Experimental investigations for erosive wear of Mild Steel Pipe bends at different positions in Pneumatic Conveying System (PCS)

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Abstract. Pharmaceutical and chemical industries have been using transportation of various material/powder through pipes. The bend was punctured in the conveying system during the flow of material and finally stops the production. The scientists and researchers are working on material and mechanism to reduce the material loss of the bends. An experimental investigation have been carried out for erosive wear in pipe bends of a pneumatic conveying pipe line. Six bends has been considered for the investigation of wear at 90\textdegree{} from rotary feeder to air filter. The Comparison of erosive wear was investigated for all six pipe bends. The bend 2 was the most critical place in the pipeline. Other five bends had less erosion than the bend 2 due to maximum velocity of the flow.

Keywords: Erosive wear, Sieve Analysis, Pipe bend, Mean particle size, calibration of load cell, solid loading ratio, weight of silica sand circulated etc.

1. Introduction:-

Pneumatic conveying is widely used for transportation of varieties of dry powders and granular solids through pipelines and bends using high pressure gas/air. It is a frequently used method of material transport for short distances in industries/plants. It offers flexibility in terms of pipeline routing as well as dust minimization.

It is worth mentioning for information that about 80\% of pneumatic conveying in industries is done in dilute phase which use relatively large amount of air/gas to achieve high particle velocity to stay away from trouble of choking in the pipelines. However, in many applications higher particle velocity lead to excessive levels of particle attrition and wear of pipelines. Moreover, bends are known to be responsible for various problems such as high pressure loss, product segregation and degrading, roping, and erosive wear. It is needed to mention here that one of the ways to reduce the erosive wear of pipe bends is to use proper bend materials and prolong the life of bends. However, another good approach may be to design different type of bends for manipulating the direction of particle impact at the bends, which can lead to reduction in erosion and choking in the pipe bends and pipelines, respectively.

In pneumatic conveying pipelines, the particles are free to roll, slide and impact. Thus, surface of pipe bend is subjected to complex mechanism of material removal. This is known as wear of the bend’s
wall material. Due to severe wear, a puncture is formed in the pipe bend as shown in Figure 1. Majority of material loss occurs around the punctured area. Therefore, it is vital to understand the wear mechanisms in the punctured area of pipe bend for reducing the failures and prolonging the service life of the pneumatic conveying pipelines.

![Figure 1](image)

**Figure 1.** (a) Photographic view of punctured pipe bend (b) bend with hole and erosion pattern

Attempts have been done by many authors [4-7] to understand the behaviours of various parameters (impact angle, particle impact velocity, hardness of particle, particle size, solid loading ratio, bend geometry, surface finish of bend, bend material etc.) on the wear of pipe bends. These researchers have used mathematical method CFD analysis and other methods to find out the dense phase as well as dilute phase pneumatic conveying erosion on pipe bends. Researchers have given many solutions to minimize bend erosion like strengthening of bend, using different materials of bend and using swirl mechanism etc but to perform experiment identification of most critical bend in pneumatic conveying pipe line is required. The identification of most critical pipe bend in pneumatic conveying pipe plant work was performed and erosion effect on all bends is taken in to consideration.

2. Experimental Setup

The Sketch and photograph of pilot plant is shown in Figure 4 and Figure 5 respectively. The test plant had low pressure blow tank with rotary feeder used to feed material in pipe line. A storage hopper is used with butterfly valve to feed material above the Blow Tank. The same storage tank is used to collect material from return line. Bag filters are mounted above the storage hopper which separates air and material on discharge from return line. The storage hopper is fitted with three equally spaced load cells at 120 degree apart. This will record material flow rate. A nozzle bank consisting of choked flow, convergent divergent nozzles are used to control and measure air flow rate to blow tank as well as to conveying line. Pressure gauges are mounted to record conveying line pressure drop and blow tank pressure. A two stage root blower is used for compressed air into pipe line.

The test loop in pilot plant is 40 m long and has an internal diameter of 51mm. the whole setup is in horizontal plane. The distance between the bends is kept at 5 m or more which is sufficient to reaccelerate the particle back to its terminal velocity.
2.1. Operating parameters

**Table 1. Operating Parameters**

| Sr. No. | Parameters                                      |
|---------|------------------------------------------------|
| 1       | Rotary feeder speed=125 r.p.m.                 |
| 2       | Pressure of root blower=1 bar                 |
| 3       | Free air CFM=100CFM=0.0472m3/sec              |
| 4       | Cycle time= 45*60=2700 sec.                   |
| 5       | Mass of silica sand circulated in 1 Run=200kg |
| 6       | Mass flow rate of particle=200/2700=0.074kg/Sec|
| 7       | Mass flow rate of air=0.0472*1.16=0.0547kg/sec|
| 8       | Air inlet velocity=23.11m/sec                 |
| 9       | Solid loading ratio=2                         |
| 10      | Pressure drop=0.18 bar                        |
| 11      | Swirling device speed=35 r.p.m                 |
| 12      | Distance of swirling device from bend=2.71 meters|

2.2. Performance parameters:

1) Weight of bend 2) Mean particle size of silica sand particles
3. Result and Discussion:

The following results are shown below:

1. Calibration of load cell 2. Sieve analysis to find mean particle size of silica sand 3. Bend erosion weight loss at different positions.

3.1. Calibration of Load Cell

Load cells are calibrated with loading of different weights of silica particles and taking their readings in mVolts is shown in table 2 below and graphical representation between weight of silica particles and load cells in mVolts is shown in Figure 4.
Table 2. Calibration of load cell

| Weight of silica sand (kg) | load cell calibration readings in mVolts |
|---------------------------|-----------------------------------------|
| 20                        | 41.7                                    |
| 40                        | 85.5                                    |
| 60                        | 130.1                                   |
| 80                        | 179.4                                   |
| 100                       | 212.1                                   |
| 120                       | 263.4                                   |
| 140                       | 310                                     |
| 160                       | 358                                     |
| 180                       | 402                                     |
| 200                       | 450                                     |

Figure 4. Calibration of load cell vs weight

3.2. Sieve Analysis

This method is used to find out the mean particle size of fresh silica sand particles and after 3 Run, 6 Run, 9 Run of circulation. In this a sample of silica sand is taken and different size of sieves are used to collect cumulative weight in grams by using a shaker motor. Sieve analysis readings are shown in table-2 and graph between %age oversize and silica sand particle size is shown in Figure 5.

Table 3. Comparison of Sieve Analysis of fresh silica particle, after 3 run, after 6 run and after 9 run

| Sieve size | Fresh silica particles | After 3 Run 600 kg | After 6 Run 1200 kg | After 9 Run 1800 kg |
|------------|------------------------|--------------------|---------------------|---------------------|
|            | Cumulative %age        | Cumulative %age    | Cumulative %age    | Cumulative %age    |
| >250       | 73                     | 36.5               | 28.8                | 14.4                | 17.3                | 8.65                | 5.3                 | 2.65                |
| >212       | 118.1                  | 59.05              | 73.4                | 36.2                | 64.5                | 32.25               | 30.4                | 15.2                |
| >180       | 118.3                  | 59.15              | 73.7                | 36.85               | 65                  | 34.5                | 30.6                | 15.3                |
| >150       | 138.7                  | 69.35              | 97.9                | 48.95               | 96                  | 48                  | 55.7                | 27.85               |
| >125       | 140.2                  | 70.1               | 100                 | 50                  | 100.9               | 50.45               | 57.5                | 28.75               |
| >106       | 171.5                  | 85.75              | 150.4               | 75.2                | 146.3               | 73.15               | 116.8               | 58.4                |
| >90        | 180.9                  | 90.45              | 165.8               | 84.9                | 161.7               | 85.85               | 138.8               | 69.4                |
| >63        | 186.2                  | 93.1               | 167                 | 86.5                | 172.2               | 86.1                | 153.8               | 72.9                |
| <63        | 200                    | 100                | 200                 | 100                 | 200                 | 100                 | 200                 | 100                 |
3.3. Bend erosion weight loss at different positions:

Comparison between bend weight loss at different positions after 3 run, 6 run, 9 run and 12 run is shown in Table 4 and graphical histogram between erosive wear at different bend after 3 run, 6 run, 9 run and 12 run is shown in Figure 6. Total weight loss after 12 Run (2400kg of sand circulation) is shown in Table 5.

**Table 4**: Comparison of bend weight loss at different bend positions after 3 run, 6 Run, 9 Run and 12 Run

| Bend positions | Bend Erosion weight loss at mean particle size = 212 µm after 3 Run (600 Kg circulation) in grams | Bend Erosion weight loss at mean particle size = 150 µm after 6 Run (1200 Kg) | Bend Erosion weight loss at mean particle size = 125 µm after 9 Run (1800 Kg) | Bend Erosion weight loss at mean particle size = 106 µm after 12 Run (2400 Kg) |
|----------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|
| Bend-1         | 3.6                                                                                             | 3.2                                                                  | 2.8                                                                 | 2.4                                                                 |
| Bend-2         | 4                                                                                               | 3.6                                                                  | 3                                                                   | 2.6                                                                 |
| Bend-3         | 3.7                                                                                             | 3.2                                                                  | 3                                                                   | 2.5                                                                 |
| Bend-4         | 3.5                                                                                             | 3.3                                                                  | 2.9                                                                 | 2.2                                                                 |
| Bend-5         | 3.3                                                                                             | 3                                                                    | 2.8                                                                 | 2.4                                                                 |
| Bend-6         | 3.4                                                                                             | 3.2                                                                  | 2.9                                                                 | 2.2                                                                 |
3.4. Results and Discussions

It was found that erosive wear weight loss in pipe bend at position no 2 as shown in table 5 is 13.6 grams in 12 runs of circulation of silica particles while at bend 1, 3, 4, 5 and 6 weight loss in gms is 12, 12.2, 11.9, 11.6 and 12.1 respectively. Hence erosive wear has been found dangerous for all the bends but most critical bend 2 which have maximum weight loss because maximum velocity is at bend 2 in this pilot plant and as velocity increases erosion rate increases. Erosion rate decreases after 3 run, 6 run, 9 run and 12 run because mean particle size decreases from 212µm, 150 µm, 125 µm and 106 µm respectively.

4. Conclusions

- Erosive wear is dangerous for all bends.
- In sieve analysis mean effective particle size decreases with circulation in pipe.
- Bend at position 2 is most critical punctures in lesser time than other bends due to high velocity at bend 2.
- As mean particle size decreases erosion rate decreases because sharpness of particles decreases.
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