Experimental Study of Magnetic Leaking Stoppage Device used on Gas Cylinder

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Abstract. In view of the current necessity of the road transportation safety of the dangerous goods, the lack of effective emergency blocking technology is the current issues that need to be focused on. This paper designs a kind of emergency blocking equipment for the leakage of dangerous goods transport vehicle tanks. By introducing a strong magnet and blocking with a rubber layer, the leakage on the surface of the ferromagnetic equipment can be quickly blocked. A simulated test of the designed 1.5 MPa leak stopper was carried out on a vehicle gas cylinder. The test results showed that there was no pressure drop in the gas cylinder during the holding time of 1.5MPa, and the leak plugging effect was better, which can be widely used in maintenance work. In addition, the continuous test found that the leakage limit pressure at the shoulder and bottom of the gas cylinder is lower than that at the cylinder body, and it should be focused on in the subsequent promotion process.

1. Introduction
As a major issue related to social and public safety, the road transport safety guarantee of dangerous goods has always attracted the attention of all countries in the world. Especially in China, with the rapid growth of the national economy and the rapid development of the chemical industry, the types of dangerous goods are more diverse, the nature of dangerous goods is more and more complicated, and the degree of danger is also getting higher and higher[1-3].

Dangerous goods have special physical and chemical properties such as flammable, explosive, rotten candles, and poisons. Therefore, the dangerous goods in the process of road transportation are equivalent to a flowing hazard. Once an accident occurs, it will cause huge economic losses, Casualties and environmental pollution. In addition, because of the leakage. Not only the energy and materials are continuously lost, but also the toxic, harmful, corrosive, flammable, explosive, high temperature and high pressure various liquid media are continuously leaked, causing environmental pollution, causing fire, explosion, poisoning and personal injury. In an accident, an enterprise often shuts down the entire production system due to a small leak [3, 4].

Therefore, it is necessary to develop emergency blocking technology for dangerous goods. At present, the conventional methods of plugging include mechanical plugging, riveting, and steel strapping plugging [5-7]. However, these methods have the problem of time-consuming and are not suitable for the transportation of dangerous goods. Magnetic plugging plays an active role in emergency rescue [8]. It is mainly used in some magnetically attractive pipeline media to actively...
exert the suction of the magnet itself and the plugging effect of the adhesive. This method can reduce the occurrence of chemical corrosion problems and reduce the negative impact of static electricity on the pipeline. At the same time, it also has strong pressure resistance and seismic resistance, and is suitable for emergency leak plugging of hazardous chemical transportation vehicles.

2. Device design
In order to facilitate the operation of dangerous goods transportation vehicle drivers, a magnetic pressure leak plug is designed, using a neodymium iron boron strong magnet as the magnetic source, and the outer side is covered with rubber, and the use of the two together can occur on the surface of ferromagnetic equipment The leakage is quickly blocked. Its structure is shown below:

![Figure 1. Schematic diagram of magnetic leakage plug](image)

The whole device consists of four parts: rubber layer, magnet, magnetic rotary switch, and handheld frame (See in Fig.1). The device is simple. Its operation is that the operator holds the handheld bracket, buckles the leak plug directly on the leakage point, rotates the magnetic rotary switch, and turns Squeeze down to make the leak plug magnetically attracted and attracted to the surface of the tank to achieve the effect of plugging. Because the outer rubber is relatively soft, it can adapt to the shape of the surface of the object, and can be operated to make the leak stopper fully contact with the leak point, so that no leakage occurs.

3. Test verification

3.1. Selection of plugging parameters
The tank of the dangerous goods transportation vehicle is composed of a cylinder, a head, a manhole, a gas phase and a liquid phase connection, a safety valve connection, a liquid level gauge connection, a thermometer connection, a radial anti-shock plate, a support, a sewage hole and a lifting ring (The ears) and other components, the leakage parts of which mostly occur on safety valves, valves, flanges, pipelines and tank bodies, of which the probability of leakage accidents in the heads and tank bodies is high.

The common dangerous goods transport vehicles are atmospheric or low-pressure transport vehicles. In order to meet the actual application, the test design specification is 220mm × 140mm plugging plate, built-in 50 strong neodymium iron boron magnets, generating 220 kg of magnetic adsorption force, can Free to bend. Calculate according to the following formula,

\[
S = \frac{D_o}{2} \left[ 1 - \sqrt{\frac{FR_c - \sqrt{3} p_b}{FR_c}} \right]
\]
Among them, $S$ is the thickness of the tank; $D_0$ is the nominal outer diameter of the cylinder; $R_e$ is the yield stress of the material of the cylinder body; $P_h$ is the plugging pressure and $F$ is the design stress coefficient. The calculation result shows that the theoretical pressure-bearing pressure of the magnetic leakage plugging does not exceed 1.96 MPa. Considering a certain safety factor, the design plugging pressure is 1.5MPa.

3.2. Selection of test items and test methods
Because the tanks of hazardous chemical transport vehicles are large, they are not suitable for simulation tests. The service conditions of vehicle-mounted gas cylinders are similar to those of dangerous goods tankers. In this paper, vehicle-mounted gas cylinders are used as laboratory simulation materials for the tanks of dangerous goods transport vehicles. In different positions of the gas cylinder, the defect of perforation is reserved for manufacturing, and then the plugging test under pressure is performed, and the plugging pressure is measured.

Three gas cylinders were selected for comparison in the test. All the cylinders were made a reserved holes, for testing the effect of the plugging device. The reserved holes were located at the shoulders, middle of the cylinder and the bottom of the cylinder, named as 1#, 2# and 3# cylinder, respectively. The morphology and reserved hole location of the three gas cylinders are seen in Fig. 2.

![Figure 2. Three gas cylinders chosen for the reserved hole](image)
(a) The hole made on the shoulder of the cylinder; (b) The hole made on the central part of cylinder; (c) The hole made on the bottom of the cylinder

For checking the effect of the plugging device, the gas cylinders with the plugging device covered on the reserved holes was tested by hydraulic. All the diameter of reserved hole was 8mm. The parameters of three gas cylinders and their corresponding reserved holes was seen in Table.1.

| Bottle number | 1# | 2# | 3# |
|---------------|----|----|----|
| Reserved hole location | Shoulder of the cylinder | Central part of the cylinder | Bottom of the cylinder |
| Diameter of reserved hole | $\phi$8mm | $\phi$8mm | $\phi$8mm |
| Wall thickness of reserved hole | 7.3mm | 6.1mm | 9.3mm |
The hydrostatic test process of the gas cylinders with a leak plug is as follows: drain the air in the cylinder and then increase the pressure slowly to the the design plugging pressure (1.5MPa) with the rate of pressure increase of 2.25MPa/min. The holding time of the design pressure was 1min. During the holding time, the gas cylinder should not be leaking. Then, the improvement of the pressure was continued until the bottle leaks, and the leak plug drops. The rate of pressure increase was the same as before. Also, the pressure of the bottle leakage should be recorded.

3.3. Test results

![Figure 3. Pressure–time curves of the hydraulic test of three gas cylinders](image)

Pressure–time curves of the hydraulic test of three gas cylinders was seen in Fig.3. It could be seen that after 40s, all the pressure of the cylinders reached 1.5MPa. During the pressure holding time (1min at 1.5MPa), there was no pressure drop in the gas cylinder, indicating that the gas cylinder has a good leak plugging effect. After that, the pressure continued to increase, and the three gas cylinders ruptured at 1.62MPa, 1.76MPa, and 1.69MPa, respectively, and the ruptures occurred in the elastic deformation stage of the gas cylinder, far from reaching the plastic yield stage, indicating that the cause of the leak is plugging. The drop of the device directly leads to pressure relief, and the cylinder body is intact. Table 2 summarized the test leak pressure of three gas cylinders and the corresponding results of the pressurized water volume, and calculates the elastic deformation of the gas cylinder under the maximum pressure according to the pressurized water volume.

| Bottle number | 1#     | 2#     | 3#     |
|---------------|--------|--------|--------|
| Leakage pressure | 1.62MPa | 1.76MPa | 1.69MPa |
| Pressed water ml   | 5077   | 5122   | 5089   |
| Elastic deformation | 0.71%  | 0.77%  | 0.76%  |

By further comparing the three sets of data, we found that when the reserved leak part is in the middle of the cylinder, the ultimate leak pressure that the gas bottle can withstand is the largest. Secondly, the ultimate pressure that can withstand leakage at the shoulder of the bottle is the smallest. Comparing the wall thickness of the bottle body, it is found that the wall thickness at the bottom of the bottle is the last, and the wall thickness at the middle barrel is the thinnest. The wall thickness at the leak is not directly related to the leakage limit pressure. The low leakage limit pressure at the shoulder
of the bottle and the bottom of the bottle may be due to the stress on the bottle body being higher than the stress in the middle of the cylinder at the arc transition. Leakage occurred first.

4. Conclusion
(1) A kind of emergency plugging equipment for the leakage of dangerous goods transport tanks is designed. By introducing strong magnets and cooperating with the rubber layer to block, the leaks on the surface of the ferromagnetic equipment can be quickly blocked.

(2) A set of plugging device with a plugging pressure of 1.5MPa was designed, and a simulation test was carried out on a gas cylinder using in the vehicle. The results showed that there was no pressure drop in the gas cylinder during the 1.5MPa holding time In some cases, the leak plugging effect is good, and it can be popularized and applied in maintenance work.

(3) Continue to test and find that the leakage limit pressure at the shoulder and bottom of the gas cylinder is lower than that at the cylinder body, which should be paid attention to in the follow-up promotion process.

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References
[1] S. Niu, S. V. Ukkusuri, Risk Assessment of Commercial dangerous -goods truck drivers using geo-location data: A case study in China, Accident Analysis & Prevention, 137 (2020)
[2] B. Fabiano, F. Currò, A. P. Reverberi, R. Pastorino, Dangerous good transportation by road: from risk analysis to emergency planning, Journal of Loss Prevention in the Process Industries, 18 (2005)
[3] S. Bęczkowska, The method of optimal route selection in road transport of dangerous goods, Transportation Research Procedia, 40 (2019)
[4] Q. Yu, The Research of the Safety Level for Road Transport of Hazardous Materials, China Southwest Jiaotong University Master Degree Thesis, (2014)
[5] B. Tian, J. J. Ma, J. H. Qin, Z.Y. Wan, F.L. Jiang, L.L. Han, Practical rapid plugging technology for the pipeline of oil tankfarm, China Gas Storage and Transportation, 32, (2013)
[6] F.L. Li, Application of Pressure Sealing Technology in Oil Refining and Chemical Plants, China Contemporary Chemical Industry, 45, (2016)
[7] C.Y. Xu, X.P. Yan, Y.L. Kang, L.J. You, J.Y. Zhang, Structural failure mechanism and strengthening method of fracture plugging zone for lost circulation control in deep naturally fractured reservoirs, Petroleum Exploration and Development, 47,(2020)
[8] J. Yan, Z. Chang, Y. Meng, H.B. Shan, P. Liu Development and application of magnetic-combinationpressurized pipeline leakage blocking units, China Gas Storage and Transportation, 35 (2016)