Study on the Accelerated Life Experiment of Mine Rubber Seals

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Abstract Mine is a kind of disposable weapon which can be kept in reserve for a long time. The quality of standing storage of mine's parts and components is an important factor affecting its life. This paper takes the rubber seal ring used commonly in mines as the research object, analyzing the failure mode and failure mechanism of its standing storage, and studying the accelerated life test of mine rubber seal in terms of the principle of accelerated test, the determination of test stress and test procedures. By processing the experimental data, this paper predicts its storage life, which is important to determine the testing cycle of maintenance and security of mine equipment during the storage, the rate of good condition of combat readiness and the costs for logistic maintenance.

Introduction

Mine is a kind of disposable strategic weapon equipment with long-term storage. The study of failure mode, failure mechanism and distribution of life of mine and its components in long-term storage process is important to the determination of test cycle of maintenance and security of mine equipment during storage and the determination of readiness and logistics costs, providing the basis for storage reliability, maintainability and supportability for the new mine equipment[1] [2]. In mine weapons, rubber seal is one of the sealing elements widely used. The merits of performance of rubber seal may determine the working reliability of mines products, and its length of life determines the degree of difficulty and costs of servicing the mine products.Taking a mine for example, mine body uses a standard O-ring with advanced self-sealing method. It does not require special installation tools and does not need so many screws to be assembled and dissembled. It can be easily operated, with maintenance and standardization improved[3] [4]. Its shallow-water sealing depends mainly on the role of radial O-ring, and its deep-water sealing performs better because with water depth and external pressure increasing, the compression force acting on the O-ring becomes greater and the sealing reliability is improved. A mine has more than 30 rubber parts, of which the majority has a sealing O-ring. Rubber mats (such as O-rings, etc.) are replaced in storage every five years.Rubber products are mostly used in the stress state. Stress has a significant impact on the chemical reaction rate of rubber. Because of the rubber structure and uneven distribution of stress, during the deformation fatigue process, stress will seriously damage the molecular structure of rubber, which is macromolecular break, generating free radicals, causing oxidation reaction of macromolecular chain of rubber, leading to rubber aging and not being able to be used.When rubber seal is stored in assembled state, due to mechanical stress, dielectric and effects of oxygen in air and temperature, permanent accumulation deformation is produced, leading to a decrease in the compression ratio causing sealing leakage and the loss of sealing performance. Accelerated aging test can give an evaluation on the expected storage life of seals[5].

1.Failure Mode and Failure Mechanisms of Rubber Seal Ring

Since rubber material has characteristics of high elasticity, ability to store up energy, good resistance to wear, insulating resistance to sound and damping, it is often applied as a dynamic and static seal, a part damping and isolating vibration, a driving part or every kind of wear-resisting piece. Rubber is an organic polymer material having a high elasticity in a wide temperature range , which is an important performance characteristic different from other construction materials. The main failure mode of rubber seal rings in mines is material aging.The degradation of material of rubber seal during the aging process is mainly due to the degradation of molecular chain and cross-linking reactions. Degradation reactions lead to molecular chains breaking, namely decreases in quantity of molecules, so the material becomes soft, sticky and loses mechanical strength. Cross-linking often make polymer material become brittle or lose elasticity.When the degree of cross-linking is low, the strength increases rapidly with the degree of cross-linking increasing and reaches a maximum value. When the degree of cross-linking is too high, the rubber strength decreases again. At this point, the material becomes hard and brittle and loses elasticity. Each kind of rubber has a vulcanization point, at which point the strength and elasticity of material is the best. But undervulcanization, overvulcanization or early natural vulcanization in storage may affect the strength and elasticity of rubber.The degrees of difficulty of aging of various rubber materials have something to do with the structures of polymer chain. Generally, miscellaneous chain polymer is susceptible to erosion of chemical factors, and the carbon chain polymer tends to be relatively stable to chemical agents, but is prone to age under the effect of physical factors and oxygen.Thermal aging: Polymer material ages under the influence of heat, which is known as thermal aging. In heating, the polymer may have the following types of reactions : (1) side chain (group) elimination reaction; (2) random decomposition reaction (3) "zipper" decomposition reaction (4) cross-linking reaction.Light aging: Polymer material ages under the action of light, which is called light aging.Energetic irradiation aging: Irradiation of rays, fast neutrons, slow neutrons and ion etc. is energetic irradiation.Oxidative aging: Polymer material reacts with oxygen and ozone, resulting in the degradation or cross-linking of polymer.The role of water in aging: Aging effects of water on the polymer material include chemical and physical effects. Chemical effects generally refer to the hydrolysis of polymer caused by water. Physical effects include: (1) the swelling plasticizing effect; (2) embrittlement; (3) tensile stress introduced on the surface of material.Rubber seal ring plays a major role in sealing mine, and is one of the main components affecting the performance of mine. Due to the weaknesses of the molecular structure of rubber itself, rubber seal ring is prone to age and be damaged, which will thus affect the life of mine. The rubber ring is used in a sealed state, therefore the thermal oxidative aging process determines its storage life. In the accelerated aging test, hot (temperature) stress is usually considered as an important factor in promoting the aging of polymer material, and the temperature as the accelerating (enhancing) factor. Thermal effect is to accelerate cross-linking, degradation,chemical changes of rubber material, macroscopically manifested as the changes of physical and mechanical properties of rubber material, such as the law that permanent compression deformabilty shows a certain change with the aging time prolonging.

2 Accelerated Aging Test of Mine Rubber Seals

2.1 Principle of Accelerated Aging Test of Rubber Sealing parts

In warehouse storage conditions, thermal stress is the main factor causing changes of performance in rubber sealing parts. Within a certain temperature range, the accelerated aging caused by aging chamber is the same as the failure mechanism under warehouse storage conditions.

The data of the accelerated aging test with the use of aging chamber can be extrapolated to the storage life at warehouse temperature. Tensile elongation is employed as the aging characteristic index for non-deformed rubber parts, and accumulated permanent compression deformabilty for deformed rubber parts.

2.2 Selection of the Test Sample

Although the structures of mine seals vary, but they basically have the same material composition, typically nitrile rubber. For convenience of test and measurement, standard samples of permanent compression deformabilty shall be selected according to GB / T7759 requirements. The semi-finished plastic material which has the same material as rubber parts is made into 6.3 ± 0.3mm high, 13 ± 0.5mm diameter cylindrical specimens (ie type B sample). There are 3 for each group, four groups, totally 12, wherein the height difference between three samples in the same group may not exceed 0.01mm.

2.3 Test Instrument

(1) Four aging chambers. Aging chamber shall comply with the relevant requirements of GB / T3512.(2) A gauge meter with 0.01mm precision.

2.4 Test Temperature

The selection of test stress depends on the difference of materials. There are four aging test temperatures of which the adjacent temperature intervals are not less than 10K. Ceiling test temperature varies due to the difference of raw rubber and vulcanizing system. Generally, the following data are referred to: 363K for natural and neoprene rubber; 383K ~ 363K for NBR, SBR, butyl and butadiene rubber; because the material of rubber parts is nitrile rubber, the test temperatures are set at: 373K, 363K, 353K, 343K.

2.5 Test Time

Termination time of test varies due to different temperatures. At the end of the test at the lowest temperature, the permanent compression deformabilty shall not be less than 50%, and the stress relaxation and elongation shall not exceed 50% of the initial value. The number of test data at each temperature is not less than 10. The time interval may depend on the changes of performance. Generally, pre-interval is shorter, and post-interval is longer.Test intervals are respectively 0.5d, 3d, 5d, 7d, 9d, 12d, 20d, 25d, 32d .... For the three higher test temperatures, the value of permanent compression deformabilty needs to reach a critical value before ending. At the end of the test at the lowest temperature, permanent compression deformabilty needs to be over 50%.

2.6 Test procedure

(1) The compression rate is employed at 25%, and the test and determination of permanent compression deformabilty is implemented according to GB / T7739. (2)Permanent compression deformabilty is tested and determined according to GB / T7759. The initial height of sample is measured when the sample has been kept for 1d after it is installed on a fixture and is kept for 1d in standard laboratory environment, and then the load is removed. The height of the sample after being aged is measured after the fixture is taken out of the aging chamber with the load removed, and then is kept for 1d in standard laboratory environment. After each measurement, the sample is returned into the fixture which is to be put into the aging chamber for the next cycle of aging. In standard laboratory environment, the original heights of four samples are measured first, according to which the heights of limiter h for each group of samples are selected. Each group of samples is placed in a fixture and kept for 1d in standard laboratory environment. Then the load is removed, and the height is measured after another 1d. As an initial sample height h0, then the samples are placed in aging chambers at temperatures of 373K, 363K, 353K, 343K respectively. (3)After the sample has been through 0.5d, 3d, 5d, 7d, 9d, 12d, 16d ......, the fixture is taken out of the aging chamber, with the

load removed. After it is kept for 1d in a standard environment, its height is measured, being named h2. After each measurement, the sample is returned into the fixture and aging chamber for the next cycle of aging. (4)For the sample height h2 measured at each time interval, according to the formula:, each permanent compression deformability value is calculated. The median of the calculation result recorded in the raw data of permanent compression deformability is shown in the attached table.

2.7 Test Data Processing

The data of permanent compression deformabilty of rubber seal samples in the accelerated aging test is shown in Table 1. With the least square method for processing the data of permanent compression deformabilty, storage life of rubber seal is 6.04 years.

Table 1 Data of Permanent Compression Deformabilty of Rubber Seal Samples

Time	373K	363K	353K	343K
0. 5	0.808	0.848	0.876	0.921
3	0.596	0.642	0.725	0.842
5	0.49	0.576	0.66	0.75
7	0.424	0.53	0.59	0.689
9	0.351	0.464	0.536	0.632
12	0.27	0.346	0.47	0.586
16	0.238	0.325	0.438	0.52
20	0.177	0.272	0.366	0.461
25		0.199	0.327	0.434

3 Conclusions

Setting the permanent compression deformabilty as the evaluation index, through the accelerated life test of temperature stress in the rubber sample of rubber seals, we found out that the lifetime of mine rubber seals which are kept in storage below 25 ℃ is six years. Storage conditions of the environment is a major factor affecting the storage life of mine. With ambient temperature increasing, the failure rate of mines increases significantly, thus improving the storage environment is an important measure to extend the storage life of mine rubber seals.

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