ANALYSIS OF THE OPERATION OF AN L-VALVE FEEDING DRY SPENT COFFEE GROUND

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ABSTRACT – We analyzed the transient and stationary behavior of a 23 mm diameter L-valve operating with spent coffee ground of two different particle-size distributions. The solids mass flux in the valve discharging to the atmosphere was stable in a wide operating range ($100<\dot{G}_s<1250$ kg/m²s). Besides, regions of low, medium and high aeration velocities could be identified based on experimental data of pressure loss and solids mass flux, and on a qualitative analysis of the flow patterns. We concluded that the L-valve is an appealing feeding device to handle biomass residues and that the solids height in the standpipe is a variable that must be monitored throughout the process.

1. INTRODUCTION

Feeding powders continuously under a stable mass flux is crucial for the proper performance of several unit operations. Encouraging results and wide operation ranges have been reported using L-shaped feeders operating with conventional powders such as glass spheres, alumina and sands (Smolders and Baeyens, 1995; Arena et al., 1998; Lim et al., 2013). The transport of solids though an L-valve is based on pneumatic action and because this device has a simple geometry and no moving parts, it has a lower price and suffers less wear when compared to conventional mechanical feeders, such as rotary valves and screw feeders.

No analysis focused on the L-valve transient behavior or on its stability when operating with biomass residues, that present low bulk densities and variable particle size distributions, has been found in the consulted literature. This study is aimed at evaluating the feasibility of using an L-valve to control the solids mass flux of spent coffee ground (SCG) powders in the discharge from a conical silo to the atmosphere. Both the transient and stationary regimes of the L-valve are analyzed for two different particle-size distributions (PSDs) of the biomasses.

2. METHODOLOGY

The SCG powders were obtained after brewing coffee grounds (brand Três Corações), acquired in São Carlos-SP, Brazil. To reduce the powder’s moisture content, 5 mm thick layer samples were oven-dried at 105±2°C for 24h and stored under ambient temperature until further use. Two samples of SCGs with different PSDs were prepared through sieving: sample A is composed of 0.8 kg of SCGs retained between sieves of 500 and 300 µm, while sample B is
composed of 0.72 kg of SCGs retained between sieves of 500 and 300 μm, and 0.08 kg retained between sieves of 300 and 150 μm.

To investigate the transient operation of an acrylic L-shaped valve (D_{LV}=23 mm), 0.8 kg of the samples A and B were stored in a conical silo (V=0.0125 m³, D_{TOP}=0.25 m, D_{EXIT}=23 mm, conical half-angle=30°) and a standpipe (D_{SP}=23 mm) made of stainless steel. The experimental setup is shown in Figure 1a. The powder was discharged to the atmosphere under pre-established values of aeration velocities, ranging from 0.2 to 1.8 m/s. The air entrance (D_{AIR}=2.5 mm) is positioned 5 mm above the bottom of the horizontal section of the L-valve. The static pressures in P1, P2 and P3 taps as well as the solids mass fluxes were monitored during the assays using a data acquisition system, model NI-9205 from National Instruments® and a digital balance (model 9094) from Toledo®.

3. RESULTS AND DISCUSSION

The physical properties of the powders were measured according to the procedures described in Campos and Ferreira (2013). The properties of the two SCG samples were not significantly different considering the measurements’ uncertainties. The moisture content, true, loose and tapped bulk densities were respectively equal to 2.8±0.1% w.b., 1315±3, 380±20, and 460±10 kg/m³. The experimental results of the transient operation of the L-valve are shown in Fig. 1b, at an aeration velocity of 1.7 m/s.

![Figure 1](image)

Figure 1 – a) Experimental setup and b) transient operation of the small L-valve feeding spent coffee grounds (d=400μm) to the atmosphere, aeration velocity=1.7 m/s.

In t=0s, as soon as the aeration is initiated, the static pressures and solids mass flux reach peak values. The packed-bed in the standpipe collapses and a channel of flowing particles is formed, leading to a decrease in the pressure and solid mass flux, with a stable operation region. During the experiments, it was observed that the solid mass flux and valve operation depend on the solids height in the standpipe, and that G_s decreases as the solids height level is below the
pressure tap P2, as shown in Figure 1b. Similar behaviors were observed in the interval of velocities analyzed (0.2 to 1.8 m/s), as well as when transporting sample B in the valve.

The average values of $G_s$ and P3 in the stable operating region were used to build up a flow regime map for the L-valve operating under a steady regime, as presented in Figure 2. Depending on the aeration velocity, three operating regions could be identified: 1) the standpipe packed-bed resistance controls the transport of solids, with a high pressure loss ($\Delta P$) and a low solid mass flux ($G_s$) (observed under low aeration, $U_A<0.3$ m/s); 2) the weight force of the solids in the standpipe is in sync with the buoyancy generated by the aeration velocity inlet, resulting in the highest values of $G_s$ (medium aeration, $0.3<U_A<1.05$ m/s); and 3) the gas phase controls the transport of solids with vortices formation in the base of the standpipe, leading to a diluted transport of solids in the L-valve with a low $\Delta P$ (high aeration, $U_A>1.05$ m/s). These patterns were captured by video-shooting throughout the assays and are illustrated in Figure 3.

![Image](image)

**Figure 2** – Pressure drop versus solids mass flux in the L-valve (D=23 mm) operating with dried spent coffee ground and discharging to the atmospheric pressure.

The results reported in Figure 2 show that the L-valve provided stable solids mass flux in all the aeration regions, with $100<G_s<1250$ kg/m$^3$s, depending on the aeration velocity. Therefore, it was an effective device to vary and control the SCG solid mass fluxes. For comparison, under free gravitational discharge to the atmosphere in the system without the L-valve, a constant value of $G_s$, close to 7500 kg/m$^3$s was obtained.

Finally, it was observed that the samples’ PSD affected the values of $\Delta P$ and $G_s$, particularly on the medium aeration region. In this region, the pressure drop measured in the L-valve was lower for the sample with fine particles in its composition (sample B). Additional experiments with other SCG samples with different PSDs will be performed to confirm this trend.
4. CONCLUSIONS

We verified that the L-valve is a reliable non-mechanical feeding device to control the discharge of biomass powders under atmospheric pressure. The valve provides stable solids mass flux under a wide operating range. Nevertheless, the solids height in the standpipe must be monitored to prevent disruption of feeders’ operation.

5. ACKNOWLEDGEMENTS

The authors would like to thank the São Paulo Research Foundation (FAPESP), grant 2016/25946-2, for the financial support.

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