Research Progress of Blade Coatings in Wind Turbines

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Abstract. With the expansion of wind turbine capacity, blade technology is evolving. Correspondingly, the preparation of the surface coatings of the blade should develop rapidly. Since most of the wind farms in China are built in deserts and oceans, the protection of the blades is particularly important. Blade coatings protect the blade's normal operation and extend its service life. The work discussed the preparation materials for wind turbine blade coatings and the difficulties faced by the development of coatings in China.

Keywords: coating; resin; wind turbine blade; protective material

1. Introduction: current status and development trends

With the global consumption of non-renewable energy, there is an urgent need for a renewable energy source to replace primary energy such as oil. As a low-cost technology conducive to greenhouse gas emission reduction, wind energy is mainly used. Wind power as an important alternative energy source has received attention and rapid development in recent years, becoming the third largest source of electricity after thermal power and hydropower [1]. At present, China has developed into the world's largest wind power market. It is estimated that by 2020, China's installed capacity of wind power will reach 100 million kilowatts. On the contrary, the coatings of domestic generator set have lagged, and the coatings used in wind turbines in operation are from foreign branded products. Besides high price, it is only suitable for the European maritime climate and cannot adapt to the environment of China's wind power plants. Therefore, the development of wind turbine coatings is a promising project.

2. Performance of the coatings

Wind power blades are the core part of the wind turbine equipment. In order to improve power generation and reduce costs, it should be guaranteed to operate well [2]. Large wind turbine blades are expensive to be installed and take a lot of time. The general maintenance time is about ten years after they are put into operation. Therefore, there is a high standard for coatings that protect the blades. At present, China's wind farm is land-based (about 90%). These units are built in deserts and dust-prone areas, with strong light and large temperature difference between day and night. Other wind power plants are built in the ocean due to the huge wind resources of the ocean. It can be predicted that the offshore wind power technology will develop rapidly. The preparation of the coating should also consider the environment at sea [3]. In summary, the coating should have the following properties:

1. The substrate and the coating should have excellent adhesion.
2. The blade coating should be able to withstand high and low temperature changes.
3. Good weather resistance. It can resist the erosion of blades by sand and rain, organic solvents, hydraulic oils and lubricating oils.
(4) It should have good mechanical strength, flexibility and elastic deformation to prevent cracking or even falling off of the protective film.

(5) It can withstand the irradiation of ultraviolet light, without the change of gloss, powdering, peeling and mildew in a decade.

(6) With excellent practical application, the high-thickness film can be obtained by one spray. Suitable for large-area spraying, it should have fast drying speed, short construction period and high production efficiency.

(7) It should have good anti-icing [4].

(8) When the main engine of the wind power system is in a fire, the flame-retardant coating applied to the special part of the blade surface can isolate the heat of the fire source to prevent the blade from burning and prolong its service life [5].

(9) The coating should be smooth. During the working process of the wind turbine blade, energy loss occurs due to friction with the air, thereby reducing the conversion rate of wind power generation. In order to improve the conversion of wind power generation, it is necessary to ensure the smoothness of the wind turbine blades.

3. Selection of raw materials for coatings

3.1. Selection of pigments and fillers

Pigments: They are used for coloring and covering, with certain anti-corrosion and UV resistance [6]. After comparison of tinting strength, hiding power, weather resistance and corrosion resistance, rutile titanium dioxide is the best pigment and filler.

Fillers: Ultra-fine powder filler can improve the weather resistance of the coating, delay the pulverization and discoloration, and enhance the mechanical properties of the coatings.

3.2. Selection of additives

Adding appropriate additives can improve the coating performance, aging resistance and storage of the coatings.

Matting agent: Make the layer have a suitable gloss and partially improve the abrasion resistance of the film.

Dispersant: Promote the wetting and dispersion of the pigments and fillers, as well as the storage stability and water resistance of the coatings.

Defoamer: Residual bubbles or dry bubbles can affect the appearance of the film and become the center of corrosion. The active ingredient in the defoaming agent interferes with or destroys the stabilizing effect of the bubble to achieve defoaming, thus improving the service life of the coatings [7].

Flatting agent: External pollutants, chemical changes and physical changes during the drying process of the coatings affect the flow and leveling of the coatings to reduce the protective properties of the coatings.

Anti-aging agent: Polymer materials are degraded by the external environment such as light and oxidation, which affects their service life.

3.3. Selection of curing agents

The curing agents should be selected to have excellent weather resistance and gloss retention, no yellowing and good elasticity, such as aliphatic isocyanates.

3.4. Selection of resin

3.4.1 Polyurethane. Polyurethane resin is widely used in the preparation of wind power blade coatings because of its excellent oil and abrasion resistance, chemical resistance and strong adhesion. When polyurethane is used to configure the coating, it is preferred to use aliphatic and alicyclic polyisocyanates instead of aromatics that are easily yellowed [8]. At present, the most used coatings in China are two-component solvent-based polyurethane coating and two-component water-based polyurethane coating [9].
3.4.2 Silicone resin. Silicone resin is a high polymer having a silicon-oxygen bond (Si-O-Si) as a main chain between organic substance and inorganic substance. Therefore, this material has the dual characteristics of organic materials and inorganic materials, with excellent heat resistance, chemical resistance and weather resistance. [10] Silicone coatings use organic silicone resins or modified silicone resins as effective film-forming materials. Therefore, the denatured silicone resin has good electrical insulation and weather resistance of the silicone resin. Besides, it compensates for the insufficiency of the silicone resin, such as shortening of curing time, adhesion, and improvement of mechanical properties.

3.4.3 Fluororesin. Fluororesin coatings have excellent properties, with good weather resistance and low wear. In the design of wind farms, the age requirement of wind power blade coatings is more than 20 years, which is satisfied by fluororesin. Other coatings, such as aliphatic coatings and acrylic silicone coatings, do not last for more than 10 years. Although the price of fluororesin is relatively high, it has advantages in terms of price and durability in the long run.

3.4.4 Polyacrylate material. Acrylic resin has the advantages of weather resistance, light resistance, corrosion resistance, good adhesion, and strong adhesion to the substrate; however, the disadvantages are water resistance, poor solvent resistance and non-wear resistance, so they are used as primers. By adding an appropriate amount of acrylic polymer thereto, the weather resistance and stain resistance can be improved [11]. Now, the coatings of water-based wind power blade have been developed. Using water as solvent, the vaporization temperature of water is relatively higher than that of general solvents, which may cause water to evaporate after applying the coating. Therefore, the construction environments affect its performance, and the ambient humidity should be adjusted to achieve the highest performance. [12] At present, the protective coatings commonly used in large-scale wind turbine blades are epoxy zinc-rich coatings, inorganic zinc-rich coatings, etc. as primers to provide electrochemical protection. The epoxy-based thick anticorrosive coating and the chlorinated rubber serve as an intermediate layer to provide shielding. Acrylic modified polyurethane coatings and polysilane oxide coatings are used as finishes for corrosion protection and decoration [13, 14]. These are excellent anti-corrosive materials with stable chemical properties.

**Fig. 1** Preparation of coating on wind turbine blade
4. Prospects
The significance and importance of studying wind power blade coatings is to prolong the service life and safety of wind turbine blades. Besides, it is to reduce the production cost of blades, the maintenance cost, and human resources waste caused by blade damage during operation. The research on blade coating should combine the properties of adhesion, wear resistance, weather resistance, heat and humidity resistance, mechanical strength, etc. Thus, it can be used on wind turbine blades with long-term effective protection.

5. Dilemma
China's coatings on wind turbine blade are almost imported from abroad. It is imperative to develop the domestic coatings manufacturing industry. Due to the special nature of China's environmental conditions, foreign coatings cannot fully meet China's requirements. From supply and competition, assurance, selectivity and economy need to be improved [15].
(1) With weak foundation and few implementation schemes, it is almost monopolized by several coating systems.
(2) The high price of imported coatings has led to a large investment in wind power, with great economic pressure.
(3) It has more waste and more pollution, contrary to the concept of saving resources and protecting the environment advocated by the wind power industry.

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