TECHNICAL PROGRESS REPORT NO.19

INVESTIGATION OF HEAT TRANSFER
AND COMBUSTION IN THE ADVANCED
FLUIDIZED BED COMBUSTOR (FBC)

TO

U.S. DEPARTMENT OF ENERGY
FEDERAL ENERGY TECHNOLOGY CENTER
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FOR

PROJECT NO.: DE-FG22-93MT93006--14

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SEPTEMBER 1999

ABSTRACT

This technical report summarizes the research conducted and progress achieved during the period from April 1, 1998 to June 30, 1998.

The numerical simulation was continued to determine the concentration distribution of the gas species, heat flux and heat transfer coefficients in the hot combustor model.

The different gas concentration profiles showed the gas mixing characteristics along the combustor height. The center zone of the combustor has a relatively high methane mass concentration. The injection of secondary air squeezes the uprising flue gas and methane that causes the fuel-lean zone near the secondary air nozzles. The carbon dioxide concentration increased with the increasing of the combustor height. The peak concentration of oxygen remains at the combustor wall because of the secondary injection.

The heat flux on the wall of the upper chamber is much higher than that of the lower chamber. It is believed that the heat flux is affected by the designed strong swirl and secondary air injection. The heat transfer coefficient changes along the combustor height were also affected by the multiple secondary air injection. The numerical simulation results could verify the predictions of the experimental results. It is a quite similar trend of the heat transfer coefficient changes based on the combustion test results.

TABLE OF CONTENTS

	PAGE
ABSTRACT.....	ii
SECTION	
1. RESULTS AND DISCUSSIONS	
NUMERICAL SIMULATION OF THE HOT MODEL.....	1
1.1 The Gas Concentration Distribution/Hot Model.....	1
1.2 Heat Transfer Characteristics.....	4
2. CONCLUSIONS.....	10
REFERENCES.....	11

SECTION 1
RESULTS AND DISCUSSIONS
NUMERICAL SIMULATION OF THE HOT MODEL

1.1 The Gas Concentration Distribution and Characteristics

The basic covering equations for swirling, turbulent gas-particle flows and combustion in the swirling fluidized bed combustor were formulated and described in the previous report [1]. The species conservation equations included the mass fraction of species, diffusive mass flux of species, and the net rate of production of species due to the chemical reaction [1]. Mass concentration which is the mass of species per unit volume of the solution. The various chemical species in a diffusing mixture move at different velocities.

Figure 1 shows the methane (CH_4) concentration profiles. The center zone of the combustor has relatively high methane mass concentration. It is seen that for the present case the combustion of methane mainly takes place in the center zone of the combustor. The final burnout of methane further extends into the upper part of the center tube. It is believed that the inactive zone at the bottom is primarily caused by an insufficient oxygen supply. The injection of secondary air squeezes the uprising flue gas and methane that causes a fuel-lean zone (inactive reaction) near the secondary air nozzles. It is of interest to note that the active reaction zone generally coincides with the high gas temperature zone [2].

Figure 2 shows the carbon dioxide (CO_2) concentration profiles. The carbon dioxide concentration increased with the

Figure 1 The Concentration Profiles of the Methane

Figure 2 The Concentration Profiles of the Carbon Dioxide

increasing of the combustor height. The carbon dioxide concentration near the combustor wall is lower than that of the combustor center zone. As shown in Figure 2, the lower part of the combustor has lower carbon dioxide concentration.

Figure 3 shows the oxygen (**02**) concentration profiles. It can be seen that the oxygen in the primary air was completely consumed, which implies an efficient combustion of fuel during the early stage in the combustor. The addition of secondary air supplies the needed oxygen for the continued combustion of fuel. The peak concentration of oxygen remains at the combustor wall because of the secondary air injection. The oxygen concentration increased with the increasing of the combustor height. However, the oxygen concentration of the combustor center zone decreased.

1.2 Heat Transfer Characteristics

Heat transfer data between hot flue gases and combustor walls are important factors for the design and operation of combustors [3].

The simulation results of the heat flux and heat transfer coefficients in the combustor chamber are shown in Figures 4 to 5. Figure 4 shows a side - view of the grid profiles. Figure 5 shows the profiles of the heat flux near the combustor wall zone. A large amount of heat is generated at the bottom and wall zone of the combustor. The heat flux on the wall of combustor chamber is relatively higher than that of the center region of the combustor.

Figure 3 The Concentration Profiles of the Oxygen

Figure 4 The Side-view of the Grid Profiles for Heat Flux

Figure 5 The Heat Flux Profiles near the Combustor Wall

The heat flux on the wall of the upper chamber is much higher than that of the lower chamber. It is believed that the designed strong swirl and secondary air injection affected this special characteristics of heat flux. An averaged wall heat flux amounted to 550 w/m² in the upper chamber of the combustor.

The gaseous fuel in the lower part of the combustor is largely depleted. The heat removal is reduced to much lower extent of 240 w/m². For a given fuel, a proper design of heat transfer surfaces in the fluidized bed combustor can match with the combustion process of the fuel [4].

Figure 6 shows the heat transfer coefficient changes along the combustor height. It is a quite similar trend of the heat transfer coefficient changes based on the combustion test results in the previous report [5]. The heat transfer coefficients at 0.4 (X/H) and 0.75 (X/H) are 1.2 W/m²C and 2.2 W/m²C. When the secondary air was provided effectively, the swirling flame in the upper chamber of the combustor was much stronger than that of the middle or the bottom part of the combustor. These swirling and vortex flame were dominant in the upper chamber of combustor, which affected higher heat transfer in the upper chamber. Multiple secondary air injection can cause significant effects on gas-particle flow in the combustor. This air injection was found to be the best arrangement to strengthen the swirling flow, increase mass fluxes and retain more particles in the combustor chamber [6].

Figure 6 The Heat Transfer Coefficients along the Combustor Wall Height

SECTION 2

CONCLUSIONS

The numerical simulation was continued to determine the concentration distribution of the gas species, heat flux and heat transfer coefficients in the hot combustor model.

The different gas concentration profiles showed the gas mixing characteristics along the combustor height. The injection of secondary air squeezes the uprising flue gas and methane than causes a fuel-lean zone near the secondary air nozzles. The carbon dioxide concentration increased with the increasing of the combustor height. The peak concentration of oxygen remains at the combustor wall because of the secondary air injection.

The heat flux on the wall of the combustor chamber is relatively higher than that of the center region of the combustor. The heat flux on the wall of the upper chamber is much higher than that of the lower chamber. It is believed that the designed strong swirl and secondary air injection affected this special characteristics of heat flux.

The swirling and vortex flame were dominant in the upper chamber of the combustor which affected higher heat transfer rate in the upper chamber. Multiple secondary air injection was found to be the best arrangement to strengthen the swirling flow, increase mass fluxes and retain more particles in the combustor chamber.

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