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EFFECT OF COMBINED MECHANICAL STRESS AND SALT SPRAY AGING ON DYNAMIC FRICTION BEHAVIOR OF O RINGS

TRACK OR CATEGORY
Seals

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INTRODUCTION

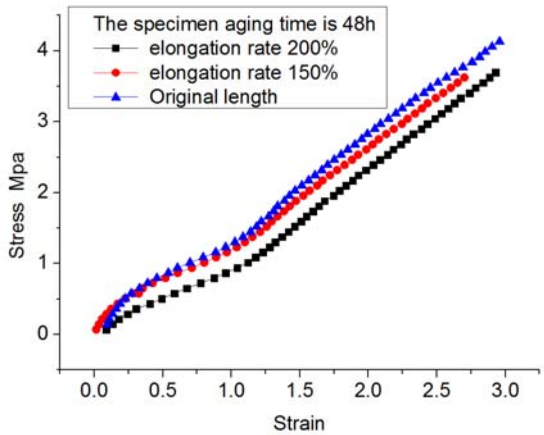
Rubber seals has become one of the key components in industry sealing devices. However, environment becomes more severe due to ocean application fields. Combined ageing of salt spray, high temperature and mechanical stress have a great influence on mechanical properties of rubber sealing materials, which leads the decline of rubber sealing performance [1-2]. The mechanical properties of rubber under salt spray aging have been studied by scanning electron microscopy and Fourier transform infrared spectroscopy [3]. The significant changes in tensile strength and elongation at break also indicate the severe degradation in air. Besides, finite element simulation was used to study the sealing contact stress, oil film thickness and surface roughness, molecular interaction between seal/rod interface [4-5].

In this paper, a combined salt spray and mechanical stress test platform was developed for studying aging process of rubber materials. Then, influence of mechanical stresses and salt spray aging on dynamic friction behavior of rubber materials have been investigated, and the coupled aging mechanism of rubber materials have been studied by Nicolet 380 ATR-FTIR and DSX510. Finally, a friction finite element model of O ring has been developed, which considered the effect of combined mechanical stress and salt spray aging. It can be seen that combined salt spray and mechanical stress aggravate rubber aging reaction; contact pressure decreases obviously, when aging time and tensile strain increases.

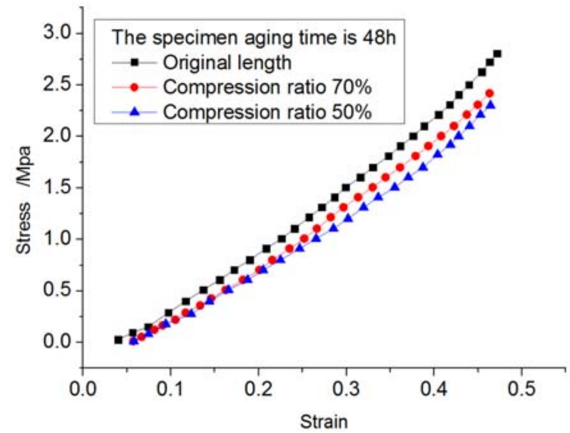
AGING TEST

The salt spray tests of rubber have been carried out according to standard of GB/T 35858-2018 under the elongation rate of 150%, 200%, the compression rate of 50%, 70%, 90% in the ageing time of 48h, and the ageing time of 12h, 24h, 36h, 48h with the compression rate of 70%.

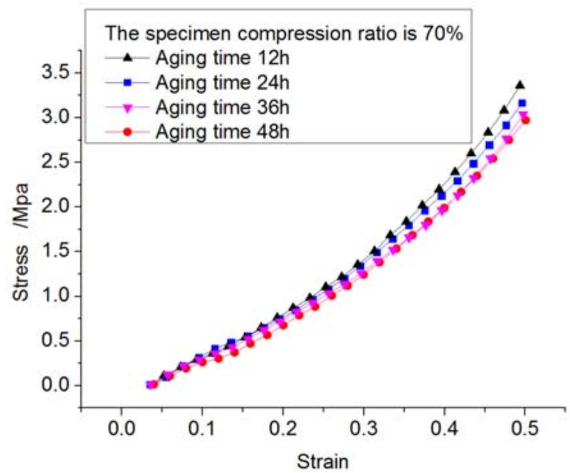
Seen in Figure1, it can be seen that when the elongation rate and ageing time increases, the elastic modulus of The rubber decreases, which indicate that the mechanical stress accelerates the aging of the sealing rubber.



(a) Effect of Tensile stress



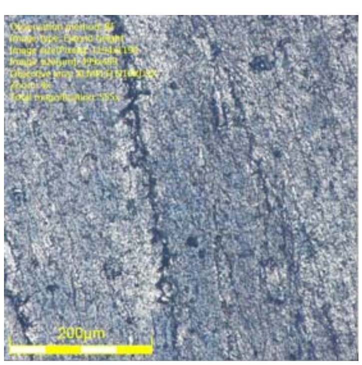
(b) Effect of compressive stress



(c) Effect of times

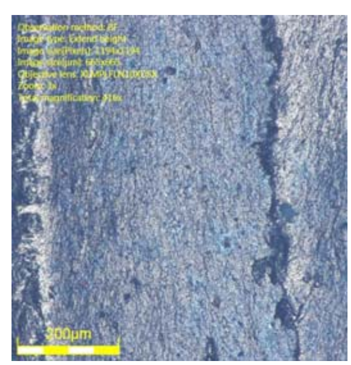
Figure 1. Effect of salt spray and mechanical stress on rubber aging.

The tensile fracture surface topography was studied by DSX 510 under the elongation rate of 150%, 200%, seen in Figure 2. Results indicate that when the elongation rate increases, the crack becomes larger. The fracture mode of rubber tends to be more brittle fracture under mechanical stress, and there are more voids in the fracture surface, especially under large tensile stress.



(a) original length

(b) elongation rate 150%



(c) elongation rate 200%

Figure 2. Surface topography of rubber aging time at different elongation rates.

Figure 3 shows the infrared spectrum results of rubber under different compression rate after aging of 48h. Results show that when rubber is under mechanical stress, the molecular chain first shift due to the role of mechanical stress. This greatly restricts the various relaxation behavior of the molecular chain, and reducing the activation energy of the fracture of the molecular chain. So the molecular chain is more prone to fracture, which resulting in more free radicals, chain degradation reaction intensified.

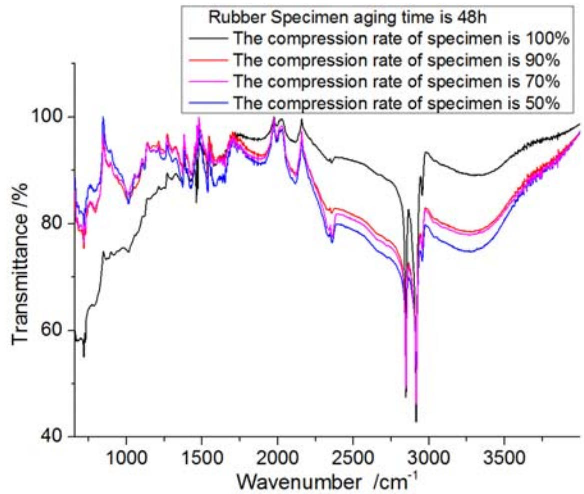
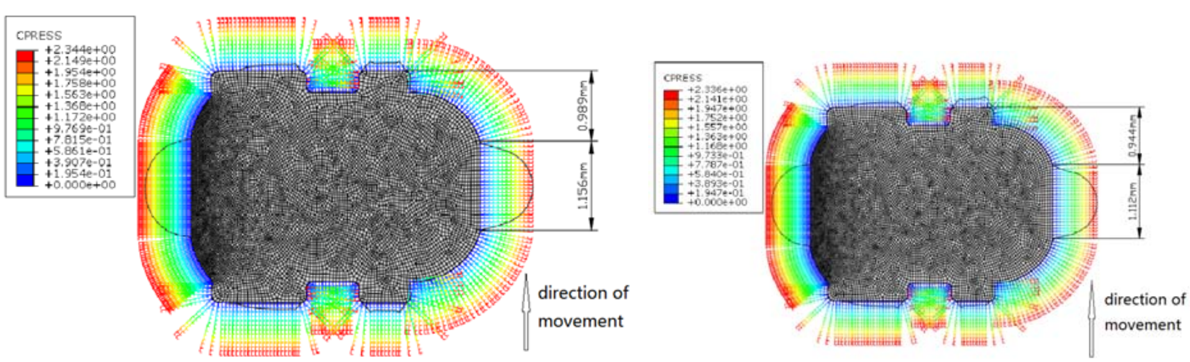


Figure 3. Infrared spectroscopy analysis of rubber aging.

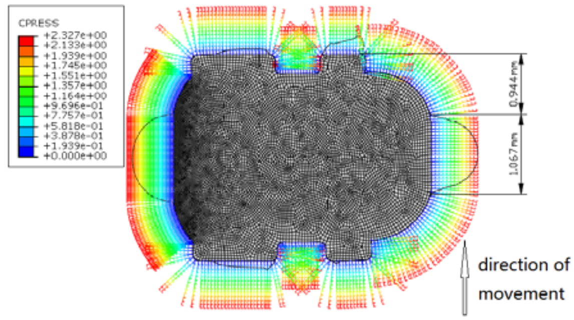
FINITE ELEMENT MODEL

In order to study the dynamic friction characteristics of the O rings during movement, a finite element simulation model of the cylinder seal was developed by ABAQUS. It is assumed that the metal surface is smooth, which ignoring the surface roughness of the metal material; it is also set to be a rigid body with regardless of the deformation. The C3D4H meshing type is used. Penalty contact model is used between rubber and metal, which the coefficient is 0.1.

Seen in Figure 4, the initial contact length of 1.156 mm was gradually reduced to 1.067 mm in the dynamic friction process of sealing ring. It can be seen that the maximum contact pressure also decreases.



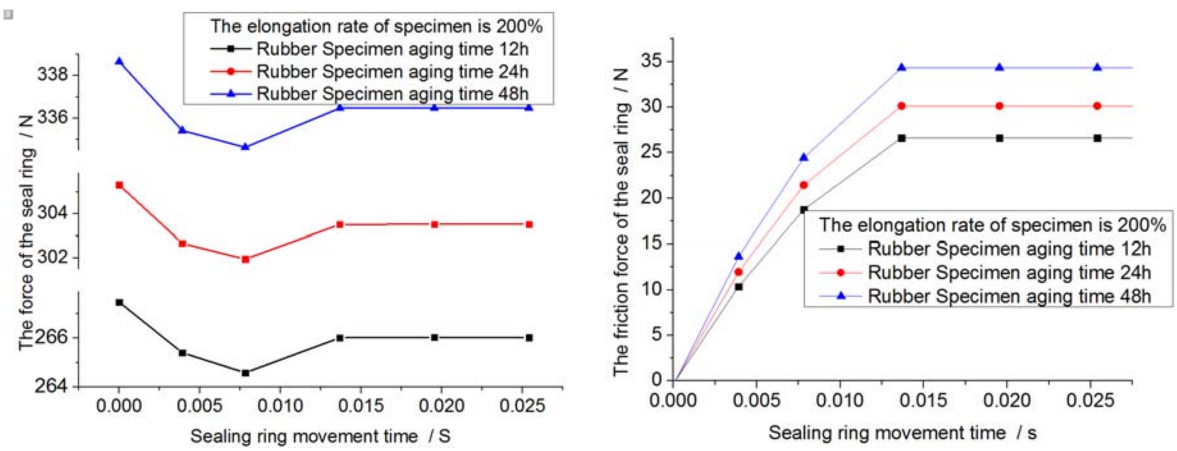
(a) Static friction **(b) Transition friction**



(c) Dynamic friction

Figure 4. Dynamic friction of the seal ring.

Seen in Figure 5, the normal force of the seal ring decreases firstly, then increases and remains stable in friction process; the normal force and frictional force increases when aging time increases. When elongation rate increases in aging process, the normal force of the seal ring decreases, which affecting the sealing performance.



(a) Normal force **(b) Friction force**

Figure 5. Effect of aging on the contact forces.

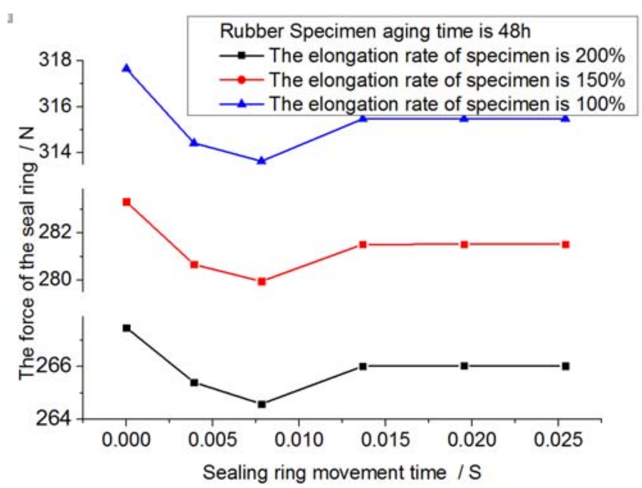


Figure 6. Normal forces in dynamic friction.

RESULTS AND DISCUSSION

The effect of combined mechanical stress and salt spray aging on the dynamic friction process was studied by experiment and simulation. According to the analyses results above, we mainly have the following points:

(1) When the aging time increases, the elastic modulus of the rubber increases, and the mechanical stress accelerates the aging process of the rubber.
(2) The maximum contact pressure and contact length decreases in dynamic friction process.
(3) When elongation rate increases in aging process, the normal force of the seal ring decreases, which affecting the sealing performance.

ACKNOWLEDGMENTS

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REFERENCES

[1] Bleszynski M, Kumosa M. Silicone rubber aging in electrolyzed aqueous salt environments. Polymer Degradation and Stability, 2017, **146**:61-68.
[2] Zhu Z, Jiang C, Cheng Q, Qian Cheng, Jianwei Zhang, Shaoyun Guo, Ying Xiong, Baoqiang Fu, Wenlong Yang, Han Jiang. Accelerated aging test of hydrogenated nitrile butadiene rubber using the time–temperature–strain superposition principle. Rsc Advances, 2015, **5**(109):90178-90183.
[3] Kashi S, Varley R, De Souza M, Al-Assafi, S., Di Pietro, A., De Lavigne, C, Bronwyn Fox. Mechanical, Thermal, and Morphological Behavior of Silicone Rubber during Accelerated Aging. Polymer-Plastics Technology and Engineering, 2018:**57**:1687-1696.
[4] Lv X R, Wang H M, Wang S J . Effect of swelling nitrile rubber in cyclohexane on its ageing, friction and wear characteristics[J]. Wear, 2015, **328-329**:414-421.
[5] Bhaumik S, Kumaraswamy A, Guruprasad S, Bhandari. Investigation of friction in rectangular Nitrile-Butadiene Rubber (NBR) hydraulic rod seals for defence applications. Journal of Mechanical Science and Technology, 2015, **29**(11):4793-4799.

KEYWORDS

Applied Tribology: Aviation, Seals: Elastomeric Seals, Friction: Friction Mechanisms.