Manufacturing Technique of High Modulus Complex Ply Yarn and Stiffening Geogrids

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Abstract. In this study, carbon fiber/ polypropylene (PP) complex braiding yarn, with its different breaking strength, was prepared. It was designed by braiding polypropylene (PP) wrapped yarn and carbon fiber core yarn using eight and sixteen spindles braiding machines, with change of take-up gear number. Environmental factors, such as pH, temperature and time, were also changed to produce geo-grids with high strength, high modulus and better weather resistance. In order to make stable structure for complex braiding yarn, the heat treatment was also considered. Finally, geo-grids braiding by optimal treatment parameters were cut into single rib and junction specimens for tensile test.

Introduction

Since 1966, Henri Vidal, a French engineer, had proposed theory about reinforced soil structures. Afterwards, they have already widely used in Geotechnical Engineering due to their satisfactory effects. In 1980s, with rapid development of geo-synthetic material, geotextiles and geo-grids have already applied in reinforced retaining structure and reinforced road embankment [1]. Currently, geo-grids, concerning soil reinforcement and soil stability enhancement, are convenient to construct, as well, their quality is easy to control. Therefore, geo-grids have become an economic and practical emerging civil engineering material, and usually service in slope engineering and channel regulation. Gu Huang [2] scholar once showed that, performance of glass fiber reinforced material was decreased when suffering harsh environment such as stronger ultraviolet radiation, acid, alkali and salts, especially in higher concentration environment, owing to fibers' damage and descending strength.

Except that geo-grids make up for the deficiency of shear force and tension in soil, reinforced wall joining in seeds greens after growth, so that, it provides habitat for animal and insect and avoids wall space erosion besides beauty. Geo-grids are not only cooperated with landscape easily, built cheaply and constructed rapidly, but also maintain earthwork balance. Furthermore, their

flexible structure has character of earthquake resistant, which is applicable to frequent earthquake in Taiwan [3-5].

This study used carbon fiber and polypropylene (PP) to prepare braiding yarn. With rapid industrial development, environment becomes more and more severe, resulting in ozonosphere breaking, ultraviolet rays and acid rain problems. Moreover, embankment are subjected to marine denudation, as well as strong acid and strong base corrosion caused by wastes, thus more and more factors need to consider when manufacturing geo-grids. As environment issues become more and more severe, we selected PP and carbon fibers having acid and alkali resistant and better strength.

Experimental

Experimental materials and apparatus

Experimental fibers, 1000 D polypropylene filament and 6 K carbon fiber (provided by Formosa Plastic CORP) , as well as soaking solutions, Sodium chloride (NaCl), Sodium hydroxide (NaOH) and Sulfuric acid (H_2SO_4), were all used in the experiment. Braiding machine, universal strength testing machine (HT-9101) and oven (TD CGPC) were also in service.

Experimental Methods

PP/Carbon complex braiding yarn was produced via spindle braider, with change of gear ratio and spindle number. And then tensile strength of PP/Carbon yarn was tested. In order to assess adaptability of complex braiding yarn to environment, the PP/Carbon complex yarn was fabricated with above optimum processing parameter, following by soaking in H_2SO_4, NaOH and NaCl solutions for 28 days(7 days as a period). And finally the samples were taken out to tensile test. The complex braiding yarn, with its optimum strength, was heated at 170 ℃, 180 ℃, 190 ℃ for 1, 2, 3 min, following by tensile measurement. Additionally, geo-grids were braided by complex yarn at beginning, then heated at optimum temperature for suitable time, and then cooled at room temperature for 12 hrs, with purpose of tensile strength test (a group of 10 samples) after cutting into single rib and junction according to CNS 11623 and ASTM D6639.

Results and Discussion

As shown in Fig.1, it is found that breaking strength of complex yarn braiding by 16 spindles machine is higher than that braiding by 8 spindles, because 16 spindles braiding generates doubled outer PP fibers comparing with 8 spindles. And braiding at gear ratio of 120:50 owns higher complex strength than the other two gear ratios regardless of spindles. Because of changing braided angles, 8 spindles braided ply yarn cannot have higher strength than 16 spindles yarn, owing to its half of outer PP filaments. From breaking strength test, it is found that, strength of complex yarn cannot reach to the anticipated value because angle causes component force when by tensile. Furthermore, cohesive phenomenon happens when wrapping yarn, making suffered force bigger than the actual measurement.

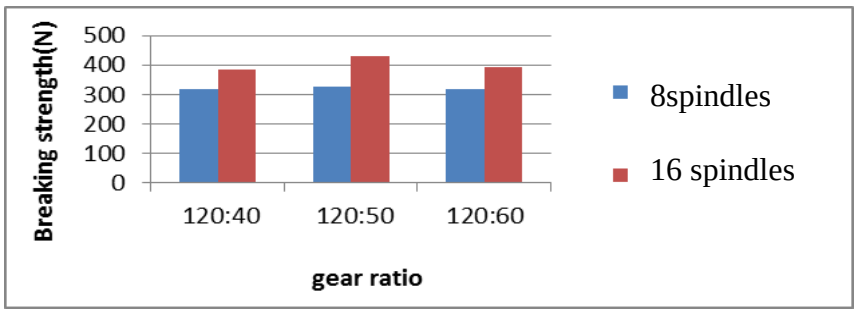

Fig.1 Breaking strength of 1000 D PP filament /6 K carbon fiber complex braiding yarn using

8 spindles and 16 spindles braider with 120 tooth take-up gear and different carrier gear (40, 50, 60 tooth)

From Fig 2, it is revealed that, breaking strength of PP/carbon fiber complex yarn tends to go down when soaking in NaOH solution; and some carbon fiber bundles appear partial raw edge and slight flake in soaking process, because carbon fiber possesses bundle directivity and suffers from extrusion. And strength loss of complex yarn doesn't exceed 10 % mostly, only about 30 N, so that are not influenced by NaCl and NaOH solution (shown in Fig.2 and Fig.3). From Fig.4, it is found that, after 28 days soaking in H_2SO_4 solution, complex braiding yarn strength is decreased slightly, nearly between 5 %-12 %, about 10 N-15 N, mainly because CH_2-$CHCH_3$ on PP fiber structure and carbon fibers both cannot react with acid and alkali solution. Therefore, regardless of immersing in acid or alkali solution, PP/Carbon complex yarn mostly remains at strength of 300 N-320 N, that is, acid or alkali solution has no impact on breaking strength of complex yarn.

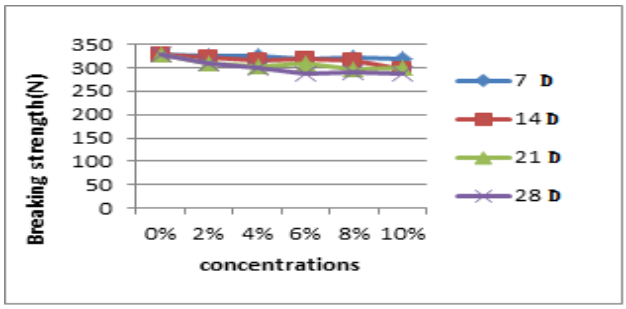

Fig.2 Breaking strength of 1000 D PP filament /6 K carbon fiber complex yarn braiding by 8-spindle braider with 120 tooth take-up gear and 50 tooth carrier gear after immersing in different concentrations of NaCl solution (0 %, 2 %, 4 %, 6 %, 8 %, 10 %) for several days (7,14,21,28 days)

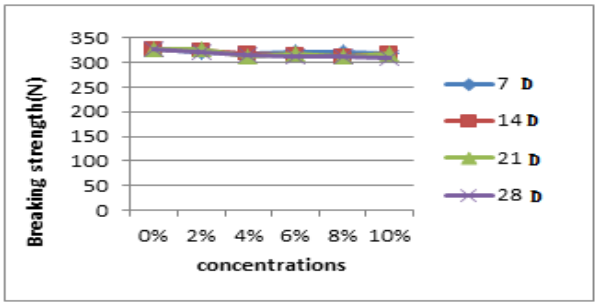

Fig.3 Breaking strength of 1000 D PP filament /6 K carbon fiber complex yarn braiding by 8-spindle braider with 120 tooth take-up gear and 50 tooth carrier gear after immersing in different concentrations of NaOH solution (0 %,2 %,4 %,6 %,8 %,10 %) for several days (7,14,21,28 days)

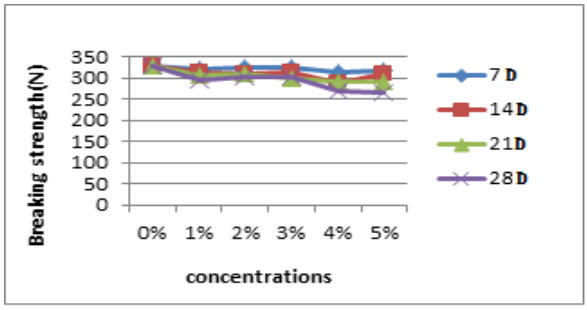

Fig.4 Breaking strength of 1000 D PP filament /6 K carbon fiber complex yarn braiding by 8-spindle braider with 120 tooth take-up gear and 50 tooth carrier gear after immersing in different concentrations of H_2SO_4 solution (0 %, 1 %, 2 %, 3 %, 4 %, 5 %) for several days (7,14,21,28 days)

As shown in Fig 5, it is found that, PP/Carbon fiber complex yarn has better breaking strength after hot-baking at 190 ℃ for 1min; thus, geo-grids were produced with these optimum parameters with change of manufacturing methods. In previous braiding, polyester fiber, as whip thread yarn, was used to fix wattle, in order to make wattle stick more closely. Fig 6 reveals that, strength of single rib and node made from geo-grids braiding by 16-spindle braider, is more than that braiding by 8-spindle, mainly because outer PP filaments content braided by 16-spindle machine is higher than that braided 8-spindles plus 8-spindle braided outer PP filaments destructiveness is higher than 16-spindle after heating for a period of time. As shown in Fig 6, single rib from 16-spindle braided Carbon fiber/ PP geo-grids owns best strength of 392.1 N, and junction has of 101.47 N. Single rib

is subjected to tensile stress from single axial direction, and junction is suffered from axial and transverse tensile stress, so that, easier fracture of grid sticking places superadded by strength inconformity among carbon and PP fibers results in bigger coefficient of variation (CV) of junction than that of single rib.

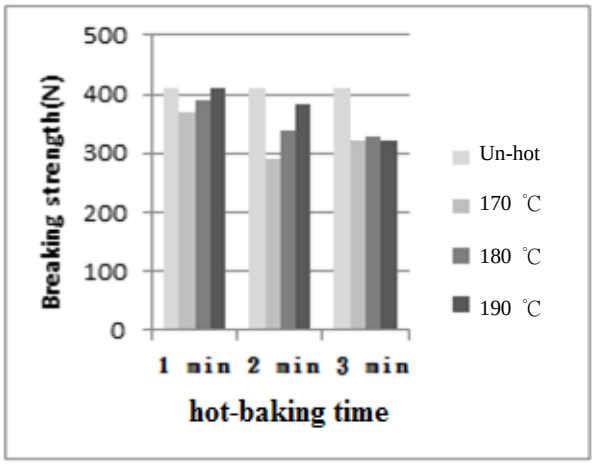

Fig.5 Breaking strength of 1000 D PP/6 K carbon fiber complex yarn braiding by 16-spindle braider with 120 tooth take-up gear and 50 tooth carrier gear after hot-braking at temperature of 170 ℃,180 ℃,190 ℃ for 1, 2, 3 min.

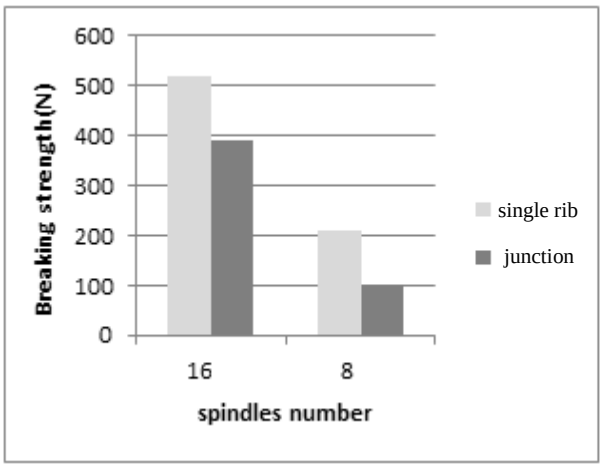

Fig.6 Breaking strength of single rib and junction from 25 cm×25 cm geo-grids braiding by 1000 D PP/6 K carbon fiber complex yarn using16-spindle braider with 120 tooth take-up gear and 50 tooth carrier gear after hot-baking at 190℃ for 1min

Conclusions

In this study, complex braiding yarn, carbon fiber wrapped by polypropylene (PP), was successfully prepared to manufacture geo-grids with high stress and modulus as well as weather resistance. When braiding at gear ratio of 120:50, PP / carbon fiber complex yarn possesses the highest fracture strength and resists acid and alkaline environment destruction. The heat treatment optimum processing parameters were at 190℃ temperature for 1 min. And 16-spindle single rib has the best strength of 592.34 N, junction has of 208.6 N; but 8-spindle single rib owns maximum strength of 392.1 N, junction owns of 101.47 N. These optimum experimental parameters, provide technology of geo-grids preparation for the industrial world, save more technique developing cost, and achieve to optimum product strength and durable time evaluation as well.

Acknowledgements

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