



Development of fiberglass/PTFE membrane structure materials

As people on architectural form and beauty, as well as the safety, energy saving, membrane structure material (hereinafter referred to as the membrane material) as a new type of space structure material, with its light and beautiful, pervious to light the advantages of energy saving, safe and durable, widely used in all kinds of large construction projects. Architectural membrane material is called after the steel, cement, wood and glass of 5 kinds of building materials, it not only can be applied to the original application fields of building materials, but have trouble with the original building materials application areas, such as large span space structure with traditional building materials incomparable superiority.

Architectural membrane material refers to high strength fiber fabric, which is after a certain finishing process, the surface coating of high performance resin material to form a flexible composite. At present the most commonly used architectural membrane material mainly has three types: (1) polyvinyl chloride (PVC) architectural membrane material, with high strength polyester fabric, which is coated on the surface of PVC resin. In order to improve its aging resistance and self-cleaning surface physical and chemical modification of membrane materials for processing or in PVC coated on the surface of PVDF membrane materials, PVF surface and a series of various types of PVC membrane material.(2) the polytetrafluoroethylene (PTFE) membrane material, with super fine glass fiber fabric, which is coated on the surface of PTFE resin. The membrane material on various aspects performance is excellent, especially on the ageing resistance and self-cleaning performance is incomparable with PVC membrane material.

This article focuses on the membrane material. (3) - Tetrafluoroethylene ethylene membrane material (ETFE), made from - Tetrafluoroethylene ethylene copolymerization body directly, no fabric reinforced base cloth. This is a new kind of recyclable green membrane material, showed a larger advantage in environmental protection and good market prospects.

Development status of PTFE membrane

Membrane development and application originated in Europe and the United States, membrane material building all over the world is the world's fair in 1970, Osaka, Japan on the USA pavilion, it used the PVC coated glass fiber cloth membrane material, but its service life is shorter. In order to overcome the PVC architectural membrane material aging resistance and self-cleaning bad and some shortcomings, under the leadership of the ford foundation support and Geiger company, in the United States Dupont, corning glass fiber company, Baird construction company, chemical fiber weaving company to jointly develop the better durability, anti-fouling strong of PTFE membrane material, make the permanent large span buildings become a reality. The membrane material used in the United States in 1973 Laverne college student activity center, 20 years later





tracking test results show that the mechanical properties of membrane material and the physical performance index fell by less than 30%, it is enough to show the superiority of this kind of membrane material on the various performance.

PTFE membrane material development depends largely on the super fine glass fiber and the weaving processing technology, etc. Commonly used glass fiber monofilament diameter of about 4 microns non-alkali fiberglass (E-glass fiber), due to the poor wear resistance and percentage of elongation of glass fiber, in the weaving process, the effect of friction on the strength of the glass fiber has great influence on mechanical properties, can't meet the requirements of membrane material base cloth weaving, so people choose a superfine glass fiber cloth as the membrane material base cloth. Along with the development of the processing and weaving technology, about 6 microns or more glass fiber applied in membrane material, but in terms of large span structure, 4 microns of glass fiber is more secure. Foreign superfine glass fiber industry and weaving technology development earlier, better product performance, low cost, satisfy the requirement of membrane material can produce a variety of the thickness of the glass fiber cloth, fabric width can be more than 4 m, can effectively reduce the splicing part of membrane material, improving the performance of membrane structure architecture.

With the development of the technology, PTFE membrane material is also toward diversification, high-performance and intelligent gradually. For now, manufacturing enterprise conclude the Chemfab of the United States, Taconic Company, Mehler of Germany, Duraskin Company, Saint-Gobain Company of France, TaiyoKogyo of Japan, etc. The United States is the earliest development of PTFE membrane material, the glass fiber and membrane material has greater advantage, has been in a leading position in the world; German film materials development is also in the top in the world, du company could produce the world's most wide (4.7 m) of PTFE membrane material, and product diversification; saint-Gobain company of French is a large glass fiber and its products production enterprise, in regard to the development of PTFE membrane material has great advantages, is the world expo in Shanghai world expo axis of PTFE membrane material suppliers; Japan could produce the finest in the world of glass fibers, made from the fiber fabric as the base cloth of membrane material, can make the membrane material has more flexibility, more durable.

Production technology of PTFE membrane material

The process flow of PTFE membrane material

PTFE membrane material use dip coating method, the super fine glass fiber cloth (hereinafter referred to as the glass fiber cloth) on the coated PTFE resin and elaboration. Glass fiber cloth by dipping tank coated PTFE dispersion concentrate first, then after drying, baking, sintering process, will be escaping through the excess water and solvent, and make the resin particles evenly distributed on both sides of the glass fiber cloth. Need to repeatedly impregnated fiberglass cloth,





and each time the amount of resin impregnated to appropriate control, it is prone to cracking phenomenon after sintering if it dip too much, whereas dipping too little, it cannot meet the performance requirements of the product. Impregnation process is divided into single slot and slot, as shown in figure 1, but generally to the continuity of production and efficiency, mostly adopts multiple slot impregnation process.

The base cloth weaving process and coating process is as follows:

(1) The weaving process: glass fiber - and twist - warping - weaving - glass fiber cloth.

(2) Coating process:

Fiberglass fabric- Heat cleaning- Dipping- Drying- Sintering- Cooling- Finished product

Key factors in PTFE membrane production

Glass fiber raw material

Because of the glass fiber elongation small and brittle, it is difficult to meet the requirements of the base fabric weaving process, so should choose superfine glass fiber (4 microns) to the weaving cloth, both can satisfy the requirement of cloth, and can meet the requirements of the mechanical properties of membrane material. In Japan b-grade yarn (around 3.8 microns) and DE yarn (about 6 microns), for example, to illustrate the advantages of super fine glass fiber. Intensity is inversely proportional to the diameter of fiber, B grade yarn tensile strength of 3.1 GPa, and DE grade yarn tensile strength is 1.5 GPa, than B grade yarn fell more than 50%, and the bending strength also fell by 30%. So the class B yarn made of membrane material mechanics performance is better, use more secure.

Glass fiber base fabric and its weaving

In the impregnation of membrane materials and sintering process, the demand for glass fiber fabric is higher, especially the flatness and surface tension of the base fabric uniformity greatly influence on the formation and properties of membrane material. Generally, base fabric require surface smooth, uniform tension, yarn joint and yarn breaking, oil and other defects. Base fabric structure generally uses woven plain or panama, weft yarn density general control within 13 root/cm.

Warping process is the key technology, generally uses the partial warping again and shaft or warping. In the wide weaving fabric, generally adopts the partial warping and shaft process, this kind of technology in the electronic grade fiberglass.LTD application more widely; In a narrow fabric weaving, adopt a warping can better guarantee the fabric smoothness, but exist in species is not convenient, the production efficiency is relatively low. Commonly used in weaving of rapier loom, telescopic rapier loom better rigidity, and warp no wear and tear is advantageous to the glass fiber cloth weaving.





Dip coating process

The key factors in the process of dip coating include PTFE dispersion concentration, drying, baking, sintering temperature and speed. The concentration of dispersion directly affects the thickness of the membrane material, resin content and roughness, etc. The higher the concentration, the greater the thickness of after impregnating resin, not too much, but each time the dipping thickness generally multiple impregnation process, dispersion concentration increasing. In addition, the dispersion of softening agent, surface active agent and other auxiliaries' application is also very important. Generally within three vertical oven drying, baking and sintering process of resin, continuous gradient, temperature in the oven is divided into three main temperature area: dry area dry after dipping fiberglass cloth, remove the moisture in dispersion, is in commonly 80 ~ 100 °C, the temperature too high may produce bubbles or flow mark; Baking area to remove residual moisture and surfactant on cloth, etc., is in commonly 260 ~ 290 °C, low temperature may make the cloth cover sticky, etc.; High temperature sintering area make the resin melt, eliminate interface, with the glass fiber fabric has better bonding force, so that the membrane material plasticizing, usually in the temperature of 380 ~ 400 °C. Dipping tank temperature is usually at room temperature (20 ~ 25 °C). Speed directly affect the quality of the product's drying sintering and the production efficiency, speed too fast, it influence impregnated resin content as well as the effect of drying and sintering, etc.; Speed is too slow, it influence the production efficiency, is not conducive to reduce the cost.

The performance and characteristics of PTFE membrane material

General coated fabric, enhanced lining fabric has decided to the mechanical properties of membrane material, the outer coating material decided to physical properties of the membrane material. PTFE membrane material can give full play to high strength about the mechanical properties such as glass fiber, and can play PTFE physical properties such as resistance to ageing, self-cleaning advantage. Table 1 is the performance of PTFE membrane material compared with PVC membrane material.

Table 1 performance comparison of PTFE membrane material with PVC membrane material

The experimental project	PTFE membrane material (Milky white)	PVC membrane material (white)
The surface density /(g.m ⁻²)	1215	933
thickness /mm	0.8	0.79
density /[root·(2.5cm) ⁻¹](warp×weft)	26×19	17×17
Tensile strength /[N·(3cm) ⁻¹](warp×weft)	4704×4361	1695×1627
Tear strength /N (warp×weft)	341×403	209×221
service life /a	25	5~15
Light transmittance /%	13	4.8
Flame retardant wire	A grade	B grade





Good mechanical properties

Glass fiber has high tensile strength and elongation of small features, it make the membrane material has good tensile strength and tear strength, and also won't appear obvious under long-term load stress relaxation and creep. Generally moderate intensity of PTFE membrane material, its thickness is less than 1 mm, weight 1 kg/m² or so, its tensile strength has reached the level of steel. Sintering process make glass fiber cloth and combining PTFE resin good, the peel strength is very high, almost impossible to separate.

Good weather resistance

Weather resistance is mainly embodied in the aging resistance and self-cleaning .Because PTFE has the character of inertia, low friction and not sticky, almost without any chemical erosion, so PTFE membrane material in resistance to ultraviolet radiation, the erosion of acid rain, microbial damage has obvious advantages, its aging resistance of PVC membrane material is incomparable. On self-cleaning aspect, membrane material with hardly any adhesive material, even with a small amount of dust pollution, after the rain wash, can achieve natural clean. Therefore, PTFE membrane material suitable for permanent membrane material, its life can reach more than 30 years.

Good flame retardant fire prevention performance

PTFE has excellent high temperature resistance, can be continuous use between 240 ~ 260 °C, has significant thermal stability, glass fiber also non-flammable, so the membrane material with flame retardant fire performance can meet the requirements of national building materials fire. PTFE membrane material also resist low temperature, can use for a long time under the conditions of -180 ~ 260 °C.

Pervious to light energy

PTFE membrane material of sunlight transmission rate was 12% ~ 21%, generally related to the thickness and the weight of the membrane material, membrane material has well pervious to light quality. Transmitted light evenly diffuse light inside the structure, natural soft, no lighting during the day, can save energy, at night, under the light irradiation and interior lighting the appearance, the appearance of buildings that show a dreamy effect.

Sound absorption and sound insulation performance

Because the glass fabric has sound-absorbing sound insulation performance, PTFE membrane material has good reflectivity for 500 ~ 2 000 Hz audio generally, absorbing some low-frequency melody; high-frequency sound absorption is limited, but with other sound-absorbing material, it has good sound-absorbing sound insulation effect.





The application of PTFE membrane material

PTFE membrane material, as a permanent membrane material with light free, pervious to light energy saving, security, good shape, long life and other advantages, is widely used in various kinds of large buildings. Mainly divided into the outer membrane and lining, it has a big difference in performance.

PTFE membrane for outer membrane

PTFE membrane for outer membrane is mainly used a general roofing material, canopy material and external decoration, etc. As roof material commonly used in stadiums, exhibition halls, the airport hall, shopping centers, recreation centers and other large public facilities. Such as the one thousand in the Thames dome, membrane material covering area of over 180000 m², is a single area of the membrane structure; Saudi Arabia Jeddah airport lounge suspension membrane structure, covers an area of 420000 m². Eighty thousand Shanghai stadium in China, covering the area of 3. 60000 m² is our country for the first application of membrane structure in large buildings, far-reaching influence. As the canopy material is commonly used in square, park green space, park, station and other facilities. As external decoration mainly using artistry and plasticity of membrane material, such as the Shanghai world expo axis, the expo axis of cable membrane structure is the world's largest continuous tensioned membrane structure by far, every piece of membrane single chip area of 1800 m², total an area of 70000 m², there are six eye-catching inverted cones which distribute well-proportioned, it is a beautiful scenery line of the Expo Park..

PTFE membrane for inner membrane

PTFE membrane for inner membrane is mainly used as sound insulation material, its mechanical performance requirements is lower than the outer membrane. The most typical engineering is the national stadium, the main Olympic stadium the bird's nest, the structure of PTFE + ETFE, upper is ETFE membrane structure, rain and snow prevention role; Bottom is 53000 m² of PTFE membrane structure, main effect is acoustic ceiling , by PTFE membrane absorption which can guarantee the stadium sound clear.

Problems and prospect

Architectural membrane material as an emerging industry, has strong advantages and broad market prospects, but there are some problems in its development: (1) the flexibility of the PTFE membrane material needs to be improved, due to the brittle glass fiber and bending performance is bad, make the products in the process of PTFE membrane material in bending strength and other mechanical performance degradation is more, in the course of processing, transport, construction and other inconvenience, so package forms commonly used PTFE membrane material. Glass fiber strand should be strengthened, the processing technology and coating technology research, improve the flexibility of the PTFE membrane material, make it easy to processing and installation.(2) the high cost of PTFE membrane material, including raw material production,





transportation, construction and maintenance cost, etc. Superfine glass fiber raw materials and its processing cost is higher, due to the flexibility of the membrane material is bad, the transport, construction more difficult, also lead to higher costs. Enhanced PTFE membrane material of raw materials and the production research, strengthen technological innovation, constantly improve the performance of the membrane material and reduce cost, make it in terms of performance, cost has a strong market competitiveness.(3) PTFE membrane material recycling and environmental protection. New ETFE materials with no fabric reinforced, to melt it into particles can be recycled, this is a kind of environmental protection material; And enhanced PTFE membrane material with glass fiber cloth, how the substrate with enhanced body separation or recycling, it is an environmental problem to be solved.

