Research on the properties of compressed rubber sheet gasket reinforced by non-asbestos fiber

Peng Du\textsuperscript{1,2,*}, Jianzhi Tuo\textsuperscript{1}, Xinning Wang\textsuperscript{3}, Sujiang Xie\textsuperscript{4}

\textsuperscript{1}College of Electromechanical Engineering, Weifang Engineer Vocational College, Weifang, Shandong, SD 536, China
\textsuperscript{2}College of Electromechanical Engineering, Qingdao University of Science and Technology, Qingdao, Shandong, SD 532, China
\textsuperscript{3}College of foreign languages, Qingdao University of Science and Technology, Qingdao, Shandong, SD 532, China
\textsuperscript{4}School of Mechanical and Power Engineering, East China University of Science and Technology, Shanghai, SH 21, China

*Corresponding author’s e-mail: Pok009@126.com

Abstract. In the past, the asbestos as a kind of reinforcing fibre is used in the sealing field because of its excellent properties. With the prohibition of asbestos, the sealing gasket made of non-asbestos fibre has become a research hotspot. Fibre and rubber, as important components of compressed rubber sheet gasket reinforced by non-asbestos fibre, play a key role in the performance. In this paper, sealing materials with different properties are prepared by adjusting the content of fibre and rubber respectively. The tensile strength, compression-resilience, creep relaxation and leak rate of the non-asbestos gaskets were tested and analysed. The results show that the sealing gasket has the best comprehensive performance when the content of aramid fibre is 10\%, mineral fibre is 20\%, natural rubber is 3\% and nitrile butadiene rubber is 12\%.

1. Introduction
Sealing gasket is a kind of sealing element, which is widely used in the fields of engineering machinery, petrochemical industry, automobile and so on. In the sealing industry, especially in the field of non-metallic gasket, the sealing material which is made of asbestos and rubber has been widely used for a long time. In recent years, with the prohibition of the use of asbestos, non-asbestos fiber materials have become a research hotspot. It is found that one kind of non-asbestos fiber material can not achieve the desired effect. At present, most of the solutions are to mix a variety of asbestos-free fibers as a substitute for asbestos fiber materials.

Compressed rubber sheet gasket reinforced by non-asbestos fiber made of various non-asbestos fibers can be close to the gaskets made of asbestos rubber sheet in some performance. For example, asbestos-free sealing gasket is composed of aramid fiber, mineral fiber and carbon fiber as reinforcing fiber materials, together with nitrile rubber, graphite carbon black and vulcanizing agent. Sujiang Xie proposed a kind of asbestos-free static sealing material and its preparation method, which is made from the following weight ratio: rubber(21--40)\%, vulcanizing agent (3--7)\%, white carbon black (2--10)\%, kaolin (5--10)\%, mica powder (8--16)\% and aramid fiber (11--30)\%.
To sum up, although the asbestos-free sealing material in some performance up to the level of asbestos gaskets, asbestos-free sealing gasket cannot reach the level of asbestos-rubber sealing material. This is due to the obvious difference between asbestos fiber and asbestos fiber, such as the length of asbestos fiber is generally shorter than that of asbestos fiber, the degree of fibrillation is not as high as that of asbestos fiber, and the non-asbestos fiber usually has a negative charge, it is difficult to bond with rubber. The above problems make it difficult to overcome some problems in the process of choosing non-asbestos fiber to replace asbestos, such as poor closeness between fiber and rubber, and great difficulty in the preparation process. With the increasingly harsh working environment, such as the pressure and temperature of the working medium, the performance requirements of asbestos-free sealing gaskets are further improved. In order to obtain asbestos-free gasket material with excellent comprehensive performance, this paper studies the influence of various factors on the sealing performance.

2. Material selection

2.1. Non-asbestos fibre
There are many different kinds of fibres on the market at present. In the selection of raw materials, non-asbestos fibre material has a great influence on the tensile strength, creep-relaxation, compression-resilience of the gasket. It is found that aramid pulp has a large specific surface area, good dispersion and mixing performance, which enables aramid pulp to fully contact with rubber, filler and other raw materials, which is the key to fully play its role as a reinforcing fibre. This makes it possible to give full play to the role of fibre as reinforcing fibre. Though the comprehensive performance of non-asbestos sealing material prepared by aramid pulp is better than that of other non-asbestos fibres, the cost is higher. The response is that aramid pulp is usually mixed with other fibres to improve the competitiveness of sealing materials. In this paper, mineral fibre and aramid fibre pulp are selected as reinforcing fibre.

In order to study the influence of fiber content on the performance, sealing gaskets with different fiber content were prepared and their performance was compared. The ratio of aramid pulp content to mineral fiber is 1:2, in which aramid pulp content included five grades, respectively is 5%, 7.5%, 10%, 12.5% and 15%.

2.2. Elastic adhesive
As an elastic binder, rubber is used to bond the fibre material with other components in the sealing gasket. The rubber improves the gasket sealing performance, media resistance and compression-resilience. Up to now, there are hundreds of kinds of rubber. Natural rubber, nitrile rubber, butyl rubber, neoprene, ethylene propylene rubber and silicone rubber are commonly used in the preparation of sealing gaskets. In order to study the influence of rubber content on the performance, sealing gaskets with different rubber content were prepared and their performance was compared. The ratio of Natural rubber content to nitrile rubber was 1:1, in which rubber content included five grades, respectively is 10%, 12.5%, 15%, 17.5% and 20%.

3. Experimental study on sealing performance
In order to analyse the influence of different material content on the comprehensive performance of gaskets, this paper conducted tests from four aspects: tensile strength, compression-resilience, creep relaxation and leak rate.

3.1. Performance test
3.1.1. Tensile strength
Tensile strength is used to indicate the resistance of a gasket to tension under practical conditions. The higher the tensile strength of the gasket, the more reliable the gasket is under the condition of higher
compression force and medium pressure. The dumbbell shape is specified in test standard ASTM F152. Put the sample in the oven of 100℃ for 1h before the test, the tensile speed at test is 305mm/min. The Japanese standard JIS K601 and the Korean standard KSL5406 are similar to ASTM 152, both of which use dumbbells. However, there is a slight difference in the tensile speed. They all set the test speed at 300mm/min. ASTM F152 - 95(2009) is used in this paper. This paper adopts ASTM F152.

3.1.2. compression -resilience properties
The compressive-resilience reflects the compressive deformation ability of the seal gasket under compression load and the rebound ability after unloading the load.

Compression-resilience can be tested according to different test standards, such as ASTM F36-Standard Test Method for Compressibility and Recovery of Gasket Materials, BS7531,DIN52913 and so on. ASTM F36-99(2009) is used in this paper.

3.1.3. creep-relaxation
Creep relaxation of gaskets is an instantaneous stress-strain behaviour. As the strain of the gasket increases, the residual stress on the gasket will decrease and the bolt pretension will be lost. When the residual load of the gasket drops below the minimum required load, the sealing surface will leak. It can be seen that it affects the reliability of sealing gasket and determines the working life of sealing system. ASTM F38 is selected as the test standard in this paper

3.1.4. Sealing performance
The sealing property of gasket is the most important index to measure the sealing gasket. The sealing performance of gasket is realized by various properties of gasket, which requires the material to have good tensile strength, compression-resilience, creep relaxation and dielectric resistance, as well as good compact performance. The sealing performance test method in this paper refers to DIN3535.

3.2. Performance test results

3.2.1. Performance test of non-asbestos fibre with different content
When aramid fibre content increases gradually from 5% to 10%, the tensile strength, creep relaxation and resilience can be improved obviously. At the same time, the leakage rate of gasket decreases obviously, which is mainly because with the increase of fibre content, the constraint effect on matrix deformation is strengthened. In practical application, the performance of sealing gasket is related to the factors such as fibre orientation, fibre dispersion and elastic adhesive binding. In order to improve the performance, simply increasing the fibre content cannot meet the needs. When aramid pulp content reaches more than 10%, creep relaxation rate, compression-resilience and tensile strength no longer increase with the increase of fibre content. This is due to non-asbestos fibres such as arena pulp affect the bonding effect with negatively charged rubber. At the same time, the increase of fibre content lead to the increase of material defects, resulting in the decrease of composite strength and resilience. The experimental results show that the sealing gasket has the best comprehensive performance when the content of aramid fibre pulp is 10% and the mineral fibre is 20%.
Fig. 1 Effects of the fibre contents on the properties

3.2.2. Performance test of rubber with different content

(a) compression -resilience properties          (b) tensile strength

(c) creep-relaxation                                            (d) leak rate

(a) compression -resilience properties          (b) tensile strength
With the increase of rubber content, the leakage rate and creep relaxation rate of gasket decreases obviously. The compressive resilience and tensile strength are significantly improved. This is mainly related to the properties of rubber such as large elasticity, high elongation at break and high creep rate. However, rubber is sensitive to the surrounding environment and working medium, we should try to reduce the content of rubber as long as we meet the requirements of working conditions. To sum up, we only need to determine the rubber content to meet the basic performance requirements of the sealing gasket. The test shows that the rubber content of about 15% makes the sealing gasket can obtain good comprehensive performance.

4. Conclusions
When the fibre content is low, the overall performance of the sealing gasket is poor. High fibre content will not only improve the properties of the board but also lead to increased production costs and poor process performance. Finally, the content of aramid fibre and mineral fibre are determined to be 10% and 20% respectively.

The increase of rubber content will improve the sealing performance of gasket, but it will lead to the increase of creep relaxation rate. The high creep relaxation rate will make the gasket leakage risk in long-term use, reduce the reliability of the sealing system, and even cause major accidents.

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