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MEASURING AND MODELING SOLIDS MOVEMENT IN A LARGE,
COLD FLUIDIZED BED TEST FACILITY

Fourth Quarterly Report for Period July 1, 1980—September 30, 1980

By
Thomas J. Fitzgerald
Robert V. Mrazek
Stephen D. Crane

September 1980

Work Performed Under Contract No. AC01-79ET13152

Oregon State University
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Corvallis, Oregon

U. S. DEPARTMENT OF ENERGY

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TESTS OF MAGNETIC FLOW MEASURING DEVICE

The principle of operation of the magnetic-particle mass-flow measuring device was described in the first quarterly report. In addition, the results of a few preliminary tests which were carried out to show the feasibility of using this device were described in the third quarterly report. It was noted that the output signal from the device is proportional to velocity and that saturation of the material in the vicinity of the read coil had not yet been achieved. Thus, efforts during this quarter were concentrated upon two objectives - achieving saturation of the magnetic material in the vicinity of the read coil and establishing calibration procedures to be used with the device installed in a fluidized bed.

Two possible coil configurations were identified for use in the bed - the "folded C-type" coil and the antiparallel set of coils. These two configurations are shown in Figure 1. In both cases, the mass flux to be measured is along the axis of the read coil. One of these two possible configurations - the "folded C" - was arbitrarily chosen for use in establishing standardized calibration procedures. The coil used can be visualized as occupying eight edges of a cube, 1.5 inches on an edge. The coil consisted of 90 turns of number 20 wire giving an impedance of approximately 1.5 ohms at 500 hertz when the coil enclosed a Tygon tube filled with 16-mesh iron powder. The read coil was the same as that described in the last quarterly report.

The sequence of record, read, and erase pulses was the same as used previously. However, the timing of these pulses was modified to allow data acquisition at a rate of 10 samples/second. The sequencing is shown in Figure 2. The timing sequence is as follows:

Folded "C" Configuration

Anti-Parallel Configuration

Figure 1: Coil Configurations

Notes: 1. The sequence, Record → Delay → Window → Erase → Record-----, is controlled by the trailing edge of the preceeding function, indicated by ( ) on the block diagram.

2. Individual pulse widths are adjustable independently; the cycle time is the total time of all functions.

3. Amplitudes of RECORD and ERASE signals are adjustable independently; as well as together by the attenuator of the POWER AMPLIFIER.

Fig. 2. Timing diagram of control circuit.

record pulse:	1 ms
first delays:	20 ms
window:	3 ms
erase pulse:	6 ms
second delay:	<u>70 ms</u>
	100 ms

The device designed and used to produce a known movement of magnetizable material (iron powder) through the coils is shown in Figure 3. Sixteen-mesh iron powder was confined in a Tygon tube of either 3/4-inch or 1-inch diameter. The tube could be moved through the coils at a known linear velocity by a pulley system driven by a variable-speed motor. Knowledge of the length of the loop of Tygon tubing and the total mass of iron it contained allowed conversion from linear velocity to mass flow rate.

Before attempting a calibration in terms of mass flow rate, operation in a region in which the material in the vicinity of the read coil is magnetically saturated must be ensured. In each case, saturation was established by monitoring field strength as a function of the power input used to magnetize the iron powder at a fixed tube velocity. Since the output signal from the read coil is dependent upon the field strength, this was accomplished by simply measuring the output signal as a function of the write-coil current input, and increasing the write-coil current until two identical output readings were obtained. Any current above this level would produce the same output signal, and thus an indication of magnetic saturation was obtained. The results of a typical saturation test are depicted in Figure 4 and given in Table I.

Calibrations were carried out, at currents above the saturation threshold, for both a 3/4-inch and a 1-inch Tygon tube filled with 16-mesh iron

Figure 3: Calibration Assembly

Tube: 3/4 inch; 0.675 lb_m iron powder/ft of tube

Mass flow rate: 0.45 lb_m iron powder/sec

Coil: Folded "C"; 90 turns, #20 wire

Figure 4: Typical Saturation Curve

Table I: Results of a Typical Saturation Test

Tube: 3/4 inch; 0.675 lb_m iron powder/foot of tube
 Mass Flow Rate: 0.45 lb_m iron powder/second
 Coil: Folded "C"; 90 turns, #20 wire

Voltage across write coil (volts)	Current in write coil (amp)	Output signal in read coil (volts)
10	7.14	0.40
20	15.2	0.80
30	22.3	1.10
40	29.5	1.35
50	35.7	1.50
55	40.2	1.55
60	43.8	1.60
65	46.4	1.65
(70	50.0	1.70 ← Saturation
72	50.9	1.70

powder moving through the coils. A range of linear velocity of 0-2.25 feet/second was used in both cases. For the same linear velocity in the two tubes, the ratio of mass-flow rate for the larger tube to that for the smaller tube is 1.778. The results of these tests show that, as expected, the output reading is proportional to mass flow rate, not linear velocity. These results are shown in Figure 5, and it can be seen from these data that the dependence of output signal upon mass flow rate is effectively linear for the range in mass flow rates of 0.5-2.25 lb_m/sec. Some drop-off occurs below a mass flow rate of 0.5 lb_m/sec. In addition there is a drop off above a mass flow rate of 2.25 lb_m/sec. These higher mass flow rates should be beyond the range of interest for measurement in the fluidized bed. If the three points on Figure 5 above a mass flow rate of 2.25 lb_m/sec are excluded, a linear regression of the data produces the line shown, with a regression coefficient of 0.996.

The tests described above were carried out with iron powder inside the coils only. The possible effects of iron powder outside the coils raises two questions which must be considered. They are: what is the effect simply of having the coil surrounded by iron powder, and what is the effect of the movement of iron powder outside the coil. The effect of having the coil surrounded by iron powder, i.e., without movement of the powder outside the coil, should be to require a higher current for saturation. The currents used in the tests described above were 59 amp and 73 amp for the 3/4-inch and 1-inch tubes, respectively. Although these currents are quite different, the output as a function of mass flow rate was effectively the same for the two cases. Thus, the simple presence of iron powder surrounding the coils, while requiring a higher current for saturation, should leave the output reading unaffected. The only limitation is the capacity of the amplifier.

Figure 5: Typical Calibration Curve
for 1 1/2" Folded "C" Coil

The movement of the iron powder outside the coils will undoubtedly affect the output reading. However, as one moves away from the coils, the magnetic field is very much less concentrated than it is either inside the coils or in the immediate vicinity of the outside of the coils. Thus the dependence of the output reading on the movement of iron powder outside of the coil should be negligible except for material very close to the coil. Indeed, the total effect of the movement of material outside the coil should be minor compared to the effect of the movement of material inside the coils.

These two tentative conclusions on the effects of the material outside the coils will be verified experimentally before final calibration procedures are adopted. The results will be given in a subsequent report.

A SMALL SCALE EFFORT TO PRODUCE A WELL MIXED CIRCULATION PATTERN

A short investigation was carried out to determine if desired solids circulation patterns could be created by using unequally spaced tube patterns, partitions, and/or unequal gas distribution. It was hoped that a rapidly circulating and hence well mixed bed could be created by using one or a combination of the above conditions.

Experiments were conducted in a two-dimensional cold fluidized bed (19" x 5" x 72") using scaled 1/2" diameter dummy heat exchange tubes and scaled copper bed material. The size distribution of the bed media and the tube diameter and spacing were 1/4 that of Babcock and Wilcox's 6' x 6' (1.83 x 1.83 m) hot fluidized bed located in Alliance, Ohio. The ratio of the solids density to gas density was also scaled.

Three configurations were used at scaled superficial gas velocities of 2.4, 3.1 and 5.5 ft/sec. The first configuration consisted of a closely spaced tube bundle on one side of the bed and a loosely spaced bundle on the other (see Figure 6). The second configuration used the same tube array but with a partition separating the regions of different tube spacing. The last arrangement included the unequal tube array and the partition, but in addition, half of the holes in the distributor plate on the widely spaced tube array side were blocked thus reducing the volume of air passing through the bed media. Slow motion movies were taken of each system in order to make comparisons of the mixing characteristics.

Although each experimental condition showed a slight effect on the bubble growth pattern, it was difficult to distinguish any changes in the solids flow patterns. In all cases there was a downward movement of the solids near the walls indicating all of the upward movement was toward the center of the bed and thus blocked from view. Therefore, a more sophisticated approach is needed to determine if a change in the solids flow patterns is occurring.

Figure 6: 2-Dimensional Fluidized Bed and Scaled Tube Array