CHAPTER 4

DESIGN

4.1 Design Approach

The design of fluidized bed combustion unit for this study was based on the objective as set out in chapter 1 and making uses of the state of the art of the fluidized bed combustion technology as developed for rice husk. The design incorporated neccessary instrumention for the purposes of system performance analysis.

From chapter 2 , there are a lot of rice mill capacity 30 tons/day in Thailand which are the large mill. And 5-20 tons rice mills are medium size. In this design , it is for medium rice mill produced 5 tons (minimum) of rice milling and that 1 ton of rice husk per day. For working period that 8 hrs. in rice mill will use rice husk for fuel about 125 Kg/hr. So this pilot scale is designed for operate at 100-300 kg. rice husk consumption per hour.

4.2 AFBC Programe for FBC Design

From Eugan Equation

$$\frac{\rho_f(\rho_s-\rho_f)gd^3}{\mu^2} = 150\,\frac{1-\epsilon_{mf}}{\epsilon_{mf}^3}\,\frac{U_{mf}d\rho_f}{\mu} + \frac{1.75}{\epsilon_{mf}^3}\left(\frac{U_{mf}d\rho_f}{\mu}\right)^2$$

That was the basis design for writing AFBC Program , which used generally for designing fluidized bed combustor of fuel . The detailed display program was shown in Appendix - A and inputed the data as followed below:

(1) Set the rice husk feed rate .

(2) Calculate the air feed for combustion of the rice husk .

(3) From bed materil size (sand) , calculate the minimum fluidized bed velocity.

(4) Compare the air flow rate and air velocity.

(5) From air velocety , calculate the cross-sectional area of cmobustor and height.

4.3 Design Considerations For The Fluidized Bed Combustor System

The major parts of fluidized bed system can be listed as follows

4.3.1 Reaction vessel
4.3.2 Solid feeder
4.3.3 Dust seperater
4.3.4 Instrummentation
  4.3.4.1 Presure measurement
  4.3.4.2 Temperature measurement
  4.3.4.3 Flow measurement
4.3.5 Blower

4.3.1 Reaction vessel

Detail drawings of the system and system specification are present in Appendix B , The FBC column comprised three square cylindrical sections , i.e. a planum , a fire box or bed and a freeboaed (2 sections) , all of which are made of metal steel , lined in with firebrick and covered with rockwool insulator (10 cm. thickness) which is turn in wrapped withouter shield zinc plate. The bed is 1.2*1.2 m^2 diameter and each sector hight is 1 m for 1 sector , so total hight is 3 m. (not include plenum higth)

Inbed,there is bed material which 0.40 (mm) sand diameter. There are 3 input ports , one for feed charcoal and sand , the other for rice husk feeder port. Between air plenum and combustor is distribertor plate , which is 3 (cm) thickness (detailed drawing in appendix B) There are 180nozzle stand pipes for distubute air into the bed .The distributer plate ha pressure drop 1.5 mm.Hg at superticical vlocety about 1.2 m/sec.

4.3.2 Solid feeder

For charcoal and sand feeder , there are hopper with slide valve connected the port beside the frreboard on the upper sector of of combustor.

For rice husk feeder,there are feed system comprised with star valve , 2 slide valves , screw feeder and pneumatic way through screw feeder.

On the top of the feed system in hopper contained rice husk which closed on the star valve to control rice husk feeding into the 2 section rooms which open-shut controlled with 2 slide valves to maintain pressure in feed system. Next down the slide valves is screw feeder which controlled rotation speed by motor-gear and cooled with secondary air feed and water jacket around the outter shell of screw. Screw is lined into combustor for 20 (cm) length in order to feed rice husk continuously in the bed.

4.3.3 Dust Seperator

A cyclone separator, installed at the top of the combustor, was design to function as a carryover removal unit. In a couple of test runs, pressure built-up, occurred when the flowing out gas was blocked in the cyclone, was detected. Therefore, it was neccessary to design a new cyclone separator.

Cyclone design consisted of selecting a configuration, them determining the size, grade efficiency and pressure drop of the cyclone to be used. These determinations were based on given gas flow rate, composition, temperature, pressure and grain loading, accompanied by data on particle size distribution.

Cyclone design procedure

Note Detailed calculations of cyclone disign are shown in the APPENDIX C

1) Select a value for inlet velocity, base upon experience:

In this design the velocity used ; U = 100 m/s

2) From this, and required gas flow rate, calculate cross sectional area of inlet duct:

The highest possible gas flow rate in the combustor was 7000 m^3/hr and we used this value as required gas flow rate for cyclone. So,

$$Q = 7000 \quad m^3/hr$$

$$= \quad 1.944 \quad m^3/s$$

3) Select a design configuration, and calculate all demensions from specified ratio :

Here used the "Stairmand configuration" for tangential-entrance cyclone.

The results are shown below :

a	=	0.22	m
b	=	0.08	m
D	=	0.44	m
S	=	0.22	m
D_e	=	0.22	m
h	=	0.66	m
H	=	1.76	m
B	=	0.16	m
I	=	1.09	m
N	=	2.82	m

4) Calculate the grade efficiency 9NX corresponding to n, c and K :

Calculate n

It was found experimentally that "n" could be estimated from

$$n \quad = \quad 1 - [\ 1 - 0.67(D)^{0.14}](\ T/283)^{0.3}$$

Since the body diameter of the cyclone was calculated (D=0.44 m) and the desing temperature of 1000 K was used, we got

$$n \quad = \quad 0.412$$

Calculate c

a) Calculate the natural length ; I and compare this with the value of the dimension (H-S) where

$$I = 2.3\ De(D^2/ab)^{1/3}$$

b) If $I < (H\text{-}S)$, calculate VnI and if $I > (H\text{-}S)$, calculate V_H. Then, using either VnI or V_H as determined in the system, calculate Kc. Finally calculate c from the values of Ka, Kb, Kc.

In this design, we had

$$c = 55.122$$

calculate K

The cyclone inertial impaction parameter ; K could be calculated corresponding to the sand particle size of 400 + 60 Um diameter.

Using the values of n, c, K, we were able to determine the grade efficiency of the cyclone. The result showed that the collection efficiency of sand was nearly 100%.

5) Estimate pressure drop

The pressure drop across a cyclone could be estimated by the method of Shepherd & Lapple :

$$DP = 5.12\ P_x U^2 N \quad \text{[cm water gauge]}$$

The pressure drop of 0.838 cmWater was calculated. This value was much smaller than acceptable levels of DP for cyclone operation, generally less than 20 cmWater, which was desired.

4.3.4 Instrumentation

In this system the instrument measured the 3 parameter as followed.

- Temperature
- Pressure
- Air flowrate

4.3.4.1 Temperature measurement

This is usually simple and standard temperature sensing element are adequate for continuous use. In highly corrosive atmosphere where metallic protection tube can be used.

A metallic plobe which had 2 small wires of chromel-alumel, passing through and welded at one end, with the other ends connected to a thermocouple electronic wire and linked to digistrip II datalogger which in turn is connected to a microcomputer which displays the corresponding measurements at the corresponding points on the flow diagram on the display screen. Data are recorded both on the data logger,in hand copy, and in a microcomputer on the data file readily to be processed as required.

4.3.4.2 Pressure Measurement

The four copper tubes of 3.2 mm.inner diameter were weleded above the distributer and below the distributor, at the airplenum. A rubber tube connectes the copper tubes above and below the distributor via a namometer filled with mercury (Hg). The pressure of this system should be measured by means of

- pressure drop across bed
- pressure drop across distributer
- pressure in combuster
- pressure in air feed line

4.3.4.3 Air Flowrate Measurement

The instruments which measures air flowrate in this system are 2 types.

1. Measurement in 4 inchs pipe size diameter is "Orifice plate"

2. Measurement in 2 inchs pipe size diameter is "Rotameter"

The first item is primary an air flowrate and the second is secondary air flowrate.

Flow measurement could be detected in 2 types either direct or indirect measurement. For Rotameter in 2^{o} air is measured directly and Orifice plate in 1^{o} air is indirect measuremen. So, the orifice will be connected to the manometer to determine pressure drop before and after orifice plate and up stream pressure inthe pipe , that the data for find out the flow rate of 1^{o} air in pipe using the orifice programme (Ref^{n} on British standard) to calculate the air flow rate. Detail of using orifice programme is shown in App-D and detailed drawing is shown in App-B.

4.3.5 Blower

Blower are three stages connected by series, The spectification of them as follows;

- Maximum flow rate 1200 cu.M/hr
- maximum pressure at 1200 cuM./hr is 2,100 mm. H_2O