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THE USE OF THE EJECTOR FOR AIR DISCHARGE FROM THE SMALL SIZED BLOW TANK

The possibility of using the ejector for dusty air discharge from the small sized blow tank with the purpose of improving the conditions of its loading and pneumatic conveying system performance increasing.

PROBLEM STATEMENT

Nowadays due to the economy problems of energy saving and creation of industrial “ecologically clean” technologies a series of works on outdated technologies modernization and reconstruction is carried outat several enterprises of Ukraine. At that the possibility of conducting the modernization without large investments and inevitable in these cases manufacturing stoppage or decrease is of great importance. This can be avoided by applying new developments to the existing technologies so they enter the manufacturing process without altering the equipment considerably. As a rule the well known technologies are inappropriate for satisfying the condition and there arises the necessity of applying a nonroutine decision. It is referred to the works on coal dust pneumatic conveying system modernization at Slavyanskaya Thermal Power Station. While the modernization works at the coal dust conveying site from the dust preparation workshop (DPW) to the receiving bunker there arose the necessity of pneumatic screw pumps replacement with a different type of feeder [1].

Bulk material feeding from the receiving bunker into the conveying pipeline is performed via the screw, rotated by the actuating electromotor. The disadvantages of this feeder type are the screw wear, power consumption for its rotation and the probability of compressed air break through the conveying line to the bunker thus deteriorating the bunker chamber loading conditions. At present modernized blow tanks are in preference. Yet the blow tank size is much larger than that of the pneumatic screw pump and cannot replace it in the operating pneumatic conveying systems without the bunker and the conveying line reconstructions. Therefore the small sized blow tank (figure 1) was chosen as it has a small chamber and a different scheme of load valves design and allocation.

For ensuring the blow tank required efficiency of 60 tonnes/hour at the chamber limited sizes it is necessary to reduce the time of the operating cycle, including coal dust loading and unloading. The unloading time can be reduced by increasing the pressure of the compressed air 10, supplied through the tank upper part. Air feeding is performed from the general system and increasing the pressure without mounting additional compressors is impossible. As for the loading process duration it can be shortened by creating exhaustions in the tank and improving the conditions of the dust supplying form the bunker 11. Unfortunately the existing air aspiration system of DPW does not provide the sufficient exhaustion and sometimes under considerable loads the excessive pressure was observed in it.

At that time while the blow tank loading with the coal dust the compressed air 7, needed for maintaining the conveying process of the material being in the pipeline, is supplied to the conveying line via the parallel line.

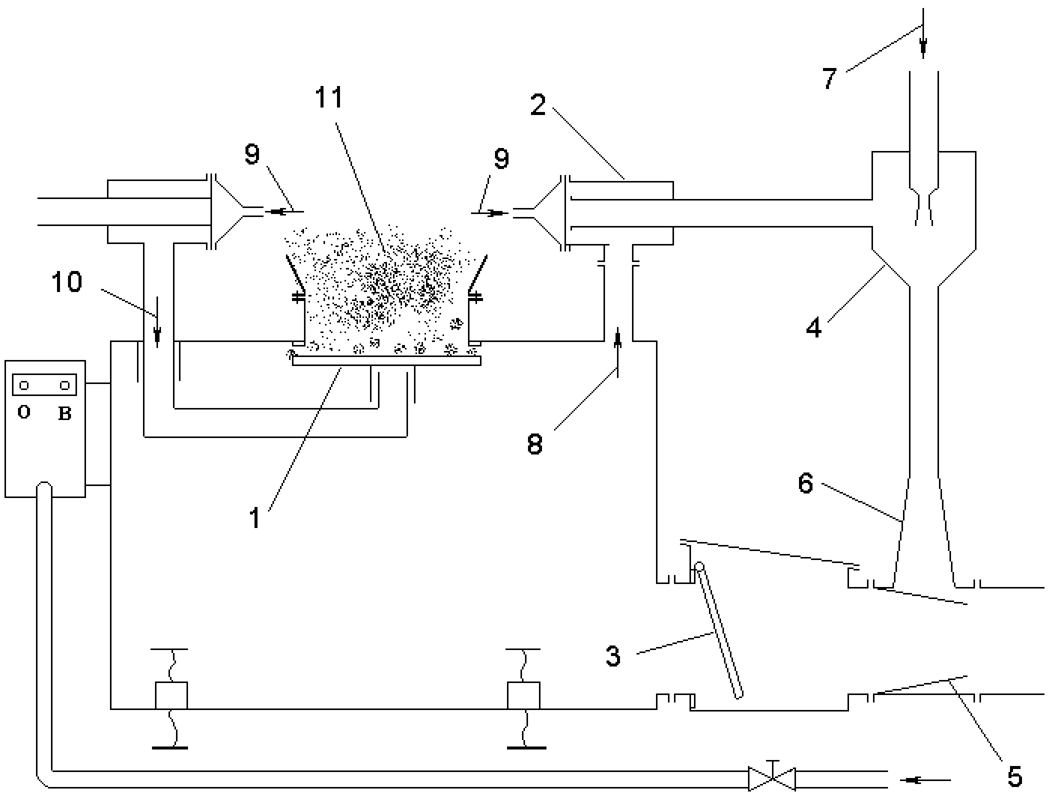

Figure 1 – The scheme of the blow tank with the ejector for air discharge:
1 – charging valve, 2 – air discharging valve, 3 – discharging valve, 4 – ejector,
5 – vortex generator, 6 – diffuser, 7 – work flow, 8 – injected flow, 9 – control signals, 10 – main stream flow while discharging from the tank,11 – bunker

The ejector 4 mounting into the line in front of the conveying pipeline allowed diluting and discharging of the dust laden air displaced from the blow tank into the pipeline while its loading. At that not only the problem of the material loading conditions improvement without depending on the aspiration condition was solved, but the ecological condition of the whole pneumatic conveying system improved as all the coal dust goes to the pipeline and does not pollutes the atmosphere.

Blow tank ejectors for air discharge into the conveying pipeline in the deaeration process were used before (for example the pump of the West German company "Claudius Peters ") [2].The difference of the suggested scheme from the known ones is that due to the blow tank dimensions theejector and the pipeline coaxial execution was impossible (it would have required to level up the blow tank and reduce the tank dimensions).This ejector application pattern can be realized if there is no limiting for the blow tank height. Due to the angle between the ejector and the pipeline close to 90°additional problems dealing with eliminating of the negative influence, caused by the main flow and the flow from the ejector crossing, on the conveying parameters and the pipeline abrasive wearing increase had to be solved.

EJECTOR DESIGN

While designing the ejector for air discharge from the blow tank into the conveying pipeline it was necessary to take into account the fact that according to the operating conditions the air pressure was detected by the air preparation system of the DPW and was limited by the maximum value of 0.25 mPa. Therefore the operating flow expansion degree in the ejector was not big (< 3.5), being much smaller than that of the industrial models (about 10 and higher). The maximum value of the operating and injected flows compression degree was 1.5 being the determinative of the mixing tank cylindrical shape enabling the pressure recovery biggest degree in comparison with the tanks of a different profile. Besides due to the blow tank cycle operation the pressure of the injected (discharged from the tank) flow occasionally changes from the maximum value to the atmosphere one and lower differing it from the operating cycle of the most typical ejectors. Considering the design features of the ejector design scheme and operating conditions of the inlet and injected flows, the direct flow ejector with the following initial data was engineered:

– operating air flow rate (at the atmosphere pressure) G_a = 2700 m^3/hour;
– injected air flow rate (at 90 cycles per hour) G_i = 500 m^3/hour;
– pressure (absolute) in front of the ejector p_1 = 0,35 mPa;
– pressure (absolute) of the injected flow p_i = 0…0,35 mPa;
– pressure (absolute) at the ejector outlet p_3 = 0, 2 mPa;
– mean temperature T = 373°K;
– adiabatic index k = 1,4;
– conveying pipeline diameter D = 300 mm.

The technique suggested in [3] was used while designing the ejector geometric parameters. The minimum injection ratio based on the required capacity should be

$$u_{\min} = \frac{G_i}{G_a} = \frac{500}{2700} = 0.19.$$

While designing jet devices it is convenient to use gas-dynamic functions, linking the given isentropic (adiabatic) gas flow velocity with its thermodynamic parameters. The given isentropic velocity is the ratio of the gas velocity at its adiabatic flowing to the critical velocity:

$$\lambda = \nu_i / a, \tag{1}$$

where ν_i – isentropic velocity, m/sec;
a – critical velocity, m/sec.

The function $\overline{P}$ – relative pressure, i. e. the ratio of the isentropic flowing in the given section gas static pressure p to the stagnation pressure p_o:

$$\overline{P} = \frac{p}{p_o} = \left(1 - \frac{k-1}{k+1}\lambda^2\right)^{\frac{k}{k-1}}. \tag{2}$$

1.The design of the cylindrical mixing tank (figure 2) is performed in accordance with the dependences:

– air critical velocity

$$a_* = \sqrt{2RT\frac{k}{k+1}} = \sqrt{2 \cdot 287 \cdot 373\frac{1.4}{2.4}} = 353\ m/\sec;$$

– relative critical pressure

$$\overline{P_*} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}} = \left(\frac{2}{2.4}\right)^{\frac{1.4}{0.4}} = 0.528;$$

– relative outlet pressure in the mixing tank

$$\overline{P_2} = 0.8\frac{p_2}{p_1} = 0.8\frac{2}{3.5} = 0.457;$$

– the ratio of the critical section areas and the flow at the mixing chamber outlet

$$q_2 = \sqrt{\frac{k+1}{k-1}}\left(\frac{\overline{P}_2}{\overline{P}_*}\right)^{\frac{1}{k}}\sqrt{1-\overline{P}_*^{\frac{k-1}{k}}}; \tag{3}$$

– value of the injection rate at the limit mode

$$u_{lim} = \frac{\frac{p_i}{p_2}\frac{1}{q_2} - \frac{p_i}{p_1}\frac{1}{q_1}}{1 - \frac{p_i}{p_2}\frac{1}{q_2}}; \tag{4}$$

– specified value of the ratio of the critical section and the flow at the mixing tank outlet is

$$q_2 = \frac{u_{lim}}{\frac{p_i}{p_2}\frac{(1+u_{lim})}{q_i} - \frac{p_i}{p_2}\frac{1}{q_2}}. \tag{5}$$

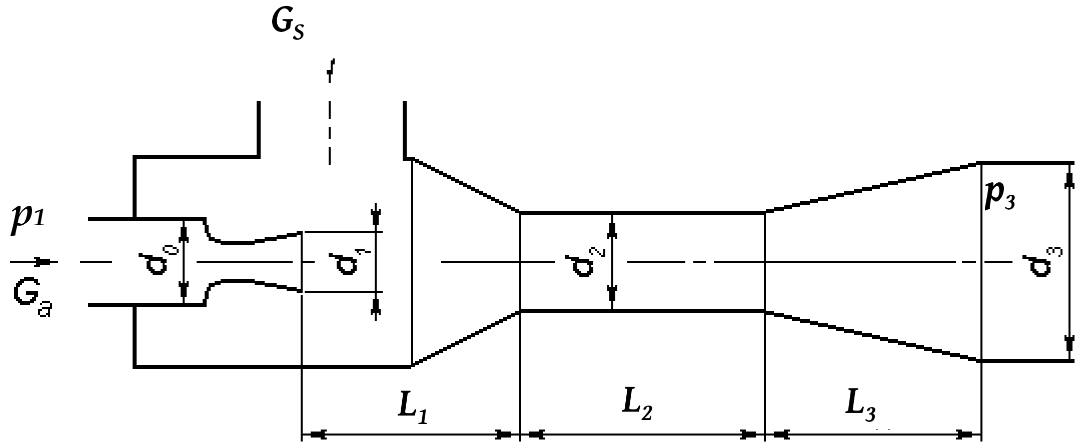

Figure 2 – Ejector design model

The design is performed using the method of successive approximations in accordance with formulas (3)–(5) until the q_2 value is attain the accuracy of 0.001. The q_i and q_2 functions unknown values are estimated by the known values of q_2 using formulas (1) and (2). The design was carried out with the help of the numerical methods using ECM. As a result the design value of the injection limit rate was 0.22 exceeding the minimum allowed, obtained from the design of the ejector (4) required capacity.

Then the mixing chamber outlet section area is estimated:

$$F_2 = \frac{4G_2\, a_*}{k\overline{P}_*\, p_2\, q_2}.$$

2. The nozzle design:

– relative operating pressure $\quad \overline{P}_1 = \frac{p_{atm}}{p_1} = \frac{1}{3.5} = 0.286;$

– inlet section area $F_0 = \frac{G_1 \overline{P}_1}{\nu_i \rho_{air}}$;

– outlet section area $F_1 = \frac{G_a a_*}{k\overline{P}_* p_1} \sqrt{\frac{k+1}{k-1}} \left(\frac{\overline{P}_1}{\overline{P}_*}\right)^{\frac{1}{k}} \sqrt{1-\overline{P}_1^{\frac{k-1}{k}}}$.

3.The diffuser and the ejector geometrical dimensions design

– diffuser inlet diameter $d_2 = \sqrt{\frac{4F_2}{\pi}}$;

– diffuser outlet diameter $d_3 = D = 0.3$ m;

– diffuser length $L_D = \frac{(D_3 - D_2)}{2tg6°}$;

– mixing tank length $L_2 = 6D_2$;

– pipe length $d_0 = \sqrt{\frac{4F_0}{\pi}}$.

The ejector 4 (figure 1) for dusty air discharge is engineered and mounted in accordance with the design data. For reducing the ejector outlet flow negative influence on the conveying pipeline the ejector of slit type 6 with a tangential inlet to the ring vortex generator 5. As the dusty air velocity at the ejector outlet is high and contributes to the vortex generator walls excessive abrasive wear the method widely used in pneumatic conveying for the conveying line bends [4] protection from wear is applied in this case. With this purpose a pocket type dust collector (not pointed in the figure) is mounted in the vortex generator lower part. The dust collected in it protects pipeline walls from wear.

Due to the ejector mounting negative pressure in the tank at the moment of its loading with coal dust was created. The pressure maximum value was 20 kPa. This resulted in the loading time shortening from 18 to 8 seconds, i. e. more than twice and the blow tank overall capacity increased by 1.5 times. Using a blow tank together with the ejector makes it independent from the workshop aspiration system which does not cope with a big amount dust sources. The amount of dust discharged into the atmosphere from the aspiration system decreases as all the coal dust entering the blow tank, passes to the conveying line in the end. This can be recommended for application in small sized blow tanks for which small sizes and the specific amount of steel per structure together with its high efficiency are of primary importance. In the cases when the blow tank sizes are not so crucial, it is reasonable to mount the ejector for dusty air discharge under the tank bringing the ejector axisin coincidence with the pipeline axis. Thus the problem of the pipeline wear and the ejector efficiency increase can be solved easier.

CONCLUSION

1. The small sized blow tank for pneumatic screw pumps substitution in operating pneumatic conveying systems without considerable expenses has been created.
2. Ejector mounting for dusty air discharge from the blow tank into the conveying pipe line in the process of loading allowed to shorten the loading time by 2.25 times and the whole cycle, including loading and unloading by more than 1.5 times.
3. The blow tank and ejector cooperation avoided the necessity for aspiration thus reducing the level of the environment contamination in comparison with a traditional blow tank model performance indexes. Furthermore a model like this allows using the blow tank in the cases when there are no possibilities for using the aspiration system or when its operation is unreliable. Thereby the model operation reliability increases as it does not depend upon external constituents.

The ejector and conveying line mutual influence on their operating characteristics, depending on the load degree and conveyed material concentration investigations, their influence on the small sized blow tank performance, the development and improvement of techniques and design solutions on the abrasive wear of pneumatic conveying systems, their reliability and durability increase can be future research opportunities in this direction.

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