

An Elementary Study on PP/MHMWPE/EPDM Netting Twine

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Abstract. The netting twine of PP/MHMWPE/EPDM was elementarily studied. The result shows PP/MHMWPE/EPDM netting twine is characterized in a high breaking load, when the high breaking load of a netting twine is not degraded. The linear density, diameter, raw material consumption and water resistance of netting gear can be reduced if the routine PE netting twine is replaced by the PP/MHMWPE/EPDM netting twine, and thus the energy saving and consumption decreasing in fishery can be realized. In the same diameter, the PP/MHMWPE/EPDM netting twine has better physical properties with a better fishery performance and a better adaptability than the PE netting twine. In the same advantage of breaking load, the PP/MHMWPE/EPDM netting twine is more economical than the PE netting twine, and it is more economically feasible to generalize in fishery. This result can be used as a reference in netting gear design and netting twine material selection.

1 Introduction

Netting twines are an important material widely used in fisheries including fishery netting gears (such as trawls) and farming netting gears (such as a deep water cages, ranged aquatic breeding barrier nets), etc. The mechanical property of the netting twine significantly determines the netting gear application effects including energy saving, consumption decreasing, anti-wave resisting ^[1-17]. The existing PE netting twine is made of the monofilament of common PE in a simple process while PE, as the fundamental structure element of netting twine, is mainly made of high density PE (HDPE) via the traditional spinning process. The progress of marine fishery brings a higher demand for the mechanical property of netting twine, and it needs to push the research and development of new materials for the netting twine forward ^[1-5, 12-13].

2 Experimental

2.1 Material and method

2.1.1 Material

Basal fiber material for making the PP/ MHMWPE/ EPDM netting twine

The basal fiber material for the PP/ MHMWPE/ EPDM netting twine is made of the monofilament of PP/ MHMWPE/ EPDM monofilament. The PP/ MHMWPE/ EPDM monofilament was made from PP, MHMWPE, EPDM and color master batch in a specific proportion by a comprehensive material modifying process based on the existing research ^[1, 6-12, 18-20] according to the following main spinning steps:

PP + MHMWPE + EPDM + Color master batch → Mix → Cross link → Melt & extrude → Cool by water → Wind in → Raw filament → Draw by heat → Wind in → Monofilament bundle → Separate → PP/ MHMWPE/ EPDM monofilament.

The routine PE monofilament as made by the traditional spinning process of heat drawing, and the performance met the indexes for the standard product ^[21].

PP/ MHMWPE/ EPDM netting twine material

The PP/ MHMWPE/ EPDM netting twine material was designed and developed by the East China Sea Fisheries Research Institute, and the specifications were respectively PP/ MHMWPE/ EPDM- 36tex×10×3, PP/ MHMWPE/ EPDM- 36tex×20×3 and PP/ MHMWPE/ EPDM- 36tex×40×3. PP/ MHMWPE/ EPDM monofilament was made into PP/ MHMWPE/ EPDM netting twine via bobbin winding, twisting, drawing up, winding down, hank reeling and checking.

The routine PE netting twine in the control test was made by the traditional twisting process similar for the same diameter of PP/ MHMWPE/ EPDM netting twine, the specifications were respectively PE-36tex×10×3, PE-36tex×12×3, PE-36tex×20×3 and PE-36tex×40×3, and the performance of each specification met the indexes for the standard product ^[21-23].

2.1.2 Method

Test instruments

British Instron-4466 strength tester and Chinese FA2004N electronic balance, etc.

Test conditions

The test was carried out in a standard lab at 20±2°C and RH 65±5% constantly, and samples were balanced in the lab for 24h above. The tensile speed of Instron-4466 strength tester was 300mm/min and the sample length was 500mm for the mechanical property test of PP/ MHMWPE/ EPDM monofilament and routine PE monofilament. The mechanical property of netting twine was tested by Instron-4466 strength tester, the sample breaking time was 20±3s, and the sample length was 750mm.

Test method

The mechanical property test for the monofilament was done according to SC/T 5005 ^[21], and for the netting twine was according to SC 110 ^[23]. Valid data obtained in the test was cleaned up according to the specification for data process in the corresponding standard ^[21, 22].

3 Results And Analysis

3.1 Performance analysis of the basal fiber material for PP/ MHMWPE/ EPDM netting twine

The basal fiber material for PP/ MHMWPE/ EPDM was PP/ MHMWPE/ EPDM monofilament, and the result of performance comparison with the routine PE monofilament is shown in Table 1. Table 1 gives the modified PP/MHMWPE/EPDM monofilament has a distinctly better strength than the routine PE monofilament, and the breaking load and knot breaking strength of PP/MHMWPE/EPDM monofilament are improved by 25.4% and 16.7% respectively than the routine PE monofilament. Table 1 also shows that the percentage of breaking elongation of PP/MHMWPE/EPDM monofilament was reduced by 16.4% than the routine PE monofilament. The percentage of breaking elongation of PP/MHMWPE/EPDM monofilament satisfies the demand for netting twine production. If the performance of PP/MHMWPE/EPDM monofilament is explained in view of the molecular orientation, the knot breaking strength will become lower than the routine PE when the breaking strength becomes higher; but the knot breaking strength of PP/MHMWPE/EPDM monofilament is increased other than decreased, because the material modifying technology modifies the molecular orientation structure of PP/MHMWPE/EPDM monofilament, makes the molecular chain arrange in the stretching direction, enhances the molecular chain orientation degree, compacts the molecular chain arrangement, enlarges the crystallinity, and gives it a higher knot breaking strength ^[4-13, 16-17, 24-25].

Table 1 Performance comparison between PP/ MHMWPE/ EPDM monofilament and routine PE monofilament

| Monofilament | Diameter mm | Linear density tex | Breaking strength cN/dtex | Knot breaking strength cN/dtex | Percentage of breaking elongation % |
|----------------------------------|----------------|--------------------------|---------------------------------|--------------------------------------|---|
| PP/ MHMWPE/ EPDM monofilament | 0.20 | 36 | 6.52 | 4.20 | 11.7 |
| Routine PE monofilament | 0.20 | 36 | 5.20 | 3.60 | 14 |

3.2 Mechanical performance analysis of PP/ MHMWPE/ EPDM netting twine

The mechanical property of netting twine was mainly determined by the basal fiber type, linear strength utilization rate and twining making process, etc.^[1-5, 13]. See Table 2 for the comparison of mechanical property and market unit price between PP/MHMWPE/EPDM netting twine and routine PE netting twine. Table 2 shows: the netting twine PP/MHMWPE/EPDM - 36tex×10×3 in a nominal diameter of 1.75mm has a higher strength than the routine netting twine PE- 36tex×10×3 in the same diameter, the breaking load and knot strength of the former are increased by 25.2% and 36.6% respectively than the latter; the netting twine PP/MHMWPE/EPDM - 36tex×20×3 in a nominal diameter of 2.50mm has a higher strength than the routine netting twine PE- 36tex×20×3 in the same diameter, the breaking load and knot strength of the former are increased by 28.8% and 34.2% respectively than the latter; the netting twine PP/MHMWPE/EPDM - 36tex×40×3 in a nominal diameter of 3.65mm has a higher strength than the routine netting twine PE- 36tex×40×3 in the same diameter, the breaking load and knot strength of the former are increased by 37.2% and 14.4% respectively than the latter; The PP/ MHMWPE/ EPDM netting twine is characterized in a high breaking load, when the routine netting twine PE- 36tex×12×3 in a nominal diameter 1.95mm is replaced by the netting twine PP/MHMWPE/EPDM - 36tex×10×3 in a nominal diameter 1.75mm for the fishing netting twine (trawl twine, cage binding twine or barrier net connecting twine, etc.), the twine breaking load can be improved by 4.6%, the linear density can be reduced by 16.7%, the application diameter can be decreased by 10.3%, the raw material consumption can be cut off by 16.7%, and the net resistance in water can be lowered correspondingly.

Breaking load is a major index for the fishing material quality evaluation and netting twine selection as it directly determines the safety, strength, deformation and service life of the related netting gear^[1-3, 5, 13]. The netting twine with a higher breaking load can strengthen the netting gear, reduce the netting gear weight and raw material consumption, enlarge the water passage, decrease the netting gear resistance in water, and realize the energy saving and consumption reducing as the netting gear can be made of thinner netting twines. If the PP/ MHMWPE/ EPDM netting twine in this test is used in the fishing netting gear, the material consumption can be reduced than the routine PE netting twine in the same breaking load, if it is used in the trawl, the trawl energy consumption can be reduced highly^[1, 2, 5, 12], if it is used in the farming netting gear (such as a cage or a barrier net) the material consumption and the twine diameter can be reduced accordingly than the routine PE netting twine in the same net strength; if it is used in the net cover of an farming netting gear, the outer layer attachment area and anti-contamination coating material can be also reduced; it improves the inner-outer water exchange rate and reduces the cost of farming netting gear, and further improves the economic benefit of the owner. Furthermore, the netting twine with a higher breaking load can absorb the impact load from the moving netting gear and the ship in any bad weather, make the load on the net cover distribute uniformly, and protect the net cover from damage of any excessive local stress. The PP/ MHMWPE/ EPDM netting twine has a higher breaking load than the routine PE netting twine, therefore, this advantage can be used to improve the trawl and farming gear resistance against impact, wind and wave.

Table 2 Comparison of mechanical property and market unit price between PP/ MHMWPE/ EPDM netting twine and routine PE netting twine

| Group | Netting twine | Specification | Nominal diameter mm | Linear density tex | Breaking load daN | Knot strength daN | Percentage of breaking elongation % |
|-------|-------------------------------|----------------------------|------------------------|-----------------------|----------------------|----------------------|--|
| I | PP/MHWMWPE/EPDM netting twine | PP/MHWMWPE/EPDM—36tex×10×3 | 1.75 | 1210 | 50.32 | 32.91 | 14 |
| | Routine netting twine | PE—36tex×10×3 | 1.75 | 1210 | 40.20 | 24.10 | 15 |
| | Routine netting twine | PE—36tex×12×3 | 1.95 | 1452 | 48.10 | 28.90 | 16 |
| II | PP/MHWMWPE/EPDM netting twine | PP/MHWMWPE/EPDM—36tex×20×3 | 2.50 | 2480 | 103.45 | 65.09 | 16 |
| | Routine netting twine | PE—36tex×20×3 | 2.50 | 2480 | 80.30 | 48.50 | 18 |
| III | PP/MHWMWPE/EPDM netting twine | PP/MHWMWPE/EPDM—36tex×40×3 | 3.65 | 4860 | 208.48 | 122.22 | 17 |
| | Routine netting twine | PE—36tex×40×3 | 3.65 | 4860 | 152.00 | 106.80 | 19 |

Extensibility is the characteristic of the netting twine being pulled and deformed, and it is also an important index to the netting twine material property and application performance^[1-2]. Table 2 shows: the elongation rate of PP/ MHMWPE/ EPDM netting twine in a diameter of 1.75mm, 2.50mm and 3.65mm is lowered by 6.7%, 11.1% and 10.5% than the routine PE netting twine in the same diameter. Elongation for both types of netting twine is caused by many factors including the basal fiber material elongation, twine linear density and post process, and the netting twine structure^[1-2, 12]. The PP/ MHMWPE/ EPDM monofilament and the routine PE monofilament are crystallized high polymer, but their extensibilities are theoretically difference because they have different crystallinities^[1-2, 6, 18-19]. The PP/ MHMWPE/ EPDM monofilament has a smaller elongation rate because of its higher crystallinity and molecular orientation degree while the routine PE monofilament has a larger elongation rate (Table 1), so the elongation of PP/ MHMWPE/ EPDM netting twine is lower than the routine PE netting twine in the same twine making conditions (netting twine structure, linear density and post process, etc., Table 2). The elongation of PP/ MHMWPE/ EPDM netting twine being lower than the routine PE netting twine in the same diameter is the result of comprehensive influence from above factors (netting twine structure, linear density, post process, and basal fiber material elongation, etc.). The high breaking load of PP/ MHMWPE/ EPDM netting twine is very advantageous for improving the impact resistance in netting gear working. The better impact resistance gives the PP/ MHMWPE/ EPDM netting twine a higher shape stability, the netting twine will not be easily deformed in the same tension, and it is suitable for making the netting twine against any mechanical tension or stress; the poor impact resistance weakens the tension resistance and wear resistance of routine PE netting twine, and the twisted netting twine will be easily deformed in the same tension. Because of the above comprehensive factors, the netting gear made of PP/ MHMWPE/ EPDM netting twine has a higher impact resistance. As all mentioned above, the mechanical properties are different between the PP/ MHMWPE/ EPDM netting twine and the routine PE netting twine, the PP/ MHMWPE/ EPDM netting twine has a higher breaking load, a smaller elongation rate and a higher impact resistance than the routine PE netting twine in the same diameter; the PP/ MHMWPE/ EPDM netting twine can be used in fishery to reduce the netting gear weight, water resistance and raw material consumption, realize the energy saving and consumption reducing, and promote the sustainable

development of low carbon fishery.

3.3 Performance-price ratio analysis of PP/ MHMWPE/ EPDM netting twine

The performance-price rate is a parameter in the commercial model focused by fishery material researchers, manufacturers and users, and it is mainly determined by the comprehensive performance, usage amount and market price, etc. [8-13] The PP/ MHMWPE/ EPDM netting twine is different from the routine PE netting twine in the linear density, breaking load and market price under the same diameter (Table 2). According to the linear density and current market price in Table 2, when the routine PE netting twine PE - 36tex×12×3 in a diameter of 1.95mm is replaced by the PP/MHMWPE/EPDM netting twine with specifications of PP/MHMWPE/EPDM - 36tex×10×3 in a diameter of 1.75mm for the fishing twine (such as trawl twine, cage binding twine or the connecting twine for the barrier nets and wire rope of ranged fish farming, etc.) without degrading the breaking load, the netting twine weight can be reduced by 16.7% and the cost can be reduced by 1.8% though the price is enlarged by 10%; and it is more economical if the routine netting twine PE- 36tex×12×3 in a diameter of 1.95mm is replaced by the PP/MHMWPE/EPDM netting twine with specifications of PP/MHMWPE/EPDM - 36tex×10×3 in a diameter of 1.75mm. In all, the performance-price ratio of PP/ MHMWPE/ EPDM netting twine is higher than the routine PE netting twine, and the PP/ MHMWPE/ EPDM netting twine is feasible in fishery application.

3.4 Adaptability analysis of PP/ MHMWPE/ EPDM netting twine

Adaptability is a new term in the fishing material used by fishing material researchers to evaluate the fishing material performance and adaptability, and it is mainly determined by the comprehensive performance, fishing adaptability and the terminal user's acceptance level. The aforesaid analysis shows the breaking load advantage of PP/ MHMWPE/ EPDM netting twine makes up the price disadvantage and satisfies the load demand in fishery. Table 1 shows that the PP/ MHMWPE/ EPDM monofilament has a higher strength than the routine PE monofilament, so the PP/ MHMWPE/ EPDM netting twine made of the high strength PP/ MHMWPE/ EPDM monofilament has higher wear resistance and higher aging resistance than the routine PE netting twine made of the routine PE monofilament theoretically [1-4, 6, 19, 24-27]. PP/ MHMWPE/ EPDM netting twines in different diameters can be made by different numbers of basal fiber material in the same twine making process and same basal fiber material; if the routine PE netting twine in Table 2 is replaced by the PP/ MHMWPE/ EPDM netting twine for fishing, the physical properties including breaking load, wear resistance and aging resistance of the fishing netting twine can be highly improved, and the fishing netting gear and farming netting gear safety and anti-wave resistance can be further improved. Moreover, with the energy production and industrialized application of PP/ MHMWPE/ EPDM monofilament, the PP/ MHMWPE/ EPDM netting twine price can be further cut down, so the PP/ MHMWPE/ EPDM netting twine is more adaptable in fishery than the routine PE netting twine.

4 Conclusion

The PP/ MHMWPE/ EPDM netting twine is different from the routine PE netting twine in mechanical properties, and the test shows the PP/ MHMWPE/ EPDM netting twine has a higher breaking load and a lower percentage of breaking elongation than the routine PE netting twines in the same diameter. When the routine PE netting twine is replaced by the PP/ MHMWPE/ EPDM netting twine for fishery without degrading the advantage in the breaking load, the twine linear density, diameter, raw material consumption and resistance of the netting gear in water can be reduced, and the energy saving and consumption reducing in fishery can be realized, and the PP/ MHMWPE/ EPDM netting twine is more economical and economically feasible in fishery than the routine PE netting twine. In the same diameter the PP/ MHMWPE/ EPDM netting twine have more favorable physical properties, fishery performance and adaptability. The PP/ MHMWPE/ EPDM

netting twine has outstanding advantages in fishery technical field because of its high strength against tension, it can be used to improve the working efficiency and the operator's safety, and realize the size enlarging, energy saving and consumption reducing of netting gears.

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