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Technical Progress Report No.5

Investigation of Heat Transfer
and Combustion in the Advanced
Fluidized Bed Combustor (FBC)

to

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P.O. Box 10940, MS 921-118
Pittsburgh, PA 15236-0940

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by

Dr. Seong W. Lee, Principal investigator

Morgan State University
School of Engineering
Baltimore, MD 21239
(phone) 410-319-3137

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SUMMARY

This technical report summarizes the research work performed and progress achieved during the period of October 1, 1994 to December 31, 1994.

The measurement of gas flow continued with the assumption of axisymmetric flow in the laboratory-scale FBC. The gas axial velocity distributions at two cross-section in the test chamber were presented.

The circulating flow is relatively strong (swirl number of 3.0) near the freeboard wall for the two cross-sections because the flow has high reversal air velocity. The recirculation flow had weak air velocity when the swirl number of 0.60. For the non-swirling flow, the axial velocity was low near the freeboard wall. However, no circulating flow was observed at the two cross-sections.

The measurement of the gas axial velocity will be continued to observe the effect of the secondary air injection angles.

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SECTION 1

Measurement of Gas Flow

1.1 Axial Velocity Distribution

The measurement of gas flow continued with the assumption of axisymmetric flow in the laboratory-scale FBC [1]. The gas velocity and pressure measuring system consisted of DA&AT 3-dimensional (5-hole directional) probe [2], a universal traverse probe holder, four manometers, and one pressure differential gage.

The gas flow field in the test chamber of the FBC was assumed to axisymmetric. Measurements were made primarily in a vertical plane passing through the chamber axis. Figure 1 shows the gas axial velocity distributions at two cross-sections. Three sets of data from the upper part of the FBC were obtained at a cross-section 3" below the air inlet of the lower-level (designated as section 1), and the other three sets were measured at a cross-section 3" below the location of section 2. The axial locations of the two sections are indicated in the bottom part of Figure 1.

As shown in Figure 1, the circulating flow is relatively strong (swirl number of 3.0) near the freeboard wall for the two cross-sections because the flow has high reversal gas velocity. The recirculation flow had a weak air velocity when the swirl number of 0.60. For the non-swirling flow, the axial velocity was low near the freeboard wall. However, no circulating flow was observed at the two cross-sections.

Figure 1 Gas Axial Velocity Distribution affected by Swirl Number

1.2 Swirl Number

Strong swirling flow is one of the major features of the advanced fluidized bed combustor. The swirling intensity is dedicated by swirl number S , which is a dimensionless number defined by the ratio of axial flux of angular momentum G_θ to the axial momentum G_x multiplied by the equivalent chamber radius [3].

$$S = \frac{G_\theta}{G_x d/2}$$

where

$$G_\theta = \int_0^\infty (\rho u w + \rho \overline{u'w'}) r^2 dr$$

G_θ includes the x - θ component of the turbulent shear stress.
and

$$G_x = \int_0^\infty (\rho u^2 + \rho \overline{u'^2} + (p - p_\infty)) r^2 dr$$

G_x includes the term of turbulent normal stress in x -direction and the pressure term.

It can be deduced that the swirl number S can be approximated as the ratio of gas tangential velocity to axial velocity at the exit section. Generally speaking, the larger the swirl number, the higher the tangential velocity, and hence, the stronger the swirling flow. For cyclonic flows, if assuming a uniform velocity at exit, the swirl number of isothermal flow can be expressed as:

$$S = \frac{\pi D_e D_o}{4A_t}$$

where D_e and D_o are the diameters of the exit throat and the main section of the cyclone chamber, respectively. A_t is the total cross-sectional area of the tangential region. Since the advanced FBC has the unique configuration of multiple inlets and tangential-radial nozzles, the above equation should be modified. The swirl number for the exploratory-scale model of the advanced FBC system can be deduced based upon the original definition of equation, as follows [4]:

$$\begin{aligned} \text{Swirl Number} &= \frac{\text{Inlet Angular Momentum}}{\text{Outlet Axial Momentum} * D_e/2} \\ &= \frac{\pi \gamma^2}{4} \left(\frac{D_i D_e}{A_t} \right) \end{aligned}$$

where D_e = Diameter of exit tube
 D_i = Diameter of imaginary circle of secondary air injection
 D_o = Diameter of freeboard
 β = Injection angle of nozzle
 A_t = Total outlet area of secondary air nozzle
 γ = Volumetric flow rate ratio between secondary air flow and total air flow

It is worth nothing that the swirl number of the FBC is not only dependent on geometric factors but also related with the operating parameters.

SECTION 2

The progress of this project has been on schedule. The gas axial velocity distribution was measured and presented in the advanced laboratory-scale FBC, which was affected by swirl number. The measurement of the gas axial velocity will be continued to observe the effect of the secondary air injection angles.

REFERENCES

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