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論　文　内　容　の　要　旨

FRP (Fiber Reinforced Polymer) is a composite material made of a polymer matrix reinforced with fibers. These kinds of materials have obvious benefits with lightweight, high specific strength and chemical corrosion resistance etc. Fiber-reinforced polymer is best suited for any design program that demands weight savings, precision engineering, finite tolerances, and the simplification of parts in both production and operation.

However, because the oriented structure of fiber, FRP are strongest and most resistance to deforming forces when the reinforced fibers are parallel to the force being exerted, but the weakness is that when the compressive force are exerted or fiber are perpendicular to the force, due to fiber buckle or kink bands, the resistance ability are weak. In spite of significant improvement in other properties (e.g. impact resistance and tensile strength), the compressive strength of FRP ranges around half of their tensile strength. The compressive strength of composites is generally lower than tensile strength, which significantly reduces the advantageous position of FRP materials in structures in which compressive strength is the primary design requirement.

Compressive failure is a complex failure mode in FRP composites. Depending on the material and fiber assemble modes, different of compressive failure modes, including micro buckling, kinking and longitudinal fiber splitting fiber failures are possible. For unidirectional glass fiber and carbon fiber composites, micro buckling or kinking of fibers are now understood to be the compressive failure mechanisms. In summary, micro buckling is the main failure modes in FRP under comprehensive state. Kinking, on the other hand, is a highly localized fiber buckling. Kink bands are formed after attainment of the peak compressive load when the region between the fiber breaks is deformed plastic.

The UHMWPE fiber, which has excellent tensile modulus and strength and low density gives it the highest specific modulus and strength of all commercial reinforcing fibers, is very flexibly, the knot strength is as high as tensile strength, and the UHMWPE fiber reinforced polymer composite has well impact resistance. But the compressive behavior of this kinds of fibers reinforced polymer composite have few studied. The purpose of this study is to improve the compressive performance of UHMWPE fiber reinforced epoxy resin based on micro-buckling failure theory. The buckling of the fibers throughout a unidirectional composite is initiated by the buckling of the weakest fibers. The surrounding matrix and composite provide appreciable support for a single fiber, so the strain field in the matrix is expected to be localized around the fiber. The critical buckling loads P is related with the mechanical properties of reinforced fibers, polymer matrix and critical wavelength l, in general, compared to the strength and modulus of the fibers, those properties are relatively low. In this study, the influencing factors of resin are not considered.

Firstly, the compressive and bending module of UHMWPE fibers was improved by surface coating. If the modulus of a coating is higher than that of a fiber, the compressive and bend modulus of the fiber should be improved upon coating. Consequently, the buckling load of the fiber would increase. In this paper, we used pyrrole vapor deposition to coat the surface of UHMWPE fibers with carbon VGCFs and CNTs. Pyrrole is a volatile organic compound that is readily oxidized to form polypyrrole (PPy). A new process to coat UHMWPE fibers with VGCFs and CNTs by pyrrole vapor deposition was developed. The PPy have the combined advantages of excellent mechanical strength from VGCF and the cladding ability of PPy. Because the coating was homogeneous and composed of isotropic materials, the coated fiber has better axial compressive strength than the uncoated equivalent, which makes it attractive for use in anti-compressive fiber-reinforced composites. The transverse compressive strength and bending moment of single UHMWPE fibers were measured by micro-compression and single fiber bending testing. The experimental results indicated that the nanoparticle coating improved the transverse compressive modulus of the fibers, particularly for the CNT/ PPy-coated one. The bending modulus of the fibers was also improved by a nanoparticle coating. However, the coating method must be conducted with one by one of the UHMWPE fibers, the efficiency was very low, at the same time, the coat of the coating materials is high, so this method was proved has no feasibility. Therefore, the coated fiber reinforced plastic was not prepared.

Next, a filament covering is proposed to improve the longitudinal compressive properties of unidirectional fiber reinforced plastic. Based on compressive buckling theory, fiber buckling can be prevented by shortening the buckling critical wavelength by covering the filament. A UHMWPE fiber bundle and a PBO filament were selected as the reinforcing fiber and the covering filament, respectively, to verify this statement. The effect of a covering PBO filament on a UHMWPE fiber reinforced epoxy resin on compressive performance was investigated by a compressive test and morphology observations. Results show that the filament covering has positive effect on the compressive strength of the FRP, and the tension-exerted filament covering increased the compressive strength and increased the longitudinal compressive modulus of the UFRP. Four kinds of filament were used as the covered yards, including polyester fibers, basalt fibers, PBO fibers and UHMWPE fibers. The effect of different filament and covered spacing on compressive strength and modulus were studied. Results showed that compression strength and modulus of the unidirectional composites reinforced with filament-covered bundles depended strongly on the compressive failure mechanism, which was decided by the type and spacing of the covering filament. With shortening the covered spacing, the compressive strength was increased, that can be explained by the critical wavelength theory. While the compressive modulus was decreased, that can be explained by the wind angle was become small, resulting the resistance of compressive force provided by covered filament fiber became decreasing.

In this dissertation, in order to improve compressive performance of unidirectional fiber reinforced composite, the compressive behavior of single UHMWPE fiber and unidirectional UHMWPE fiber reinforced FRP were investigated. Two novel methods were proposed, the coating nano-particles with pyrrole vapor deposition method was proved can be improve the compressive and bend strength and modulus for single fibers, it has the potential to improve the compressive performance of unidirectional FRP, but this method has the high coat and low Effectiveness. The other method was filament covering fiber bundle, filament-covered fiber bundles can improve the compressive properties of the unidirectional composites. The tension-exerted covering filament could improve the compressive modulus. Compression properties and mechanism of compressive failure of the composites change with the increase of the spacing. By varying the components of composites, we can tailor their mechanical properties according to our target applications.