International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 02 | Feb 2019 www.irjet.net p-ISSN: 2395-0072

Parameters Affecting Erosion Wear in Pneumatic Conveying System- An Overview

Abhishek Srivastava[1], Amit Suhane[2]

[1]M-Tech Scholar, Department of Mechanical Engineering, MANIT Bhopal, 462003, India.
[2]Assistant Professor, Department of Mechanical Engineering, MANIT Bhopal, 462003, India.

Abstract - *The erosion of a surface by solid abrasive particles in a fluid stream is perhaps the dominant factor which makes industry reluctant to install pneumatic conveying systems for handling abrasive materials However, the demands for environmental protection are likely to require that many more abrasive solids will ultimately be transported pneumatically[1]. Erosive wear reduces the life of mechanical equipment and therefore a critical issue for design, selection and operation of pneumatic transportation system. Engineering interest is to estimate the service life of equipment subjected to pneumatic erosion and to investigate the possibilities of enhancement of their life. Present overview is to explore the effect of tribological parameters on erosion wear mainly target material, erodent material, impact angle ,impact velocity, particle size and solid concentration .Finally some inference can be drawn from an overview and concludes future research scope that will be helpful to a new researcher in field of erosion wear.*

Key Words: **pneumatic transportation system, impact angle, impact velocity, solid particle erosion.**

1. INTRODUCTION

Wear is the damaging, gradual removal or deformation of material at solid surfaces. It is purely a mechanical process .It may occur due to corrosion, abrasion or erosion. Corrosive wear is caused due to chemical reactions, abrasive wear caused when hard rough surface slides against softer surface and erosion wear takes place due to impact of solid particle on surface of object. Erosion wear classified into three categories solid particle erosion, liquid erosion and cavitation erosion. The solid particle erosion is again classified into two categories gas solid and slurry erosion .In gas solid erosion the solid particle is suspended with gas and in slurry erosion solid particle is suspended within liquid.

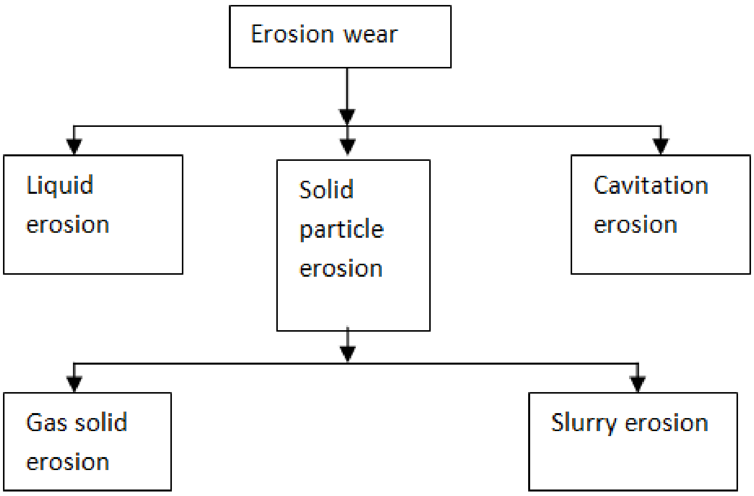

Fig-1: Classification of erosive wear

Gas solid erosion is a severe problem in pneumatic conveying system, particularly when abrasive materials have to be handled .It poses great challenge in maintenance and operation of pneumatic conveying system because of high velocities required for conveying bulk particulate materials. Erosion due to bulk particulate material reduces service life of equipment/components. Pneumatic conveying system is particularly suitable for handling toxic and hazardous materials and is extensively used in chemical process industry, pharmaceutical industry, mining industry, agricultural industry, mineral industry, and food processing industry. Virtually, all powders and granular material can be transported using this method [1].

Wear taking place due to erosion is a complex phenomenon it can be minimized by controlling its affecting parameters such as impact angle, solid concentration, impact velocity and particle size .The objective of current research paper is to overview the research with reference to various tribological parameters affecting rate of erosion wear with particular reference to bend wear.

2. Parameters affecting erosion wear:

The erosive action of particles depends upon their hardness, strength, particle shape and size, whilst the erosion of a surface by these particles depends upon the nature of the surface, the number of particles striking the surface, their velocity and their direction relative to impact. The flow conditions define the last three parameters, and erosion is more severe for sudden changes in flow direction, as encountered in pipe bends and valves. Erosion in straight runs of piping does occur but it is not normally as severe, although local turbulence, due to misaligned sections or roughened surfaces, may greatly increase erosion [1].

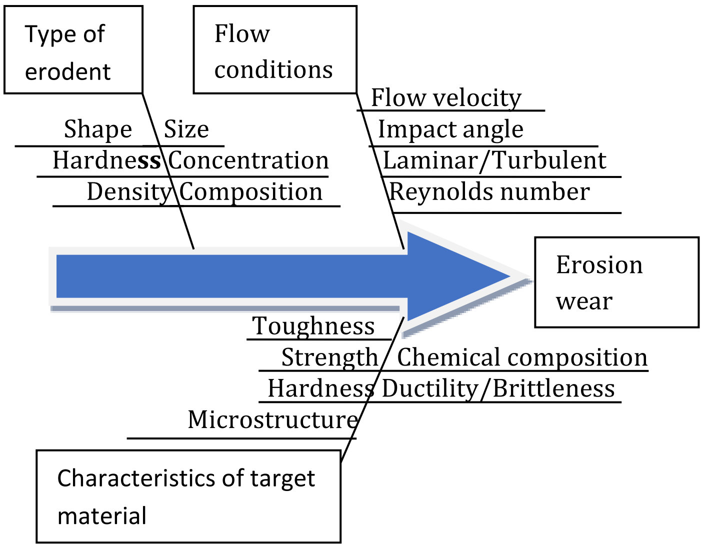

Fig 2: Fish bone diagram explaining causes of Gas solid erosion wear

Experimental studies on erosion wear by different researchers are shows the effect of input parameters such as particle size, shape, hardness, density, solid particle concentration , impact angle, velocity of flow, target material hardness, surface roughness, and microstructure erosion wear performance[2-5] . A typical cause and effect diagram showing various input parameters for gas solid erosion wear as shown in Fig. 2.

The importance of major parameters affecting erosion wear is summarized in following subsection separately.

2.1 Impact angle and surface material:

A curve presented by Tilly [6] and shown in Fig 3 illustrates the variation of erosion with impact angle for two different surface materials and is typical of the early work carried out to investigate the influence of these variables. Both materials showed very significant differences in both erosion rate and the effect of impact angle. These materials do, in fact, exhibit characteristic types of behavior that are now well recognized. The aluminum alloy is typical of ductile materials: it suffers maximum erosion at an impact angle of about 20° and offers good erosion resistance to normal impact. The glass is typical of brittle materials: it suffers severe erosion under normal impact but offers good erosion resistance to low angle, glancing impact. These particular tests were carried out with sand particles sieved to between 60 and 125mm and impacted at about 100m/s. That brittle and ductile materials respond to erosion in very different ways can be clearly seen from Fig 3, and it is obvious that different mechanisms of material removal must be involved

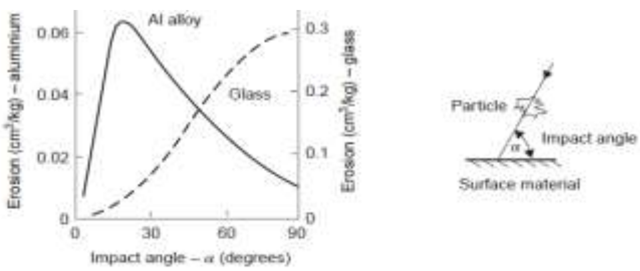

Fig 3: Variation of erosion with impact angle for various surface materials [7]

The variation in erosion wear with impact angle is different for ductile and brittle material .For ductile material erosion rate is maximum for impact angle ranging from 200-300 and for brittle material it occurs at 900 [1, 8]. The influence of impact angle and the different response of ductile and brittle materials to erosive wear is an aspect of the problem that will be considered at many different points. The relationships can be used to explain a number of observed phenomena in erosive wear, and are particularly useful in predicting the possible behavior in new and untried situations.[8]. By using DOE Yoganandh et al. [9] displays the contribution of impact angle in erosion wear was 21% that is second largest from main four parameters i.e. impact velocity, impact angle, solid concentration and particle size.

2.2 Impact velocity:

It is probably the most important among all affecting parameters. Erosive wear is dependent on simple power of velocity, such as:

Erosion = constant * (velocity)^n

The value of n ranges from 2-6 have been reported [7]. Tilly and Sage [10] tested a wide range of different materials and obtained very good agreement with respect to the exponent, n, in each case. Their results are reproduced in Fig.4 as shown below:

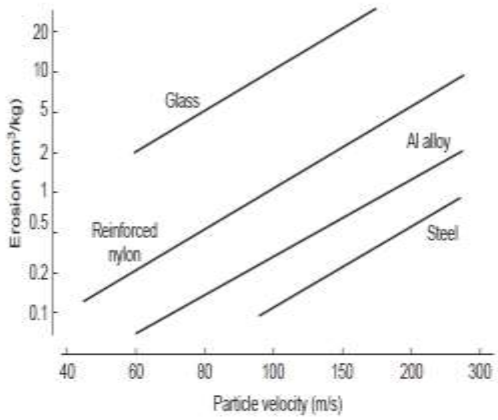

Fig. 4: Variation of erosion with velocity for various surface materials [7]

This is a log plot and the slope of all the lines was approximately 2.3. The value of the velocity exponent remains reasonably constant at about 2.5 for all surface materials. Tilly and Sage [4], however, has carried out several extensive research programmes into the erosion of pipe bends in an actual pneumatic conveying system, at velocities appropriate to dilute phase suspension flow [11].D mills and J Mason carried test out over a range of conveying air velocities from 15–35m/s and at solids loading ratios from 0.5 to 8. Steel bends of 53mm bore having a bend diameter, *D*, to pipe bore, *d*, ratio of about 5:1 were eroded by 70 and 230mm sand, and over the ranges tested the velocity exponent was found to be consistent at 2.65. A graph showing the influence of conveying air velocity on the specific erosion of the bends is given in Figure 4. From the literature overview various researcher have considered variable velocity for study of effect of impact velocity on erosion wear. Yoganandh et al. [9] Conduct the experiment with L9 orthogonal array for finding influence factor of erosion wear he concludes velocity is the most dominating parameter for the erosion wear. He also concludes contribution velocity for the erosion wear is up to 60%, impact angle 21%, solid concentration is up to 10%. Since velocity is most dominant factor so it is therefore important that excessively high conveying velocity should be avoided .From Fig 4 it can be concluded that specific erosion rate increases at a rapid rate on higher end of conveying velocity. With the bends reported in Figure 5, tested at solids loading ratio of 2, bend failure occurred when about 60 g of metal was eroded from the bend. In Figure 6 the conveying capacity of these bends, in terms of the mass of sand that could be conveyed through the pipeline before bend failure occurred, is presented. From this it will be seen that with a conveying air velocity of about 30m/s only 3 tonne of sand could be conveyed before bend failure.

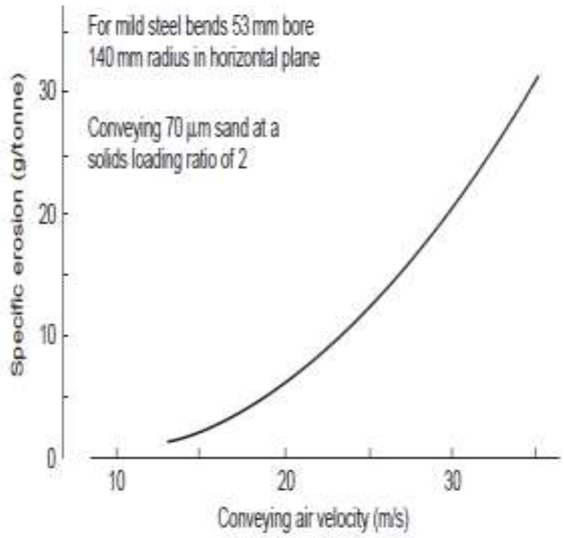

Fig. 5: The influence of velocity on erosive Wear.[7]

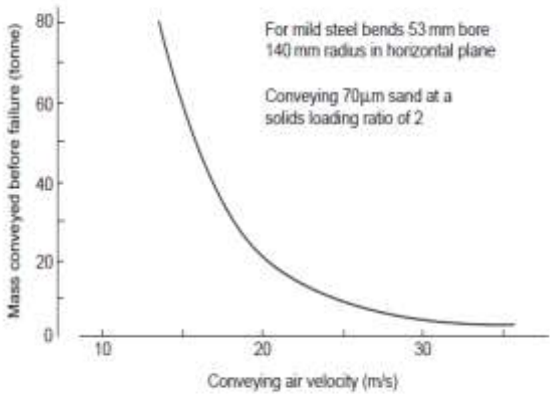

Fig. 6: The influence of velocity on Conveying capacity of bends shown in Fig.5[7]

2.3 Particle Size:

There is general consensus of opinion with regard to particle size is that there is threshold value of wear rate for which , for velocities appropriate to pneumatic conveying occur at particle size of about 60 microns . Below this size wear rate reduces, but for particle sizes greater than 60mm it remains constant. Results of work carried out by Tilly [6] are presented in Fig 7.

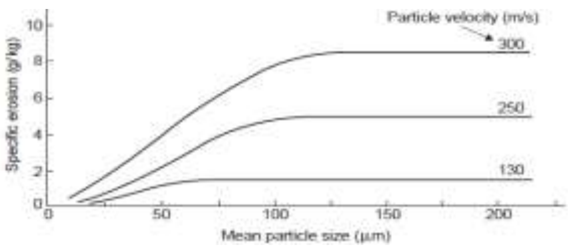

Fig 7: The influence of particle size and velocity on erosion [7].

Fig 7 shows that there exists a critical value of mean particle size below which the specific erosion rate decreases drastically. Wear rate is expressed in specific terms, that is the mass (or volume) of surface material eroded per unit mass of particles impacted. In a given mass of particles, the number of particles will reduce as the particle size increases, and so although the specific erosion remains constant with increase in particle size, the erosive wear per particle will increase approximately with the cube of the particle size. D mills and J Mason carried out work on actual pipe bends in pneumatic conveying system [13]. Batches of sand with mean particle sizes ranging from 70 to 280mm were used in a programme of conveying trials. Six test bends in the one pipeline were monitored for erosive wear, and the average mass eroded from each bend was found to be independent of particle size .Further it was found that that the finer particles are influenced by the secondary flows and turbulence that can be generated by the bends and that this causes accelerated wear of some bends, although there is no obvious reason why some bends were more vulnerable than others in the pipeline. This could well account for some of the premature failures that have been reported in situations where very fine materials have been conveyed.

2.4 Particle Hardness:

Particle hardness is major indicator erosion potential of material .Goodwin et al[14] found erosion is related to hardness by the expression :

Erosion = constant *$H_p^{2.4}$

Where H_P is particle hardness (kg/mm^2)

However, there is threshold value of particle hardness beyond which erosion remains essentially constant [7].There is wealth of information in field of abrasive wear on relationship between surface material hardness and wear resistance of metals . Finnie et al. [15]] were the first to produce a hardness to wear resistance relationship. Results of their work are presented in Figure 8 which helps in concluding that erosive wear resistance is inverse of wear rate.

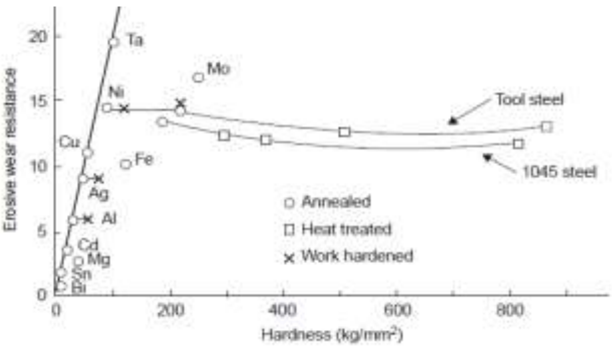

Fig.8: Variation of erosive wear resistance with indentation hardness for various surface materials [7].

The Fig 8 above shows that for annealed metals erosion resistance can be approximated by knowing their hardness value .Cold worked FCC metals having high hardness value has no effect on abrasive wear resistance .Mason et al[16] from their experimental work concluded that resilient material such as natural rubber is superior to mild steel at velocities below about 120 m/s ,but above this value the performance of rubber rapidly deteriorated, probably that may be due to the fact that beyond certain impact energy level the rubber is no longer able to absorb the energy .Using natural rubber as a bend wall material will be beneficial for air velocity below 120m/s .From intense literature overview it was found that hard brittle material are generally used in cases of severe erosive wear .Alumina is one of the most used material in case of severe erosive wear. The general industry specification is alumina content of 85%., although higher alumina contents can be supplied.

2.5 Particle Concentration:

Particle concentration is one of the most important factors that effects wear rate of pipe bends in pneumatic conveying system. The erosion of surfaces, in terms of the mass of material eroded from the surface per unit mass of abrasive particles impacted upon the surface, has been shown to decrease slightly with increase in particle concentration. From research work conducted in past years [18-21] it was found that unit mass of material eroded from surface of material per unit mass of abrasive particles impacted against the surface, found to decrease slightly with increase in particle concentration. T.Deng et al [17] explains this reduction in specific erosion rate is due to shielding effect during the particle impacts. Uuemois and kleis [20] has explained that the reduction in specific erosion rate might be due to high inter particulate collision at high level of flux .These inter particulate collision act as protective shield ,impeding the progress of particle travelling towards bend surface therefore causing reduction in specific erosion rate .D.Mills[22] explains as suspension density increased ,the probability of interparticulate collision also increased .This lead to reduction in average kinectic energy of particle striking the bend wall as well as causing particle impact to be diffused over greater pipe wall area.

To quantify the mass eroded at failure with particular reference to particle concentration or suspension density a dimensionless term called SLR (solid loading ratio) has been derived. The advantage of solid loading ratio is that this dimensionless quantity does not vary with conveying air velocity or pressure so that it remains essentially constant over along the length of pipeline.

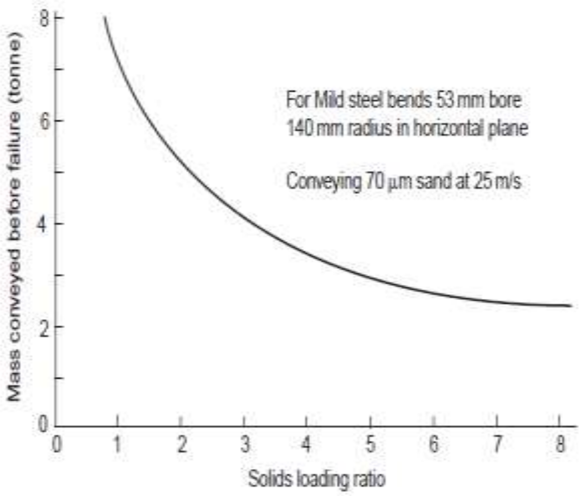

Fig 9: The influence of solid loading ratio on conveying capacity of bends [7]

The shape of curve obtained in Figure 9 can be well explained by inter particulate collision theory by virtue of which fewer impacts occur between the particle and bend wall surface due to interference of an increasing number of other particles. From work on the erosive wear of pipe bends following relationship has been derived for erosive wear:

Mass eroded= constant*(solid loading ratio)$^{-0.16}$

In terms of the mass of metal that has to be eroded from a bend before failure occurs the following relationship has been derived:

Mass eroded at failure =constant *(solids loading ratio)$^{-0.74}$

From Fig 9 it can be concluded that as solid loading ratio increases the life expectancy of bend reduces considerably. Although the specific erosion decreases with increase in solid loading ratio, the influence of increasing penetration rate has a dominant effect. It was also observed that as solid loading ratio increases the degree of scatter also increases. Therefore in terms of component life both particle penetration rate and possible scatter in the results are potentially important as mass eroded.

2.6 Particle shape:

Particle shape is also a variable which helps in predicting the erodent particle characteristics. Angularity is a function of particle shape. Walker et al [23] conducted experiment and has explored two methods of measuring particle shape – Circularity Factor (CF) a ratio of perimeter to projected area of particulate matter and spike parameter(SPQ) which is an analytical method of fitting triangles to prominent feature of the particle outline .From research overview it is found that smooth and rounded particles do not cause much erosion as sharp angular particles ,under similar condition of impact velocity and particle hardness. D mills and J Mason [3] reported that for test work on erosive wear of pipe bends in pneumatic conveying system there is need to re circulate the conveyed material. As a result of recirculation of conveyed material, the sharp corners and edges of fresh material are gradually worn away, and they became more rounded and hence significantly less erosive. This is major problem when test facilities are used to asses erosion potential of conveying material.

2.7 Surface finish:

Highly polished surface will reduce the rate of erosive wear, but the effectiveness of polished surface in reducing erosive would not last long. It will generally reduce wear rate initially. Once the material surface starts to wear it will have little further influence on steady state erosion rate.

3. Conclusion from research overview:

From the overview of literature available on erosive wear it was found that various researchers have tried to study the erosive wear in pneumatic conveying system by taking into consideration various tribological parameters. The conclusions that can be drawn by conducting the literature overview are as follows:

- Very less literature available with variation of impact angle .Impact angle was found to be the second most dominant parameter and contribution of it in erosive wear was almost 21%.
- At low value of impact angle, heat treated surfaces shown significant improvement in erosion rate. Therefore, pipeline and bend material heat treated to higher hardness value if subjected to low angle glancing blows, could offer added protection in this situation.
- Impact velocity is one of the major parameter and contribution of it in erosive wear is as high as 60%. Many researchers have used variable impact velocity to study erosion wear. From the literature available it can be concluded that excessive high conveying velocity increase the rate of erosion and should be avoided.
- Very little work has been undertaken with particle larger than 1mm size and it is not known to what particle size threshold value remain constant.
- Particle hardness significantly affects erosive wear whereas surface hardness is not a significant parameter in selecting material for erosive wear resistance.
- Particle concentration has received very little attention in basic research work on subject, With general opinion being that erosion decreases only marginally with large increase in concentration.
- For pipe bends it was observed that particle concentration over the range investigated has two additional effects of major significance; the appearance of eroded surface differ, and depth of penetration of particle into bend surface material increase considerably.
- Very high solid loading ratio (SLR) value significantly reduces the life of bends because particle tend to focus on a smaller area of wall such that rate of penetration of particle increase.
- Particle shape is an important parameter in determining their erosive potential, angular particle generally being an order of magnitude more erosive than spherical particles
- The erosivity of spherical particles increased with particle size to a peak and then decrease at still larger particle sizes.

- The angular particle erosivity increased with particle size to a level which became more or less constant with size at lower velocities, but increased continuously at higher velocities.

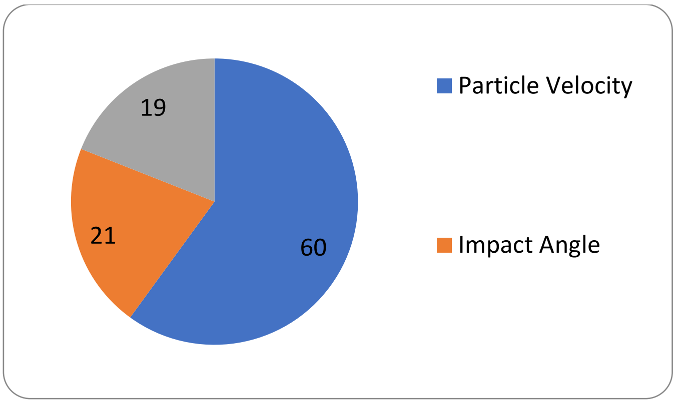

Fig 10: Contribution of various parameter in erosive wear

4. Future Scope:

The range of literature available has been explored and overview was done with special focus on most important variables and parameters affecting rate of erosion wear. Based on same, this section discusses some important research area and possible future research directions in field of pneumatic erosion wear:

- Less work has been conducted with variable impact angle, so there is a future scope of carrying out work with special focus on variable impact angle.
- Less work is done on the effect of the surface condition of target material on the erosion wear, so there is a scope to study the different type of surface condition with the effect of erosion wear. i.e. Surface Roughness, Toughness, strength, microstructure and chemical composition

REFERENCES:

[1] J.S Mason, B.V Smith, The erosion of bend by Pneumatically conveyed suspension of abrasive Particles, 1973

[2] D.Mills and J.S Mason, Particle concentration effect in Bend erosion, Powder Technology. 17 (1977)37-53.

[3] D.Mills and J.S Mason, Particle size effect in bend erosion, Wear, 44 (1977) 311 – 328.

[4] F.A. Bikhbaev, V.I Kransnov, M.Z Maksimenko, V.L Berezin, I.B. Zhilinski and N.T otros, Main factor affecting gas abrasive wear of pneumatic conveying pipe, Chemical and petroleum Engineering,(1973)73-75.

[5] D. Lopez, J.P Congote, J.R Cano, A toro, A.P Tchiptschin, Effect of particle velocity and impact Angle on Corrosion-erosion of AISI 304 and AISI 402 stainless steels, Wear 259 (2005) 118–124.

[6] G P Tilly. Erosion caused by impact of solid particles. Treatise on Materials Science and Technology. Vol 13, pp 287–319. Academic Press Inc. 1979.

[7] Dr David Mills, Pneumatic conveying design guide, ISBN 0750654716

[8] I. Finnie, G. R. Stevick and J. R. Ridgley, The influence of impingement angle on the erosion of ductile metals by angular abrasive particles, Wear, 152 (1992) 91-98.

[9] Yoganandh, J., Natarajan, S., and Kumaresh Babu, S. P., Erosive Wear Behavior of Nickel-Based High alloy white cast iron under mining conditions using orthogonal array, Journal of Material Engineering and performance, 22(2013)2534-2541.

[10] G P Tilly and W Sage. The interaction of particle and Material behavior in erosion processes. Wear. Vol 16, pp 447-465,1970.

[11] D Mills and J S Mason. Conveying velocity effects in bend erosion. Journal of Pipelines. Vol 1, pp 69–81. 1981.

[12] G P Tilly. Erosion caused by airborne particles. Wear, Vol 14, pp 64–69. 1969.

[13] D Mills and J S Mason. The effect of particle size on erosion of pipe bends in pneumatic Conveying systems. Proc Powtech ’79. NEC Birmingham. March 1979.

[14] J E Goodwin, W Sage and G P Tilly. Study of erosion by solid particles. Proc IMechE, Vol 183, No 15, pp 279–292. 1969–70.

[15] I Finnie, J Wolak and T Kabil. Erosion of metals by solid particles. ASTM Journal of Materials. Vol 2, pp 682–700. September 1967.

[16] J S Mason et al. The rapid erosion of various pipe wall materials by a stream of abrasive alumina particles. Proc Pneumotransport 2. Paper E1. Guildford. 1973

[17] T. Deng,, A.R. Chaudhry, M Patel, I. Hutchings, M.S.A. Bradley, Effect of particle concentration on Erosion rate of mild steel bends in pneumatic conveyor, Wear 258 (2005) 480–487.

[18] D.R. Andrews, N. Horsfield, Particle collisions in the vicinity of an eroding surface, J. Phys. D:Appl.Phys.16 (1983)525-538.

[19] K. Anand, S.K. Hovis, H. Conrad, R.O. Scattergood, Flux effects in solid particle erosion, Wear 118 (1987)243-257.

[20] H.H. Uuemois, I.R. Kleis, A critical analysis of erosion problems which have been little studied, Wear 31(1975)359-371.

[21] G.P. Tilly, W. Sage, The interaction of particle and material behavior in erosion process, Wear 16(1970)447-465.

[22] D. Mills, Erosive Wear Problems in Industry with Particular Reference to Process Plant, Power Station and bulk solid handling systems, SOLIDDEX’86 Conference/Exhibition, Harrogate, June 1986.

[23] Walker, C. I., and Hambe, M., Influence of particle shape on slurry wear of white iron, Wear, 332-333(2015)1021-1027.