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Experimental study of particle erosion in a cavity with a height difference between its walls

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ABSTRACT

Experiments were carried out to analyze the effects of cavity height on cavity erosion under gas–solid flow. Spatial distributions of particles and erosion rates were documented for cavities with a variable difference in their leading and aft wall heights in experiments using two particle sizes. Results showed that the number of particles found inside the cavity decreased dramatically, as the difference in cavity wall height increased. Besides, the micro-erosion appearance on the top area of the aft wall flattened out with the increase of height difference (h). The erosion curves also indicated that the erosion rate on the top area of the aft wall for the cases of $h \neq 0$ is larger than that on the same y position for the case of $h = 0$. Meanwhile, the maximum erosion rate is more serious for larger particle. The experiment also indicated that increasing the height difference between cavity walls reduced erosion of the aft wall. And the maximum erosion rate was markedly reduced, when the height difference between cavity walls was altered from 0 to about 0.2H.

1. Introduction

Cavities typically appear in pneumatic conveying equipment, such as double flat gate valves and pipe connections. The transport of solid particles causes pneumatic conveying equipment to erode, inevitably causing cavities [1–4]. So it is worth studying the erosion processes within such cavities to improve the erosion resistance of such equipment.

Erosion damage is a major problem in pneumatic conveying systems, and many researchers studied erosion occurring in pipes, elbows, sudden expansions, sudden contractions and valves over the past decades [5–17]. Shirazi et al. [5] used a semi-empirical procedure to predict the penetration rates of particles in elbows and tees. Wang and Shirazi [6] investigated the effect of bend radius on the erosion rate of an elbow, and demonstrated that the erosion rate decreased with the increase of radius. Habib et al. [7] used a numerical simulation method to investigate the effect of contraction ratios on the erosion around an abrupt pipe contraction. McLaury et al. [8] investigated erosion in the throat of a choke with different entrance shapes, and showed that sudden changes in flow resulted in a high erosion rate. Niu and Tsao [9], Mills and Mason [10], and Bikbaev et al. [11,12] investigated erosion in elbows using simulation methods, and reported that erosion rate depends on the diameter of particles, the inlet velocity and the mass loading ratio. Nøkleberg and Søntvedt [13] studied the particle erosion in pressure reduction valves. Forder et al. [14] employed a computational fluid dynamics (CFD) method to study the erosion in oilfield control valves. Wallace et al. [15] studied the erosion in two choke valves (a simplified structure and an original structure) using both CFD and experimental methods. Mazur et al. [16] used a CFD method to investigate the effect of valve inlet geometry on solid particle erosion in a bypass valve. Nemitallah et al. [17] studied the solid particle erosion downstream of an orifice using a simulation method.

Few researchers have investigated particle erosion in cavities. Postlethwaite and Nesic [18] used silica sand to explore erosion of an ideal cavity, and showed that the leading edge of the aft wall is easily rounded. Wong et al. [4] used experimental and numerical methods to investigate erosion in a vertically placed ideal cavity, and showed that the most serious erosion is located at the leading edge of aft wall. In our previous work [19], we used a CFD method to determine the effect of height difference (between the leading and the aft walls) on the spatial distribution of particles and erosion in a flow channel with a horizontal cavity, as shown in Fig. 1.

However, due to the limitation of the present CFD method, the simulation results cannot reflect the micro-erosion appearances and the effect of particle concentration on erosion. Thus, in order to get a full understanding of erosion, experiments were carried out for the cavity with height differences.

2. Experimental method

Experiments were carried out under gas–solid flow in the erosion test platform of the Zhejiang Provincial Key Laboratory of Fluid Transmission

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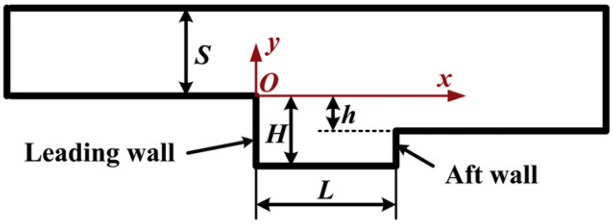

Fig. 1. Structure of a cavity whose leading wall and aft wall have different heights.

Technology at Zhejiang Sci-Tech University. There are four components to the test system: a pipeline system, a high-speed camera, a stereo microscope and an erosion measuring device. These components are described below respectively.

2.1. Pipeline system

The pipeline system comprises the main part of the erosion test platform. It is made up of a compressor, a dryer, an air storage tank, a safety valve, a switch valve, a flow meter, a regulating valve, a particle feeder, a gas–solid injector, pressure sensors, a vacuum cleaner, a control computer and pipes. A schematic diagram and an image of the pipeline system are shown in Fig. 2. Compressed gas is generated in the compressor, while solid particles are added via the particle feeder. Gas and particles are mixed in the gas–solid injector, before they enter the test section, and then removed by the vacuum cleaner.

To facilitate photographic documentation, the test section is made of square tubes, and the cavity is made of plexiglass. The geometry of the test cavity is shown in Fig. 3. The width (W) and the height (S) of tube cross section upstream of the cavity are 20 mm and 40 mm. To ensure well-developed flow, the length of tube upstream of the cavity is 1500 mm. The length of the cavity (L) is 40 mm, and the height of the leading wall (H) is 20 mm. Based on our previous work, the height difference (h) between the leading and aft wall of the cavity was set to 0, 0.2H, 0.4H and 0.6H, by changing the aft wall height to 20 mm, 16 mm, 12 mm and 8 mm, respectively. The height of tube downstream from the cavity was adjusted to correspond with these height differences, and its length was 200 mm (10H). The next square tube section further downstream had the same cross section as the tube upstream of the cavity, and its length was 1000 mm (50H).

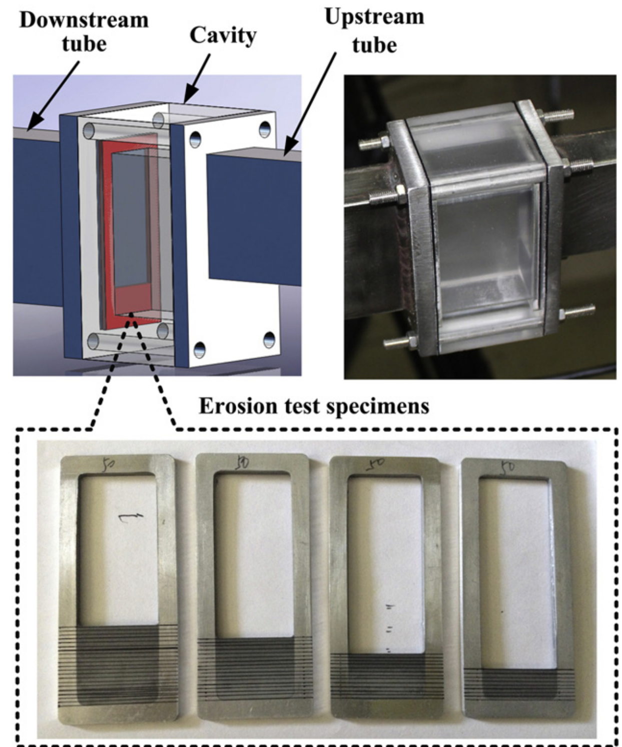

Fig. 3. Structure of the test cavity and the aluminum erosion test specimens.

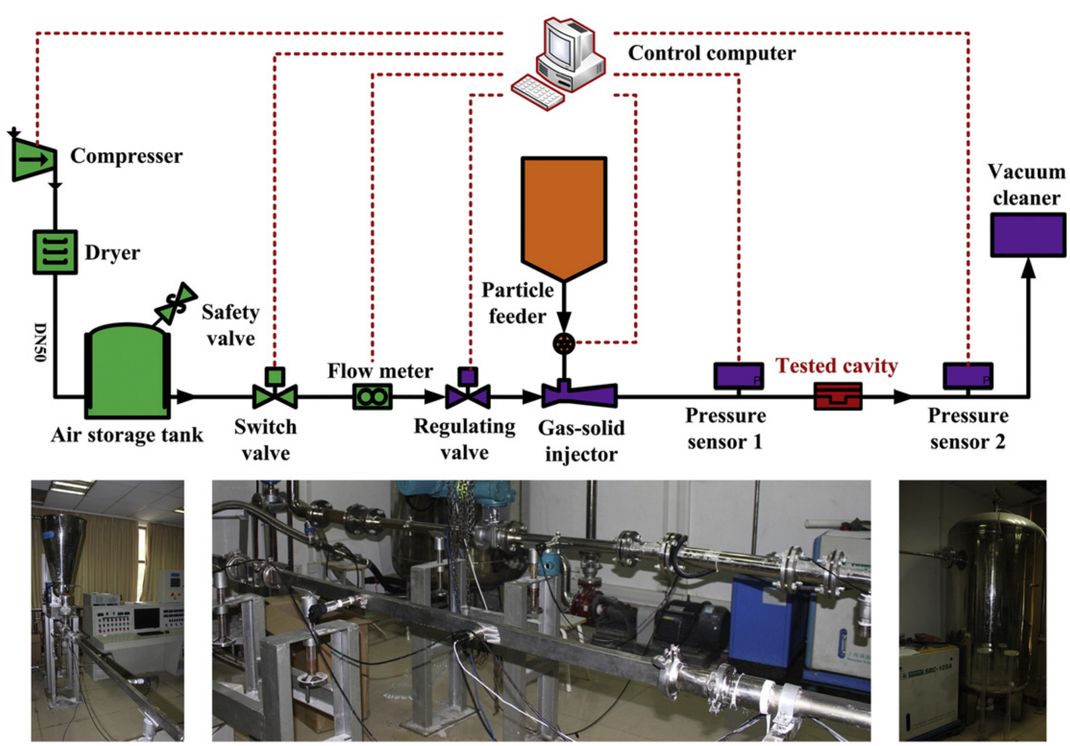

Fig. 2. Schematic diagram and actual picture of the pipeline system.