A Quantitative Study of Fluidization Quality in Baffled and Conical Gas-Solid Fluidized Beds

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Literature relating to improvement of fluidization performance in case of gas-solid systems by the incorporation of baffles in columnar beds and use of conical conduits has been briefly reviewed. Investigations relating to gas-solid fluidization have been carried out in four different types of conduits, viz., cylindrical, baffled cylindrical with VT baffles, baffled cylindrical with ST baffles and conical. From a dimensional analysis approach, correlations have been proposed for the prediction of fluctuation ratio in terms of static and dynamic characteristics of the system for the conventional and the modified conduits. The quality of fluidization, measured in the scale of fluctuation ratio, has been compared for the above cases and the quantitative improvement achieved in case of the modified conduits over the conventional one has been presented.

The quality of fluidization can be quantified by a term called ‘fluctuation ratio’ which is defined as the ratio of the highest and the lowest levels which the top of the fluidized bed occupies for any particular gas flow rate. Thus a lower value of fluctuation ratio indicates less fluctuation of the top of the bed in fluidized condition and thereby better quality of fluidization with reduced bubbling and slugging.

Incorporation of baffles in the bed and fluidization in conical conduit instead of a columnar one, have been reported to result in significant improvement in the fluidization performance. A few aspects of fluidization dynamics for various types of baffled bed have been investigated by Krishnamurthy et al and Chandra et al in the recent past and correlations have been proposed. For gas-solid fluidization in tapered conduits Kumar et al developed correlations for minimum fluidization velocity and pressure peak. Further investigations in conical beds relating to minimum linear fluidization velocity and fluctuation ratio for regular and irregular particles have been reported by Biswal et al in form of empirical correlations. As evidenced from literature no effort has yet been made to quantitatively compare and determine the quality of fluidization, as represented by the fluctuation ratio, in case of unbaffled, baffled and conical beds. In this communication an attempt has, therefore, been made to propose correlations to predict the fluctuation ratio in terms of system parameters and to compare the quality of fluidization, in the scale of fluctuation ratio, for four different conduits, viz., cylindrical, baffled cylindrical (vertical and stirrer type baffles) and conical beds.

NOTATIONS

d_p = particle diameter, m
D_o = inlet diameter of the fluidizer, m
G_f = superficial fluid mass velocity in fluidized state, kg/hr m^2
Gmf = G_f at minimum fluidization, kg/hr m^2
h_s = static bed height, m
r = fluctuation ratio, dimensionless
W_e = weight of bed material, kg
\alpha = angle of cone, degrees
\rho_f = density of fluid, kg/m^3
\rho_s = particle density of solid bed material, kg/m^3

INTRODUCTION

As an established fluid-solid contacting technique, fluidization has found extensive applications in unit operations like drying, adsorption and in chemical processes viz., solid-catalyzed reactions, carbonization, gasification and combustion. In spite of the many advantages claimed of fluidization, the efficiency and the quality in large scale and deep gas-solid cylindrical fluidized beds are seriously affected by bubbling, slugging and channeling behaviour of such beds, resulting in poor gas-solid contact, lower diffusion and heat transfer rates.

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EXPERIMENTAL PROCEDURE

The experimental set-up used for the investigation was a conventional one in which four different types of conduits had been used for fluidization. Fig 1 shows the details of the cylindrical and conical conduits and the baffles used in the experiment. Table 1 lists out the different experimental variables studied.

![Fig 1 Conduit and baffle details](image)

<table>
<thead>
<tr>
<th>TABLE I EXPERIMENTAL VARIABLES</th>
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<tbody>
<tr>
<td><strong>BED MATERIALS</strong></td>
</tr>
<tr>
<td>Glass-Beads (GB)</td>
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<tr>
<td>Mustard Seed (MS)</td>
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<tr>
<td>Urea</td>
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* Cyl refers to cylindrical bed, VT refers to cylindrical bed with vertical baffle, ST refers to cylindrical bed with stirrertype baffle, cone refers to conical bed with apex angle within the bracket

A known weight of the bed material was charged to the column from top. The surface of the bed was made smooth by fluidizing and then allowing it to settle slowly for a number of times. The compressed and dried air was admitted to the column from a constant pressure tank maintained at 2 kg/cm². The bed pressure drop was recorded, against the fluid mass velocity in the fixed bed region and both the pressure drop and the fluctuation ratio were noted in the fluidized bed region. Minimum fluidization velocity for the different cases was then obtained by plotting separately the pressure drop against fluid mass velocity.

DEVELOPMENT OF CORRELATIONS

The fluctuation ratio is found to be a function of the static properties, ie, d, D, h, f, and the dynamic properties, ie, G and G_m, in case of cylindrical columns with and without baffles. In the case of conical fluidized beds, in addition to these, another static property of importance is the apex angle of the cone.

From a dimensional analysis approach, the following correlations have been developed for the prediction of fluctuation ratio for four different conduits in terms of the static and dynamic properties of the system (Figs 2-5).
DISCUSSION ON RESULTS

The developed correlations (equation Nos 1-4) can be used to predict the value of the fluctuation ratio for the corresponding conduits.

The fluctuation ratio is used as a parameter to compare the fluidization quality in different conduits. A lower value of the fluctuation ratio indicates less fluctuation of the top of the bed, resulting in smoother and better fluidization with reduced bubbling and slugging. It has been observed from the experiments that for cases of equal particle size, weight and density of the bed material, fluidized at identical mass velocity in the four types of conduits, the fluctuation ratio decreases in the following order, viz, cylindrical, baffled cylindrical with vertical (VT) type baffle, baffled cylindrical with stirrer type (ST) baffle and conical beds, indicating thereby an improvement of fluidization quality in the same order.

In Table 3, the percentage improvement of fluidization quality, represented by a decrease in fluctuation ratio, has been presented for the three modified conduits compared to the conventional cylindrical one.

### TABLE 3 IMPROVEMENT OF FLUIDIZATION QUALITY IN MODIFIED CONDUITS

(With Reference to Cylindrical Bed)

<table>
<thead>
<tr>
<th>Expt Variables</th>
<th>Improvement of Fluidization Quality, %</th>
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<tr>
<td>( \frac{\rho_s}{\rho} \times 10^3 )</td>
<td>( W_0 ), kg</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
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CONCLUSIONS

1. The developed correlations can be used to predict the value of fluctuation ratio for the four conduits.

2. The fluidization quality has been found to improve considerably in case of baffled cylindrical and conical beds.

3. Conical fluidized beds can be subjected to much higher range of fluid mass velocity, at which the entire bed material will be entrained and carried away in case of other conduits.

4. Based on this study, the fluidization quality in existing units can be improved by the incorporation of suitable baffles and in case of new proposal, conical beds should be preferred.
REFERENCES


