

Design and Simulation of Two Stage Pressure-controlling Anti-overflow Breathing Valve in Tanker

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Abstract: The effect of breathing and anti-overflow of the breathing valve mounted on petroleum tank have great influences on the safety of the whole truck. This paper designs one kind of new two stage pressure-controlling anti-overflow breathing valve. The 3D model of the breathing valve is built in Pro/E, and the kinetics analysis of the key point of the breathing valve is done in ADAMS, which can provide theoretic guidance for designer to optimize structural design. Copyright © 2013 IFSA.

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1. Introduction

The functions of the breathing valve are as below [1]: the first is inhaling or discharging air to insure the pressure in safe range when the liquid level in the petroleum truck changes, the second is preventing the oil gases or other poisonous gases from diffusing in the air, the third is insulating the flame and the medium in petroleum tank on condition of occasional fire, decreasing the pressure caused by the ascending temperature to prevent explosion. The spring type breathing valve (shown in Fig. 1) or steel ball type breathing valve (shown in Fig. 2) mounted on petroleum tank only has function of breathing but cannot prevent petroleum spillover from tanker, normal anti-overflow breathing valve (shown in Fig. 3) can prevent petroleum spillover while petroleum truck tanker tilt by means of closing the channel of the breathing valve, but the breathing

valve cannot breathe simultaneously. With these breathing valves, petroleum is easy to spill when the truck mounting petroleum tank is bumping on the load and it is dangerous [2-5]. To solve this problem, a new two stage pressure-controlling spill-protecting breathing valve is designed in this article, this breathing valve can protect the oil from spillover while the petroleum tanker tilt forward or backward, the left or the right, bump or turn on rough road. And the valve can breathe simultaneously to control the pressure in the oil can to guarantee the security.

2. Structural Design

The structure of two stage pressure-controlling anti-overflow breathing valve is shown in Fig. 4. It is composed of breathing valve body, exhaust valve spring, inlet valve spring, etc. It has function of

protecting spillover and two stage breathing. The principle of the first stage breathing is when the petroleum tanker is refueled (or the temperature increase), the pressure increase, when the pressure difference between the air in the petroleum tank and the air out of the petroleum tank is greater than 6 – 8 kPa, the pressure in the petroleum tank overcome the spring force of the exhaust valve, jack up the breathing valve plate and the exhaust valve

core, discharge the gas. When the petroleum is drawn out of the petroleum tank (or the temperature decrease), the pressure decrease, when the pressure difference between the air out of the petroleum tank and the air in the petroleum tank is greater than 2 - 3 kPa, the atmospheric pressure overcome the spring force of the inlet valve and open the breathing valve plate downward to draw in the air.

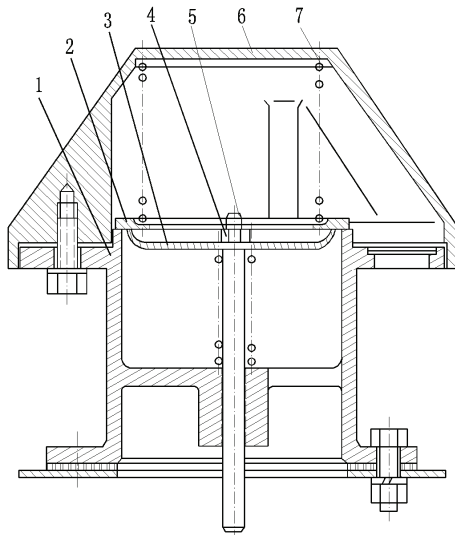


Fig. 1. Spring type breathing valve.

1. Valve body, 2. Upper valve plate, 3. Lower valve plate,
4. Inlet spring, 5. Valve bar, 6. Safeguard cover,
7. Outlet spring.

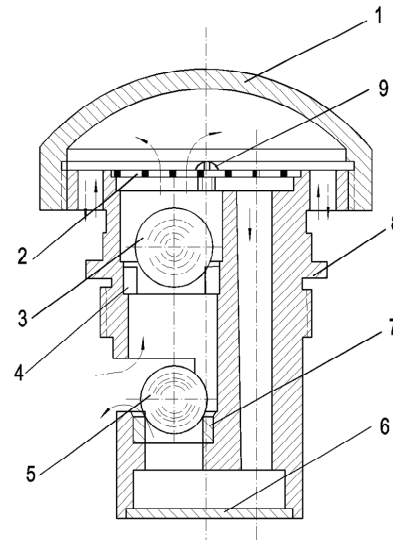


Fig. 2. Steel ball type spring breathing valve.

1. Valve body, 2. Filter board, 3. Outlet steel ball,
4. Press valve seat, 5. Inlet steel ball, 6. Bottom plate,
7. Inlet valve seat, 8. Valve body, 9. Bolt .

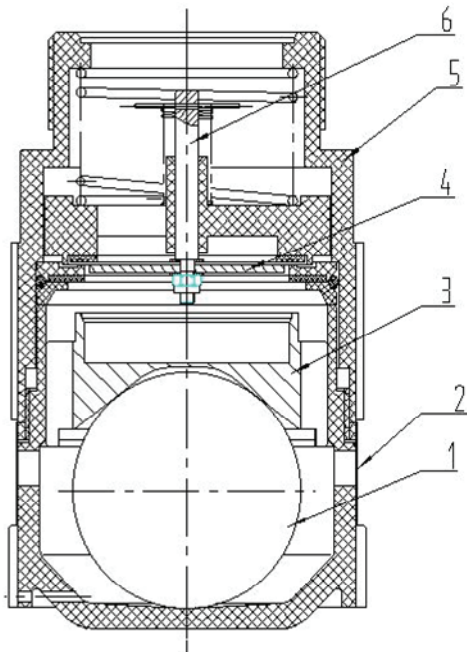


Fig. 3. Anti-overflow type breathing valve.

1. Ball body, 2. Anti-fire net, 3. Tilting valve plate, 4. Press
- valve seat, 5. Valve body, 6. Valve bar.

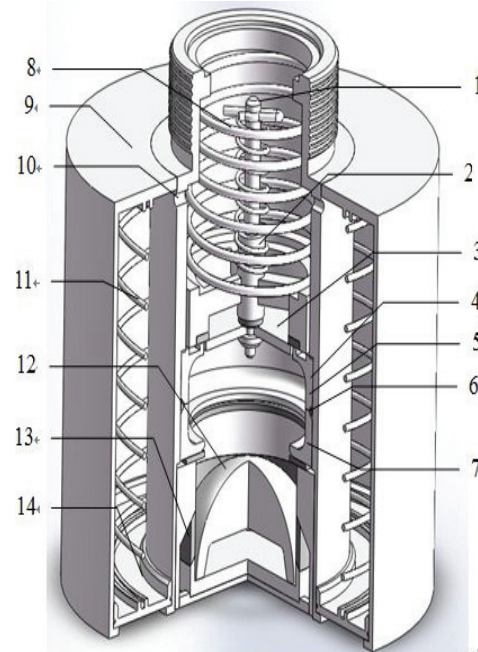


Fig. 4. Two stage pressure control anti-overflow breathing valve structure.

1. Valve bar, 2. The intake valve spring, 3. Breathing valve plate,
4. Upper valve seat, 5. "O" type ring, 6. Lower valve seat,
7. Sealing gasket, 8. Exhaust valve spring, 9. Valve body, 10. Air outlet,
11. Plate spring, 12. Sealing hemisphere, 13. Fire resistance, 14. Bottom plate.

The first stage anti-overflow principle of the breathing valve (shown in Fig. 5) is when the tanker drive in the steep slope or uneven off-road conditions, tanker tilt in a certain angle, the sealing hemisphere rotates, its sealing surface seal lower valve seat, shutting off first stage breathing ventilator, so petroleum cannot overflow out of tanker.

The second stage breathing principle (shown in Fig. 6) is when the sealing hemisphere seal lower valve seat, the first level of respiratory ventilator is

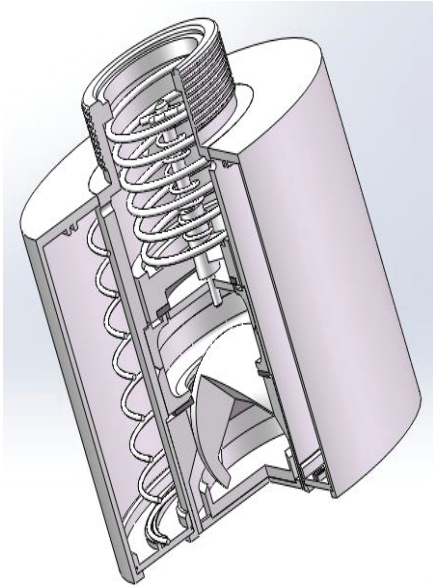


Fig. 5. The first stage anti-overflow breathing principle structure.

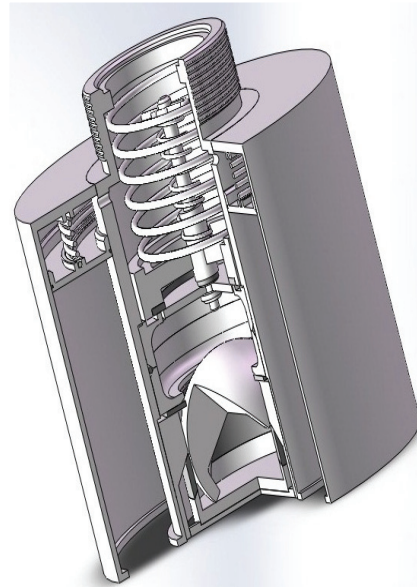


Fig. 6. The second stage anti-overflow breathing principle structure.

3. Analysis

In order to explain the influence of the vary amplitude of temperature and vary time on the breathing flow, two heat power course are used to simulate the process of the petroleum tank discharging gas while temperature is rising. The first course is with constant volume but rising temperature. Suppose that the initial pressure in the petroleum tank is critical air suction pressure P_1 , the initial temperature is T_1 , close the petroleum tank, the temperature ascend to T_2 and the pressure is P_2 , the constant volume course has the function (1).

$$P_2 = P_1 \frac{T_2}{T_1} \quad (1)$$

The second course is with constant temperature but volume expansion. The pressure in the petroleum tank is P_2 after the first course, suppose that the petroleum tank volume expand and the pressure lower to critical discharge pressure P_3 . The initial volume of the petroleum tank is V_1 , the volume after expansion is V_3 , the constant temperature expansion course has the function (2).

closed. When pressure in the tank rises to 8 kPa higher than the outside atmospheric pressure, the bottom plate overcome spring pressure and gradually rise, the air in the outer cavity of the breathing valve is expelled out of tank through the second stage air outlet and the first stage breathing channel, and then petroleum flows into the bottom of the cavity space, thereby increasing the available space in the tank to reduce the pressure in the tank.

$$V_3 = V_1 \frac{P_2}{P_3} \quad (2)$$

According to function (1) and function (2), we have:

$$V_3 = K \frac{T_2}{T_1} V_1, \quad (3)$$

where K is the ratio of breathing pressure,

$$K = P_1 / P_3.$$

The whole intake air volume of the petroleum tank with temperature ascending from T_1 to T_2 is:

$$\Delta V = V_3 - V_1 = V_1 \left(K \frac{T_2}{T_1} - 1 \right) \quad (4)$$

From function (4) we can see that when $\frac{T_2}{T_1} = \frac{1}{K}$, $\Delta V = 0$. So the pressure in the petroleum tank varies from P_1 to P_2 while the temperature ascended, the petroleum tank shouldn't

discharge air, if the temperature has risen greatly and $\frac{T_2}{T_1} > \frac{1}{K}$, the petroleum tank should discharge air.

The higher the temperature rose, the more gas should be discharged.

When the petroleum tanker with full petroleum stop on the slope road or turn over, the petroleum tank with normal breathing valve will spill, the petroleum tank with spill-protecting breathing valve will close the petroleum tank to prevent petroleum from spillover, if the atmospheric temperature rise, the pressure in the petroleum tank should increase and cause risk. The atmospheric temperature vary is usually 20°C from day to night. Suppose that the temperature of the air in the petroleum tank rise from 20°C to 40°C , the volume of petroleum tank is 4000L, the top volume of air is about 200L, when the temperature rise, the whole volume of gas space discharged is:

$$\Delta V = V_1 \left(K \frac{T_2}{T_1} - 1 \right) = 300 \times \left(0.992 \times \frac{273+40}{273+20} - 1 \right) = 11.94\text{L}$$

4. Simulation

The 3D model of two stage pressure-controlling anti-overflow breathing valve is built in Pro/E, the assembling model is saved as paraboloid (.x_t) type, and is imported in ADMAMS (shown in Fig. 7).

The material is chosen as carbon steel. A glide pair is built between the valve bar and the bottom plate, two spring dampers are built between the bottom plate and the top of the valve body, the stiffness of the spring is 1.8 Newton/mm, the damper coefficient is 3.1 Newton-sec/mm. 287.83 Newton is exerted on the bottom plate along the valve bar which simulates the force operating on the bottom plate. Associate simulation parameters are set and the simulation is done on the bottom plate MARKER_49, MARKER_53 and MARKER_55, the results of

kinematics and dynamics simulation are shown in Fig. 8 - Fig. 10.

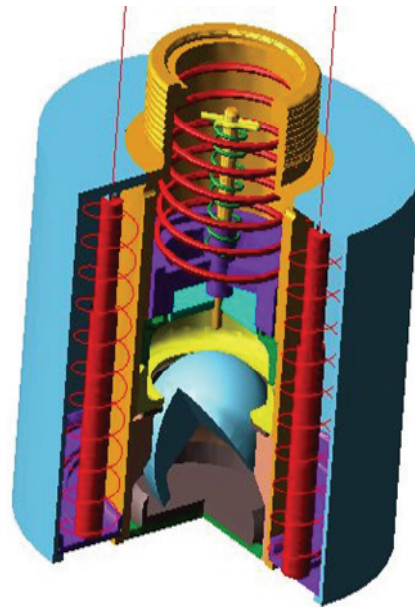


Fig. 7. ADMAMS model of the breathing valve.

5. Conclusions

We can see from the above simulation results, when the tanker drive in the steep slope or uneven off-road conditions, causing tank tilting in a certain angle, the sealing hemisphere rotate and close first respiratory passage, when the tank pressure continues to rise to 8 KPa higher than the external pressure, the bottom plate overcome spring pressure and gradually rise, the air in the outer cavity of the breathing valve is expelled out of tank through the second stage air outlet and the first stage breathing channel, and then petroleum flows into the bottom of the cavity space, thereby increasing the available space in the tank to reduce the pressure in the tank.

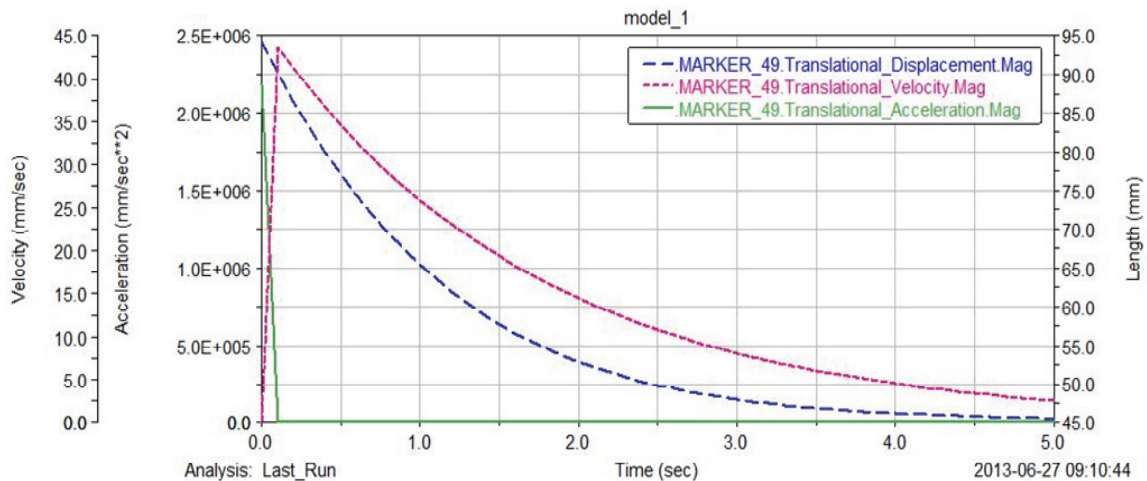


Fig. 8. Displacement, velocity and acceleration curve of the point Marker_49.

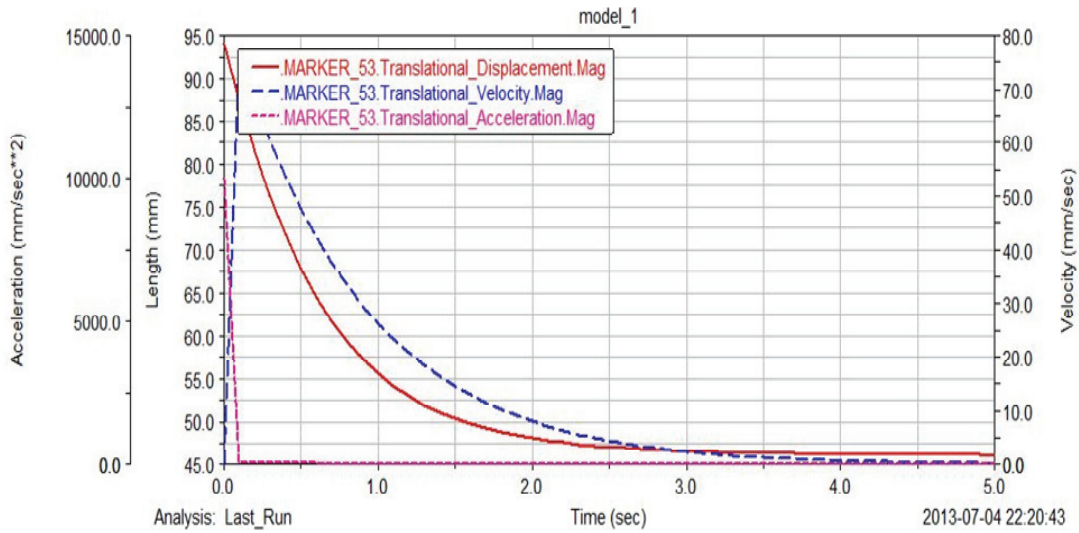


Fig. 9. Displacement, velocity and acceleration curve of the point Marker_53.

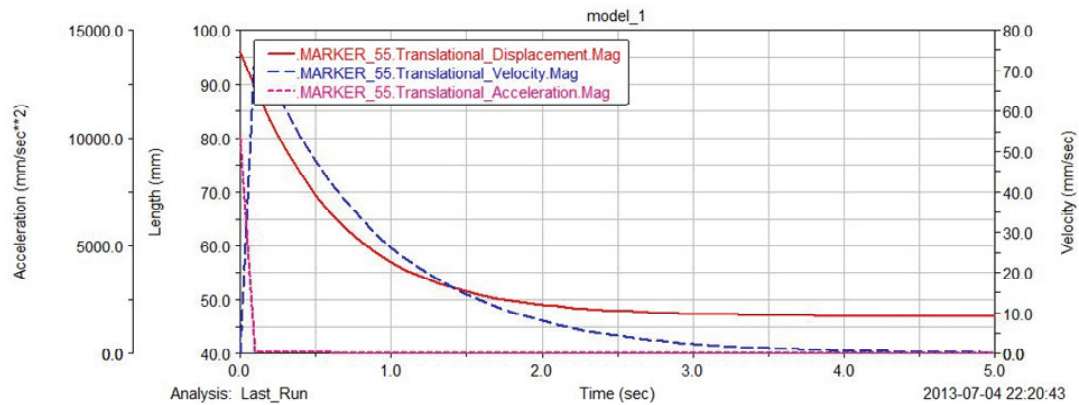


Fig. 10. Displacement, velocity and acceleration curve of the point Marker_55.

The distance that bottom plate move is about 75 mm, because the cross-sectional area of valve body cavity is 267 mm², so the volume of the exhausted gas from second stage breathing outlet for 12.84 L. It is more than theoretical exhaust total value 11.94 L, meeting the design requirement. So the design of two stage pressure-controlling anti-overflow breathing valve is accurate and effective.

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