RECIRCULATING FLUIDIZED BED OPERATIONS

by

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Fluidized bed
RCFB

CERTIFICATE

This is to certify that the thesis entitled **"Recirculating Fluidized Bed Operations"** being submitted by **Munish Kumar Chandel** to the Indian Institute of Technology, Delhi, for the award of the Degree of Doctor of Philosophy is a bonafide record of research work carried out by him under my supervision and guidance. The thesis work, in my opinion, has reached the requisite standards fulfilling the requirement for the Degree of Doctor of Philosophy.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Fluidized bed rectors are used extensively these days for a multitude of processes including environmental pollution control and minimization. Recirculating fluidized bed (RCFB) is a type of circulating fluidized bed. RCFBs are in use for a variety of operations and processes due to the possibility of accurate control of solid circulation and the flexibility in its design and operation. The concept of RCFB is widely applied in different processes such as coating tablets, granulations and agglomeration of fine powders, grain drying, blending and mixing, low temperature carbonization of coal, devolatilization of coking coal and heavy crude oil gasification. In the field of environmental engineering, RCFB can be used for gasification and incineration of hazardous and non-hazardous wastes and flue gas desulphurization.

RCFB is a spouted bed with a central riser tube. The smaller central riser tube carries the particles upwards with the fluidizing gas and the outer tube carries the free falling particles downward. Though Circulating Fluidized Beds (CFBs) have been studied in detail, there are not many studies on RCFBs.

The present work is a study on the various aspects of a recirculating fluidized bed. A cold model semicircular recirculating fluidized bed was designed, fabricated and used for this study. Solid circulation rate, pressure drop across the various components of the reactor, gas bypassing and cluster formation and annular downflow layer are studied in detail for the various operating and design parameters.

The effects of particle size, spacing between the riser bottom and the air distributor, inventory of solids and air flow rate on the solid circulation rate were studied

experimentally. Increase in the inventory of bed materials and air flow rate generally lead to an increase in the solid circulation rate in a RCFB. There is an optimum spacing between the draft tube bottom and the distribution plate which gives the highest solid circulation rate. A mathematical model was developed for the solid circulation rate incorporating the effect of the various operating and design parameters. The model is based on the present experimental work and the data available in the literature for the same kind of RCFBs. Dimensional analysis and non-linear regression models were used to develop this model. The final model equation is a non-linear relationship between the solid circulation rate and different operating and design variables. The model gives good results for the same kind of systems and in the range in which the variables were verified.

The effect of various operating and design parameters on the pressure drop of a RCFB was also studied in detail. Pressure drop across the riser, across the downcomer and between the riser bottom and the downcomer bottom were measured. The different parameters considered were air flow rate, inventory of solids and spacing between the riser bottom and the distributor, and size of the sand particles (Geldart D and B).There was an increase in the pressure drop across the riser with an increase in the inventory of solids. The pressure drops across the riser and across the downcomer were high for the fine particles as compared to the coarse particles. There was an increase in the pressure drop with the increase in the spacing between the riser bottom and the distributor, possibly due to the increase in the gas bypassing. A mathematical model was developed for the pressure drop in the RCFB. The model for the pressure drop in the riser was developed on the basis of Bernoulli force balance equation. The major contribution in the pressure drop across the riser was of the head. The acceleration and friction components increased with the increase in the superficial gas velocity.

Gas bypassing from the riser air supply towards the downcomer affects the flow behavior in a recirculating fluidized bed. Gas bypassing is calculated on the basis of the mathematical model and the effects of various parameters on gas bypassing were analyzed. There was a decrease in gas bypassing with an increase in the solids inventory for coarse as well as for fine particles. Gas bypassing increased with an increase in the spacing between the riser bottom and the distributor. There was a decrease in gas bypassing with a decrease in size of the particles.

Cluster formation in circulating fluidized beds is of prime importance as it significantly influences heat and mass transfer. The clusters near the wall of the riser form a continuous downflowing layer known as the annular layer. The present work describes the measurement of annular layer thickness in a recirculating fluidized bed using high speed video camera. The effect of various operational and design parameters on the annular downflow layer thickness was studied experimentally. Inventory of soiids, air flow rate, particle size, axial height (measurement position in the riser) and the spacing between the distribution plate and riser bottom were the various operating and design parameters considered in this study. A frequency factor is defined which acts as an indicator of the stability of the annular downflow layer. A correlation between the annular layer thickness and the operating and design parameters was developed based on the experimental results. The correlation developed can be useful in the better understanding of the hydrodynamics of the RCFBs. The results indicate that annular layer thickness decreases with the increase in air flow rate as well as with the axial position along the riser. The annular layer thickness increases with the increase in the spacing between the riser bottom and the distribution plate. Fine sand has relatively more stable annular downflow layer as compared to the coarse sand.

The present work can be useful for the optimization of the design and operation of recirculating fluidized bed reactors. The study can be used to design the various components of the reactor for desired solid circulation rate with more flexibility in choosing the different parameters. The pressure drop and gas bypassing study can be useful in the air/gas facility design. The annular downflow layer thickness model can be useful for the calculation of heat transfer and mixing coefficients.

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