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Jian Wu, Jiyi Dong, Youshan Wang, Bipin Kumar Gond

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Thermal Oxidation Ageing Effects on Silicone Rubber Sealing Performance

Jian Wu[1*], Jiyi Dong[1], Youshan Wang[1], Bipin Kumar Gond[2]

[1]Center for Rubber Composite Materials and Structures, Harbin Institute of Technology at Weihai, Weihai, China

[2]Mechanical Engineering Department, Indian Institute of Technology Kanpur, Kanpur, India

Phone +86-0631-5680913, Fax +86-0631-5687930, e-mail: wujian@hitwh.edu.cn

Abstract: Silicone sealing material, because of their excellence performance, are gradually replacing traditional materials and widely used in various sealing devices. They are known for their aging and degradation problems, stockpile reliability problems and service life, and hence they became a focus of attention. In this paper, thermal oxidation aging test, XPS and NMR analysis are used to analyze the aging mechanism of silicone rubber. Then the FEM contact model before aging and after aging is developed to study the influence of aging on sealing performance. The results show that hardness and compression set increases with aging of silicone rubber; more surface roughness and aging can lead to a degradation of sealing performance. It helps staff to estimate the sealing performance of silicone rubber in further research.

Keywords: Silicone rubber, accelerated aging, sealing performance, aging mechanisms, surface roughness

1. Introduction

Silicone rubber seal is a key component to ensure normal operation of equipment, and it is widely used in the aerospace industry due to excellent chemical and mechanical properties. However, there are also many aging problems when long-term using, which leads to change in physical properties as well as in rubber surface roughness [1,2]. It has a great influence on static sealing performance, especially when the rubber seal is contacted with smooth metal surfaces. Therefore, studying the aging effect on static sealing performance of silicone rubber seal is particularly important.

In recent years, some research works have been reported on the effect of aging. It is found that rubber surface will crack and the tensile strength will decline, when it is used under different environment for a long time, like drying under high temperature, humidity [3] under moderate or high temperature, or even under ultraviolet light [4] etc. Besides, the hardness of the specimen, tensile strength and the elongation at break will also increases [5,6] with the exposure of time. By using oven accelerated aging test, the permanent deformation and stress strain behavior of silicone rubber have been analyzed by many scholars [7-9]. Others took on a systematic study on the dynamics [10-12] of rubber aging, but less study of aging mechanism [13,14] was took on. Tg DMA [15-17] , FTIR [18] or TGA and FTIR coupling technique [19] XPS [20,21] NMR [22,23] are the common methods used to test the rubber specimen after aging. As different aging can lead to different surface roughness, some researchers also studied the effect of surface roughness on sealing performance based on the contact theory. The rough surface was modeled as spherical asperities with the techniques of random process theory [24]. Then, the parabolic asperities with different height and curvature were used to describe the rough surface, which was a slightly more accurate approximation than the spherical asperities [25]. Based on reasoning about the stress distribution over the area of contact at different magnification levels, a contact theory with the self-affine fractal surfaces was proposed [26], and the self-affine roughness was defined by the RMS amplitude, the correlation length and the roughness exponent [27]. Moreover, the Boundary Element Method is applied to rough contact theory to analyze the self-affine surface having a random roughness [28]. However, the above contact models and methods are focus on the establishment of metal surface topography, which is not suitable for the contact between rubber and smooth metal surface [29]. Therefore, it is necessary to establish the surface topography of silicon rubber seal. Rough rubber surface can be modeled as consisting of many spherical asperities of varying heights but having the same radius [30]. By using a modified Hertz theory, the contact model including a viscoelastic sphere and a rigid flat was used to describe rubber-metal contact, and the single-asperity of rubber surface was extended to the multi-asperity case based on statistical approach [31].

In this paper, aging test and finite element analysis are used to study the effect of aging on sealing performance. Firstly, thermal oxide aging test of silicone rubber is carried out to study the physical properties variation with aging. XPS and solid-state NMR analysis are used to analyze the aging mechanism of silicone rubber under different condition. Secondly, a FEM contact models are established by using ABAQUS to analyze the influence of surface roughness on sealing performance, also, the effect of aging on static sealing performance is studied.

2. Experiments set

2.1. Aging testing

The silicone rubber thermal oxidation ageing test is conducted base on ISO188. Four samples are placed in each clamp. The distance between each sample is more than 5mm and the compression ratio is 25%. The silicone rubber