Fundamental Study of a Pit Sweeper for Collecting the Muddy Deposits Especially Containing the Volcanic Ashes (Effects of Diameter Ratio of Injection to Suction on Concentration)

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Abstract

In the case of collecting the granular grains and removing the muddy deposits, it was found to be very difficult to lift them up effectively only by use of suction force. We also found from our investigations that a proposed sand collecting system with an injection at the collecting mouth can transport such materials more effectively and more smoothly than other conventional systems by means of the fluidization of the settled bed before collecting the solid particles. In this paper, the effects of the inner diameter ratio of the injection mouth to the suction mouth on the concentration of the muddy deposits are discussed using volcanic ash as a collecting material, both in the case of the inner diameter of the suction mouth kept constant, and in the case of that of the injection mouth kept constant. It was found from the experimental results that the performance of the collecting unit depends greatly upon the injection velocity, so the greater the injection velocity, the larger the concentration of the ash.

1. Introduction

The subjects of collecting relatively small particles and resources piled up on the bottom of the sea and the river, the pneumatic transportation of many kinds of grains from the ship and the cleaning of the particles are to be very important problems in the near future and are expected to having high efficiency more and more. In the case of collecting the muddy deposits, it is so difficult to lift them up only by the suction forces(1) (2) (3). It was reported by the author that the effective collection can be performed by the fluidization of the settled bed of the sands adding the injection at the collecting mouth using the spherical glass beads as a collected material(4) (5) (6).

On the basis of the experimental results, the sand collecting system which is used for collecting the muddy deposits especially containing the volcanic ashes settled in the pit, so called a pit sweeper, was constructed. One of the reasons why the ash is sellected as a collected material is as follows: The surface of the ash which are created by the eruption of the volcano are rough or irregular, then the friction forces among them are very large. Therefore, it is so difficult to collect them effectively by the conventional systems.

In this paper, the effects of the inner diameter ratio of the injection mouth to the sution mouth on the collected weight and the concentration of the volcanic ashes were investigated in the case of the inner diameter of injection mouth kept constant and in the case of that of suction mouth kept constant.

2. Experimental Method and Apparatus

The experiments were carried out in order to clarify the effect of the inner diameter raito of the injection mouth to the suction mouth on the concentration of the collected material and to determine the diameter ratio which gives the effective transportation of the collected particles.

Figure 1 shows a schema of the experimental apparatus of the pit sweeper. In this figure, the clean water issues vertically in the down direction from the injection mouth ① where the ashes settle. The ashes and water two-phase flow entering from the suction unit ② flows through the suction pipe ③ into the separator ④. The ashes are separated from the water here and deccerated by the stationnary plate ⑤, then the ashes are collected in the sand accumulator ⑥ temporally. The sand exhaust valve ⑦ opens when the ashes are collected and the ashes are moved into the sand collecting tank ⑧. On the other hand, the cleaned water flows into the main pump ⑨ and is used as the injection again.

The inner diameter ratio of the injection mouth D_i to the suction mouth D_s is defined as

$$R_{\mathrm{d}} = \frac{D_i}{D_s}, \tag{1}$$

The detail of the suction unit and the values of R_d, D_i, D_s, and the effective flow sectional area at the suction mouth A_{eff} used in this experiment are shown in Table 1 together with each shape of

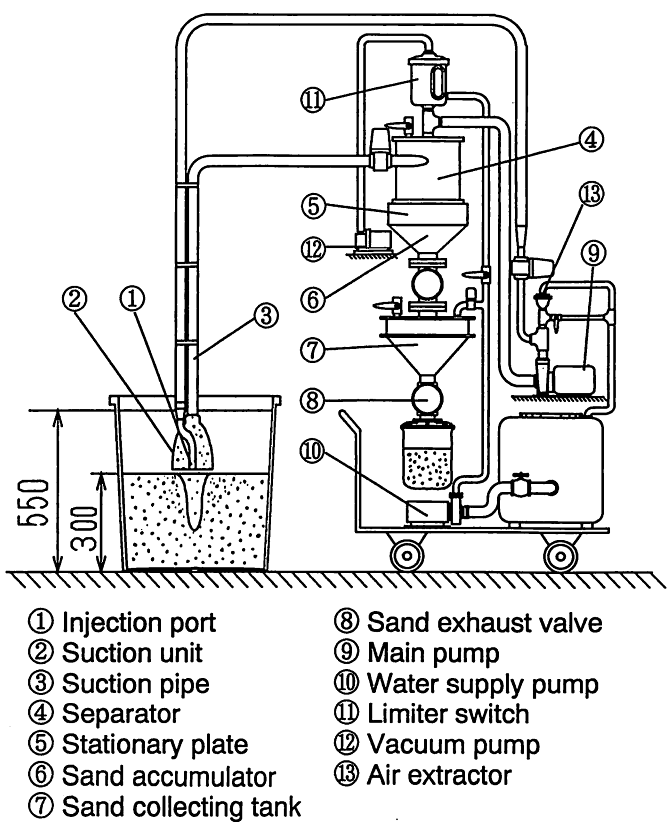
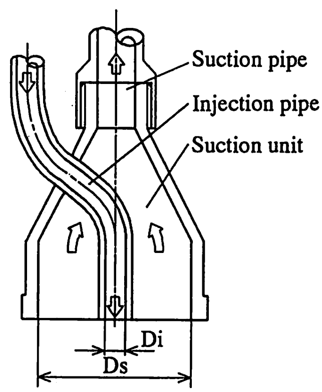


Fig. 1 Schema of pit sweeper

Table. 1 Dimensions and shapes of collecting mouth

Di(mm)	15.0			
Ds(mm)	150.0	100.0	79.0	50.0
Rd(=Di/Ds)	0.1	0.15	0.2	0.3
Aeff(cm²)	172.2	74.0	44.5	15.1
Shape of collecting mouth	Ds, Di			

Ds(mm)	100.0			
Di(mm)	10.0	20.0	30.0	40.0
Rd(=Di/Ds)	0.1	0.2	0.3	0.4
Aeff(cm²)	77.75	75.40	71.47	65.97
Shape of collecting mouth	Ds, Di			



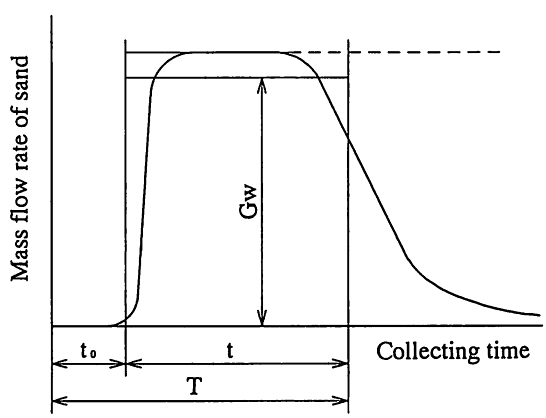


Fig. 2 Relations between mass flow rate of sand and collecting time

the collecting mouth both in the case of the inner diameter of the injection mouth kept constant and in the case of the inner diameter of the suction mouth kept constant.

In the actual system, the suction unit must be moved vertically and horizontally as the ashes are collected. In this experiment, the height of the suction unit is set just on the surface of the settled bed at the begining of collecting. Therefore, as shown in Figure 2, the mass flow rate of ash varies with time, then a mass flow rate of ash per unit time is defined by averaging a total mass of ash by the measuring time. In this figure, t_0 denotes a time lag from the switching on to the ash reaching at the collecticg tank, t a real collecting time and G_w a mean mass flow rate of ash.

In order to investigate the effects of the inner diameter raito on the concentration of the ash, the inner diameter ratio of the injection mouth to the suction mouth is used as a geometrical parameter and the flow rate of circulation as a dynamic parameter.

3.1 In the case of the inner diameter of the injection mouth kept constant

Figure 3 shows the relations between the mass flow rate of ash G_w and the flow rate of cir-

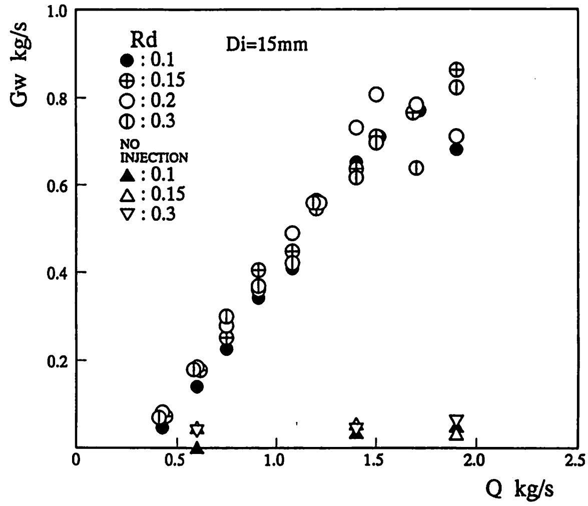


Fig.3 Relations between mass flow rate of sand and flow rate of circulation

culation Q in the case of the inner diameter of the injection mouth kept constant. In the case of the flow rate of circulation smaller than 0.4kg/s, none of the ashes are collected for each diameter ratio and this shows the viscous force acting upon the paticle vertically upward being smaller than the gravity force [7]. Figuer 4 shows the relations between the concentration C_w and the flow rate of circulation Q. The concentration of the ash is defind as

$$C_w = \frac{Q_p}{Q_p + Q_s}, \tag{2}$$

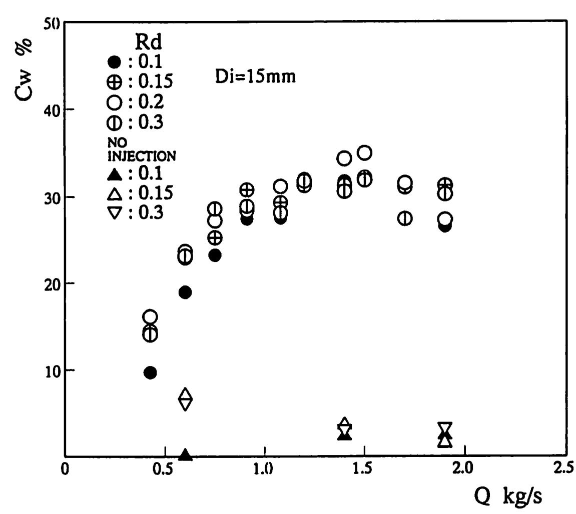


Fig.4 Relations between sand concentration and flow rate of circulation

where Q_p is a mass flow rate of ash and Q_s a mass flow rate of water. Also for the concentration of the ash, the differences of the concentration cannot be observed and they are about 30% in the wide range of the flow rate of circulation larger than 1.0kg/s. So far as the flow rate of circulation is not much smaller than nominal value of the pump, the inner diameter ratio of the collecting unit can be selected very widely. This value of the concentration, however, lowers by about 20% compared with that in the case of the spherical glass beads. This comes from the fact that the shapes of ash are irregular, then the drag itself increases. So far as the concentration is concerned, little difference is observed among the inner diameter ratios, but the mean velocity at the suction mouth of $R_d = 0.3$ becomes 2.9 times as large as that of $R_d = 0.2$ as shown in Table 1, then it is expected that the drag in the vicinity of the suction mouth increases as the inner diameter ratio increases. On the other hand, as the inner diameter ratio becomes too much small, the suction unit itself becomes very large,then it is not available at the point of view of the operation. Therefore, in the case of the inner diameter of the injection mouth 15mm, from the above experimental results it is considered that $R_d = 0.2$ is the most effective ratio for collecting the ashes.

3.2 In the case of the inner diameter of the suction mouth kept constant

Figure 5 shows the relations between the collected mass flow rate of ash and the flow rate of circulation using the inner diameter ratio as a parameter. As the inner diameter ratio increases, the collected weight of the ash tends to decrease compared with that in the case of the inner diamater of the injection mouth kept constant as shown in Fig.3. Only in the case of $R_d = 0.1$, the collected weight of the ash shows especially high value. It is considered that the deep fluidization progresses since the injection velocity reaches the highest value as the inner diameter of the injection mouth is smallest. On the other hand, in the case of the inner diameter ratio larger than 0.2, the inner diameter of the injection mouth is larger than that in the case of the constant diameter $D_i = 15$mm as shown in Table.1, then the collected weight of the ahes decreases as the inner diameter ratio

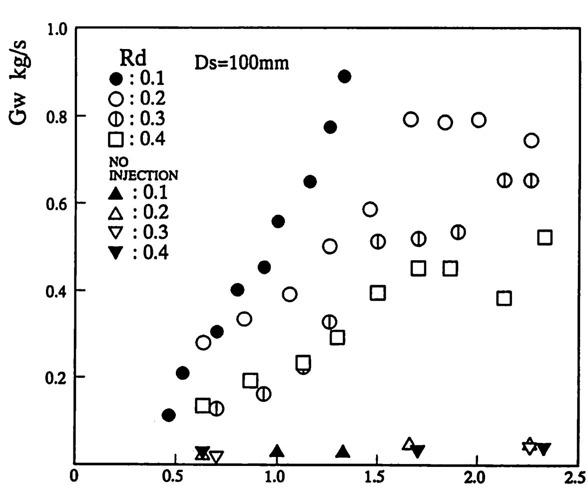


Fig.5 Relations between mass flow rate of sand and flow rate of circulation

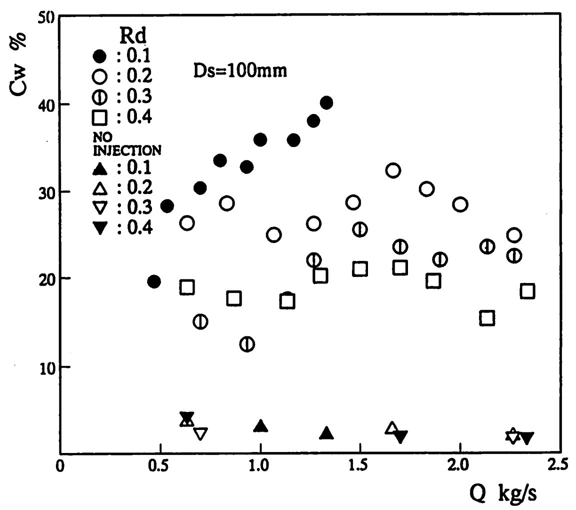


Fig.6 Relations between sand concentration and flow rate of circulation

increases. This is similar to the relations between the concentration of the ash and the flow rate of circulation shown in Fig.6 and means that the collected weight of the ash and the concentration depends strongly upon the fluidization of the settled layer by means of the injection flow. In the case of the constant inner diameter of suction, as the inner diameter ratio becomes larger, the injection velocity is smaller for the equivalent flow rate of circulation. Then the effect of fluidization becomes weaker.

4. Conclusions

The mesurements of the collected weight of the ash and the concentration were done using the inner diameter ratio and the flow rate of circulation of the collecting unit of the sand collecting system (pit sweeper). As a result, in the case of the inner diameter of the injection mouth kept constant, the concentration of the collected ashes is nearly constant independent of the inner diameter ratio. Furthermore, the high concentration of the ash is obtained for wide range of the flow rate, whereas this value is lower than that in the case of the spherical glass beads by about 20%. On the other hand, in the case of the inner diameter of the injection mouth kept constant, the concentration varies considerably by means of the inner diameter ratio and the concentration increases as the diameter ratio is smaller. It was clarified from the above results that the performance of the collecting unit depends strongly upon the injection velocity itself and high concentration of the ash can be obtained.

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