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SPECIFIC PRESSURE LOSSES DESIGN WHILE PNEUMATIC CONVEYING OF FINE DISPERSE MATERIALS

The design method of pressure losses while fine dispersed materials pneumatic conveying within the wide range of changes of conveying pipeline material types and standard sizes for determination of solid phase friction losses coefficient is developed. The maximum design error while the conveying flow motion without the superposition phase is no more than 20% that can be considered acceptable for solving engineering problems.

Problem description

Systems and devices for fine dispersed materials pneumatic conveying are widely used in those fields of industry (coal, chemical, electric power, agriculture, construction and others) where they are an integral part of various production processes. Still despite a number of pneumatic conveying advantages their further development is slowed down due to relatively low reliability and the critical problems of energy efficiency. That is why the further development of design methods of specific pressure losses while bulk materials pneumatic conveying is an important task and will enable creation of pneumatic conveying systems with higher figures of power consumption, conveying quality and durability.

Latest researches analysis

For the present day, numerous researches in the sphere of pneumatic conveying systems design methods, particularly power consumption while bulk materials conveying through a pipeline, have been carried out. Some of them are based on experimental and theoretical data and well developed [1,2,3,4]. However it should be mentioned that their scope is often limited by characteristics of materials used in them and pipes standard sizes. Though different methods agree with each other and experimental data quite well, yet in quantitative estimations there are significant differences between them of up to 70 percent and more.

Thus most of authors for pressure losses estimation for *dp* material conveying, related to the pipeline length unit, use the known dependence [1]:

$$\frac{dp}{dl} = \lambda_m \frac{\rho_a V_a^2}{2D},$$

where the friction losses coefficient is determined as

$$\lambda_m = \lambda_a + \lambda_s.$$

Here *D* is the pipeline inner diameter, m indexes refer to the air and the material mixture, *a* – to the air, *s* – to the solid fraction.

Clean air friction coefficient λ_a determination is generally carried out by analogy with hydraulically smooth pipelines (Blasius formula):

$$\lambda_a = \frac{0,316}{\mathrm{Re}^{0,25}}.$$

Regarding the friction losses coefficient constituent for solid phase λ_s, as mentioned above, there are numerous methods more or less adequately describing the process. Within the present article it is impossible to give the whole range of the available methods for λ_s, determination, still as an illustration, there are the results of specific pressure losses while polystyrene particles conveying by compressed air, determined by the methods suggested by Klinzing G. E. (full line) and Mills D.

(dashed line) [2, 3] in figure 1. Here experimental values are marked with a fine dashed line [2]. The conveying pipeline diameter is 50 mm, particles mean diameter – d_s = 2.4 mm, line 1 stands for clean air, lines from 2 to 6 – solid phase mass flow rate G_s = 251; 497; 743; 995 and 1244 kg/hour respectively. There are design results for the same methods for malt (d_s = 5 mm, line 2) and ash (d_s = 40 micron, lines 3 and 4) [2]. Conveying pipeline diameter is 100 mm, line 1 – clean air, the values G_s = 228; 500 and 600 kg/hour, respectively. As seen from the given dependences, the results of agreeing the designed and experimental curves derived from the same method differ significantly, being satisfactory for one material and unsatisfactory for another one.

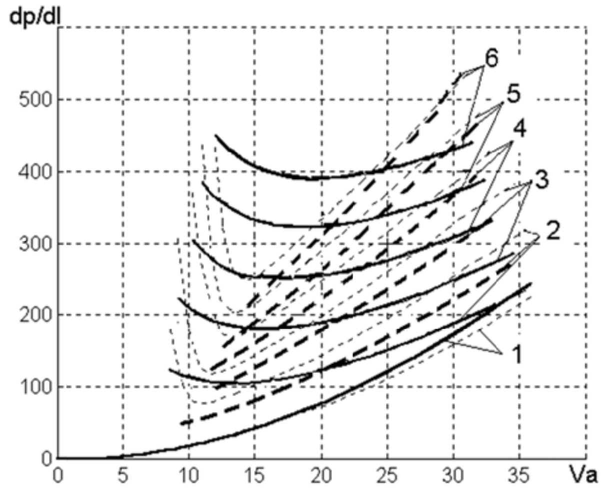

Figure 1 – Specific pressure losses in the pipeline while polystyrene conveying

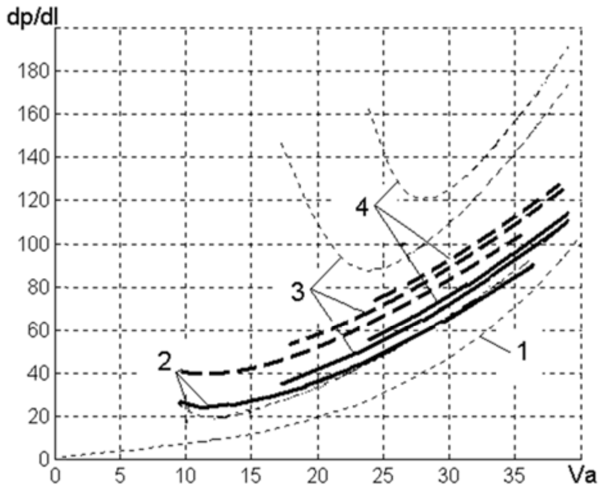

Figure 2 – Specific pressure losses while malt and ash conveying

The same tendency is typical for other methods determining specific pressure losses within the wide range of the conveyed material particles density and diameters (from tens of micron to millimeters) and pipelines diameters.

Task statement

On the basis of the given analysis of the existing methods for determination of specific pressure losses while fine disperse materials pneumatic conveying, the task of specific pressure losses design method, considering solids and the pipeline diameters ratio and putting together geometric and mode parameters of the suspension flow precising is stated. For the stated task solution it is necessary to carry out mathematical treatment of the existing specific pressure losses experimental data and derive a generalized dependence for λ_s determination on the basis of the design results.

Pressure losses design

While finding the analytic dependence for λ_s experimental data for the wide range of conveyed materials and cement conveying pipelines standard sizes was used: cement, coal dust and ash [2], polystyrene, malt and barytes [3], wheat and barley [4] within the pipelines diameter range from 40 to 150 mm. Ratios of pneumatic conveying flow basic characteristics: density ρ_a, diameter d_s and solids suspension velocity w_s; density ρ_a and compressed air velocity V_a; the pipeline diameter *D*; the material mean velocity in the pipeline V_s; and dimensionless parameters – mass concentration of solid phase $\mu_s = G_s / G_a$ and Froude numbers for air $Fr_a = V_a / \sqrt{gD}$ and particles $Fr_s = w_s / \sqrt{gd_s}$ were used as significant factors.

Experimental data treatment was carried out by numerical methods with the use of mathematical statistics [5]. The obtained maximum error values of dp/dl determination depending on the listed factors were controlled by dispersion reproducibility with the confidence probability of 0.95:

$$S_e^2 = \left(\frac{\sum \delta_i}{2}\right)^2,$$

where $\sum \delta_i$ – summary error of dp/dl determination, including its statistical constituent.

After mathematical treatment of experimental data of specific pressure losses in conveying pipeline the analytic dependence for the coefficient of pneumatic conveying flow solid phase friction losses was derived:

$$\lambda_s = 4 \cdot 0{,}00316 \cdot \mu_s^{-\frac{d_s}{D}} \cdot Fr_a^{-0{,}25} \cdot Fr_s^{0{,}25} \cdot \left(\frac{V_a - V_s}{w_s}\right)^{0{,}25}.$$

It should be mentioned, in case when the conveying air velocities are lower than the critical conveying velocity, the summary error of dp/dl determination significantly increases. This can be explained by the material sedimentation on the pipeline walls causing superposition. In this case the conveying process gets irregular and hardly mathematically treated. In general the given dependence can be accepted for determination of friction losses while the motion of the conveying flow without the superposition phase. The maximum design error is no more than 20% within the wide range of pipeline standard sizes and conveyed material types changes that can be considered acceptable for solving engineering problems. As an illustration there are the results of specific pressure losses design by the developed method in fig. 3 and 4 taking into account the conditions corresponding with those given in fig. 1 and 2 (symbols are the same).

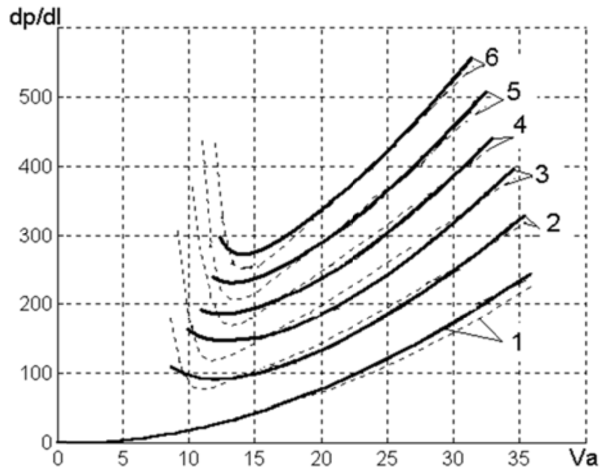

Figure 3 – Specific pressure losses in the pipeline while polystyrene conveying

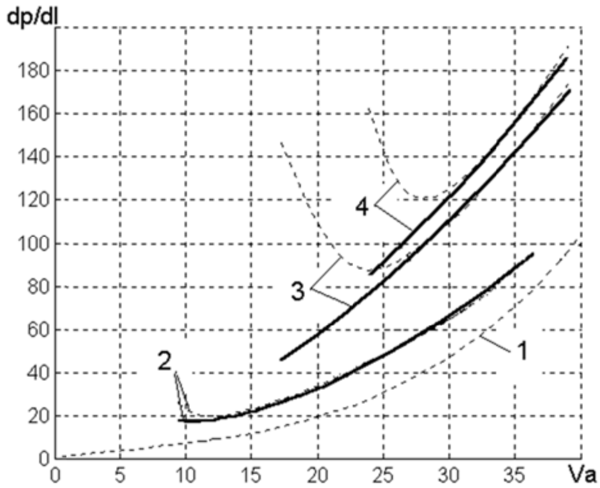

Figure 4 – Specific pressure losses while malt and ash conveying.

Conclusions and possibilities of future researches

The method for specific pressure losses design while fine dispersed materials conveying within the wide range of changes of transport pipeline materials and standard sizes is developed. The point of it is the solid phase friction losses coefficient determination. The maximum design error is no more than 20%. This can be considered acceptable for solving engineering problems.

The given method does not present satisfactory agreement of the designed and experimental data at high concentration of pneumatic conveying flow solid phase with superposition elements therefore the point of future researches is supplying the method with the conditions considering the events occurring while conveying at precritical speed.

Bibliography

1. Голобурдин А. И. Пневмотранспорт в резиновой промышленности / А. И. Голобурдин. – М.: Химия, 1983. – 161 с.

Goloburdin A. I. Pnevmotransport v rezinovoy promyshlennosti (Pneumatic Conveying in Rubber Processing Industry) / A. I. Goloburdin. – M.: Khimiya, 1983. – 161 s.

2. Klinzing G. E. Pneumatic conveying of solids / G. E. Klinzing. – Pittsburg, USA, 1997. – 592 p.

3. Mills D. Pneumatic conveying design guide / D. Mills. – Glasgow, UK, 1990. – 638 p.

4. Зуев Ф. Г. Пневматический транспорт на зерноперерабатывающих предприятиях / Ф. Г. Зуев. – М.: Колос, 1976. – 344 с.

Zuyev F. G. Pnevmaticheskiy transport na zernopererabatyvayushchih predpriyatiyah (Pneumatic Conveying in Grain Processing Industries) / G. F. Zuyev. – M. Kolos, 1976. – 344 s.

5. Корн Г. Справочник по математике для научных работников и инженеров / Г. Корн, Т. Корн. – М.: Наука, 1977. – 832 с.

Korn G. Spravochnik po matematike dlya nauchnyh rabotnikov i inzhenerov (Mathematics Manual for Researches and Engineers) / G. Korn, T. Korn – M.: Nauka, 1977. – 832 s.