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On the Mechanical Properties of Cords Left in High Water Pressure

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Abstract

This paper is about the measurements of the load-elongation curves and the breaking strength of cord made from Nylon 6 fiber and polyethylene fiber which was left in high water pressure over a period of time. The mechanical properties of the cord left in this condition were then investigated.

The breaking strength and the load-elongation curves of the cord of polyethylene did not change over time in the water and in the high water pressure, but the cord of Nylon 6 showed changed properties over time, and this may be caused by the hygroscopic property.

Neither of the cords exhibited the fatigue phenomenon which is caused by leaving the cord in the high water pressure at about 150–170 kg/cm^2 for 717 hours.

Introduction

The fact that the fishing ground in the deep sea has not been used by the fishermen has attracted special interest recently. We think that this fishing ground will be used widely in the future. As this fishing ground has the condition of high water pressure, a serious problem will arise in the use of the present fishing gear. So far, many experimental investigations on the fatigue phenomenon of the cord, the netting and the rope used over time have been performed[1–16].

However, the research on cords left in high water pressure for a long time is minimal. In this study we measured the load-elongation curves and breaking strength of the overhand knot of the cord made from Nylon 6 fiber and polyethylene fiber left in high water pressure over time, and then investigated the mechanical properties of these cords left in high water pressure.

Here, the fundamental data will be obtained for designing fishing gear that can be used in the deep sea.

Materials and Methods

The fiber of Nylon 6 has a much greater ability to absorb water, and polyethylene does not have the hygroscopic property. These fibers were widely used as the materials for the fishing gear. From the above reason, the cord of Nylon 6 monofilament No. 40 and polyethylene multifilament 360 D. 3/60 were used as the experimental materials.

From the first, the samples of the cord were left in the constant high water pressure, and put to test for breaking strength, the stress-strain properties, the

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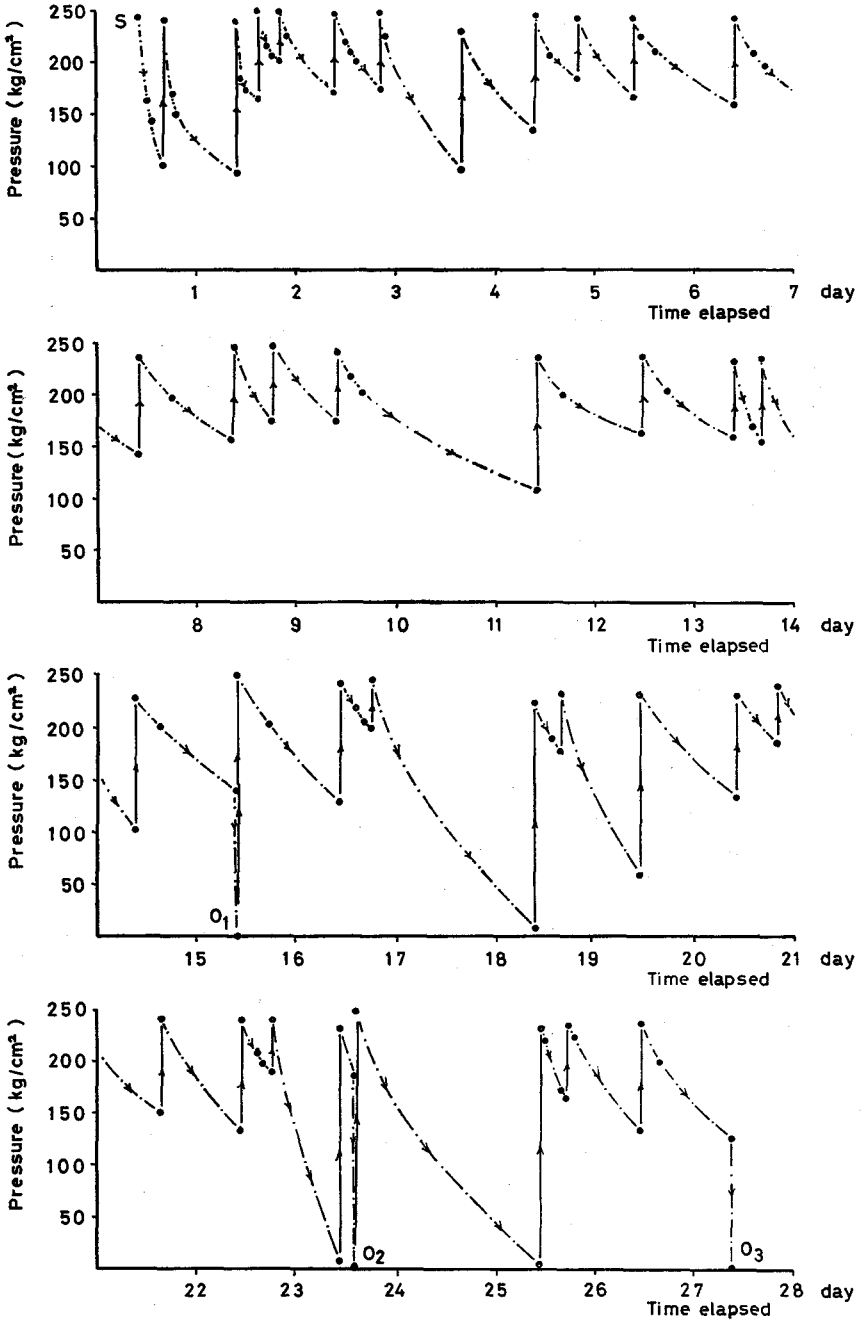

Fig. 1. Relation between the changing water pressure compressing the sample and time left in the high water pressure.

wearing out and the fatigue phenomenon by the tensile force. There are many points which must be solved in the mechanical properties, but the test concerning the condition under constant high water pressure cannot be done by the available apparatus of the hydraulic press in our laboratory.

In this study, after the samples of the cord were left in the constant high water pressure and returned to the state of the atmospheric pressure, its breaking strength, load-elongation curves and diameter were measured. The experimental samples were made by the hydraulic press which has an inside diameter of 14 cm, a height of 14.5 cm and a volume of 14.5 l. Although the power of the hydraulic press can be compressed up to 1000 kg/cm^2, in this study it was only used to compress up to a maximum pressure of about 250 kg/cm^2, and the sample was left in the constant high water pressure for a maximum time of 717 hours. As the airtight condition of the hydraulic press is poor, the water pressure decreased gradually with elapsed time. The hydralic press compressed at the regular intervals repeatedly, and the water pressure was held as constant as possible.

Fig. 1 shows the relation between the water pressure which compressed the samples and the time duration in the high water pressure. Point "s" shown in Fig. 1 indicate the starting time of the sample in the high water pressure. Points "O"$_1$-"O"$_3$ shown in Fig. 1 indicate the times the samples were taken from the hydraulic press. In this experiment, the samples were left in the high water pressure at a mean of 160 kg/cm^2 for 360 hours, 556 hours, 643 hours, and 717 hours. Other samples were left in the air and in the water for a same period of time. The temperature of the samples left in the air, in the water and in the high water pressure varied from 2°C to 10°C.

The experiment was carried out by using a testing machine of Instron type. The length of the test piece was 150 mm and the speed of the testing machine was 400 mm/min. The load-elongation curves of the cord and the breaking strength of the overhand knot were measured. The breaking strength of the cord was measured of the overhand knot, because the testing piece of the cord in the straight condition breaks at the chuck position, causing the value of the breaking strength to be inaccurate. The load-elongation curves were measured using the differential transformer type extensometer and records on the X-Y recorder. This extensometer has a range of 100 mm and a fullscale recorder with 0.2% accuracy. These experimental results show the average of ten measurements. These experiment were done in room temprature varying from 15°C to 20°C.

Results and discussion

The measurement of one series was finished in a period of 2 hours. Fig. 2 shows the load-elongation curves for the polyethylene multifilament 360 D. 3/60 under various conditions in which the samples were left in the air (Dry condition), in the water (Wet condition) and in the high water pressure (Pressure condition) for 717 hours. Fig. 3 shows the load-elongation curves of polyethylene multifilament 360 D. 3/60 under the condition of leaving the samples in high water pressure for 360 hours, 556 hours, and 643 hours. These samples have different elasticity properties; the elongation of the cord left in the high water pressure and in the

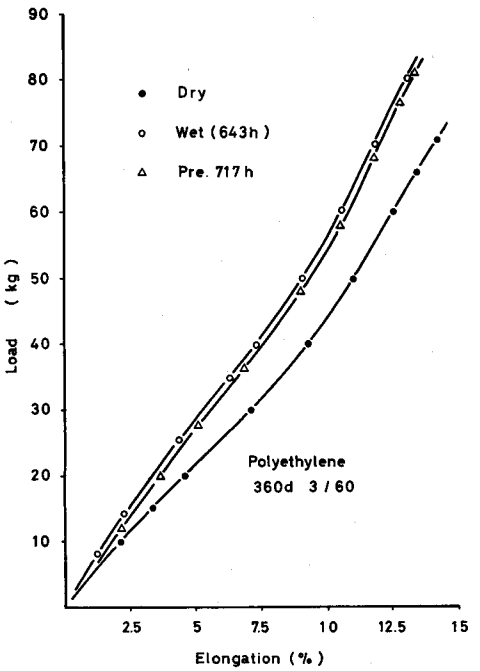

Fig. 2. Load-elongation curves on cord of polyethylene multifilament 360 D.3/60 left in air, in water and in high water pressure for 717 hours.
●, dry condition;
○, wet condition (left in water for 643 hours);
△, pressure condition (left in high water pressure at about 165 kg/cm² for 717 hours).

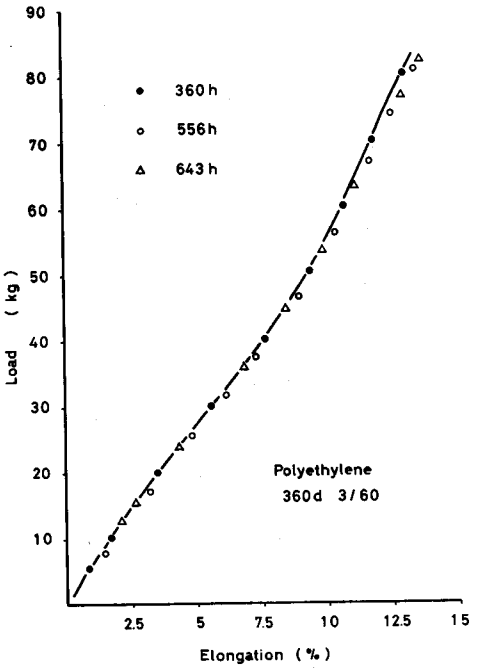

Fig. 3. Load-elongation curves on cord of polyethylene multifilament 360 D.3/60 left in high water pressure at 150–170 kg/cm² for 360 hours, 556 hours and 643 hours.
●, left for 360 hours at mean water pressure of 171 kg/cm²;
○, left for 556 hours at mean water pressure of 171 kg/cm²;
△, left for 643 hours at mean water pressure of 168 kg/cm².

water is less slightly than the cord of the dry condition. However, the large difference of the load-elongation curves between the sample in the wet condition and that left in the high water pressure due to time elapsed is not recognized.

Fig. 4 shows the load-elongation curves for Nylon 6 monofilament No. 40 under various conditions in which the sample was left in the air (Dry condition), in the water (Wet condition) and in the high water pressure (Pressure condition) for 717 hours. It is clear from the above mentioned figure that the form of the load-elongation curves is different for each condition of the samples. According to figure number 4, the elongation of the wet and the pressure conditions of the sample have a gentle slope. This phenomenon may be caused by the hygroscopic property. Fig. 5 shows the load-elongation curves of Nylon 6, monofilament No. 40 of the samples left in the high water pressure for 360 hours, 556 hours, and 643 hours. These curves had no significant difference in terms of time left in the high water

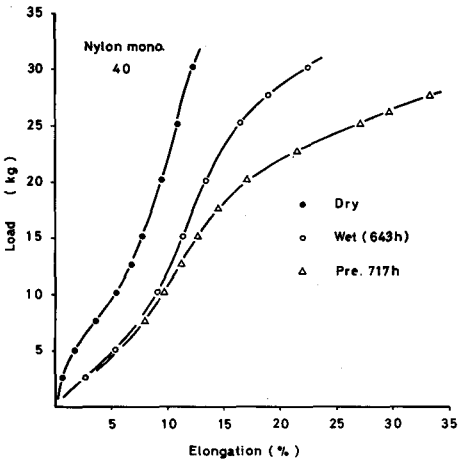

Fig. 4. Load-elongation curves for cord of Nylon 6 monofilament No. 40 left in air, in water and in high water pressure for 717 hours.
●, dry condition;
○, wet condition (left in water for 643 hours);
△, pressure condition (left in high water pressure at about 165 kg/cm² for 717 hours).

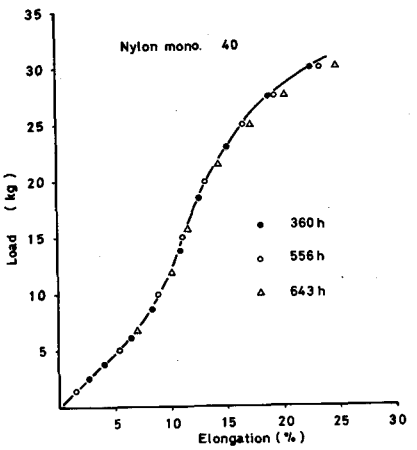

Fig. 5. Load-elongation curves for cord of Nylon 6 monofilament No. 40 left in high water at 150–170 kg/cm² for 360 hours, 556 hours and 643 hours.
●, left for 360 hours at mean water pressure of 171 kg/cm²;
○, left for 556 hours at mean water pressure of 171 kg/cm²;
△, left for 643 hours at mean water pressure of 168 kg/cm².

pressure at the low tension, but as the tension increases, the difference of the curves increase in size in relation to time duration.

Table 1 and 2 show the breaking strength of the overhand knot, the diameter of the cord, and Young's modulus for the samples under the various conditions respectively. Here, the diameter of the yarn in the strand of the cord of polyethylene multifilament 360 D. 3/60 was measured. Concerning the cord of polyethylene, it is clear from Table 1 that the Young's modulus of the sample is slightly different under the condition of leaving it in the air, in the water and in the high water pressure. The Young's modulus on the sample left in the water (Wet condition) and the high water pressure (Pressure condition) is larger than the samples in the dry condition, but the difference between the sample in wet condition and in pressure condition is not recognized. The differences in the breaking strength of the overhand knot and the diameter of the cord under the three conditions of samples for polyethylene multifilament 360 D. 3/60 were not recognized.

On the samples of Nylon 6, No. 40, it is clear from Table 2 that the diameter, the Young's modulus and the breaking strength of the overhand knot is different under the three conditions of the samples. On the sample of the wet condition and the pressure condition, the diameter of cord increased compared with the dry condition left over much time, but the Young's modulus decreased, and the breaking strength of the overhand knot is reduced. The relation between the breaking strength of the overhand knot and the time it was left in high water

Table 1. *Diameter, Young's modulus and breaking strength of overhand knot on cord of polyethylene multifilament* 360 *D*.3/60 *left in air, in water and in high water pressure.*

No.	Diameter* (mm)	Young's modulus** (kg/mm²)	Breaking strength (kg)	Condition	Leaved time (hour)	Mean water pressure (kg/cm²)	Index (hour.kg/cm²)
1	0.211	440	67.6	Dry			
2	0.227	—	74.0	Wet	74		
3	0.219	—	—	〃	360		
4	0.215	568	72.5	〃	643		
5	0.223	—	76.2	Press.	74	147	10878
6	0.224	520	72.5	〃	360	171	61560
7	0.226	544	74.3	〃	556	171	95076
8	0.221	544	75.2	〃	643	168	108024
9	0.218	544	72.9	〃	717	165	118308

* Diameter is measured on yearn in strand
** Young's modulus is measured at elongation of 5%

Table 2. *Diameter, Young's modulus and breaking strength of overhand knot on cord of Nylon monofilament No. 40 left in air, in water and in high water pressure.*

No.	Diameter (mm)	Young's modulus* (kg/mm²)	Breaking strength (kg)	Condition	Leaved time (hour)	Mean water pressure (kg/cm²)	Index (hour.kg/cm²)
1	1.045	221	21.1	Dry			
2	1.069	—	19.8	Wet	74		
3	1.105	—	17.9	〃	360		
4	1.101	—	17.4	〃	643		
5	1.075	101	10.0	Press.	74	147	10878
6	1.107	96	16.6	〃	360	171	61560
7	1.087	99	15.1	〃	556	171	95076
8	1.078	101	15.7	〃	643	168	108024
9	1.099	91	15.7	〃	717	165	118305

* Young's modulus is measured at elongation of 5%

pressure is shown in Fig. 6. As is shown in Fig. 6, the breaking strength of the overhand knot decreased with elapsed time in which the samples were left in the high water pressure.

It is generally known that polyethylene fiber does not have the hygroscopic property, and that Nylon 6 fiber has the hygroscopic property. The difference on the mechanical properties of both cords left in the high water pressure may be caused the hygroscopic property. The mechanical properties of Nylon 6 monofilament changed over the time it was left in the high water pressure. This phenomenon was not caused by the fatigue resulted from leaving the sample in the high water pressure, but rather to the reason that the samples absorbed water.

The mean pressure of the various samples left in the high water pressure was different, and it is impossible to compare exactly the experimental results. As shown in Tables 1, 2, an index is introduced as the product of the mean water pressure on the samples and the elapsed time. From this index, it is not clear if the change of the breaking strength is caused by the fatigue phenomenon for the

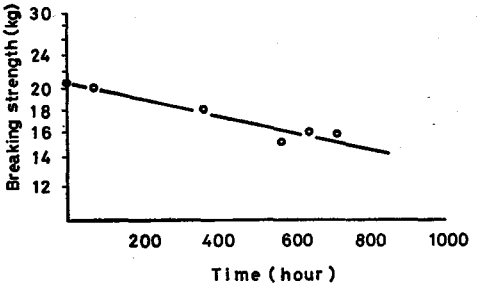

Fig. 6. Breaking strength of overhand knot for Nylon 6 monofilament No. 40 left in high water pressure over elapsed time.

samples left in the high water pressure.

As these experimental results may represent the base of the study of the mechanical properties of the cord for the fishing gear left in the high water pressure, in the future, we will investigate the fatigue phenomenon for the cord left under various conditions such as the constant tensile force, and the repeative tensile force in the high water pressure over a long period of time.

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