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The 6th International Chemical Engineering Congress

Article Code	04185	Status:	
Article Title:	Effect of pulverized coal combustion to reduce pollutants		
Article Scopes:	Environmental Engineering - Environmental Engineering	Send Date:	25/03/1388
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Key words:	combustion chamber, pulverized coal, pollution, premix, steam, magnussen model		

Abstract:

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In this research, effect of steam injection in pulverized coal combustion to reduce pollutants such as <!--[if !vml]--> <!--[endif]-->, <!--[if !vml]--> <!--[endif]-->, <!--[if !vml]--> <!--[endif]--> and <!--[if !vml]--> <!--[endif]--> in a 2D combustion chamber have been studied. A numerical method which incorporates pressure base algorithm and implicit solver has been employed to simulate non-premix combustion model. The air was diluted by steam , whose percentages varied from 0% to 20%. Steam and air were preheated by a high-temperature gas generator , and the preheated oxidizer temperature could achieve <!--[if !vml]--> <!--[endif]-->. Numerical simulations were also carried out to provide more information about fluid field. The combustion simulation with the generalized finite rate chemistry model , referred to as the Magnussen model and the reacting flow with the mixture fraction PDF/equilibrium chemistry model, referred to as the PDF model are studied. As a result of addition steam into oxidizer, adiabatic flame temperature and rate of pollutants decreases.

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Effect of steam injection in pulverized coal combustion to reduce pollutants

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چکیده

در این مقاله اثر تزریق بخار آب در احتراق زغال سنگ در یک محفظه احتراق دو بعدی ، به منظور کاهش آلاینده ها مورد بررسی قرار گرفته است. در این مدلسازی از یک روش عددی جهت شبیه سازی فرایند احتراق در حالت غیر پیش آمیخته بهره گرفته شده و تاثیر بخار آب در سه حالت (0 ، 10 و 20 درصد جرم هوای ورودی) بر کاهش دمای شعله و در نتیجه کاهش آلاینده ها بررسی شده اند. در روش عددی فوق از الگوریتم فشار مبنا با حل کننده ضمنی برای حل معادلات گسسته استفاده شده است. ذرات زغال سنگ دارای قطر میانگین 137 میکرون بوده و با آهنگ $0.1 kg/s$ از مرکز به داخل محفظه احتراق تزریق می شوند. سوخت، بخار آب، و هوا قبل از ورود به محفظه احتراق ، توسط یک گرمکن تا دمای $1400°C$ گرم شده و سپس وارد آن می شوند. شبیه سازی فرایند احتراق با استفاده از مدل شیمیایی نرخ محدود که به مدل مگنسون ارتباط دارد انجام شده است. تزریق بخار آب در فرایند احتراق باعث کاهش دمای شعله آدیاباتیک شده و در نتیجه آلاینده های خطرناکی چون NO_x ، CO، CO_2 و C کاهش یافته اند.

کلمات کلیدی: محفظه احتراق ، زغال سنگ ، آلاینده ها ، پیش آمیخته ، بخار آب، مدل مگنسون

ABSTRACT

In this research, effect of steam injection in pulverized coal combustion to reduce pollutants such as NO_x, CO, CO_2 and C in a 2D combustion chamber have been studied. A numerical method which incorporates pressure base algorithm and implicit solver has been employed to simulate non-premix combustion model. The air was diluted by steam , whose percentages varied from 0% to 20%. Steam and air were preheated by a high-temperature gas generator , and the preheated oxidizer temperature could achieve $1400^{\circ}c$. Numerical simulations were also carried out to provide more information about fluid field. The combustion simulation with the generalized finite rate chemistry model , referred to as the Magnussen model and the reacting flow with the mixture fraction PDF/equilibrium chemistry model, referred to as the PDF model are studied. As a result of addition steam into oxidizer, adiabatic flame temperature and rate of pollutants decreases.

Key words combustion chamber, pulverized coal, pollution, premix, steam, magnussen model

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INTRODUCTION

Atmospheric pollution has become a worldwide concern. This concern led to the consideration of the effects of injection large amounts of any species on the ozone balance in the atmosphere.When discussing nitrogen oxide formation from nitrogen in atmospheric air, one refers specifically to the NOx formed in combustion systems in which the original fuel contain no nitrogen atoms chemically bonded to other chemical elements such as carbon or hydrogen.

Pulverized coal combustion was one of the major sources to produce energy for applications such as train and power plants. It also is one of the pollutant sources. However air pollution is a major problem which strongly relative to human life. In (2006) QUINGLIN,ARTUR,WEIHONG and BLASIAK[1] investigated numerically properties of pulverized coal combustion in high temperature air/steam mixture. They proved thet the addition of steam into oxidizer will suppress the formation of NOx and the coal injecting velocity also have impacts on NOx formation. The numerical simulation of pulverized coal combustion by SAHAJWALLA,EGHLIMI, and FARRELL(1997)[2] have been chosen for the present simulation. They investigated a pulverized coal combustion simulation with gas phase flow field and its interaction with a discrete phase of coal particles. In 1995 ,THERSEEN[3], proved numerically and experimentally the devolatilisation of high volatile bituminous coal particles under a rapid heating conditions. They obtained acceptable results for flame's peak temperature.

Numerical procedure

Fluent[6] software which base on generalized finite volume method[4] using structured grid arrangement with the SIMPLE algorithm[5] was utilized for modeling the pulverized coal combustion. Quick scheme was adopted for the discretizetion of all convective terms of the advective transport equations(Eqs.(2)-(4)). The final discretized forms of the Eqs.(1)-(4) were solved by using the SIMPLE algorithm. The rate of steam injection into oxidizer provided by Prepdf software which base on equilibrium chemistry. The coal combustor studied in this research is a non-adiabatic system, whit heat transfer at the combustor wall and heat transfer to the coal particles from the gas. Therefore, a non-adiabatic combustion system must be considered in Prepdf[7].

Physical problem and governing equations

The geometry of the problem herein investigated in fig.1. The coal combustion system considered in this research is a 12m by 1m two dimensional burner. Only half of the domain width is modeled because of symmetry. The inlet of the 2D burner is split into two streams. A high-speed stream near the center of the burner at 30 m/s and spans 0.125 m and the other stream enters at 10 m/s and spans 0.375 m. both streams are air at the temperature of 1400 k.

The flow is considered turbulence and incompressible. The government equations can be written as

$$\frac{\partial U}{\partial x} + U\frac{\partial V}{\partial y} = 0 \quad (1)$$

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} = -\frac{\partial P}{\partial x} + \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2}\right) \quad (2)$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} = -\frac{\partial P}{\partial y} + \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}\right) + \frac{Ra}{\mathrm{Pr}.\mathrm{Re}^2}T \quad (3)$$

$$\frac{\partial T}{\partial t} + U\frac{\partial T}{\partial x} + V\frac{\partial T}{\partial y} = -\frac{\partial P}{\partial y} + \frac{1}{\mathrm{Pr}.\mathrm{Re}}\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) \quad (4)$$

$$Nu = \frac{hD}{k} = 2 + 0.6\,\mathrm{Re}_D^{1/2}\,\mathrm{Pr}^{1/3} \quad (5)$$

$$K = A_1 \exp(-E/RT) \quad (6)$$

The reactions were considered in a present research

$$mv\_coal + 1.614O_2 \rightarrow 2.763H_2O + CO \quad (7)$$

$$CO + 0.5O_2 \rightarrow CO_2 \quad (8)$$

$$H_2 + 0.5O_2 \rightarrow H_2O \quad (9)$$

$$C + H_2O \rightarrow CO + H_2 \quad (10)$$

$$C + CO_2 \rightarrow 2CO \quad (11)$$

The two dimensional flow described by these equations is represented by the two velocity components u,v which , respectively, correspond to the two coordinate direction ,x,y.

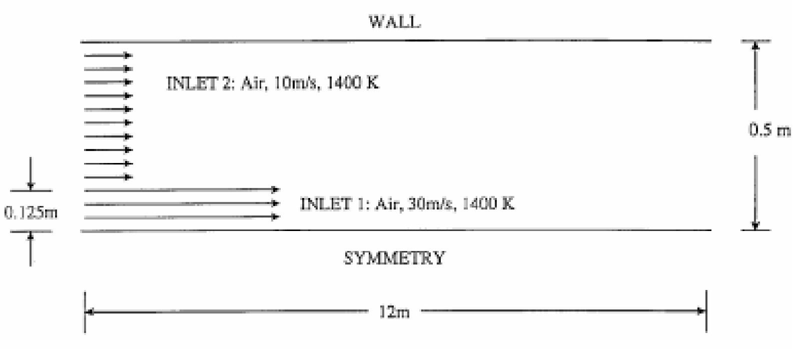

fig.1.studied geometry[2]

Result and discussion

In the following section, the results of pulverized coal combustion modeling illustrated under influence of fraction of steam/air injection. So numerical studies have been done on pollutants as well as NOx and combustion properties of pulverized coal combustion. All plots are according to center line of the combustion chamber.

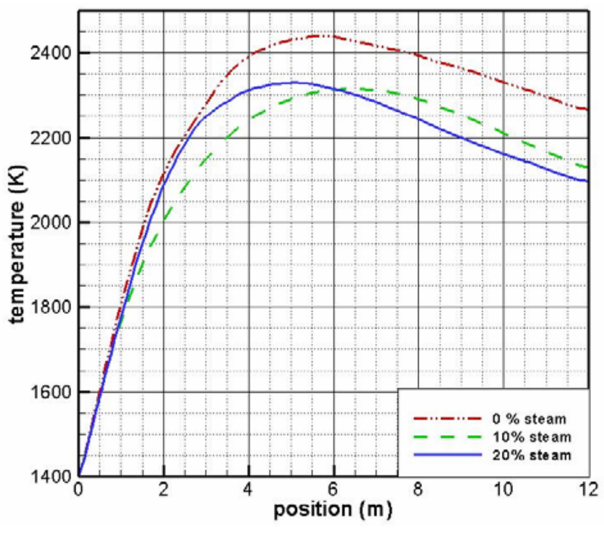

Fig.2.temperature profiles

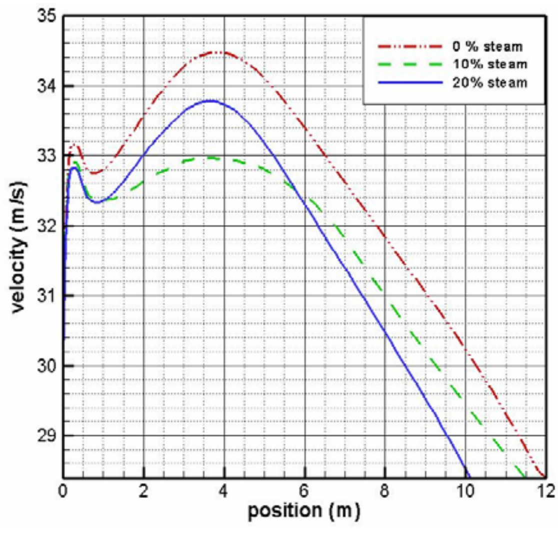

Fig.3.velocity profiles

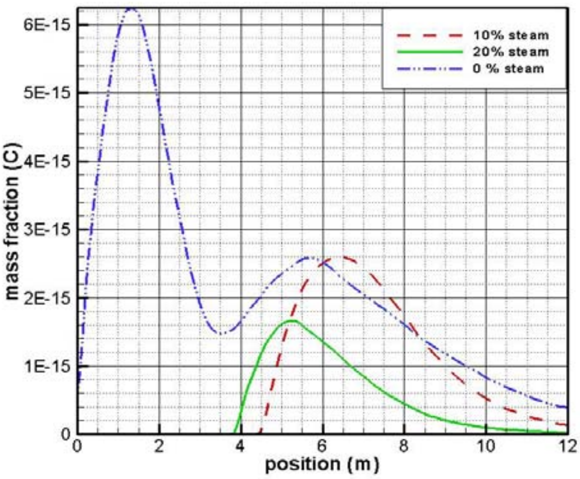

Fig.4.mass fraction of C profiles

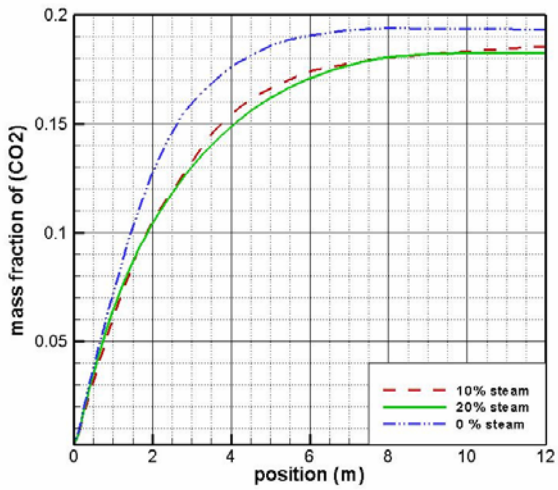

Fig.5.mass fraction of CO2 profiles

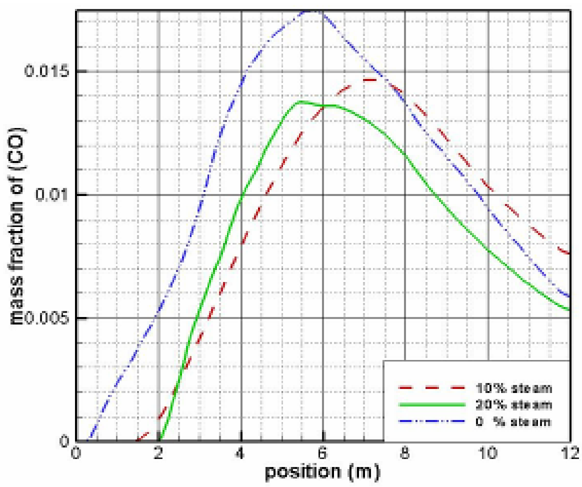

Fig.6.mass fraction of CO profiles

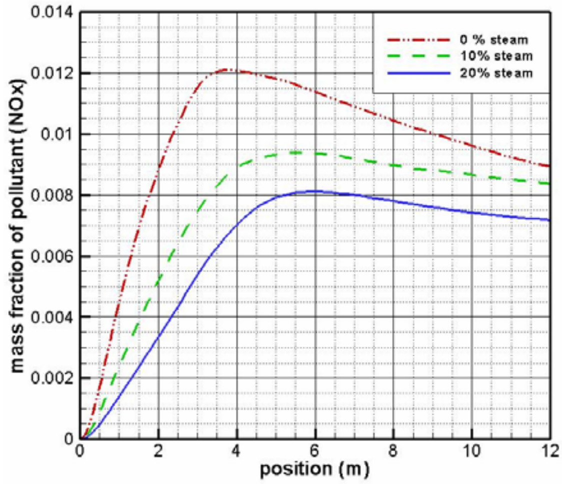

Fig.7.mass fraction of NOx profiles

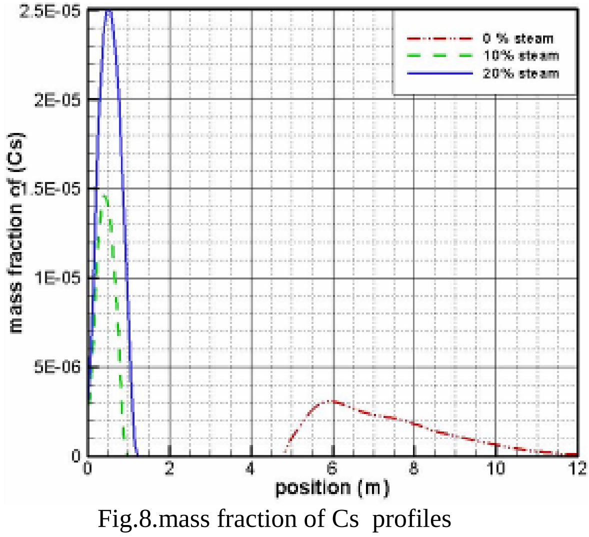

Fig.8.mass fraction of Cs profiles

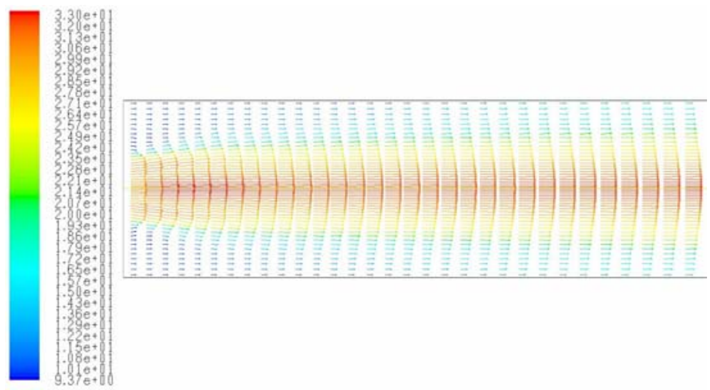

Fig.9.velocity vectors profiles

Fig.2 shows in position close to nozzle that the combustion was affected by OH radicals more than steam latent heat at 20% steam ratio, but at further position the latent parameter was affected more than OH radicals. For non-premixed systems like pulverized coal combustion and almost obtained in carbureted spark ignition engines , the temperature , and hence the mixture ratio, is the prime parameter in determining the quantities of NOx formed. As can be seen from above charts, as a result of addition steam into oxidizer the rate of formation of pollutants as well as NOx suppressed. The main reason for this phenomena is decreasing of maximum temperature of combustion, which restricts the NOx formation by thermal NOx mechanism. Furthermore, the rate of formation of pollutants will decrease if the steam injection will increase.

Conclusion

The simplest method of reducing NOx , particularly from internal combustion engines , is by adding water to the combustor can. Water vapor can reduce the O radical concentration by the following scavenging reaction $H2O + O \rightarrow 2OH$. Fortunately, OH radicals do not attack N2 efficiently. However, it is more likely that the effect of water on NOx emissions is through the attendant reduction in combustion temperature. The rate of formation of NOx emission will suppressed by addition steam into oxidizer.

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