

# Application Significance and Prospect of High Thermal Conductive Insulation Materials in High Voltage Motors

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## Abstract

With the development of economy, the quality and demand of power supply are becoming more and more strong. At the same time, China is actively developing new energy in the west, and needs to apply new transmission technology to long-distance transmission of power. The emergence of high conductivity insulation materials just conforms to the national demand, but there are still some problems with this material that cannot be overcome, and it still needs to make technical breakthroughs. The research and application of this technology is of great significance to ease China's energy shortage and achieve carbon neutrality.

## Keywords

High thermal conductivity insulating material; High voltage motor; HVDC transmission technology

## 1. Introduction

Insulation material refers to a material that effectively isolates the inside of a conductor from air or other solid materials during processing, thereby achieving the purpose of electrical energy transmission, conversion and safety protection. With the continuous progress of society, my country's commerce and industry have developed rapidly, and electricity consumption has also been rising steadily. As a result, high-voltage transmission technology has been widely used, and high-thermal conductivity insulation materials have become a research hotspot as new power equipment. At present, various large and medium-sized ultra-high temperature supercritical units that have been built and put into use in my country use high-flame retardant composite insulators. Although this type of equipment has advantages such as good dielectric loss characteristics and low power density, it also has certain temperature stability problems in actual operation, which limits the high-heat utilization of this type of high-voltage transmission equipment [2]. Therefore, it is necessary to increase research on this technology and equipment and carry out corresponding improvements so that this technology can benefit thousands of households and alleviate the problems of energy shortage and uneven energy distribution in my country.

## 2. Application of High Thermal Conductivity Insulation Materials in High Voltage Motors

With the rapid development of my country's economy, higher requirements have been put forward for high conductivity technology. High voltage transmission line insulation materials also play an important role in the power field, and their application scope is becoming more and more extensive. First, giving full play to the role of materials can greatly improve the performance of equipment. The high voltage direct current used to transmit electrical equipment, circuit boards, etc. on the surface of insulators generates heat vaporization after ignition and combustion to generate crosslinking agents to achieve the purpose of increasing the voltage level; secondly, the application of some materials has a great impact on safety. When used as electrodes and liquid solutions or gases that must be used in industrial processes to discharge electrolytes, a flow guide is used to prevent the entire metal mesh from being destroyed

and causing an explosion due to the local electric field. In high voltage transmission lines, the conductivity of the electrolyte has an important influence on the surface of the insulator and the surrounding environment, which directly determines whether the high voltage direct current grid is safe; in addition, related materials still need to be studied to improve the performance of the materials. Various insulating materials used in industrial production processes will also be subject to high temperature thermal aging and mechanical damage [3]. Therefore, it is very necessary, urgent and effective to develop new high-efficiency, low-toxicity, corrosion-resistant and mass-produced equipment.

## 2.1 High Thermal Conductivity Insulation Materials

High thermal conductivity insulation materials refer to a new type of vibration-isolating steel made from a composite of metals such as copper and aluminum, and their oxides. These materials feature low density, low weight, stable chemical properties, excellent damping properties, and excellent weather and corrosion resistance, meeting the demand for high-performance insulation products. In recent years, they have been extensively researched and utilized in high-voltage motors and are gradually being applied to large-scale power equipment. The performance of high thermal conductivity insulation materials used in large-scale equipment such as high-voltage motors and elevators directly determines the safety and reliability of the entire system, making relevant technical research essential. High thermal conductivity insulation materials also offer excellent overall performance, including excellent weather resistance and sound insulation exceeding 20dB. Therefore, this new type of high-performance insulating plastic is a future development trend. Currently, a new type of high-performance insulating plastic synthesized using molten salt solution and ionic liquid polymerization methods is being used as a vibration isolation circuit. This replaces traditional metal mesh, which is made into a composite insulation layer using an electric furnace or other heat-conducting channel material. This approach improves the feasibility of high-damping steel in large-scale equipment such as high-voltage motors and elevators, and further expands its application range.

## 2.2 Preparation Process and Reliability

The application reliability of high thermal conductivity insulation materials in HVDC transmission projects is reflected in the following aspects: (1) Improved reliability of power grid system operation. Since high thermal conductivity medium has a small resistance, when the temperature rises, it will undergo drastic changes inside. At the same time, this effect is also obvious in high temperature environment. By adopting insulation measures such as low dielectric constant, no contact with metal and no radiation discharge phenomenon, it can effectively prevent external short circuit faults and suppress voltage fluctuations and flashover interference; (2) Improved system insulation operation reliability. In HVDC transmission projects, since high thermal conductivity medium has a large temperature coefficient and does not contact with metal and no radiation discharge phenomenon occurs, its internal electric field can achieve a very large strong coupling effect; and the characteristics of low dielectric constant, small resistance and shielding ability with extremely low conductor manufacturing cost can effectively reduce the overall cost of power equipment and improve the insulation operation reliability of power grid system. The application of high thermal conductivity insulation materials in power grid operation reliability is of great significance and will further promote the development of high voltage transmission technology of power system towards efficient and safe power supply.

Methods for preparing high-thermal-conductivity insulating materials include dip plating, melt deposition, and coating. Dip plating is the most common method. This method uses copper wire or zinc rod as the raw material, which is melted in an iron tool and brought into contact with a base metal oxide. The material then melts at high temperature to form a current-resistant insulating plate. The material is then cooled and hardened using vacuum steam in a high-pressure heating furnace, creating a slag-splattering effect. After drying, it can be directly used in the factory. Another common method for preparing high-flame retardants is melt deposition, which combines the high-thermal-conductivity insulating material with a base metal oxide or graphite, lowering their melting point from 50°C to 60°C. The material is then melted at high temperature to form a current-resistant insulating plate. Using a furnace as a carrier, high-voltage power supplies and auxiliary equipment such as presses are then used to produce highly conductive polyethylene. In the preparation of high-thermal-conductivity insulating materials, different melt deposition methods with varying types, specifications, and properties can be employed, depending on specific needs.

## 2.3 Difficulties in the Application

At present, the application technology of high-voltage insulation materials in China is mainly characterized by high

electrical conductivity, low energy consumption and low cost. However, it still faces many problems in actual production, such as: (1) Due to the low level of manufacturing technology of power equipment in my country and the particularity of high-voltage transmission lines, existing high thermal conductivity insulation materials have many weaknesses. For example, the tensile strength is insufficient or cracks are easily generated when the temperature is greatly affected. On the other hand, because high-voltage insulation materials are composed of a polymer compound with a metal matrix and are very unique, thermal conductive materials have a large energy absorption capacity at high temperatures, so they are difficult to be widely used. (2) Because high-voltage insulation materials are composed of a polymer matrix with paraffin as the main component, and then undergo a series of processes such as sintering to obtain products [1], the temperature characteristics are related to temperature, and the combustion performance also affects the safety of equipment operation and service life.

### 3. Application Research of High Thermal Conductivity Insulation Materials

The application research of high conductivity insulation materials mainly includes the following aspects: (1) Under high voltage direct current and supercritical temperature, they have good thermal stability, high temperature resistance and good electrical insulation. At present, the use of high conductivity polyethylene as protective core material in the production and manufacturing of power equipment in my country is very common and effective. (2) Under high voltage alternating current or supercritical temperature conditions, they have good insulation performance and high resistivity. (3) Under high voltage direct current conditions, they can effectively prevent or reduce leakage and flashover. (4) High-damping, pollution-free gas-type composite dielectric polymers are widely used as new high-performance insulating polymer materials. In addition, inorganic ceramic cellulose is used as a reinforcing filler to fill the flexible matrix to improve the insulation performance, etc. [5]

#### 3.1 Application Scope

The application scope of high-voltage insulating plastics is mainly in the following aspects: First, in the power industry, in order to improve the power grid's resistance to sudden high-conductivity current, high-resistance insulators must be used. The principle is to increase the voltage by applying pre-tension to the high-voltage conductor. This method has certain advantages, such as lower temperature, relatively stable and larger impact breakdown field, so it can replace other methods in some special cases to improve voltage stability and current conduction capacity; however, it may reduce the system impedance, thereby increasing equipment costs and affecting safe operation. Secondly, in the power industry. Because the pre-tension of the high-voltage conductor is large and there are harmful substances such as thermal radiation, combustible gas and dust that can cause damage to the equipment or cause fire accidents, in order to avoid such problems, high-conductivity insulators must be used to replace traditional steel wire ropes as protective layers, thereby greatly reducing their dangers. Finally, the communications industry: Since high-voltage cables have a long length and a wide transmission distance, cables can be used instead of metal insulators.

#### 3.2 Optimization

At present, the optimization of high thermal conductivity insulation materials is mainly aimed at high-voltage direct current transmission technology, and its application field is relatively wide. Most of the power equipment used in the high-voltage AC power supply network, such as generators and transformers, adopt high current conduction devices. For these power generation systems, the voltage level must be improved. With the continuous development of my country's economy and the construction of power grids and the continuous improvement of related scientific and technological levels, the application scope of high thermal conductivity insulation materials has continued to expand, which is mainly reflected in the following aspects: (1) Improving the operating voltage level of high-voltage lines in power systems. In the actual engineering operation process, in order to reduce the loss of power equipment and improve economic efficiency, multiple generators are used to jointly provide high-quality AC power to the power grid; and for high thermal conductivity insulation materials, through technical upgrades, it can better meet the requirements of different AC loads and higher performance indicators. (2) Improve the operating voltage level of the power supply network and improve the insulation performance of the transmission line. In the high-voltage direct current transmission line system, the economic efficiency is improved by reducing the loss of power cables. (3) Improve the transmission capacity of the power supply network. The application of high thermal conductivity insulation materials can not only meet the relevant requirements, but also reduce the loss during power transmission and improve its economic efficiency. (4) Improve the reliability of the power supply network [2].

### 3.3 Characteristics

High thermal conductivity insulation materials have the following characteristics, such as the insulating oil temperature is smaller than the heat flux density, the temperature distribution is uniform and does not produce large-scale fluctuations, which is conducive to improving system stability, reducing motor losses, and thus effectively improving the quality of power. This is the main advantage of high thermal conductivity insulation materials. Secondly, high thermal conductivity and voltage are relatively stable and lossless under high temperature conditions, and the requirements for long equipment life are not high. At the same time, it also has excellent performance and low loss. These characteristics make the application range of high thermal conductivity insulation materials very wide. Now my country has regarded high thermal conductivity as one of the main energy sources in high-voltage direct current transmission systems and has carried out research, development and development work on it, providing possible directions for the future development of new technologies [2].

## 4. Prospects for the Application of High-Thermal-Conductivity Insulation Materials in High-Voltage Motors

With the rapid development of my country's national economy, highly conductive media are playing an increasingly important role in the power industry, railways, and other fields, placing higher demands on these materials. The application areas of high-thermal-conductivity insulation materials are mainly concentrated in high-voltage transmission and frequency converters, high-voltage technology, and high-performance electrodes. These materials often utilize existing high-thermal-conductivity insulation materials, while research on new materials, such as high-thermal-conductivity polyoxyethylene composites, is relatively limited. With the rapid development of my country's power industry, many domestic research institutes and enterprises are increasingly focusing on these new insulation technologies, and their research and development and production will become a trend in the coming years. To date, high-thermal-conductivity insulation materials have been widely used in the electrical industry due to their excellent comprehensive mechanical properties. This is primarily due to their excellent flame retardancy, making them suitable as new high-performance insulation products to replace traditional materials such as inks and metal salts. However, a number of drawbacks of these polyoxyethylene composite systems have hindered the development of this technology. Therefore, in the next few years, as the conductivity density of high thermal conductivity polymers continues to increase, the requirements for the surface performance of high-voltage frequency converters become more and more stringent, and environmental pollution becomes increasingly serious, these will lead to the acceleration of research and application of high thermal conductivity insulation materials, which will become one of the important directions of future research and development [1].

### 4.1 Application and Service Life

The application of high thermal conductivity insulation materials in high voltage electrical engineering mainly includes the following aspects: (1) Low temperature super condenser. It is a new type of high-efficiency heat exchanger with a certain temperature range formed by the co-crystallization of ceramic melt, copper wire or metal oxide and high temperature organic. (2) Circulating furnace mainly plays a cooling role in high voltage electrical engineering. The main function of the circulating furnace is to convert the insulating material in the high temperature medium into flammable and explosive properties, thereby improving the thermal efficiency of the equipment. (3) High voltage arc discharge device has obvious advantages over other conventional non-destructive testing methods: it can avoid local overheating caused by long-term exposure to low voltage, and can be transmitted over long distances, effectively reducing power consumption and environmental pollution. (4) High-permeability magnetic materials are mainly used in circulating furnaces for non-destructive testing and ultra-high voltage isolation, thereby extending the service life of the equipment [4].

### 4.2 Service Life

During the process of high-voltage power transmission, high-thermal-conductivity insulating materials generate a large amount of heat due to the increase in temperature and the interaction between electric fields. This heat can be discharged through cooling circuits, condensers, etc. However, when it is at low or high temperatures, it will cause damage to the equipment. Therefore, it is necessary to consider how to extend its service life, improve its pollution resistance, and reduce the occurrence of overvoltage. In addition, low-temperature super condensers, circulating furnaces and molten salt coolants can be used to control the temperature and greatly improve its conductivity,

thereby reducing the economic losses caused by the damage to the equipment due to the resistance of the insulating material [3].

## 5. Conclusion

This paper mainly studies the modern applications and future development prospects of high thermal conductivity insulation materials. It is found that due to the characteristics of high specific energy density and low density, high thermal conductivity insulation materials can make up for the defects caused by the performance differences between traditional metal matrices and polymer composite materials as a special new type of high-performance filler. With the continuous improvement of scientific and technological levels and people's increasingly stringent requirements for its performance, high-voltage direct current transmission technology will inevitably become the mainstream trend in the future development process, and for high thermal conductivity insulation materials, its application prospects are broad. Insulation materials are the most widely used high-conductivity insulation equipment in today's society. They play an important role in the power system. At the same time, this technology has high economic benefits and can be widely used in the power system, thereby achieving the goal of energy conservation and emission reduction.

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