

The Analysis and Research on the Influencing Factors Affecting the Pulling-Out Force of a Certain Type of Sealing Covers

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Abstract. The sealing cover is an important part for the sealing and moisture-proof of the product. If the pulling force is too large, it will affect the use of the products. Therefore, the analysis and research on the reasons for the pulling force of the sealing cover are carried out, and the solutions are put forward.

Keywords: cartridge sealing covers, the rubber ring, the pulling-out force.

1. The Overview

The sealing covers of the cartridges are used for the sealing and moisture-proof of the product. They are mainly composed of levers, pressure plates, support plates, rubber rings and cover bodies. The structure is shown in Fig. 1. The larger pulling-out force will affect the use of products, so the analysis and research on the influence of the pulling force on the sealing covers are carried out, and solutions are put forward.

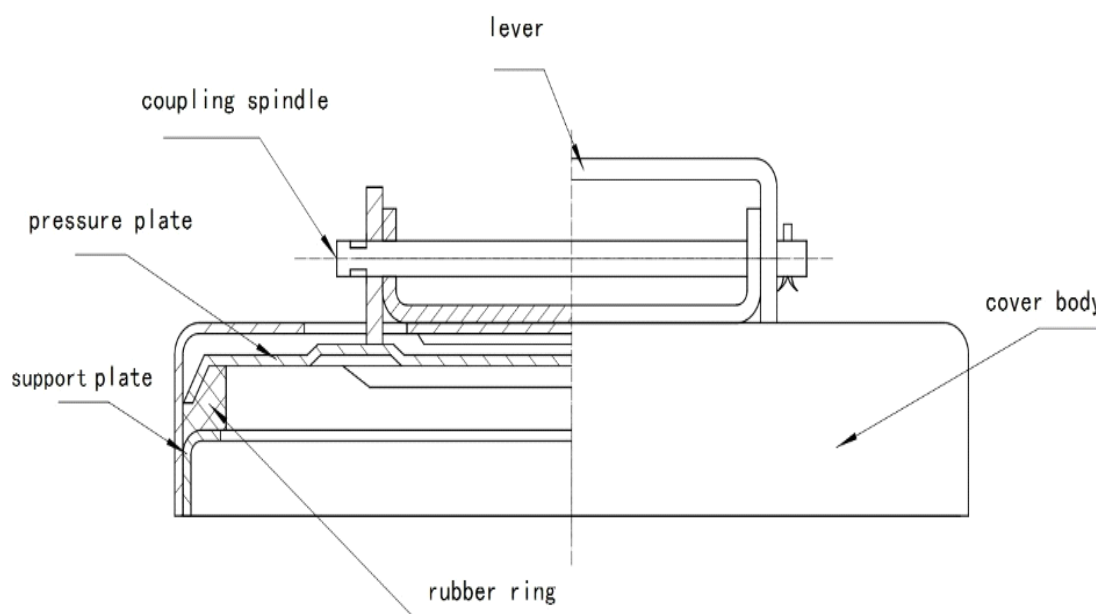


Figure 1. Schematic Figure of the Sealing Cover Structure

2. Analysis of the Influencing Factors of the Pulling-out Force

According to the principle of sealing covers, after the levers are closed, the distance between the pressure plates and the cover bodies is narrowed and the rubber rings are squeezed. The rubber rings are compressed and deformed, and the mouths of the cartridges are tightened from the circumferential direction, and are closely fitted with the pressure plates and the cover bodies, so as to realize the sealing function of the mouths of the cartridges. Before use, the levers should be loosened, and the rubber rings lose the forced constraint of the press plates, relying on their own elastic rebound, and are in a free state again, so as to pull out the sealing covers smoothly.

Seen from the sealing cover action principle, the direct reason for the excessive pulling-out force of the sealing covers is that after the levers are loosened, the rubber rings are in a free state, but the friction between them and the cartridges is not completely eliminated. Known from the principles of force, the pulling-out force equals to the friction force plus the gravity of the sealing covers, since the weight of the sealing covers is only about 0.67Kg (6.7N), so it can be ignored. Therefore, after the lever is loosened, the friction between the rubber rings and the cartridges is too large, which is the main reason for the excessive pulling-out force, The force analysis figure is shown in Fig. 2.

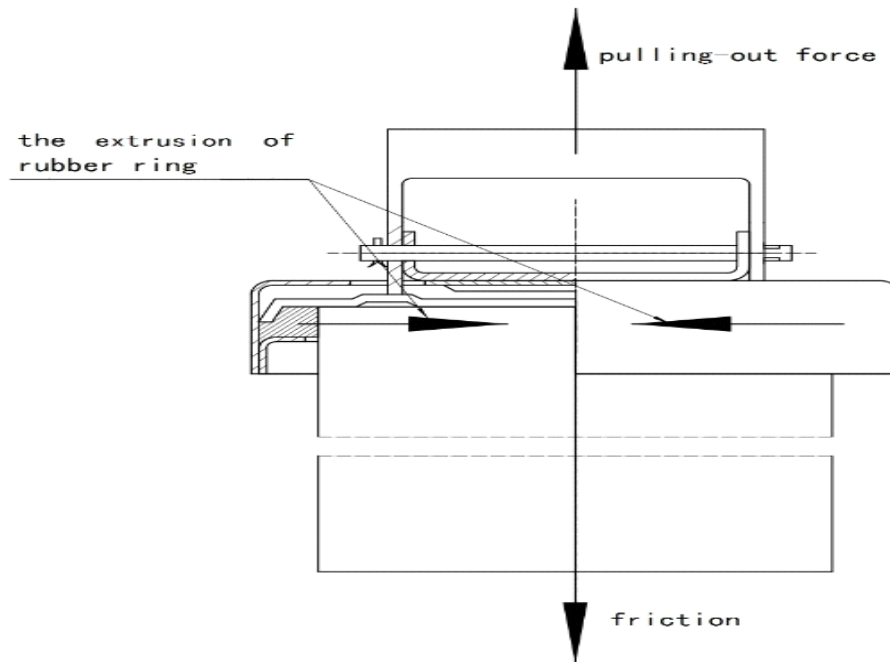


Figure 2. Force Analysis Figure of the Sealing Cover

According to the force analysis, when the sealing covers are removed, the friction between the rubber rings and the diameters of the cartridge should be overcome. When the vertical pulling-out force is greater than or equal to the friction between the rubber rings and the cartridges, the sealing covers can move upward. The friction force is the extrusion force formed by the deformation of the rubber rings and the cartridges multiplied by the coefficient of friction between the two. Therefore, the calculation formula of pulling-out force is as follows:

$$F = f \text{ friction} = f \text{ pressure} \times \mu$$

F is the pulling-out force, f friction is the friction force, f pressure is the extrusion force caused by the deformation of the rubber rings and the cartridges, and μ is the friction coefficient between the rubber rings and the cartridges.

The friction force is affected by the extrusion force and friction coefficient between the rubber rings and the cartridges. The extrusion force is mainly related to the dimension deviation of the cartridges and the rubber rings, the performance of the rubber rings, storage environments, storage time and other factors. The friction coefficient depends on the smoothness of the rubber ring surface. The influence of sulfide precipitated from the rubber surface and talc applied on the surface can reduce the friction coefficient between the rubber rings and the cartridges, thus affecting the friction force.

(1) The dimensional coordination of the cartridge mouths and the rubber rings of the sealing covers.

The sizes of the cartridge mouths are too large and in the meantime the sizes of the rubber rings are too small, which may lead to too tight assembly of the sealing covers, resulting in too large pulling-out force of the sealing covers of the cartridges.

(2) The influence of the Shore hardness of the rubber rings

The Shore hardness of the rubber rings affects the degree of softness and hardness of the rubber rings. If the Shore hardness of the rubber rings meets the requirements of the standards, it will lead to too large pulling-out force of the cartridge sealing covers.

(3) The influence of the precipitated sulphide from the rubber rings

The white material on the surface of the rubber rings is the precipitated sulphide from the rubber rings, which is inevitable after the vulcanization reaction of the rubber rings, and it will result in too large pulling-out force of the cartridge sealing covers.

(4) The assembly of the cartridges having not been applied talcum powder as required

The sealing cover process requires that "when the steel sealing cover is too tight, talcum powder should be rubbed around the rubber." If the talcum powder is not applied as required, it may cause too large pulling-out force.

(5) The temperature and humidity of the cartridges in the assembly process failing to meet the requirements

Process regulations require the temperature of the assembly workshop to be 10°C~30°C and the humidity to be 60~80%. If the temperature and humidity in the production process do not meet the specified requirements, the performance of the rubber rings may be changed, resulting in too large pulling-out force of the cartridge sealing covers.

3. Verification Test of the Influencing Factors

According to the analysis of the influencing factors affecting the pulling-out force, the possible influencing factors such as cartridges and the dimension deviation of the cartridges and the rubber rings, environmental conditions, the precipitated sulphide on rubber surface, and the talcum powder applied on the surface were tested to verify the influence on the pulling-out force.

3.1. Verification of the size of cartridges and rubber rings

Twenty cartridges were selected to test the pulling-out force of the sealing covers, and the sizes of the mouths of the cartridges were measured. The average pulling-out force of the 20 sealing covers was 114.6N, and the average diameter of the mouth of each cartridge was 127.08~127.93mm, which were all within the specified range. Through comparative analysis, no corresponding relationship was found between the pulling-out force and the diameter of the mouths of the cartridges, and the difference between the sizes of the cartridges and the rubber rings of the sealing covers was 0.58~1.27.

3.2. The verification of the Shore hardness of the rubber rings

3 sealing covers with higher and lower pulling-out force in the above test were selected respectively, and 3 sealing covers from the other batches were randomly selected to carry out Shore hardness tests, the weight measurement tests of the rubber rings and the pulling-out force tests. The test results are as table1:

Table 1. Partial Parameter Test Results of the Rubber Rings

Serial Number	Weight (g)	Shore hard-ness	Elongation at different tension values mm						Breaking Force (N)	Elongation at breaking (mm)
			400N	500N	600N	700N	800N	900N		
1	34.57	49	115	116	225	271	-	-	811	332
2	34.63	47.8	140	192	232	274	300	340	953	345
3	34.25	50.5	183	250	297	365	413	476	1113	570
4	36.22	46.9	108	146	191	228	226	300	950	343
5	35.09	49.4	140	191	235	280	310	354	1000	403
6	34.55	45.7	145	218	245	-	-	-	633	256
7	34.15	49	192	227	265	296	345	400	987	445
8	35.32	48.9	145	203	264	-	-	-	614	270
9	35.46	48.3	99	130	185	236	285	-	969	333
10	35.19	49.7	110	152	190	220	252	-	826	262

The results showed that there was no direct correlation between the weight, Shore hardness, breaking force and elongation value of rubber rings in different batches and the pulling-out force of sealing covers. No significant difference was found between the test results of sealing cover rubber rings with larger or smaller pulling-out force and those of different batches of rubber rings.

3.3. Verification of the precipitated sulfide on the rubber ring surface and the application of talcum powder

The assembled sealing covers (marked as old) and the unassembled sealing covers of the same batch (marked as new) were extracted and divided into two categories according to the Shore hardness of the rubber rings and were numbered. The sealing covers were assembled in six different schemes, including retention of sulfide, erasure of sulfide and application of talcum powder. The pulling-out force was tested 3 days later. The results showed that in the same scheme, the pulling-out force of the sealing covers with similar rubber ring hardness values was found to have different degrees of beating, without obvious rules. The pulling-out force of the sealing covers with different rubber rings hardness values was not much different, indicating that the size of the rubber rings hardness value had no obvious correlation with the size of the pulling-out force. Under the same conditions, wiping the mouths of the cartridges and the sulfide of the rubber rings was relative to the products that retained the sulfide, and removing the individual samples with obvious pulsation, the overall pulling-out force was larger, indicating that the sulfide precipitated on the surface of the rubber rings helped to reduce the pulling-out force of the sealing covers. Compared with the results of all schemes, the average pulling-out force of talcum powder coating is the lowest, indicating that talcum powder coating is helpful to reduce the pulling-out force of sealing covers.

3.4. Verification of the influence of the environmental factors

In order to verify the influence of temperature and humidity environmental factors and simulate the assembly conditions in a high temperature and humid environment, 20 batches of new sealing caps were combined with the empty cartridges, and the cartridge primer was sealed. After assembly, they were put into a 40°C drying room for 24 hours and then taken out. After natural cooling, the pulling-out force was tested. In the scheme one, a small amount of water was dipped in the sealing cover to simulate the humid environment, and scheme two was normal assembly. The average pulling-out force of scheme 1 was 321.6N, and that of scheme 2 was 181.9N. Compared with normal temperature, the average pulling-out force was 114.6N. It can be seen from the test results that the average pulling-out force of the scheme that simulated the humid environment after the sealing covers were wet was higher than that of the normally assembled sealing covers.

Comparative analysis shows that the pulling-out force of the sealing covers under high temperature conditions is higher than that under normal temperature conditions. The pulling-out force of the sealing covers under humid conditions is higher than that of the sealing covers under normal conditions. Therefore, the high temperature and humid environmental conditions will increase the pulling-out force of the sealing covers.

3.5. Verification of the composite factors

In the same batch of sealing covers and cartridges, 38 products were selected, all without talcum, to simulate the storage of 40°C and humid environment. After 18 days of storage, 10 products were taken out. After 2 days of storage at normal temperature, the pulling-out force of 10 products was tested. After 30 days, the pulling-out force of the remaining products was tested, and the size of the mouths of the cartridges and the diameters of the rubber rings were measured.

In the test results, 8 out of 38 products had the pulling-out force of the sealing covers between 167N and 520N, and 30 products had the pulling-out force of the sealing covers between 605N and 2205N, among which 20 products exceeded the serious defect index of 1000N and it would seriously affect the use of sealing covers. Through the comparison of the sizes, the dimension deviation of the cartridges and the rubber rings of sealing covers in the sample whose pulling-out force was higher than

the specified value in the figure was between 2.20mm and 2.70mm.

For the 32 cartridges extracted again from this batch of products, the outside diameters of the cartridges and the inside diameters of the rubber rings of the sealing covers were measured. The difference between the inside diameters of the 16 cartridges with high pulling-out force and the sizes of the rubber rings were also above 2.22mm, and the data of the validation test were summarized for 16 cartridges with lower pulling-out force. The results can be shown in the Fig. 3.

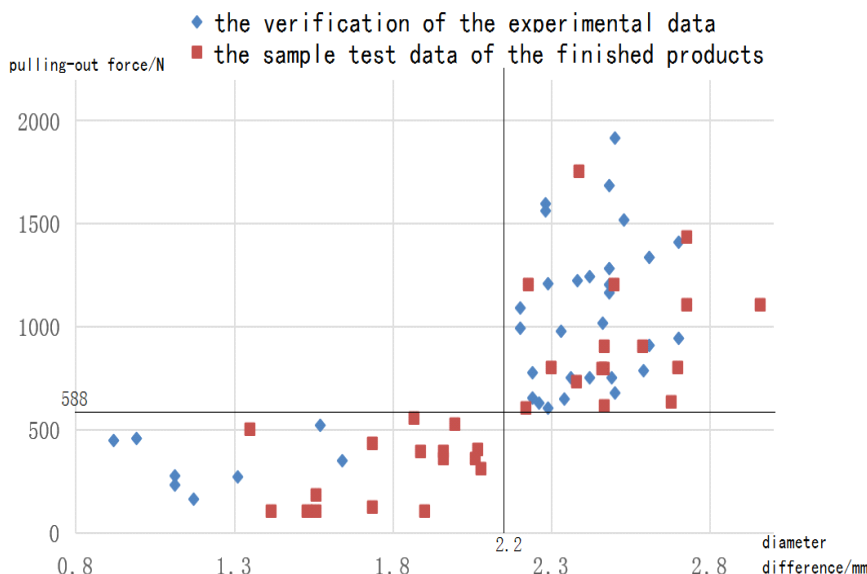


Figure 3. Distribution of Difference Between Outside Diameters of Cartridges and Sizes of Rubber Rings

The abscissa is the difference between the sizes of the cartridges and the sizes of the rubber rings of the sealing covers, and the ordinate is the pulling-out force. ◆ represents the validation of the test data, ■ represents data of another 32 products selected from the product. Through comparative analysis, 2.2mm is the dimension deviation line of 60kg pulling-out force, that is, if the pulling-out force is below 60kg, the dimension deviation between the cartridges and the rubber rings is below 2.2mm, and if the pulling-out force is above 60kg, the dimension deviation between the cartridges and the rubber rings is above 2.2mm.

Because of the characteristics of rubber products, its size will change under the influence of temperature, and size control should consider the influence of temperature. The changes of rubber sizes with temperature are reflected by the coefficient of linear expansion, which is the ratio of the change of the length of a solid substance at a temperature change of 1 degree Celsius to the length at 0°C, in 1/°C. After inquiring the relevant information, it is found that 1142 rubber is natural rubber, and its coefficient of linear expansion is $216 \times 10^{-6}/^{\circ}\text{C}$ [1]. According to the calculation of the limit temperature of 55°C, the dimension deviation of rubber rings at 55°C is about 0.01188mm, so the diameter change of rubber ring is about 0.02376mm. According to the statistical analysis, the dimension deviation between the cartridges and the rubber rings with large pulling-out force of the sealing covers is basically more than 2.2mm. Considering the diameter change of 0.02376mm caused by rubber dilatational strain under high temperature condition, the dimension deviation between the cartridge mouths and the inside diameters of the rubber rings is controlled within 2.1mm.

4. Mechanism Analysis

According to the analysis of the product assembly process, the comparison and test are carried out on all possible related factors such as the limit size fit, the sulfide on the surface of the rubber rings, applying the talcum powder, hot and humid environmental conditions, etc. Through the analysis and test, it is found that some factors have a certain trend:

Firstly, theoretically, when the diameters of the cartridge mouths are at the upper limit and the inside diameters of the rubber rings are at the lower limit, the friction between them will increase. According to the mathematical statistical analysis, compared with other batches, the diameters of the cartridge mouths of this batch of products have a larger spread and the diameters of the rubber rings have a smaller spread. During the assembly process of this batch of products, there is a high probability of a larger difference between the diameters of the cartridge mouths and the inside diameters of the rubber rings.

Secondly, the experimental results show that there is an increasing tendency of pulling-out force when the sulfide is erased. This is because the white material precipitated from the rubber ring surface is the compound agent precipitated from the inside of the vulcanized rubber, and when the internal compound of the rubber rings reaches saturation state, the rubber near the surface of the compound firstly precipitates, from the inner layer to the surface with migration precipitation, when it is in the light, ultraviolet, temperature and other special environments, the migration precipitation will be accelerated. The white powder precipitated on the surface of the rubber rings can prevent the film from sticking and plays the role of an isolating agent. Under high temperature and humid environment conditions, there is an increasing trend of pulling-out force, because of the characteristics of rubber, it will be affected by storage and the natural and artificial environmental conditions in the use process [2]. Due to heat, oxygen in the air, sunlight, wind, rain, etc., the rubber performance and appearance deteriorate with time.

Thirdly, when talcum is applied in the assembly process, the pulling-out force tends to decrease. Talcum powder is an industrial product, with lubricity, anti-viscosity, insulation, chemical inactivity and other excellent physical and chemical properties. Process regulations stipulate that talcum should be applied around the rubber rings when the sealing covers are too tight, which can reduce the friction coefficient and friction between the rubber rings and the cartridges, so as to reduce the pulling-out force of the sealing covers. The measure of applying talcum powder changes the friction coefficient between the rubber rings and the cartridges, but after the sealing cover levers are pressed, the rubber rings and the cartridges are still in the state of extrusion, which will not affect the air tightness of the cartridges.

Therefore, from the perspective of component coordination and function realization, it is believed that friction force between the rubber rings and the cartridges is too large, which leads to the excessive pulling-out force. It should be the limit size fits between the diameters of the cartridge mouths at the upper limit and the inside diameters of the rubber rings at the lower limit. The rubber rings are still in a certain degree of deformation after the sealing cap levers are loosened. The removal process of the sealing covers will be affected by the extrusion pressure of the rubber rings. The friction coefficient between the rubber rings and the cartridges will increase if the rubber rings are affected by the environmental conditions of high temperature and humidity, and it is not required to apply 100% talcum in the assembly process. The friction force is affected by the extrusion pressure of the rubber rings and the friction coefficient. When the sealing covers are pulled out, the friction between the rubber rings and the cartridges needs to be overcome. When the friction force increases to a certain extent, the test result of the pulling-out force of the sealing covers will be beyond the value specified in the figure.

5. Measures to be Taken

To make sure that the pulling-out force of sealing covers meets the requirements in the figure and ensure the quality of subsequent products, the following measures should be taken:

(1) Optimize the sealing covers assembly process: before the rubber rings are loaded into the sealing covers, evenly apply talcum on the inside surface of the rubber rings. It should be ensured that the talcum powder is not damp, and when in the high temperature and wet rainy season, talcum powder should be dried.

(2) When selecting the cartridges, it should be ensured that the difference between the inside

diameters of the rubber rings and the sizes of the cartridge mouths is less than 2.1mm.

(3) Strengthen the control of the assembly process, increase the sampling inspection proportion in the production process, and check 100% of the air tightness of the cartridge.

References

- [1] WU Zaikun, DU Xingwen, WANG Yanlin. Thermal expansion characteristics of rubber composites [C]. Proceedings of the '97CRC National Rubber Technology Symposium. Beijing: Chinese Society of Chemical Industry, 1997: 139~142.
- [2] HU Youmu. About the properties of the effect of compounds on the kinetic properties of rubber [J]. Rubber Translation Series, 1996(1):3. DOI: CNKI: SUN: SJXG.0.1996-01-001.