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Technical Feasibility Study of Pneumatic Conveying System for a Concentrated Solar Thermal Plant

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In the last decades, high temperature particle receivers have been widely investigated to increase the operating temperature of heat transfer medium in order to increase solar to process efficiency. However, one of the key challenges is to convey solid particles, especially for medium high operating temperature, from the ground to the solar receiver at the tower top. Mechanical conveyors, such as bucket elevators and skip hoist, have been widely applied in particle conveying in industry and have been proposed recently in concentrated solar power application. However, the moving parts required by these conveyors could impede the implementation at high temperature and/or large scale application. Pneumatic conveying systems have been proposed for conveying solid particles in solar thermal plants due to their advantages in high temperature tolerance and transport ease. However, no work has been done to assess the influence of the intermittent nature of the solar resource on the design, operating and performance for pneumatic conveying systems applied in solar thermal plants.

In this study, the influence of the intermittent DNI on the operating and performance of the pneumatic conveying system has been assessed. Various configuration concepts and operating strategies are proposed and modelled. To assess the energy consumption of a compressor, the pressure drop in the conveying pipelines has been calculated by considering the pressure drops due to acceleration of solids, friction of gas and solids with wall, static head of both gas and solids, together with the additional pressure drop at bends.

Figure 1 (left) shows the thermal energy loss and electricity consumption as a function of number of conveying pipe. The reduction in thermal energy loss with the increase in the number of conveying pipe was due to the low turn-down of the compressors for the pneumatic system. This is because the ratio of the compressor to the solid loading ratio (or solid to gas mass ratio) is a non-linear function. In addition, the frequent turn-down of the compressor can cause the unsteady type-B choking in the conveying pipe and could potentially lead to the failure of particle pneumatic transportation system. Interestingly, the electricity consumption of a single pipe or multiple pipes conveying system is relatively similar. This is because the overall pressure drop for multiple pipes is higher than a single pipe. Figure 1 (right) shows the increase in the number of conveying pipes and compressors leads to the decrease in both the averaged start-up/shut-down and turn-up/down per day. However, this variation tends to be small while the number of the conveying pipes is greater than 4. Moreover, the size of the buffer storage unit on the top of the tower significantly can influence the operating strategy of the compressors.

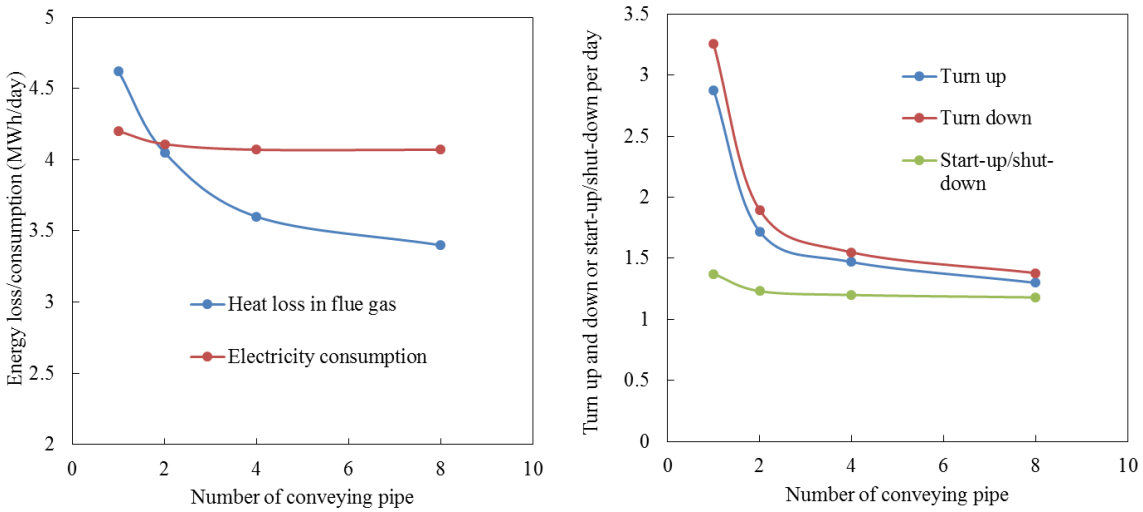

Figure 1. The influence number of conveying pipe on thermal energy loss and electricity consumption (left), and turn-up/down and start-up/down per day (right).