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PIPE BEND SHUT OFF PROPERTY AND ITS PRACTICAL USE EXPERIENCE

The conditions of the choke formation in the pipe bend filled with a bulk material are considered. The device mathematical model has been developed. A simple and reliable engineering solution of the shut off device for pneumatic conveying system feeders has been suggested.

The blow tank most important units in the system of bulk materials pneumatic conveying are its charge shut off devices, enabling the switch of the charge and discharge modes. As a rule, different types of valves and shutters equipped with electromagnetic, pneumatic or any other type of actuators are used as shut off devices. All the equipment complicates the device design, effects the reliability and due to the actuators lags decreases its efficiency. Thus increasing the reliability and response time of the shut off devices are an important task for blow tanks development.

An unusual way for solving the problem is using a shut off bend as a discharge shut off device.

It is well known how dangerous pneumatic conveying systems operation is. Pipeline blockage may occur when bulk material compact chokes are formed in it. Mostly it happens in the so called bends.

If a bend of a particular shape is equipped with an aerator the blockage can be used as a control shat off device. The bulk material in the bend under the pressure from the tank forms a compact choke which however can easily be destroyed and removed by means of compressed air injected into the choke. Despite the aerator knee simple design it is quite a complex function object, requiring the detailed study of the material compact and firm choke forming conditions. The inaccurate choice of the bend parameters may cause either an early choke destruction by pressure from the tank and the device operating mode disturbance or the increase of the resistance and pressure losses in the conveying line. Therefore it is reasonable to conduct the analytical studies of the shut off bend parameters and the choke compactness formed in it.

Let’s consider the bend simplified design scheme given in figure 1.

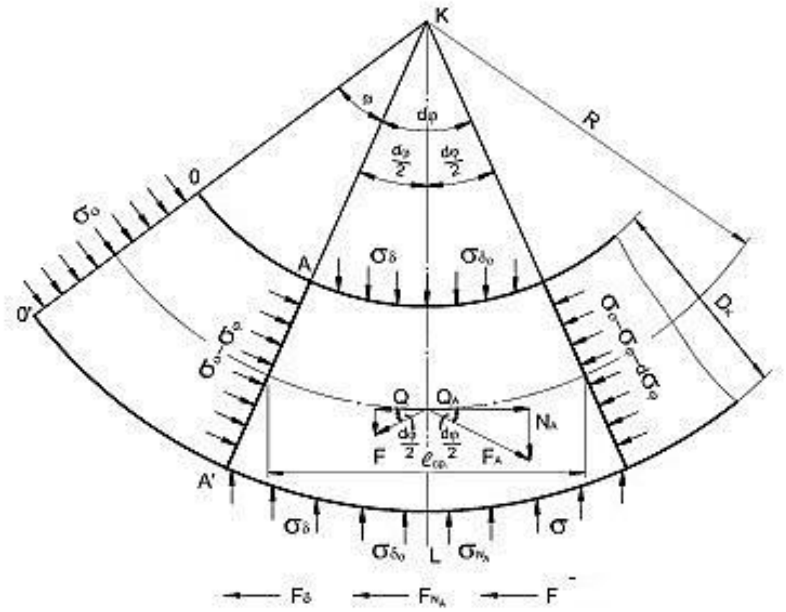

Figure 1 – The scheme of forces and stresses in the shut off bend

The bend with the diameter D_k and the bend radius R is filled with a bulk material. At the beginning of the bend (section OO') the material is under the pressure σ_0. Along the bend length the friction force causes the pressure decreasing. In the section AA', passed at the angle φ to the plane OO', the pressure decreases by the value σ_φ and goes to $\sigma_0 - \sigma_\varphi$.

By two infinitely near sections AA' and BB' with the angle $d\varphi$ between them, we will select any element AA'B'B.

The element mean length at the φ angle measurement in radians is $L_m = Rd\varphi$

The bend cross section perimeter is $P = \pi D_k$.

The cross section area is $S_K = \dfrac{\pi D_k^2}{4}$.

In the selected element the longitudinal pressure losses are $d\sigma_\varphi$ thus the pressure in the section BB' will be $\sigma_0 - \sigma_\varphi - d\sigma_\varphi$. The compressed material under the bend walls side pressure the value of which at the granular mediums stress condition design is directly proportional to the longitudinal pressure value $\sigma_0 = \psi\left(\sigma_0 - \sigma_\varphi\right)$, where ψ is the side pressure coefficient.

Longitudinal forces $F_{\text{À}}$ and $F_{\text{Á}}$ act on the bend element. If the longitudinal pressure is considered homogeneous throughout the bend cross section,

$$F_A = S\left(\sigma_0 - \sigma_\varphi\right) = \frac{\pi D_k^2}{4}\left(\sigma_0 - \sigma_\varphi\right),$$

$$F_{A'} = S\left(\sigma_0 - \sigma_\varphi - d\sigma_\varphi\right) = \frac{\pi D_k^2}{4}\left(\sigma_0 - \sigma_\varphi - d\sigma_\varphi\right).$$

We decompose the forces F_A and $F_{\text{Б}}$ so that the longitudinal components Q_i situate on the tangent to the bend axis within the selected element:

$$Q_A = F_A \cos\left(\frac{d\varphi}{2}\right) = \frac{\pi D_k^2}{4}\left(\sigma_0 - \sigma_\varphi\right)\cos\left(\frac{d\varphi}{2}\right),$$

$$Q_{A'} = F_{A'} \cos\left(\frac{d\varphi}{2}\right) = \frac{\pi D_k^2}{4}\left(\sigma_0 - \sigma_\varphi - d\sigma_\varphi\right)\cos\left(\frac{d\varphi}{2}\right),$$

$$N_A = F_A \sin\left(\frac{d\varphi}{2}\right) = \frac{\pi D_k^2}{4}\left(\sigma_0 - \sigma_\varphi\right)\sin\left(\frac{d\varphi}{2}\right),$$

$$N_{A'} = F_A \sin\left(\frac{d\varphi}{2}\right) = \frac{\pi D_k^2}{4}\left(\sigma_0 - \sigma_\varphi - d\sigma_\varphi\right)\sin\left(\frac{d\varphi}{2}\right).$$

Under the transverse forces N_A and $N_{\text{Б}}$ material and bends walls friction forces occur:

$$F_{N_A} = f N_A = f\,\frac{\pi D_k^2}{4}\left(\sigma_0 - \sigma_\varphi\right)\sin\left(\frac{d\varphi}{2}\right),$$

$$F_{N_{A'}} = f N_{A'} = f\,\frac{\pi D_k^2}{4}\left(\sigma_0 - \sigma_\varphi - d\sigma_\varphi\right)\sin\left(\frac{d\varphi}{2}\right),$$

where f – friction coefficient and the corresponding pressures σ_{N_A} and $\sigma_{N_{A'}}$.

One more friction force F_δ is coursed by side pressure σ_δ.

$$F_\delta = f\sigma_\delta P L_m = f\psi\pi D_k R\left(\sigma_0 - \sigma_\varphi\right)d\varphi.$$

The material weight in the bend is not considered.
Longitudinal axis forces balance equation is:

$$Q_A - Q_B - F_\delta - F_{N_A} - F_{N_{A'}} = 0.$$

We substitute the forces values and after the transformations obtain:

$$d\sigma_\varphi \cos\frac{d\varphi}{2} - f\frac{2\psi R}{D_k}\left(\sigma_0 - \sigma_\varphi\right)d\varphi - 2f\left(\sigma_0 - \sigma_\varphi\right)\sin\frac{d\varphi}{2} + f\,d\sigma\sin\frac{d\varphi}{2} = 0.$$

Taking into account that $\sin\frac{d\varphi}{2} \approx \frac{d\varphi}{2}$, $\cos\frac{d\varphi}{2} \approx 1$ and neglecting the differentials product we will write:

$$d\varphi + f\left(1 + \frac{4\psi R}{D_k}\right)\sigma_\varphi d\varphi - f\left(1 + \frac{4\psi R}{D_k}\right)\sigma_0 d\varphi = 0,$$

from which

$$d\varphi = \frac{d\sigma_\varphi}{f\left(1 + \frac{4\psi R}{D_k}\right)\left(\sigma_0 - \sigma_\varphi\right)}.$$

Having differentiated the obtained equation we find:

$$\varphi = \frac{\ln\left(\sigma_0 - \sigma_\varphi\right)}{f\left(1 + \frac{4\psi R}{D_k}\right)} + C.$$

The constant C will be determined from the zero conditions (for OO' section) $\varphi = 0,\ \sigma_\varphi = 0$:

$$C = \frac{\ln\sigma_0}{f\left(1 + \frac{4\psi R}{D_k}\right)}.$$

Considering the obtained value of the constant C:

$$\varphi = -\frac{\ln\frac{\left(\sigma_0 - \sigma_\varphi\right)}{\sigma_0}}{f\left(1 + \frac{4\psi R}{D_k}\right)}.$$

The current pressure rating will be denoted by σ: $\sigma = \sigma_0 - \sigma_\varphi$.

Next

$$\varphi = -\frac{\ln\frac{\sigma_0}{\sigma}}{f\left(1+\frac{4\psi R}{D_k}\right)}.$$

Solving the equation for $\frac{\sigma_0}{\sigma}$, we obtain:

$$\frac{\sigma_0}{\sigma} = e^{-\varphi f\left(1+4\psi\frac{R}{D_k}\right)}.$$

The obtained formulas can also be written in the L_k coordinate form (the shut off bend arc length).

As $L_k = \left(2\pi R\big/ 2\pi\right)\varphi = R\varphi$ and $\varphi = \frac{L_k}{R}$, then $L_k = \frac{\ln\frac{\sigma_0}{\sigma}}{f\left(\frac{1}{R}+\frac{4\psi}{D_k}\right)}.$

Having denoted $a = f\left(\frac{1}{R}+4\varphi\frac{R}{D_k}\right)$, it can be written $\varphi = \frac{1}{a}\ln\left(\frac{\sigma_0}{\sigma}\right)$; $L_k = \frac{1}{a}\ln\left(\frac{\sigma_0}{\sigma}\right)$; $\frac{\sigma_0}{\sigma} = e^{L_k a_1}$; $\frac{\sigma_0}{\sigma} = e^{-\varphi a}$.

The obtained dependences allow conducting the qualitative impact analysis of the bend parameters and characteristics of the bulk material it filled with on the formed in it choke. The faster decays the pressures in the bend, the firmer the formed in it choke. The bend segment ensuring the initial pressure decrease for 90…95 % (by 10…20 times) is considered sufficient for shut off. In an actual blow tank device the bend angle can be within 90–130°. With the *R* and D_k properly chosen parameters the pressure decay in it to 0.1 and less from the initial occurs with a 60–70° bend. Changing the bend parameters within the available limits: the bend radius *R*, the diameter D_k , the bend angle φ or the arc length can assure the reliable shut off..

The suggested device functionality is proved by the shut off thorough check under laboratory and industrial conditions with the pneumatic lift mounted in the pulverizing workshop of the thermal power station Slavyanskaya. The blow tank type pneumatic lift is intended for milled coal lifting in the amount of 70 tones per hour up to the height of 30 m. The scheme of the pneumatic lift blow tank with the downstream shat off bend is given in figure 2.

The blow tank is inclined mounted in the mill catch pit and equipped with the charge valve 1 the compressed air supply system 5, 6, 7, 8. The tank 2 with the diameter of 720 mm, length of 600 mm is connected by the adapter sleeve with the shat off bend the diameter of which D_k = 324 mm, bend radius *R* = 1250 mm. While the tank charging through the opened valve 1 a part of the shat off valve gets filled with the milled material. Then the valve 1 closes and the compressed air is delivered through the nozzle 5 into the tank, compacting the choke in the bend and developing in the tank the initial pressure required for effective conveying. Then the choke gets destroyed with the air delivery into the shat off bend, the material discharge from the tank through the bend 4 into the conveying line and then to the separators is carried out.

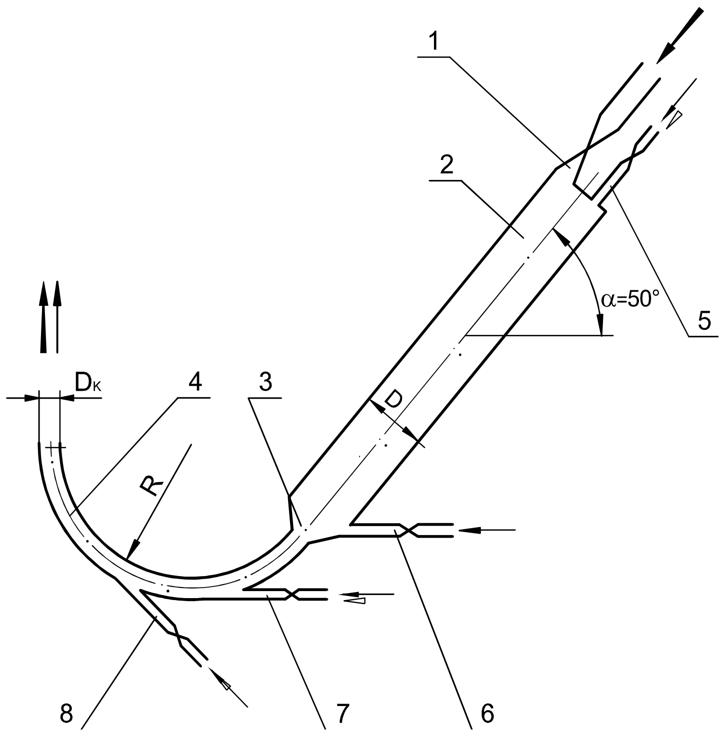

Figure 2 – The blow tank scheme with the inclined tank and the shat off bend: 1 – charge valve; 2 – tank; 3 – sleeve; 4 – shut off bend; 5, 6, 7, 8 – compressed air delivery nozzles

While the installation no failures were observed in the shut off bend operation.

Thus the workability of the pipeline bend shut off property has been proved in practice. This simple and reliable engineering solution can be suggested for pneumatic conveying systems of any purpose.

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