

Study on Sub-vehicle Cable Sealing Materials

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Abstract: This paper analyses the physical and chemical properties of rubber, plastic and graphite as sealing materials. Polyurethane, PTFE and graphite are testified to be good sealing materials. Among these materials, polyurethane demonstrates high potential of changing property. Therefore polyurethane is studied for modification to improve sealing effects.

1. Introduction

When sub-vehicles are diving deep, cables installed would be under threat of water leakage, which might bring about danger to the crew and vehicles. Currently, cable sealing structures in sub-vehicles are mostly traditional sealing materials. The advantages of these materials are simplicity, convenience, cheap cost and wide usage. The disadvantages are also obvious: poor sealing effect, heavy abrasion and short life span[1]. In order to satisfy the structure requirements in cable seal, gasket rings are considered to be better alternative, based on which we study the material choices for sealing gaskets.

2. Characteristic analysis of sealing materials

2.1 Rubber Materials.

Rubber materials are a group of special materials. They have unique characteristics that could play a huge role in sealing constructions[2]:

a. The combination of Young's modulus E and major dislocation stretching ratio (100% or even higher) helps rubber materials adjust to sealing structures and contact interfaces, while the contact stress remains within an acceptable range.

b. Theoretic limited Poisson's ratio (approaching 0.5) makes rubber disperse static stress equally to each dimension.

c. Rubber materials can easily adjust to cavity shapes because of low shear modulus G .

Table 1 shows properties and applications of some rubbers, which offers reference to choosing available sealing rubber materials.

TABLE 1. PROPERTIES AND APPLICATIONS OF RUBBERS

Name	Advantage	Disadvantage	Temperature	Application
NR	High elasticity, stretching strength, tear-resistance, electricity insulation, easy composite with other materials	Bad oxygen and ozone resistance, aging. Bad chemical solvent (oil, acid and alkali) endurance	-60°C~80°C	Tyre, shoes, pipe, cable cover
SBR	Abrasion-resistance, anti-aging and heat-resistance better than NR	Low elasticity, tear-resistance; bad processing capability, esp. adhesiveness	-50°C~100°C	Tyre, board, pipe

CR	Oxygen and ozone-resistant, NOT flammable, oil and other chemical solvent enduring, acid and alkali adaptable, anti-aging and airtight	Bad coldness endurance, poor specific gravity and electricity insulation, high cost, difficult to store and etc.	-45°C~100°C	Cable cover, molded products, sealing gasket, adhesiveness
NBR	Heat-resistant, airtight, abrasion-resistant and great adhesiveness	Poor strength and elasticity, poor acid and polarity solvent endurance, bad insulation	-30°C~100°C	Oil pipe, sealing materials
HNBR	High mechanical strength and abrasion-resistance	High cost	-30°C~150°C	Oil and heat-endurance products
FPM	Beat oil and acid-alkali endurance in RUBBER family. Good electricity insulation, mechanical and chemical properties	Poor processing capability and ventilation, high cost.	-20°C~200°C	Sealing materials in rocket, aeroplane, car and pipe
AU/EU	Best abrasion-resistance in RUBBER family. Good strength, elasticity, oil and ozone resistance, anti-aging, airtight	Poor water and alkali endurance. Poor organic solvent endurance.	-30°C~80°C	Gaskets, tyre, shock-proof products

It is unavoidable to abrade gaskets in sealing process. However, thermoplastic polyurethane elastomer entails a combined property from vulcanized rubber and common thermoplastic 料. thermoplasticpolyurethane elastomer features hardness and elasticity that can remain in good condition within a wide range of hardness(Shore hardness A10-D75). When the hardness is the same, thermoplasticpolyurethane elastomer bears more stress and its abrasion resistance is 2-10 times higher than natural rubbers. Oxygen and ozone resistance, oil and chemical corrosion resistance, heavy mechanical vibration and etc. of thermoplasticelastical polyurethane all make it a good cable sealing material that can be utilized in difficult conditions such as deep sub-vehicles.

2.2 Polytetrafluoroethylene.

Polytetrafluoroethylene(PTFE) is polymerized by perfluoroethylene. It features chemical stability, corrosion-resistance, sealing property, low adhesiveness and aging-resistance. It can even be used as anti-melt sealing gaskets in atomic bomb and cannonball.

PTFE has the following characteristics that make it a perfect sealing material:

(1) Mechanical property. The friction coefficient is extremely small, which is only one fifth of polyethylene. Meanwhile, the acting forces between C and F molecules are also extremely low, therefore this material has low viscosity. Its mechanical property remains wonderful within -196-260°C temperature scale. When all carbon bonds are occupied by fluorine, the compound does not turn fragile at low temperature.

(2) Chemical and environmental resistance. PTFE is resistant to any chemical corrosion except melt alkali metal(which is hardly found in cables). It stands concentrated sulfuric acid, nitric acid, hydrochloric acid and even boiling chloroazotic acids. PTFE is not flammable, and does not absorb moisture. Its property remains stable when exposed to oxygen and ultraviolet rays. In conclusion, it has fantastic chemical and environmental resistance.

2.3 Graphite Material.

Besides the above two materials, graphite can also be taken into consideration. Graphite is an

abundant natural resource as well as a natural solid lubricant. It has layer structure that allows alkali metal, metal halide and oxidizing acid to embed between layers. Dilated graphite is called the "sealing king" after chemical or electrical process. It features sealing reliability, flexibility, convenience, longevity and low leakage etc.

There are mainly two categories of graphite sealing products: soft seal and hard seal. When graphite is compounded with polymer organic chemicals, it can be strengthened as special seal, e.g. When compounded with elastic polyurethane, graphite can be used as oil pumper sealing gaskets. When compounded with PTFE, graphite can be used as valve sealing gaskets.

To sum up, the above three materials are feasible candidate sealing materials. However, PTFE has low potential of changing property to adjust to different sealing structures. In addition, graphite is easily got and cheap to be additive agent to improve other material's properties. Therefore in the next section, we focus on property improvement of polyurethane material.

3. Polyurethane Modification

Modification is an effective way to improve material properties. Polyurethane material has some flaws such as low temperature adaptability and poor surface performance, however these flaws can be rectified by modification. Biological degradation polyurethane elastomer is a product that utilizes the natural structure and property of biology resources to produce materials like timber that can be degraded by microorganism.

Polyurethane alloy is a new field that researchers concern to complement properties of polymer materials. Damping polyurethane elastomer has great damping effect when used as gaskets, loops and buffers. This material possesses wide usage in precise device, medical device, office appliance and electronic computers. It can stand evil environment for a long time and remain its outstanding properties such as damping effect, mechanical intensity, shape stability, ozone and ultra-violet ray resistance in low temperature condition(-17.8°C-4.5°C)[3].

Processing method modification. Besides modifying internal properties of polyurethane materials, modifying processing method sometimes can be more effective. For example spray coating is one possible way, but raw materials should better be in fluid form.

Polyurethane composite is made by adding surface modified particles and fibers in pre-poly phase. polyurethane's modulus can be improved by the firmness of fibers without losing its elasticity[4,5]. Carbon fiber is an excellent additive to make polyurethane composite, which improves abrasion-resistance, heat stability as well as being flexible and lithe[6].

Mixing different kinds of particles and powder in pure polyurethane to make powder-form composite is another modification method. Nano-composite is nowadays a heated field. Some distinguished organic powder bases are nano SO₂[7], CaCO₃[8-10] and fiberglas[11-15] etc.

4. Summary

a. Polyurethane is the most suitable cable sealing material in rubber family; PTFE is the only plastic material that is possible as special sealing material. Graphite is perfect sealing material however not suitable in cable gland structure of deep sub-vehicles.

b. Polyurethane has high potential of being modified to cater for different sealing structure and environment.

c. Multi-composite materials usually display better sealing effect than mono-composite materials. Polyurethane can act as an excellent base for a large group of additive agents.

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