+\frac{s}{2}(R_y-R_x) \quad (6)$$

where a and s represent the absorption and scattering coefficient respectively.

The E is the black-body emissive power as

$$E=S\times T^4 \quad (7)$$

where S represents the Stefan-Boltzmann constant (i. e., $5.6678\times10^{-8}\,W/m^2K^4$) and T is the absolute fluid temperature.

The composite radiation fluxs are defined as

$$R_x=\frac{(I_x+J_x)}{2} \quad R_y=\frac{(I_y+J_y)}{2} \quad (8)$$

where I_x, I_y are radiation fluxes in positive and negative axial (x); I_y, J_y in positive and negative axial (y).

The contribution of radiative heat transfer to the energy equation is a source term involving the divergence of the radiative heat flux. The source term of the energy equation is given as Eq. (9).

$$S_{rad}=2a[R_x+R_y-2E] \quad (9)$$

2.5 Residence time

To calculate the residence time in a dump combustor, the scalar variable ϕ in Eq. (12) must be solved. The accumulation of time is accounted for by special sources, which are related to the fluid residence time in a cell. This residence time, Δt, is calculated as:

$$\Delta t=\frac{\rho Vol}{\sum_j m_{inj}} \quad (10)$$

where ρ is the fluid density, Vol the cell volume, and m_{inj} the mass inflow to the cell through face j, where the summation is over all faces. This source should be the product of the cell residence time, Δt, and the mass flow rate through the cell, $\sum_j m_{inj}$. Hence, the source is given by:

$$S_\phi=\frac{\rho Vol}{\sum_j m_{inj}}\sum_j m_{inj}=\rho Vol \quad (11)$$

3. Calculations

The nonuniform, orthogonal computational grid used for the unit aspect ratio (A=L/S) simulations is shown in Fig. 1. Boundary conditions and physical dimensions are as indicated in the figure. Coordinate stretching has been employed to increase the grid density near the dump and outlet planes because we expect the fluid dynamic effects to be important there. Grid compaction is employed in the core flow to accurately capture the flame. The grid arrangement for the unit aspect ratio simulations is 47×56. The calculations have been performed for reference flame selected by computing a series of cases and for the flames changed parameters to be important factors for the design of dump combustors.

The basic conservation equations for mass, momentum, energy, turbulence quantities, radiation flux and species concentration can be expressed, in an Eulerian cartesian coordinate, as

$$\frac{\partial}{\partial x}(\rho u\phi)+\frac{\partial}{\partial y}(\rho v\phi)=\frac{\partial}{\partial x}\left(\Gamma_\phi\frac{\partial\phi}{\partial x}\right)+\frac{\partial}{\partial y}\left(\Gamma_\phi\frac{\partial\phi}{\partial y}\right)+S_\phi \quad (12)$$

in which ϕ denotes general dependent variables per unit mass. ρ, u, v, Γ_ϕ and S_ϕ stand for density, x, y velocity components, diffusion co-

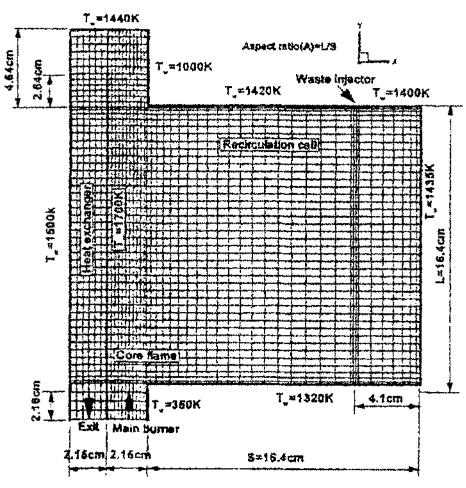

Fig. 1 Computational grid with boundary conditions and physical dimensions.

efficient and source term corresponding to ϕ, respectively. Expression for Γ_ϕ and S_ϕ are presented in Table 1 together with empirical constants for the $k-\varepsilon$ turbulent model (Khalil et al. 1975), where σ denotes turbulent Prandtl/Schmidt number, and Table 2 for ESCS with eddy break-up model.

The solution of the Eulerian gas phase equations are done by control volume based on the finite difference procedure. A detailed description of this method is given by Patankar (1980).

In brief, the method requires the division of the computational domain into a number of control volumes, each associated with a grid print. The governing differential equations in each control volume profile are approximated in each coordinate direction in this study, the power-law scheme is employed for the discretization of the convection term appeared in the governing Eq. (12).

A system of discretized linear equations is solved iteratively due to the nonlinear feature of the equation implicity imbedded in the coefficient of the discretized equation. To solve RTEs the conduction term (i. e., first term) in equation (12) is omitted.

The numerical procedure, SIMPLEST (Semi-Implict Method for Pressure-Linked Equations ShorTened) algorithm (Spalding, 1988), is used to enclosure rapid converge.

Table 1 Expression for Γ_ϕ and S_ϕ for k-ε turbulence model.

ϕ	Γ_ϕ	S_ϕ
u	μ_{eff}	$\frac{\partial}{\partial x}(\mu_{eff}\frac{\partial u}{\partial x})+\frac{\partial}{\partial y}(\mu_{eff}\frac{\partial v}{\partial x})-\frac{\partial p}{\partial x}$
v	μ_{eff}	$\frac{\partial}{\partial x}(\mu_{eff}\frac{\partial u}{\partial y})+\frac{\partial}{\partial y}(\mu_{eff}\frac{\partial v}{\partial y})-\frac{\partial p}{\partial y}-\rho g$
k	$\frac{\mu_{eff}}{\sigma_k}$	$G_{kl}-\rho\varepsilon$
ε	$\frac{\mu_{eff}}{\sigma_\varepsilon}$	$\frac{\varepsilon}{k}(C_1 C_k - C_2\varepsilon)$

$$G_{kl}=\mu_{eff}\left[2\left\{\left(\frac{\partial u}{\partial x}\right)^2+2\left(\frac{\partial v}{\partial y}\right)^2\right\}+\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2\right.$$

Constant in Turbulence Model

$C_1=1.44$, $C_2=1.92$, $C_\mu=0.09$, $\sigma_\varepsilon=1.22$, $\sigma_k=0.9$

Table 2 Expression for Γ_ϕ and S_ϕ for combustion models.

ϕ	Γ_ϕ	S_ϕ
m_{CH_4}	$\frac{\mu_{eff}}{\sigma_{CH_4}}$	w_{CH_4}
m_{CO}	$\frac{\mu_{eff}}{\sigma_{CO}}$	w_{CO}
m_{H_2}	$\frac{\mu_{eff}}{\sigma_{H2}}$	w_{H_2}
h	$\frac{\mu_{eff}}{\sigma_h}$	$(m_{CH_4}H_{CH_4}+m_{CO}H_{CO}+m_{H_2}H_{H_2})-S^*_{rad}$
f	$\frac{\mu_{eff}}{\sigma_f}$	—

* S_{rad} is in equation (9)

Constant in Combustion Models

$\sigma_{CH_4}=\sigma_{CO}=\sigma_{H_2}=\sigma_h=\sigma_f=0.9$

4. Results

4.1 Cavity hydrodynamics and flame structure

To study the cavity hydrodynamics and flame structure, a reference flame (referred to FLAME1) is selected by computing a series of cases. Calculations have been performed for premixed methane-air mixtures (i. e., core flame) of equivalence ratio (ϕ_m) $=0.8$ entering the combustor at 500K and a uniform velocity of 20m/s. The hydrocarbon waste of $\phi_s=1.2$ has entered with 300K and 5m/s. It has been injected at an angle of 45 degree towards the outer wall. Unit aspect ratio was used for FLAME1.

The use of the recirculation region within the cavity is evaluated as an oxidizing chemical reactor for the destruction of hazardous wastes. Incineration systems are generally designed to use time, temperature and mixing with sufficient oxygen to effect destruction.

Figure 2 shows the velocity fields for reacting flow. Velocity vectors increase through exit line from main burner by the reactions of core flame. Large cavity in dump is formed by fluid recirculation. The waste injector is located at the top of the cavity 3/4 of the way towards the outer wall by the result of computing a series of cases with lean core flames. The location chosen in this study is to minimize the destruction of the recirculation cell structure at high injection rates as can be seen in figure. Through different computing condition of core flames, it is found that the core flame has a very significant impact on the structure of recirculation cell, in some cases completely changing the nature of the flow within the cavity.

Methane and oxygen plots are shown in Fig. 3.

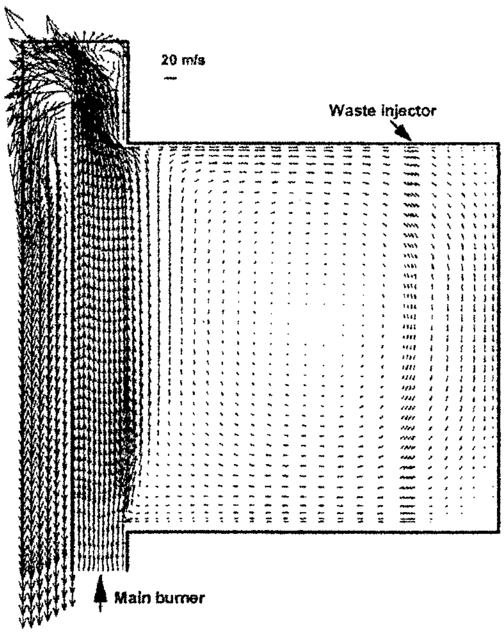

Fig. 2 Calculated velocity fields for FLAME1.

Methane contours near the main burner have the core shapes. The methane concentration decreases gradually up to flame front (which exists high temperature in dump as can be seen in Fig. (6). The main mixture is consumed by burning, they decrease drastically from the rear of flame front. The concentration in the recirculation zone is highest at the point where waste is injected. After burning, remained waste moves through stream flow. The methane has been consumed at the exit completely by which remained methane reacts with oxygen through long exhaust line(refer to heat exchanger). Oxygens entering from the main burner and waste injector decrease by burning. Remained oxygen form core flame (when main mixture is fuel-lean, that is $\phi_m=0.8$), enters either to recirculation to react with waste or to a heat exchanger to react with remained combustible components. Most of recirculation cell has uniform oxygen concentration. This oxidizing species must be supplied by diffusion across the streamline separating the recirculation zone from the core flow. As stated in the introduction of this section it is important to have sufficient oxygen in the recirculation zone and particularly at the top-wall in this combustor. This top-wall is the region of which the remained oxygen is going to waste injector. By this oxygen the intermediates (created by the burning of waste mixture) could have a chance to burn out.

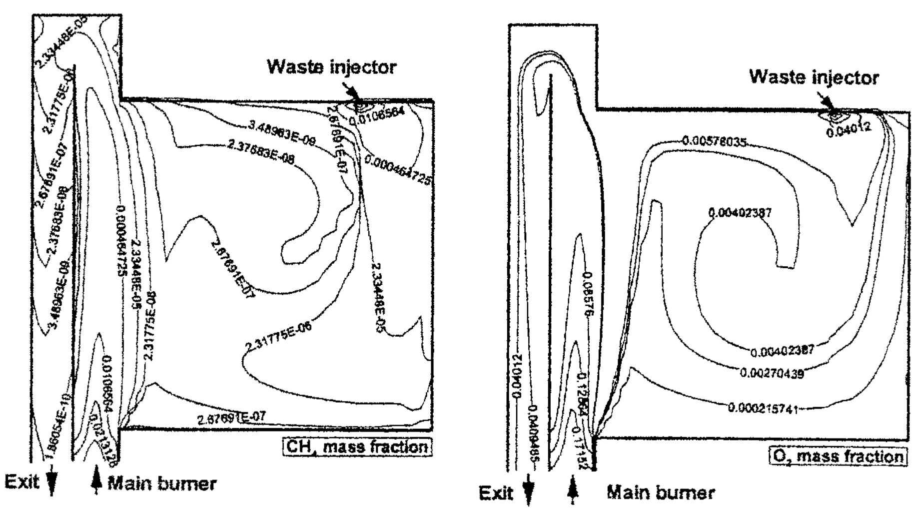

Fig. 3 CH_4 and O_2 mass fractions for FLAME1.

Carbon monoxide(CO) and hydrogen(H_2) mass fractions are presented in Fig. 4. Both species are intermediates in Eq. (4). They are the products of incomplete combustion(PICs) in this system. The shapes of both mass fraction contours show almost same while CO mass fraction is higher than H_2. They will react with O_2 to be carbon dioxide(CO_2) and vapour(H_2O) if the combustor could burn this intermediates sucessfully. For the design of dump combustor it is important factor for good PICs to be low concentration at the exit as could be seen in figure.

The contours of CO_2 and H_2O mass fractions are given in Fig. 5. It may consider that most of both species are produced at the rear of the flame front by reacting with intermediates(i. e., CO and H_2) produced at the inside of core flame, even though those in the cavity are higher. The reason showing higher concentration in the cavity is because the species producing in the rear of flame front diffuse and aviate to the cavity by different mass and through flow stream. Although doing not take part in the burning, they transfer heat by thermal diffusion to the recirculation cell. This may permit that the waste injected dump have long residence time with high temperature.

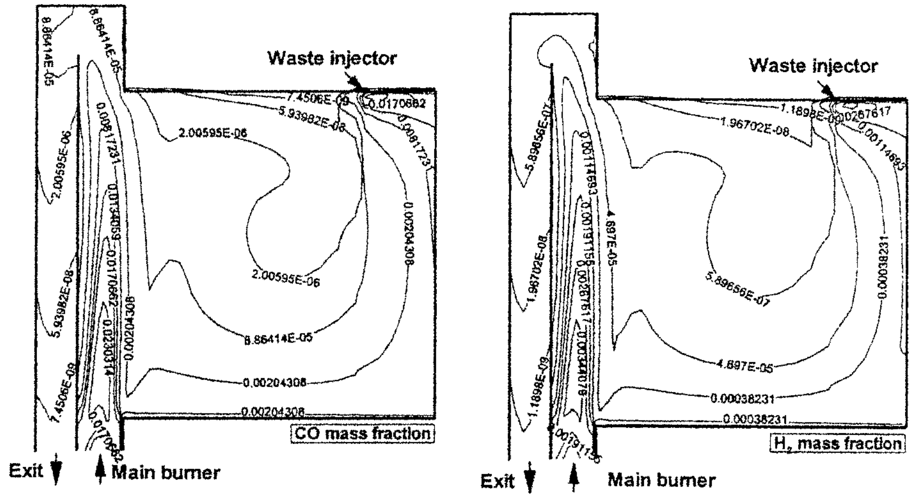

Fig. 4 CO and H_2 mass fractions for FLAME1.

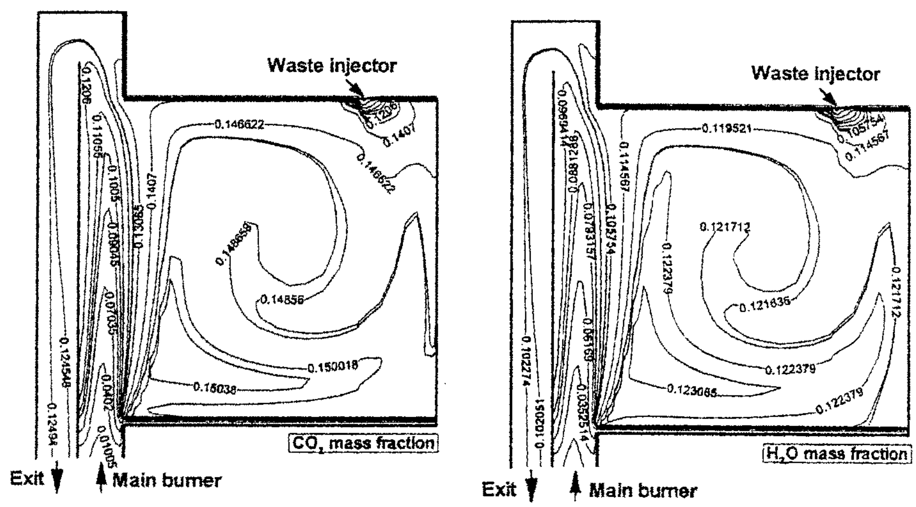

Fig. 5 CO_2 and H_2O mass fractions for FLAME1.

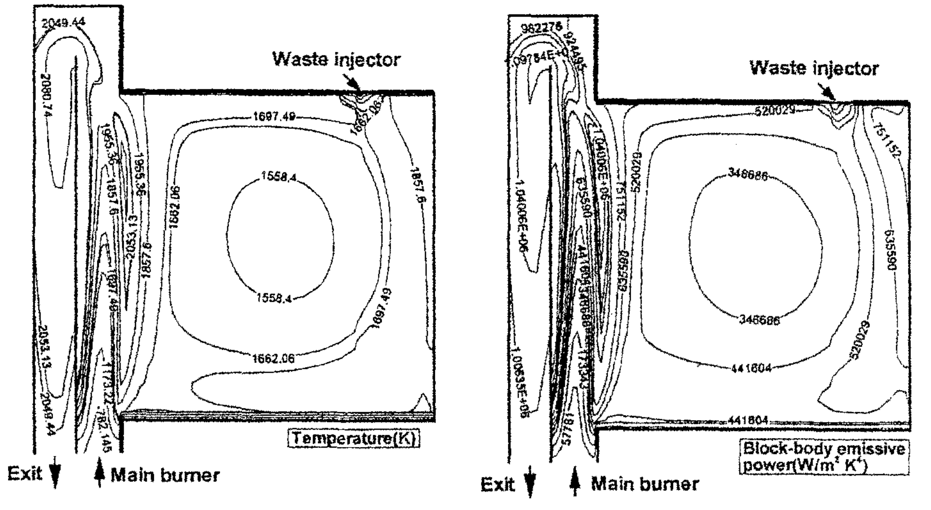

Fig. 6 Temperature and black-body emissive power for FLAME1.

Figure 6 depicts the temperature field and black-body power in Eq. (7) of four flux radiation model. The highest temperature and black-body power are found between the flame front and the streamline separating the core flow from the recirculation zone. Both counters show same shape nearly. It means that the block-body power depends on the absolute temperature as can be seen in Eq. (7). The combustor designed in this study guarantees complete destruction, because most of wastes burn in recirculation zone and that complete burning is possible in a heat exchanger. Also the latent heat in the heat exchanger transfers to dump to increase the reaction rate of mixture in main burner.

Dump combustors are characterized by the sudden expansion of a fuel-air mixture into a combustion cavity. Recirculation zones are typically stabilized within the cavity by sudden increase in cross-section at the point where the fuel-air mixture is introduced and the reactants are ignited. These zones contain mostly high temperature combustion products, and exchange mass and momentum relatively slowly with the surrounding gases. As a result, matter within the recirculation zone experiences a much longer residence time than that in the core flow. This means that waste through the recirculation zone can be destructed with high temperature.

4.2 Parametric screening studies

4.2.1 Equivalence ratio

The calculations have been performed to get the effect of equivalence ratio in waste injector with $\phi_m=0.8$, $\phi_s=5$ or in main burner with $\phi_m=1$, $\phi_s=1.2$. Through calculations, we could see that the velocity fields depend only weakly on equivalence ratio.

Figure 7 depicts the results for $\phi_s=5$ with which $\phi_m(=0.8)$ is like that of FLAME1. A great quantity of hydrocarbon waste injected from the waste injector remains in the dump for which they could not burn owing to lack of oxygen. In the side of main burner, CH_4 also is larger than FLAME1 even though ϕ_m is the same value. The reason is because remained waste in the recirculation cell is diffused at the point where oxygen exists to burn out. Remained CH_4 reacts continuously with oxygen through heat exchanger. Therefore CH_4 mass fraction at the exit is very low although it is higher than FLAME1. Because the waste mixture is fuel-rich, the mass fraction of remained oxygen in recirculation cell is very low. Excess air entering from the main burner is consumed gradually and almost depleted at the exit due to reaction with remained methane. Comparison with the temperature of FLAME1 in Fig. 6 indicates that the temperature in heat exchanger and near flame front is high by reacting with

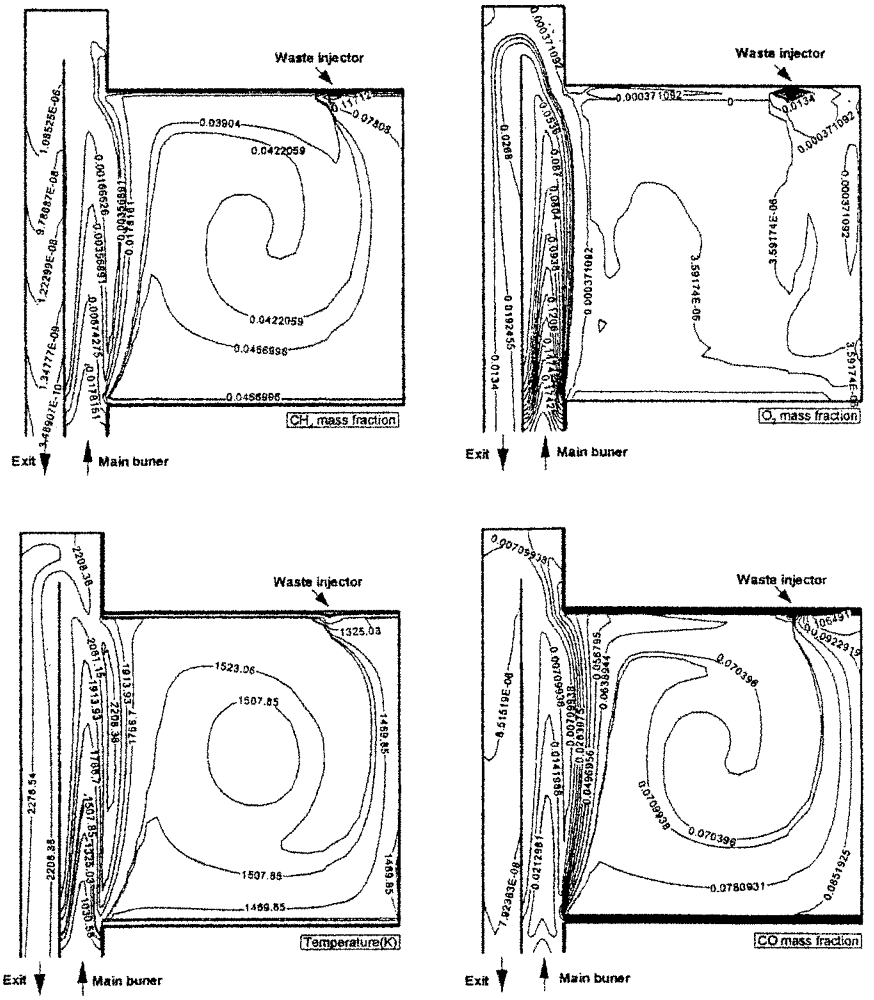

Fig. 7 Selected components changed the equivalence ratio of 5.0 in the surrogate injector corresponding FLAME1.

methane incoming from recirculation zone. The temperature of the recirculation zone is lower comparing with FLAME1. It is interesting that the temperature distribution in the recirculation zone is different with FLAME1. By increasing the equivalence ratio in waste injector, gas temperature in the center increases while that of wall sides decreases. This is due to the exothermic reaction by which the methane in the center contacts with excess air incoming from the rear flame front. Because the waste mixture is fuel-rich, most of waste pass through near wall by fluid stream having no chance enough to react. It is why the gas temperature of wall side shows low value. The CO mass fraction at the exit is very low although it is higher than FLAME1. Increasing the equivalence of waste injector means the increase of capacity of hazardous waste to be treated. In the case of this flame the temperature of recirculation zone is higher 1,000℃ which most of hazardous waste could be destructed (Proctor et al. 1987)), and CO at the exit is very low. Therefore it is useful for this flame to be used for hazardous waste incineration with hydrocarbon waste. The equivalence ratio in waste injector is important factor to destruct various hazardous wastes.

Figure 8 shows temperature and CO mass fraction contours for $\phi_m=1.0$ with which $\phi_s(=0.8)$

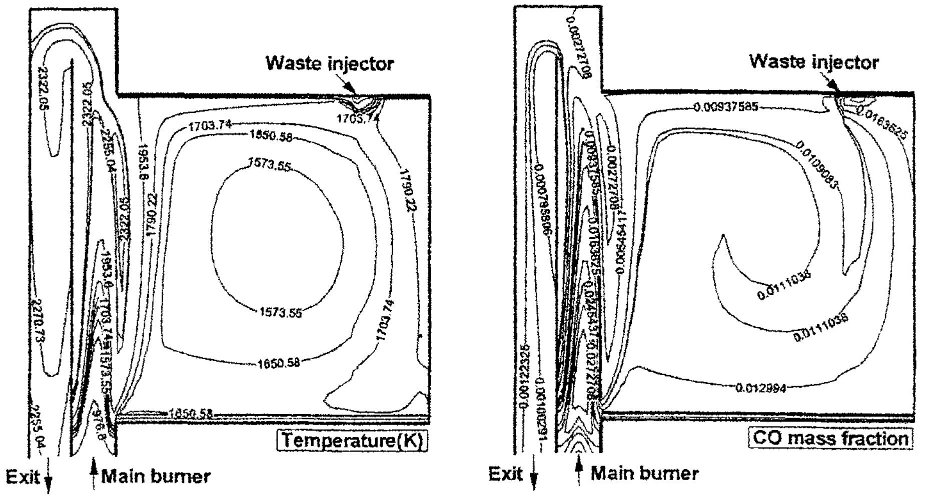

Fig. 8 Temperature and CO mass fraction changed the equivalence ratio of 1.0 in main burner corresponding FLAME1.

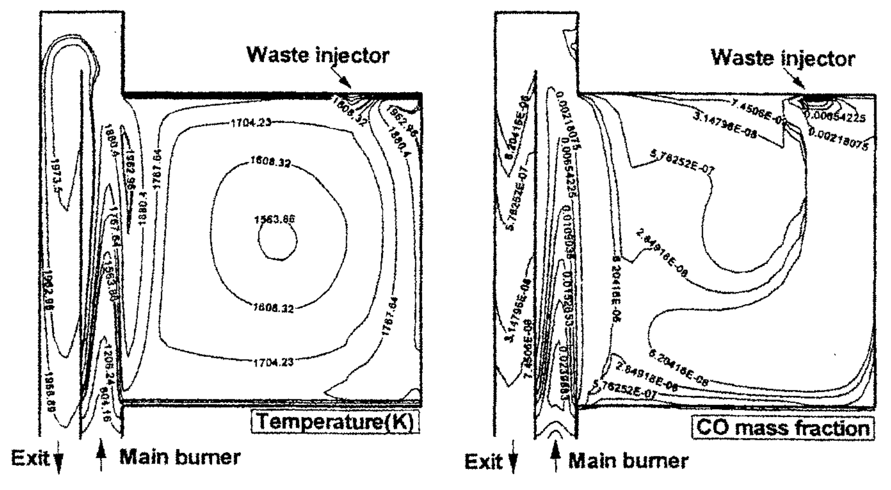

Fig. 9 Temperature and CO mass fraction changed the input temperature of 300K in main burner corresponding FLAME1.

is like that of FLAME1. The lower temperature appears in the recirculation cell with comparition to FLAME1. The reason is that low amount of oxygen diffuses to the recirculation cell from the flame front of core flame. The core flame temperature is higher due to the reduction of exhaust heat loss by excess air. With remained methane burns, the temperature of heat exchanger is increased. CO mass fraction at the exit may be increased by reduction of the equivalence ratio of main burner. This flame has a merit for low exhaust heat loss. However products and incomplete combustion (PICs) may be increased due to basically the lack of oxygen stoichiometrically. Although these flame could be used under this condition, the careful attention must be paid to equivalence in the design and operation of this incinerator.

4.2.2 Input temperature

The input temperature for atmosphere condition (i. e., 300K) is shown in Figure 9. Most of region in dump combustor is lower than FLAME1. The reason is because the enthalpy of mixture entering to dump has a low value due to low input temperature. Although the temperature in a dump combustor is lower than FLAME1, this condition is good for the destruction of hazardous waste because of increasing the enthalpy by heated input mixture. The CO mass fraction at the exit is nearly same value.

4.2.3 Injection angle and velocity

Figure 10 depicts the velocity vectors and temperature for which waste is injected at 45 degree towards the inner recirculation cell at the condition like FLAME1. The velocity vectors are almost same shape like FLAME1 while the lower velocity appears in dump comparing with FLAME1 because nearly counter injection achieves in inflow gas stream at the left side of the top wall in the recirculation zone. The vectors in recirculation cell are not disturbed by waste injection as can be seen in figure. In comparison with FLAME1, higher temperature in the center of

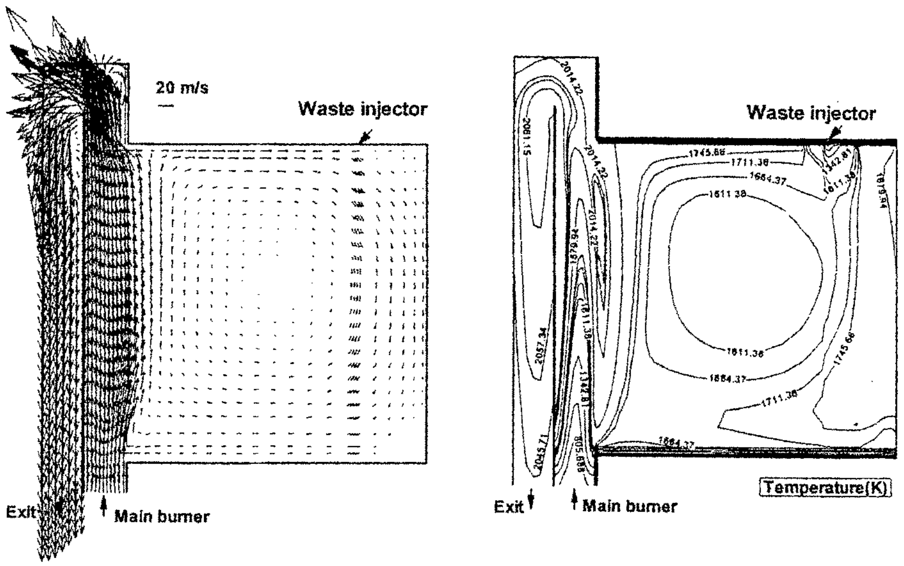

Fig. 10 Velocity fvectors and temperature contour changed the direction of surrogate injection toward inner recirculation cell corresponding FLAME1.

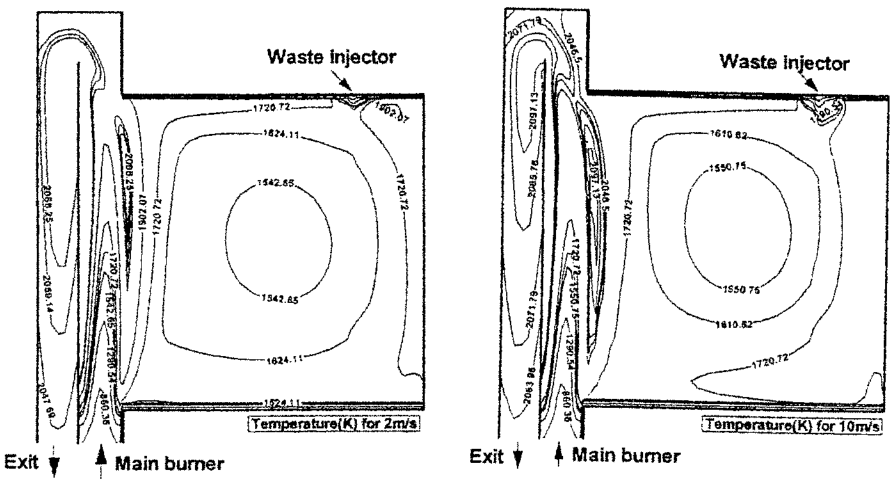

Fig. 11 Temperatures varying surrogate injection velocity corresponding FLAME1.

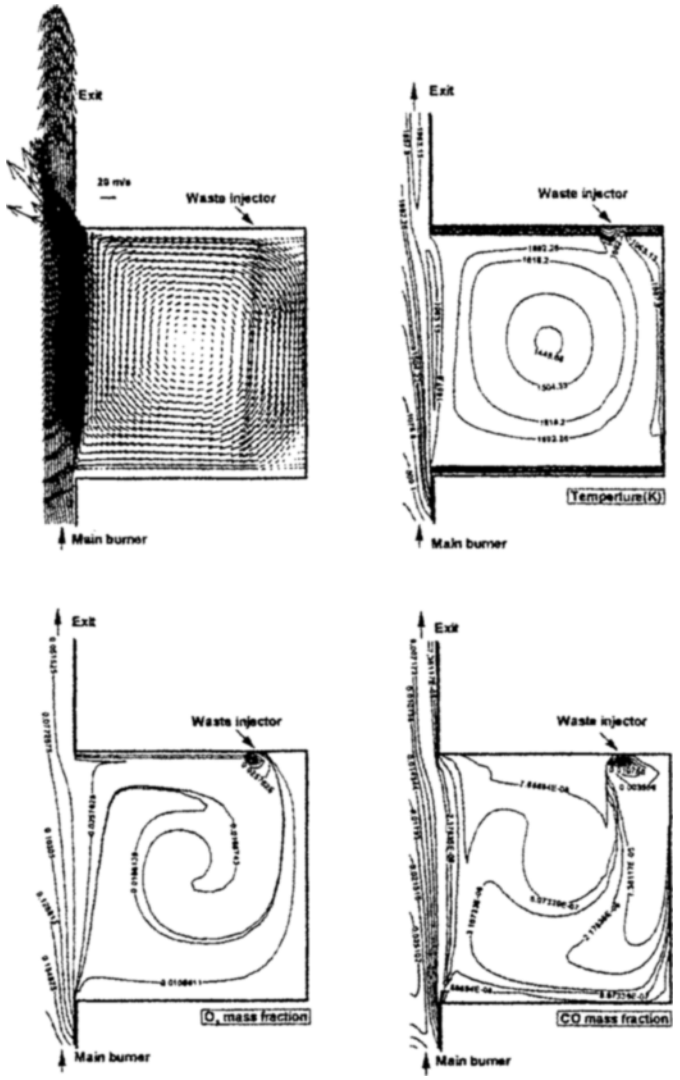

Fig. 12 Velocity vectors, temperature and selected components for FLAME2.

recirculation cell is found while the gas temperature near outer wall is a little bit low. High temperature in the center is due to the diffusion of hydrocarbon waste to core reacting with excess oxygen in the center. Therefore we could know that if the velocity vector is not be disturbed by waste injection like this flame, good destruction and removal efficiency(DRE) may be expected.

Figure 11 depicts the temperature of different injection velocities of waste such as 2m/s and 10m/s, respectively. At the waste velocity of 2m/s, temperature shows a somewhat lower than FLAME1, resulting lower waste input as the injection of low flow rates by decreasing the velocity. However the temperatures at rear flame front and heat exchanger are high due to the reaction of remained unburn methane by low velocity. For the injection velocity of 10m/s, which is higher injection velocity than FLAME1, the temperature is lower than FLAME1 by different reasons. Low temperature in the recirculation cell is the reason that the hydrocarbon waste has not enough reaction time in recirculation zone due to the injection of velocity. Remained waste reacts with excess oxygen at rear flame front and heat exchanger to be higher temperature. It is

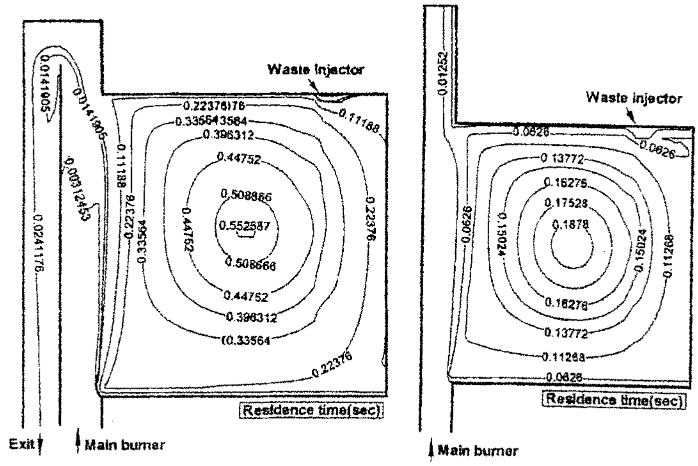

Fig. 13 Residence time of FLAME1 and FLAME2

interesting that the velocity of waste injection has optimum value to be highest temperature at the recirculation cell.

4.2.4 Variation of combustor configuration

To show general idea with variation of configuration, another combustor (referred to FLAME2) is used by which dump volume and physical properties (i. e., inlet temperature, equivalence and so on) are same condition with FLAME1. The calculations for this combustor have been performed for half domain because the shape is axymmetric.

Figure 12 shows the velocity vectors, temperature, O_2 and CO mass fractions for FLAME2. Velocity vectors show that a cavity in the recirculation cell is formed in the dump like Fig. 2 of FLAME1. Also the highest temperature is found between the flame front and the streamline separating the core flow from the recirculation cell. Comparing with FLAME1, the temperature of the recirculation cell and exhaust exit are lower due to short residence time. Remained oxygens in the recirculation cell and exhaust exit are higher than FLAME1. The reason at recirculation cell is why O_2 in the dump combustor do not have chance reacting with intermediates, which generate during the combustion process at the flame front, due to short residence time comparing with FLAME1 (see Fig. 13). The reason at exhaust exit is due to the by-pass of excess air from the main burner, while main mixture inlet and exhaust exit are located at the same line. CO mass fraction is higher than FLAME1 because it does not have a chance reacting with remained O_2 in recirculation cell due to short residence time. It may show that PIC (i. e., CO in this study) increase for FLAME2.

As a result, it is good for FLAME1 to destruct hazardous waste due to high temperature with long residence time in the recirculation cell and heat exchanger set up FLAME1 only.

5. Summary and Conclusions

We have studied cavity dynamics and flame structure about reference flame (i. e., FLAME1) selected by computing a series of cases in the complex hydrodynamic environment of a dump combustor. The basic concepts for the design of a dump combustor are provided by parametric screening studies.

Most of hazardous wastes include flame inhibitors like sulfur hexa fluoride (SF_6), commercial fire retardant (Halon 1211 or CF_2ClBr) and so on. It is reported that the inhibitors reduce adiabatic flame temperature, particularly over 20% for halogen.

In this study a methane as hydrocarbon waste is only used due to the absence of combustion models of inhibitors until now. Even though the inhibitor is to be included, good DRE and PICs may be possible for our combustor as can be known by which the temperature of dump combustor is higher than 1000℃ which is minimum temperature for the destruction of hazardous waste. Therefore our calculations by using hydrocarbon waste may be reasonable for hazardous wastes because the flow fields are not influenced by above surrogates(Smith et al. 1990).

The formation of the recirculation cell is important to have long residence time at high temperature for the destruction of hazardous waste. Therefore the waste injector has been located at the point where the recirculation cell do not disturbed. The core flame has a very significant impact on the structure of recirculation cell, in some cases completely changing the nature of the flow within the cavity.

By parametric screening studies in our combustor, we have the results as follows;

(1) They are good DRE and PICs that the mixture of main burner is supplied by fuel-lean and that of waste injector is of fuel-lean.

(2) Entering as the atmospheric temperature of main burner and waste mixture are satisfactorily good conditions to destruct hazardous waste designed in this study.

(3) A optimum velocity of waste injection exists for highest temperature in recirculation cell.

(4) The configuration like FLAME2 has good DRE, but not well PICs. However good PICs and DRE are obtained in our combustor(i. e., FLAME1) with a heat exchanger.

The dump combustor designed in this study has several good characteristics in an incineration application. For a high degree of mixing within the recirculation cell and high temperature in the heat exchanger, it may guarantee for good PICs and DRE. These have relatively long residence time for hazardous wastes within the zone of highest temperature and radical concentrations, or, equivalently, a relatively compact combustor. These characteristics lead to a very compact device, one which is potentially transportable or usable in a dedicated manner by a small generator.

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