Erosion of pneumatic conveying line elbows in abrasive bulk solids conveying applications can be a costly problem requiring frequent changeout of worn elbows and associated downtime. This article describes a study that compares the wear behavior of three common materials used to make wear-resistant elbows for pneumatic conveying systems and discusses how to design and implement a pneumatic conveying system elbow maintenance plan.

Erosion is damage to a surface caused by the impact of particles dispersed in a flowing gas or liquid. Erosion is common in nature but can be a serious problem in bulk solids pneumatic conveying systems. This is particularly true with respect to conveying-line bends, valves, and elbows. Erosion in a pneumatic conveying system is complicated, however, and varies depending on the conveyed material’s particle characteristics (such as hardness, shape, size, and mechanical properties) as well as the impact velocity and angle between the particles and the surface.

A recent study, developed and conducted in the WAM test lab in Italy in conjunction with the University of Bologna department of industrial engineering, compared the erosion resistance of long-radius conveying-line elbows made from three common materials by tracking each material’s wear characteristics in a pneumatic conveying system over a one-year testing period. Before discussing the study, however, it’s important to know some pneumatic conveying system basics.

**Pneumatic conveying system components and operation**

A basic pneumatic conveying system, as shown in Figure 1, consists of a gas mover; a material feeder (such as a Venturi eductor, rotary valve, or powder pump); and a conveying line, which includes both the main conduit and any accessories (such as flanged couplings, curves, flow dividers, and elbows). A storage vessel containing the material to be fed is typically mounted above the feeder, and a receiving vessel (not shown) is typically located at the conveying-line discharge. In a pressure system, as shown in Figure 1, the gas mover is located upstream from the feeder, while in a vacuum system the gas mover is located downstream from the receiving vessel.

In operation, the gas mover forces conveying gas (typically air) to flow through the conveying line, and the feeder feeds material from the storage vessel into the gas stream while preventing gas from escaping into the storage vessel. The gas-material mixture flows through the conveying line and then discharges into the receiving vessel or other downstream process.

Depending on the conveying velocity, the material can be conveyed in dense-phase flow, dilute-phase flow, or a combination of the two. In dense-phase flow, the gas velocity is typically about 1 meter per second and the solids-to-gas ratio is typically higher than 10. In dilute-
phase flow, the gas velocity is typically about 25 meters per second and the solids-to-gas ratio is typically lower than 5. Dense phase is generally much more energy efficient than dilute phase because of the considerably lower gas flow rate, but the higher operating pressure in dense-phase flow requires more robust equipment to handle the pressure, which adds cost to the system.

Designing a pneumatic conveying system is complex and requires both a theoretical and experimental approach, typically including flow tests conducted on a pilot system. The design must consider the system’s functional parameters and layout as well as the safety and maintenance characteristics of the system’s critical components. One of those critical components is the conveying-line elbow.

In a dilute-phase system, the particles are entrained in the gas stream and collide with each other and the conveying-line walls at relatively high velocities, which can cause particle degradation and considerable abrasion between the particles and the conveying line. This abrasion can erode conveying-line components, particularly the elbows. To reduce the frequency of holes and leaks from worn-through elbows, pneumatic conveying systems often use elbows made with anti-wear materials and coatings.

The study described in this article focused on analyzing the wear resistance of the three types of anti-wear elbows for the purpose of defining general criteria that can be used to develop a maintenance policy for conveying-line elbows in an abrasive application.

**Materials and experimental procedure**

The study tested long-radius elbows made from Type 304 stainless steel, carbon steel coated with porcelain enamel, and polyurethane. The tests used a pneumatic conveying system circuit with 30 meters (98.4 feet) of 2-inch conveying line. The system conveyed 100 liters (3.5 cubic feet) of quartzite sand at a 2,800 kg/h (1,372 cfm) mass flow rate. To determine the influence of pressure on elbow wear, the tests were done at both 1 bar (14.5 psi) and 2.5 bar (36.3 psi) operating pressures.

**Data analysis**

The test results are shown in Figures 2 and 3, which compare the wear to the three elbow types over time at 1-bar and 2.5-bar operating pressures respectively. The study used elbow weight as the wear parameter, since each elbow’s weight will decrease over time as the elbow erodes during operation. The data envelopes shown in the figures represent the mean ± 3 standard deviation of normally distributed test data. To each data envelope shown in Figures 2 and 3, a curve was fitted using the least square method. The mathematical model used to fit the data is based on a curvilinear relation between the wear parameter (weight) and the operating time (number of conveying cycles):

\[ W = aN^2 + bN + c \]
For a specified operating time, the standard deviation of wear was calculated using the equation:
\[ W_i = W(t_i) \]

The difference between the two wear values at a specific operating time for each couple of envelope curves was divided by 6 to find the standard deviation. The mean wear was calculated by adding three standard deviations to the wear value calculated using the equation of the data envelope’s lower boundary. To model the data with a curvilinear equation for a given wear amount, the standard deviation of the operating time was calculated from the inverse relationship, and the mean operating time was calculated by adding three standard deviations to the points on the data envelope’s left boundary.

**Reliability analysis**

Using these parameters, we can calculate the reliability of elbows operating under such conditions for a desired time period and an allowable amount of wear. The reliability of the elbows not exceeding a maximum allowable amount of wear \( (w_i) \) while operating for a specified time period \( (t_i) \) can also be calculated using the following equations:

1. The probability that the cumulative operating time will be less than the wear life for the given maximum allowable wear:
   \[ R(t_i) = P[W(t_i) < w(t_i)] \]

2. The probability that the actual wear is less than the maximum allowable wear for the given operating time:
   \[ R(t_i) = P[T(w_i) > t_i] \]

**Conclusions**

The study shows that, when conveying the same material, predictable elbow wear patterns develop over time. This predictability means that operators can schedule maintenance based on an elbow’s known wear behavior. The study also shows that the polyurethane elbows are more resistant to wear than the ceramic-coated steel or stainless steel elbows, so maintenance intervals can be longer with polyurethane elbows than with the other types.

The wear patterns between the different elbow materials were more similar at the 2.5-bar operating pressure than at the 1-bar operating pressure, indicating that polyurethane elbows may be most beneficial at lower operating pressures. This can have important implications when designing a conveying system. Higher conveying-line pressures require more expensive equipment, such as a bigger gas mover and a bigger dust collector. However, polyurethane elbows are considerably lighter and more flexible than the other types, which makes changeout easier and faster and may eliminate the additional cost of a crane for lifting the heavier steel elbows into place. So while the wear resistance benefit of polyurethane elbows is less significant at higher pressures, the light weight and ease

![Figure 3](image-url)
Polyurethane elbows are lighter and more flexible than ceramic-coated or stainless steel, making changeout easier and safer.

of handling of polyurethane still provides safety and cost benefits compared to ceramic-coated or stainless steel elbows.

References

For further reading
Find more information on this topic in articles listed under “Pneumatic conveying” in Powder and Bulk Engineering’s article index in the December 2016 issue or the Article Archive on PBE’s website, www.powderbulk.com. (All articles listed in the archive are available for free download to registered users.)

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