博 士 論 文 の 内 容 の 要 旨

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論文題目	Development of flexible carbon fiber reinforced composite fabrics with knitting structure **編み構造を使用した柔軟な炭素繊維強化複合材料の開発**

（博士論文の内容の要旨）

Carbon fiber composite materials have excellent properties and are used in many fields. The main properties of composite materials made of carbon fiber are high strength and rigidity, which are mainly used for bearing force. When subjected to external forces, carbon fiber composite materials may have defects such as micro-crack extension and delamination damage. Even small cracks or delamination will seriously reduce the performance of the material and the quality of parts processing. This will cause serious safety problems, lead to product scrapping, and also increase manufacturing costs. Combining carbon fiber with thermoplastic resins can assist the toughness of composite materials and improve the delamination resistance and fracture toughness of carbon fiber composite materials.

This dissertation aims to develop the processing and manufacturing technology of composite carbon fibers, as well as the processing diversification of continuous carbon fibers in carbon fiber composite materials. The experimental method combines the processing technology of long fiber reinforced thermoplastic polymer and uses the co-extrusion processing method and the hot pressing processing method to prepare the composite fabric. The continuous carbon fiber and the thermoplastic polyurethane blend are co-extruded to form a double-layer structure. The processing method of composite carbon fibers formed by coating continuous carbon fiber with thermoplastic resin is studied and evaluated, and the parameters of the thermoplastic polyurethane (TPU) blend in the outer layer and the carbon fiber tow content in the inner layer are discussed. In addition, continuous carbon fibers are processed into composite fabrics, woven and knitted composite fabrics are manufactured, and laminated composite fabrics through the hot pressing process are studied.

The overall structure of the dissertation is divided into six chapters. The first chapter is the research background data collection, literature review and introduction, the second to the fifth chapter are the research and discussion parts, of which the second chapter is mainly to evaluate the feasibility of continuous carbon fiber development, evaluate the difference between continuous carbon fiber and composite carbon fiber, and establish the manufacturing process. The third chapter is the parameter change of TPU blends. In the preparation process of composite carbon fiber, TPU is mainly used to enhance its elongation. Therefore, the influence of TPU on the composite carbon fiber should be comprehensively evaluated. In this part of the research content, the addition of MTPU is used to evaluate the effect of the blend on the composite carbon fiber. The fourth chapter is about the change of the content of carbon fiber tow. As the core layer, the content of carbon fiber tow will affect the coating process of the TPU blend. Research and evaluation of some commercially available specifications, including 1.5 K, 3 K and 6 K carbon fiber tow, and evaluate the effect of fiber content in accordance with the aforementioned processing methods. The fourth chapter is the preparation and lamination of composite fabrics. Composite carbon fibers are used to prepare composite fabrics with a knitted structure and laminated. The main purpose of the research in this part is to obtain flexible three-dimensional composite materials. The processing application and improvement effect of composite carbon fiber are also confirmed in this chapter. Finally, the sixth chapter is the conclusion, integrating the results of the total experiment, and summarizing the research value of this dissertation.

In the research process of this dissertation, in addition to the observation of the samples, the basic properties of the processing process and the finished product are also established through the evaluation of tensile properties, flexural properties, resilience and electromagnetic shielding properties. Scanning electron microscopy results confirmed the physical bond between TPU and carbon fiber, that is, TPU has a

reinforcing effect on the tensile properties of carbon fiber tow. Compared with the original carbon fiber tow, the tensile strength of the TPU-coated carbon fiber tow is increased by 35.87% to 19.62 MPa; the strain of the carbon fiber tow is also increased during the stretching process. The co-extrusion method in the LFT process can produce continuous carbon fiber tows for industrial production; it also provides higher possibilities for the subsequent processing of carbon fiber tows. The adhesion between TPU and carbon fiber is increased by adding polyester hot melt adhesive (MPTU). TPU/MPTU blends have good miscibility. When the ratio is 85/15 wt%, carbon fiber tow has a good clustering effect and nodule performance, and the tensile strength reaches 349.27 MPa/g/cm^3. In addition, the failure mode of the carbon fiber tow is improved during processing, the axial slip replaces the direct fracture, and the cross-sectional shape is changed from the original flat bundle to an ellipse. Woven and knitted composites made of composite carbon fibers still have the softness, elasticity of fabrics and failure modes similar to composite carbon fibers. Moreover, TPU can reduce the friction generated during knitting, and the prepared carbon fiber knitted composite material has flexibility and resilience. The tensile test results of the composite knitted fabric after lamination show that with the increase in the number of layers, the tensile strength of the composite material also increases. The strength can reach 43.72 MPa when six layers are laminated, but the four-layer laminate has the best elongation.

In addition to the development of composite carbon fibers and fabrics, the electromagnetic interference shielding efficiency has been studied, showing that composite materials have good EMI attenuation effects. The application of LFT technology to the subsequent processing and weaving of continuous carbon fiber is investigated for the first time. It provides a novel method for the development of carbon fiber reinforced thermoplastic, and large-size composite materials can also be manufactured. This breakthrough is a current limitation of carbon fiber processing technology.