NUMERICAL STUDY OF THE COMPARTMENT FIRE WITH TRANSIENT DEVELOPING SOURCE*

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ABSTRACT

Numerical test of air velosity, temperature and smoke concentrantion profiles of thee compartment fire has been done using a transient three dimensional model. The fire source varied with the time is the exponential function and it generates random in the cell on the floor. The computation results are reasonable on physical phenomenon. Key Word: numerical, velosity, temperature concentration transient three dimensional model.

INTRODUCTION

While the compartment fire generates, it diffuses qickly as second numbered to the three dimensional space. As this time, air velosities, temperatures and smoke concentrantions of the compartment are functions of time and space coordinate. Because of the limit of instrument response, measuring transient air velosity, temperature and smoke concentrantion profiles in fact, is very difficult. Recently, general experimental research of firing is limited to fire early stage; otherwise, numerical study by computer is off limit. In this paper, numerical test of air velosity, temperature and smoke concentrantion profiles in a fire compartment has been done using a transient three dimensional model. In the model, as the first step approach, the fire source driving the variation of air profiless is considered only varying with time, and without moving and expanding to the around space. According to Arrhenius law, it is an assumption that a fire source varied with the ttime is the exponentional fuction.

NUMERIGAL TEST

1. General Equations

The continue equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial y}(\rho w) = 0 \tag{1}$$

The momentum equations

$$\frac{\partial}{\partial t}(\rho u) + \frac{\partial}{\partial x}(\rho u^2) + \frac{\partial}{\partial y}(\rho uv) + \frac{\partial}{\partial z}(\rho uw)$$
$$= \frac{\partial}{\partial x}(\mu_{eff}\frac{\partial u}{\partial x}) + \frac{\partial}{\partial y}(\mu_{eff}\frac{\partial u}{\partial y}) + \frac{\partial}{\partial z}(\mu_{eff}\frac{\partial u}{\partial z}) - \frac{\partial p}{\partial x} \tag{2}$$

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$$\frac{\partial}{\partial t}(\rho v) + \frac{\partial}{\partial x}(\rho uv) + \frac{\partial}{\partial y}(\rho v^2) + \frac{\partial}{\partial z}(\rho vw)$$

$$= \frac{\partial}{\partial x}(\mu_{eff}\frac{\partial v}{\partial x}) + \frac{\partial}{\partial y}(\mu_{eff}\frac{\partial v}{\partial y}) + \frac{\partial}{\partial z}(\mu_{eff}\frac{\partial v}{\partial z}) - \frac{\partial p}{\partial y} \qquad (3)$$

$$\frac{\partial}{\partial t}(\rho w) + \frac{\partial}{\partial x}(\rho uw) + \frac{\partial}{\partial y}(\rho vw) + \frac{\partial}{\partial z}(\rho w^2)$$

$$= \frac{\partial}{\partial x}(\mu_{eff}\frac{\partial w}{\partial x}) + \frac{\partial}{\partial y}(\mu_{eff}\frac{\partial w}{\partial y}) + \frac{\partial}{\partial z}(\mu_{eff}\frac{\partial w}{\partial z}) - \rho g\beta(T - T_0) \qquad (4)$$

where μ_{eff} is the effect viscosity.

The engergy equation—temperature experession with the concept of enthalpy.

$$\frac{\partial T}{\partial t} + \frac{\partial}{\partial x}(uT) + \frac{\partial}{\partial y}(vT) + \frac{\partial}{\partial z}(wT)$$

$$= \frac{\partial}{\partial x}(a\frac{\partial T}{\partial x}) + \frac{\partial}{\partial y}(a\frac{\partial T}{\partial y}) + \frac{\partial}{\partial z}(a\frac{\partial T}{\partial z}) \qquad (5)$$

where a is the thermal diffusivity. $a = \frac{\lambda}{\rho cp}$

The smoke concentration equation

$$\frac{\partial C}{\partial t} + \frac{\partial}{\partial x}(uC) + \frac{\partial}{\partial y}(vC) + \frac{\partial}{\partial z}(wC)$$

$$= \frac{\partial}{\partial x}(D\frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(D\frac{\partial C}{\partial y}) + \frac{\partial}{\partial z}(D\frac{\partial C}{\partial z}) \qquad (6)$$

where D is the concentration diffusivity. $D = \frac{\mu_{eff}}{\sigma_c}, \sigma_c = 1.0$

The air state equation

$$P = \rho RT \qquad (7)$$

2. Boundary and Calculation Condition

The six boundary surfaces are in heat insulation, only a fire source which generates random n the cell on the floor could be expressed as $q = q_0(1 - e^{-\alpha\tau})$. It is $q_0 = 0.5$ kw and a=1 in the calculation. The fire souce is treated as heat flux upward on the boundary. This fire set off the change of air density, so a buoyancy upward to the Z direction causes a movement of the air flow in the compartment. The μ_{eff} is the effect viscosity, the fluction quantities with the concept of the eddy viscosity are solved by using the model of κ-ε two equations. Temperature profiles have solved from the energy equation, according to the relation of the thermal balance and the concept of enthalpy.

3. Calculation Method

The compartment sizes in the calculation are $4\times6\times4m^3$. The region is divided into $18\times18\times18$ cells. It is SIMPLE (Semi-Implicit Method for Pressure-Linked Equation) has carried out with criss-cross cells. The relaxation method also has been used in the computation, where the relaxed factors are about between o. 5~o. 8.

CALCULATION RESULTS

The computer program has run on the microcomputer VAX Ⅱ. The calculation of the transient three dimensional process spends more expensive computer time, it is about nity hours of CPU for a eight-second ransient process. The Fig. 1 to Fig. 5 are the smoke concentrantion profiles on the top ($Z=4m$) from 1s to ls. The Fig. 5 to Fig. 10 are the temperature profiles on the top ($Z=4m$) from 1s to 8s.

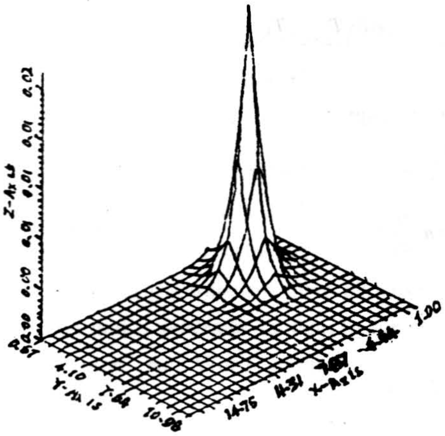

Fig.1 Profile of C at top
$C_{min}=0$ $C_{max}=0.02$ t=1s

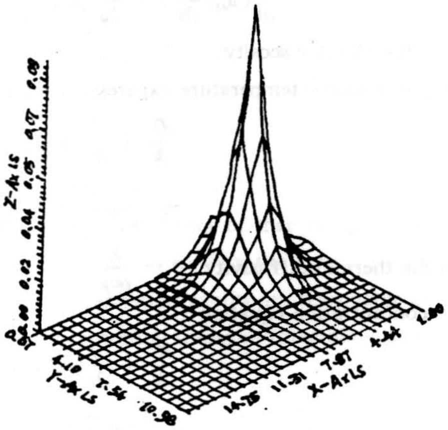

Fig.2 Profile of C at top
$C_{min}=0$ $C_{max}=0.11$ t=2s

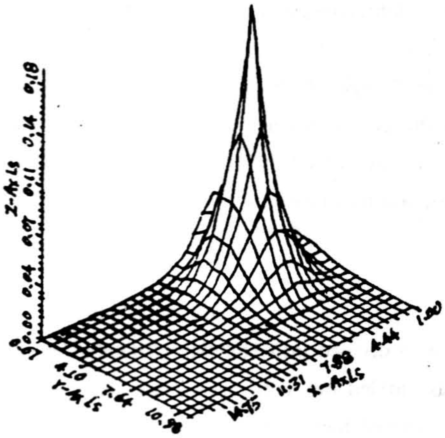

Fig.3 Profile of C at top
$C_{min}=0$ $C_{max}=0.22$ t=3s

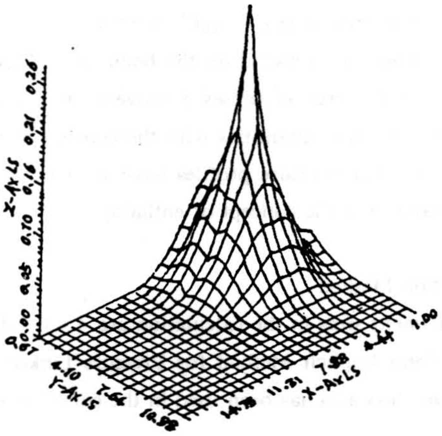

Fig.4 Profile of C at top
$C_{min}=0$ $C_{max}=0.32$ t=4s

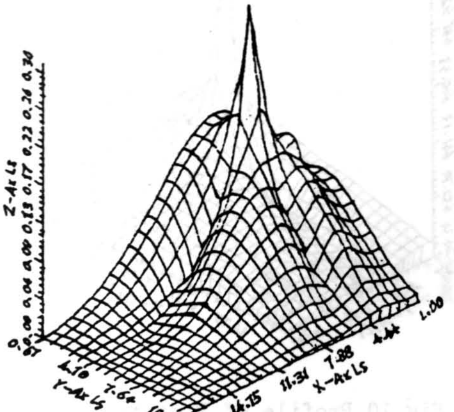

Fig.5 Profile of C at top
C_{min}=0 C_{max}=0.35 t=8s

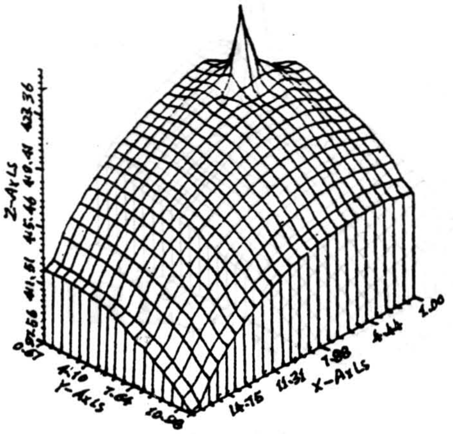

Fig.6 Profile of T at top
T_{min}=409 T_{max}=430 t=1s

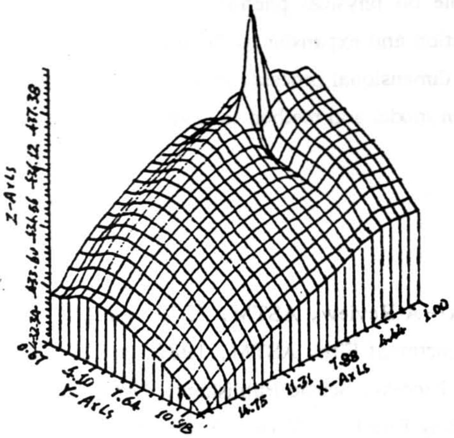

Fig.7 Profile of T at top
T_{min}=435 T_{max}=442 t=2s

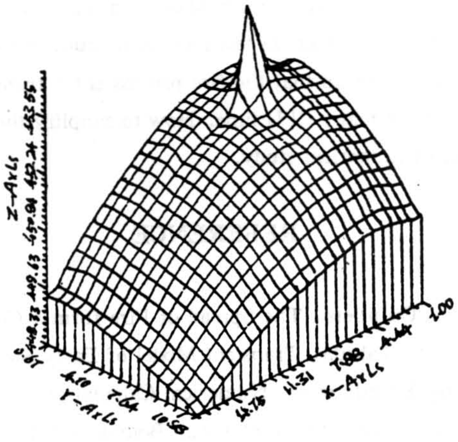

Fig.8 Profile of T at top
T_{min}=450 T_{max}=457 t=3s

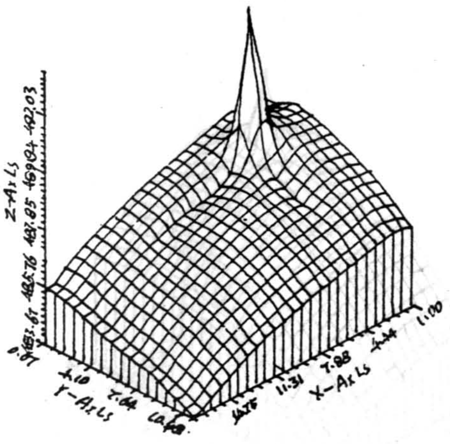

Fig.9 Profile of T at top
$T_{min}=485$ $T_{max}=497$ t=4s

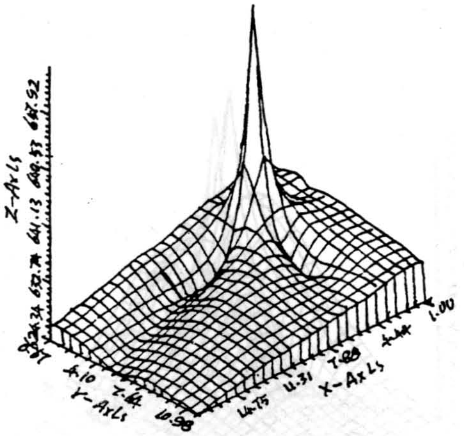

Fig.10 Profile of T at top
$T_{min}=629$ $T_{max}=676$ t=8s

CONCLUSION

1. The computation results shown in Figures are resonable on physical phenomenon, it shows that the application of numerical test method to study the fire generation and expansion is the effect method.
2. It is the reason that the fire process is the transient three dimensional process, so the computer calculation spends more many CPU time. How to simplify the calculation model and method to save CPU time is the new subject of numerical study.

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