International Conference on Renewable Energies and Power Quality (ICREPQ'15)
La Corunna (Spain), 25th to 27th March, 2015
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, No.13, April 2015

The position of the maximum erosion points in coal powder pneumatic transport installations, function of the bend radius / pipe diameter ratio

Dorina Ionescu[1]

[1] Department of Mechanical and Industrial Engineering,
School of Engineering – College of Science,
Engineering and Technology, Florida Campus, South Africa
Phone/Fax number:+27 11 471 3188, e-mail: ionesd@unisa.ac.za

Abstract. One major problem of all pneumatic transport installations is the high wear resulting from abrasion at transition sections, especially bends. Using Computational Fluid Dynamics software, by changing the bend radius (BR)/pipe diameter (PD) ratio, the maximum abrasion points, particles velocity and pressure drop were monitored. It was found that as the BR/PD ratio is increased, the erosion and particle velocity values are steadily decreasing. For bends having a BR/PD ratio between 1 and 3. 25 there will be only one maximum erosion point, situated at about 45^0 from the bend entrance. For a BR/PD ratio between 3.5 and 10.25 there will be two maximum erosion points one at approximately 38^0 and the other at about 80^0 from the bend entrance. For a BR/PD ratio between 10.5 and 12 there will be three maximum erosion points one at approximately 30^0 the second at about 60^0 and the third one at approximately $83^0 – 87^0$ from the bend entrance. As the BR/PD ratio increases, the erosion values decrease at a steady rate but the velocity and pressure drop a getting dangerously close to pipe clogging. A balance has to be kept by reaching the lowest erosion rate without clogging the pipes.

Key words

Maximum erosion points, Bend radius / Pipe diameter ratio, Anthracite powder transport.

1. Introduction

In multiphase pneumatic conveying flows, the magnitude of the erosion wear is proportional to the velocity, quantity of flow and shape of particles. The velocity of the solid particles impacting the pipe wall has been recognized by researchers as the most significant factor for erosion. F.J. Blatt [1] studied the particle velocity close to the wall of a pipe in two-phase liquid-particle flow, and concluded that the flow velocity significantly influence the erosion rate. When the flow direction is changed by using a bend, the position and magnitude of the erosion points is influenced by the DR/PD ratio and wherever the flow is changed from horizontal to a vertical upward or downward flow. Computational Fluid Dynamics (CFD) simulation results show that by increasing the DR/PD ratio there is a steady decrease in the erosion rate but also there is an increase in the number of maximum erosion points ranging from one to three.

2. Empirical and generalised erosion prediction models

To assess the severity of erosion behaviour in multiple phase flows, there are several erosion prediction models available. Most of them are based on empirical data and can only be applied to operating conditions that are similar to the experimental conditions, and cannot be generalized to other flow conditions, Mazumder *et al* [2],[3] . One of the generalised erosion prediction models is the CFD based model that takes into account details of the flow effect and pipe geometry. To simplify the CFD model some of the parameters may be excluded. For dilute phase loading of less than 10%, the average inter-particle distance is around twice the particle diameter, therefore particles interactions can be neglected and a single phase model can be used to represent the mixture, (ANSYS Fluent manual). The multiphase modelling in the present research was done through Discrete Phase Model (DPM), sub-modelling capability Erosion /Accretion where:

- Trajectories of particles/droplets/bubbles are computed in a Lagrangian frame;
- Particles can exchange heat, mass, and momentum with the continuous gas phase;
- Each trajectory represents a group of particles of the same initial properties;
- Particle-particle interactions are neglected.

3. Relation between erosion pressure drop and bend geometry

A bend in a pneumatic conveying pipeline causes a loss of energy which results in an additional pressure drop, product attrition and pipeline wear. A wide research work has been done in the field but the results are conflicting. Marcus *et al* [4] stated that the short radius bends cause the least pressure drop, whilst Mills & Mason [5] find short radius bends better in some circumstances while long radius bends were better in other. Generally it is agreed that the contribution of bends toward the overall pressure drop is very significant therefore a whole lot of research was done specifically for the pressure drop due to bends. The work done by Bradley [6] and Bradley& Reed [7] examined the pressure drop effects of bends for design purpose. Extended experiments to locate the maximum wear in an elbow were conducted by Mazumder *et al* [2], [3]. The experimental results showed that the location of maximum wear due to erosion is different for horizontal flow compared to vertical flow. Deng *et al* [8] investigated the location of maximum erosion in a bend with different bend orientations and geometry, using sand as solid particles at a mass ratio of solid particle to air of 10. Deng experimental results showed maximum damage in the horizontal to vertical downward and upward bends, with total penetration location at 25^0 and 8^0 from the entrance of the bend. Among all different bend orientations, the horizontally to vertically downward bend showed maximum erosive wear damage and therefore, had the shortest life.

4. The position of the maximum erosion points ; CFD simulations

A. Upward bends from horizontal to vertical

It is well known that pipe erosion is sensitive to the characteristics of the solid particles, therefore a generalised conclusion would be unwise. For the present study CFD simulations were done for upward bends from horizontal to vertical direction for 45 bends each with a different DR/PD ratio, starting from 1 to 12 by an increment of 0.25. It was observed that for a DR/PD ratio ranging from 1 to 3.25, there is one single point of maximum erosion; for a DR/PD ratio ranging from 3.50 to 10.25 there are two points of erosion and for a DR/PD ratio ranging from 10.5 to 12 there will be three points of maximum erosion as shown in figures 1, 2 and 3 respectively.

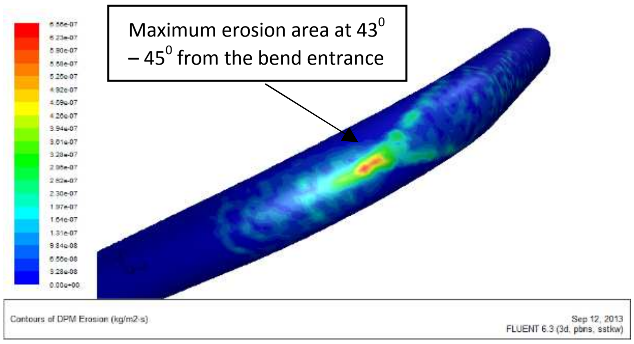

Fig. 1 – Erosion values for upward bend with a DR/PD ratio of 2.75

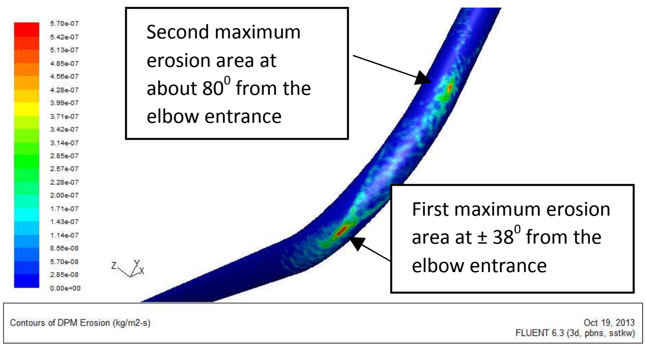

Fig. 2 – Erosion values for upward bend with a DR/PD ratio of 4.25

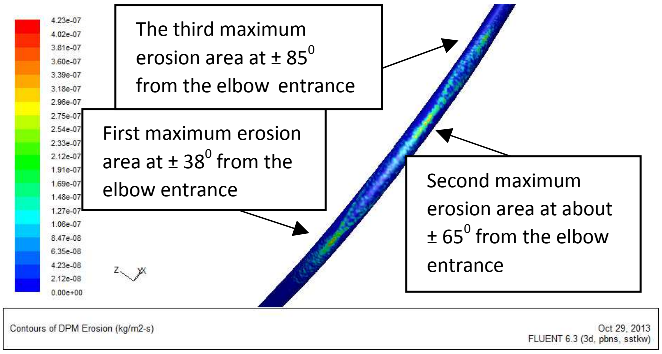

Fig. 3 – Erosion values for upward bend with a DR/PD ratio of 11.75

Figures 4, 5 and 6 show the trend line of erosion values for one, two and three maximum erosion points.

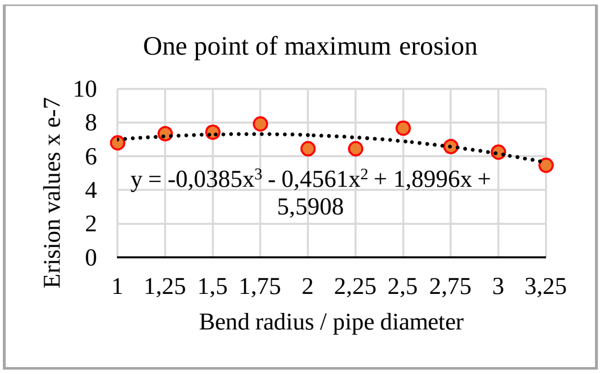

Fig. 4 – Trend line for one point of maximum erosion

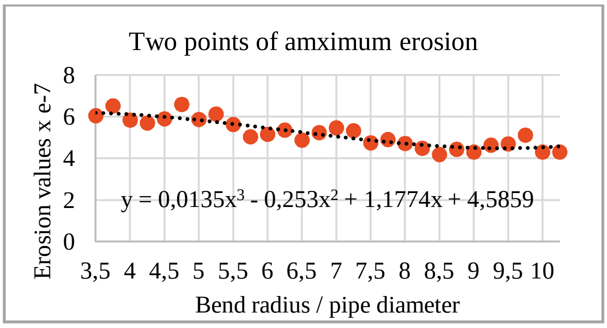

Fig. 5 – Trend line for two points of maximum erosion.

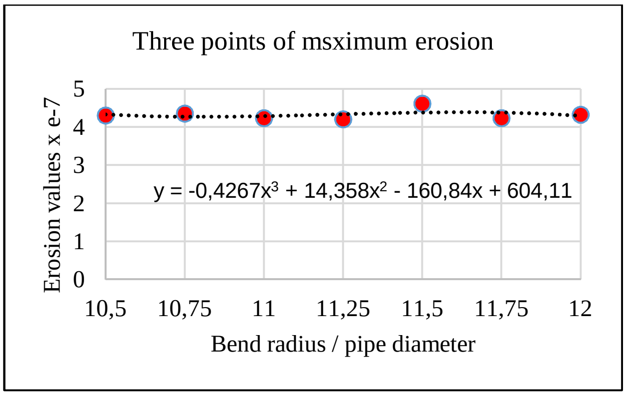

Fig. 6 – Trend line for three points of maximum erosion.

The trend line for each graph is polynomial of third degree. From the graphic representations it can be seen that there is a steady decrease of the erosion values, linked to the increase of the BR/PD ratio. Figure 7 shows the combined trend lines for BR/PD ratios ranging from 1 to 12.

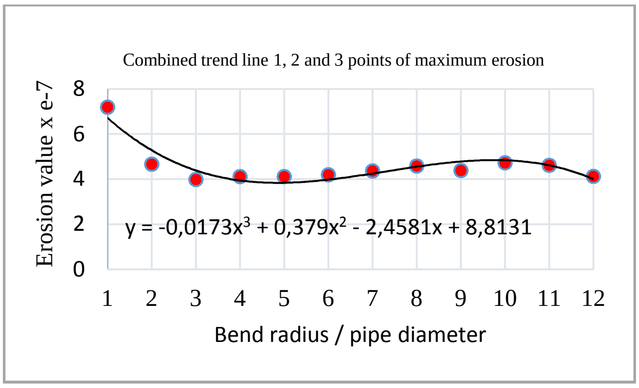

Fig. 7 – Combined trend line for the erosion values

Figures 8 and 9 show the combined trend lines for the static pressure and velocities respectively. It has to be observed that there is steady decrease of values relative to the increase of the BR/PD ratio. The velocity values are all above saltation which as pitched at approximately 12 m/s. However the pressure values have to be carefully monitored to avoid pipe clogging. Out of the different BR/PD ratios it looks like the ideal ratio will have to be between 4 and 6, with two points of maximum erosion.

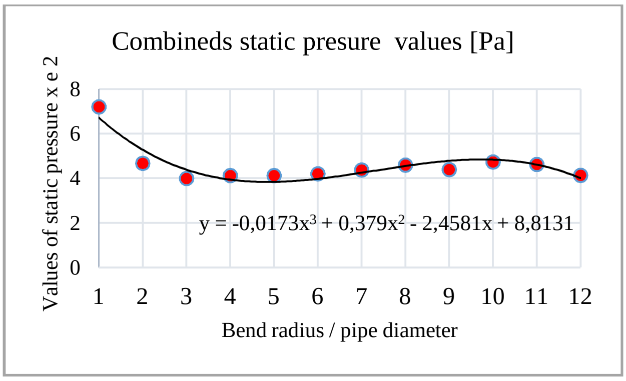

Fig. 8 – Combined trend line for the static pressure values

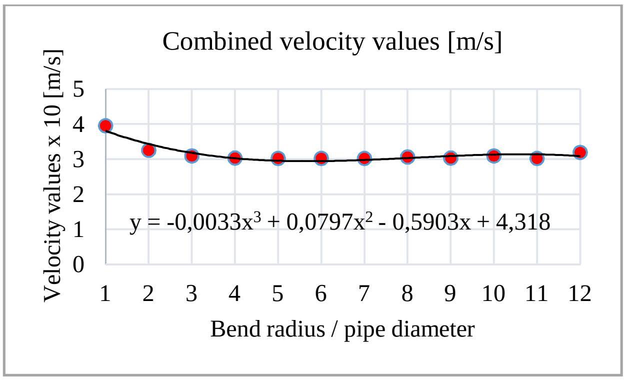

Fig. 9 – Combined trend line for the static pressure values

B. Downward bends from horizontal to vertical

Figures 10. 11 and 12 show the values of erosion for downward bends; horizontal to vertical. It can be observed that the erosion values are lower than the erosion for the upward bends for the same BR/PD ratio value, contrary to Deng *et al* [8] results which identify the downward bends to have the maximum erosion values. The number of maximum erosion points relative to the BR/PD ratio is slightly different from the upward bends. It was observed that for a DR/PD ratio ranging from 1 to 3.75, there is one single point of maximum erosion; for a DR/PD ratio ranging from 4.0 to 10.25 there are two points of erosion and for a DR/PD ratio ranging from 10.50 to 12 there will be three points of maximum erosion.

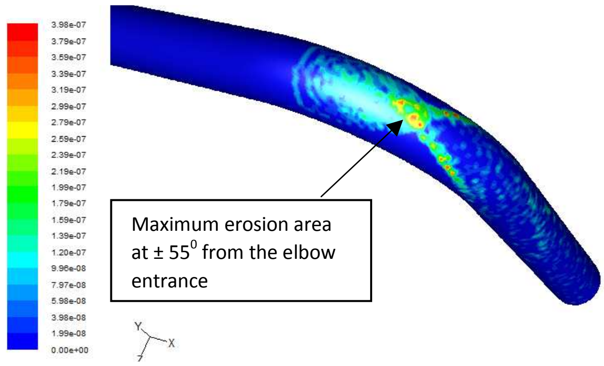

Fig. 10 – Erosion values for a downward bend with a BR/PD ratio of . 2.75

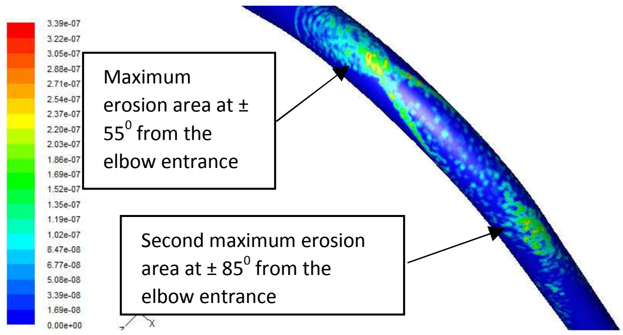

Fig. 11 – Erosion values for a downward bend with a BR/PD ratio of . 4.25

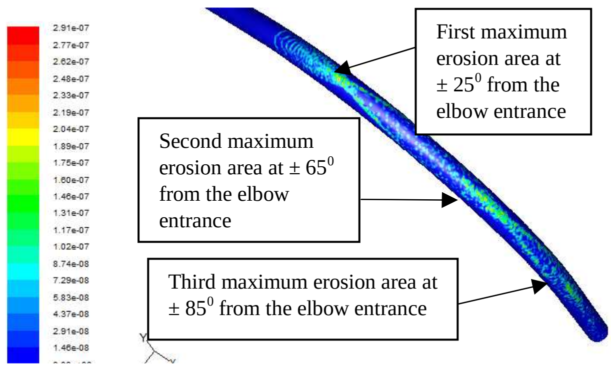

Fig. 12 – Erosion values for a downward bend with a BR/PD ratio of 11.75

Figures 13, 14 and 15 show the trend line of erosion values for one, two and three maximum erosion points, for horizontal to vertical downward bends.

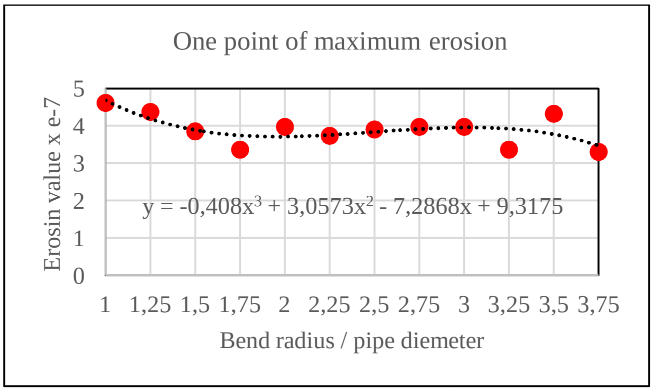

Fig. 13 – Trend line for one point of maximum erosion

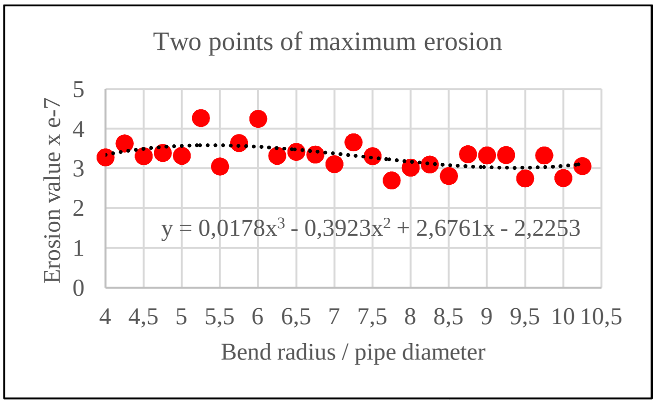

Fig. 14 – Trend line for two points of maximum erosion

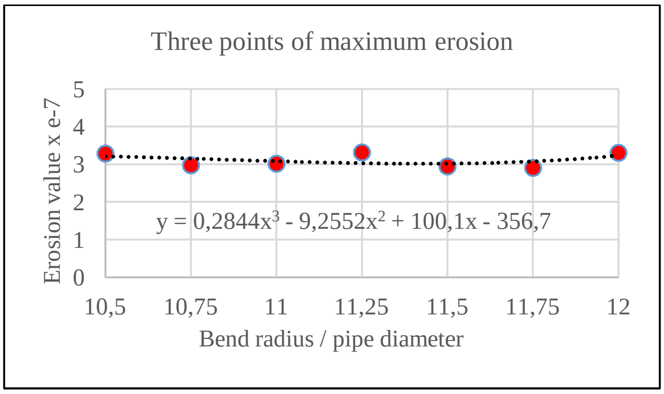

Fig. 15 – Trend line for three points of maximum erosion

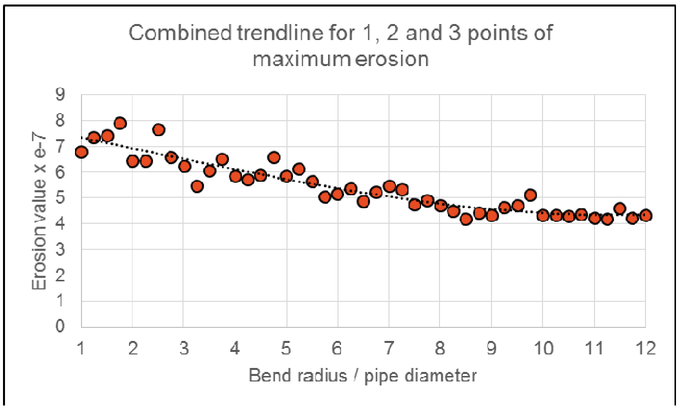

Fig. 16 – Combined trend line for erosion values

As can be seen from figure 16 with the increase of BR/PD ratio the erosion value is decerasing but are more scatered than the values for the upward bends. Taking into consideration the Velocity and preasure trend lines, out of the different BR/PD ratios the ideal ratio will have to be between 6 and 7, with two points of maximum erosion. Figure 17 shows the combined trendlines of erosion values for upward bends (red series) and the downward bends (orange series).

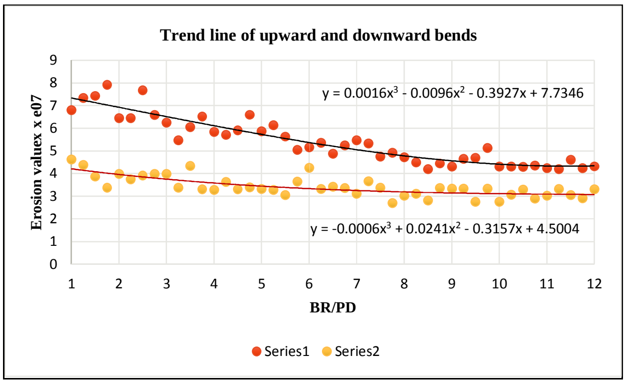

Fig. 17 – Combined erosion trend line for upward and downward bends

5. Conclusions

- From a BR/PD ratio of about 8.5 the two trend lines are approximately horizontal; therefore the increase of BR/PD ratio will not help with erosion reduction. However the pressure drop can be severe risking pipe clogging.
- If the velocity and pressure trend lines are considered, the ideal BR/PD ratio to work with would be between 5 and 6, as any installation has upward and downwards bends.

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