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Studies on Strength of Netting (2)

The Knot Strength of Knotted Netting with Meshes Opened*

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그물감의 강도에 관한 연구(2)

주름을 준 매듭그물감의 매듭의 강도

金 大 安**

주름을 준 상태의 매듭그물감의 매듭의 강도를 조사하기 위해, 길이가 70cm 되는 2개의 그물실로 매듭을 만들고 인접한 2개의 다리가 이루는 각 φ를 0°(매듭의 세로방향)로 부터 180°(매듭의 가로방향)까지 변화시켜, 12개의 점에서 그 강도를 측정했다. 또한, 45°의 φ에 전개해 있는 다리중 어떤 1개의 다리를 각 φ'(0°~30°)로 들어 올려 4개의 점에서 그 강도를 측정했다. 그물실의 재료는 mono-filament, multi-filament 및 spun 그물실로 구분하여 10종류를 사용했다.

실험의 결과, φ가 증가함에 따라서 바른매듭의 강도는 거의 직선적으로 감소하고 막매듭의 강도는 거의 직선적으로 증가했다. φ가 100°이하에서는 바른매듭이 막매듭보다 강하고, 100°이상에서는 그 반대였다. φ'가 증가할수록 매듭의 강도는 지수함수적으로 감소했다. 이들 φ, φ'에 의한 매듭강도의 변화는 前報에서 제시한 매듭강도의 식에 의한 변화경향과 거의 일치하는 것 같았다.

INTRODUCTION

In constructing a fishing gear with ropes and other accesories, a netting is fitted to the frame lines with a hanging ratio. If the fishing gear is used actually, the netting is subjected to tensile loads with meshes opened by the hanging ratio, i. e., the four bars around a knot are strained at an angle one another. In general, the four bars are regarded to be in a plane, but the external forces acting on the netting keep the bars from arranging in a plane with considerable frequency.

There exist several literatures on the knot strength of knotted netting with meshes closed lengthwise or breadthwise,[1)~6)] but no experiments have yet been made in order to investigate the knot strength of knotted netting simulating the fishing operation.

This paper deals with the knot strength of knotted netting with meshes opened. In consideration of the action of external forces on the netting in various ways, a short description is given to the knot strength of knotted netting of which any one of four bars around a knot stands at an angle above the netting plane.

MATERIALS AND METHODS

The apparatus used in the experiment are shown in Fig. 1(*a* and *b*). The plate, balanced against a weight *W* lest it should fall down, was vertically moved to have the knot kept in its

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centre. The four bars held on a constant angle until the knot breaks.

The angle φ between the adjacent bars, A—B or C—D, was varied from 0° to 180°, and at twelve values of φ knot strengths were tested (Fig. 1—a). The angle φ' between one bar and the plane made by the other three bars, ranging from 0° to 30° under φ of 45°, was changed by controlling the height of the pulley which was fitted into a hole of the plate(Fig. 1—b). At four values of φ' knot strengths were tested. The observed strength T_1 was converted to the true strength T by means of $T=T_1 e^{\mu'\theta'}$, where μ' is the coefficient of frioien between the bar and the pulley and θ' is the frictional angle between them.

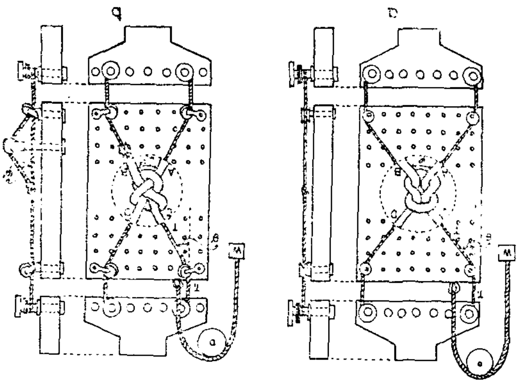

Fig. 1. The apparatus used in the experiment. a: for the angle φ between the adjacent bars, b: for the angle φ' between one bar and the plane made by the other three bars. A, B, C, D: Symbols of bars. $T=T_1 e^{-\mu'\theta'}$.

Netting twines used were polyethylene 42tex (4×3, 5×3, 6×3), nylon 23tex(5×3, 6×3, 8×3), polyester 30tex(7×3, 8×3, 10×3), and cotton 30tex(5×3), each 70cm long, which were tied to form reef knots and trawler knots. The initial interval between two clamps to grip test pieces was 50cm long.

RESULTS AND DISCUSSION

Fig. 2 shows the variation of knot strength with φ. With increasing φ, the the reef knot strength T_r decreases almost linearly, and the trawler knot strength T_e increases almost linearly. Therefore, the relation of T_r and T_e with φ may be given by

$$T_r = T_{ro} - k_r\varphi, \qquad (1)$$

and

$$T_e = T_{eo} + k_e\varphi, \qquad (2)$$

where T_{r0} and T_{e0} are values of T_r and T_e at $\varphi=0°$ respectively, and k_r and k_e constants decided by the fibre materials of netting twines (Table 1). The value of k_r is about 0.60×10^{-3} in polyethylene, 0.90×10^{-3} in Nylon, and 0.55×10^{-3} in polyester. The value of k_e is about 0.70×10^{-3} in polyethylene, 0.85×10^{-3} in nylon, and 0.70×10^{-3} in polyester. The largest value of k_r and k_e seems to be demonstrated by nylon. The two knot strengths become equal at $\varphi=100°$. At φ between 0° and 100° the reef knot is stronger than the trawler knot; at φ between 100° and 180° the reverse takes place. It is therefore emphasized that the reef knot is to be used so as to be given to tensile loads mainly in direction near to its lengthwise stretch and the trawler knot mainly in direction near to its breadthwise stretch.

Table 1. Values of k_r and k_e

Materials		$k_r(\times10^{-3})$	$k_e(\times10^{-3})$
Polyethylene	4×3	0.52	0.60
42 tex	5×3	0.47	0.60
(Mono)	6×3	0.76	0.86
Nylon	5×3	1.11	0.65
23 tex	6×3	0.85	0.72
(Multi)	8×3	0.76	0.63
Polyester	7×3	0.55	0.42
30 tex	8×3	0.51	0.43
(Spun)	10×3	0.58	0.41

The variation of knot strength with φ' is shown in Fig. 3. The reef knot strength T_r' and the trawler knot strength T_e' decrease almost exponentially with increasing φ', i. e.,

$$T_r' = T_{ro}' e^{-c\varphi'}, \quad (3)$$

and

$$T_e' = T_{eo}' e^{-c\varphi'}, \quad (4)$$

where T_{r0}' and T_{e0}' are values of T_r' and T_e'

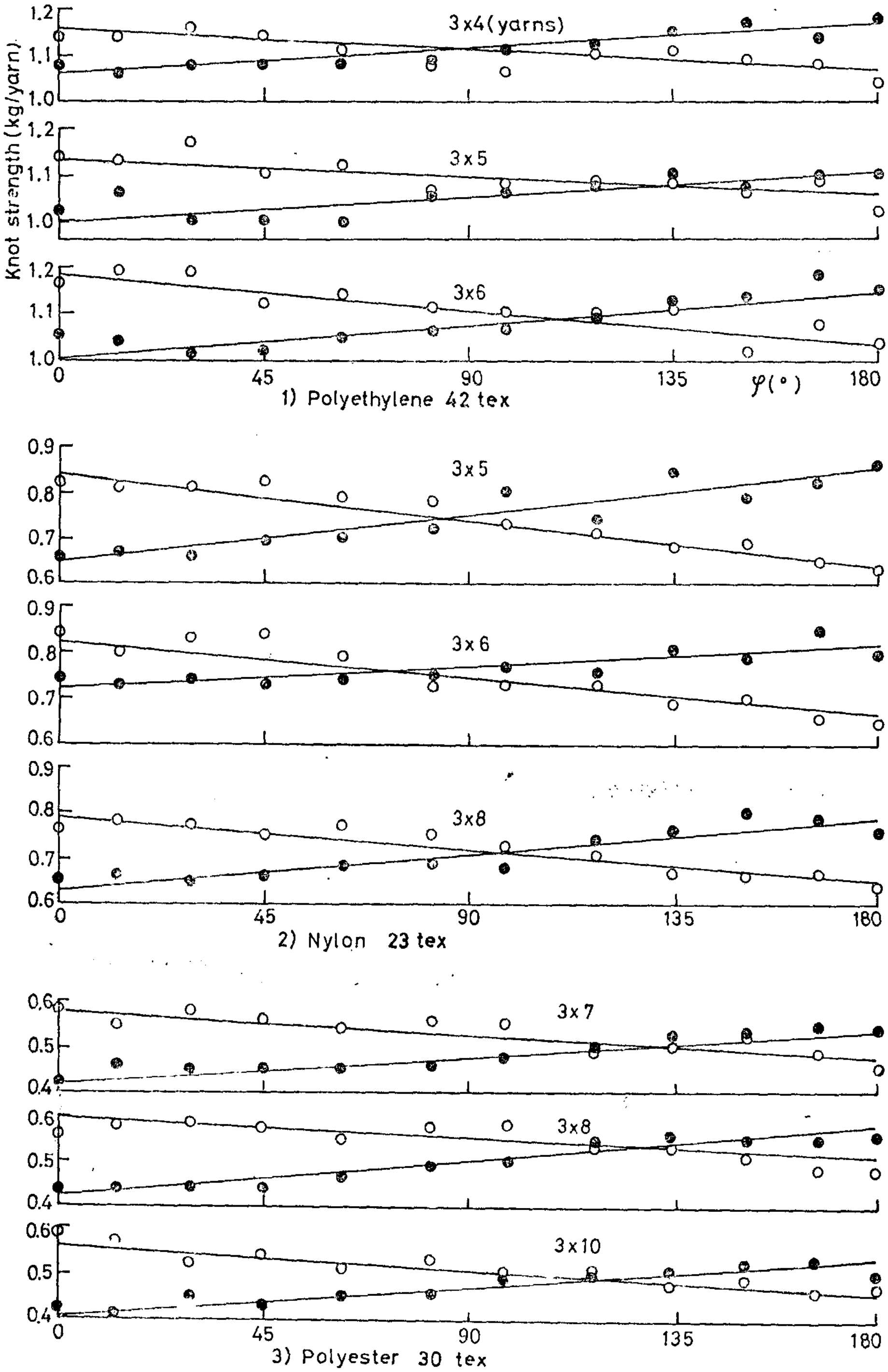

Fig. 2. Variation of knot strength with φ.

○: Reef knot, ●: Trawler knot.

at $\varphi'=0'(\varphi=45°)$ respectively, and c is the coefficient of attenuation. But the decrease seems to be within 10% of T_{r0}' or T_{e0}'. Whichever of four bars may stand at φ', the value of c in the reef knot is constant. That in the trawler knot becomes larger when bar B stands at φ'. It is considered that the knot strengths in case in which the bars are opened at φ and also at φ' may be given by

$$T_r'=(T_{r0}-k_{r\varphi})e^{-c\varphi'}, \qquad (5)$$

and

$$T_e'=(T_{e0}+k_{e\varphi})e^{-c\varphi'}, \qquad (6)$$

if Equation(3) and (4) are valid at φ from 0° to 180° or if $T_r=T_{r0}'$. In these experiments the break of knot was occurred at its tip, i.e., the boundary between it and the bar, as in the previous paper.

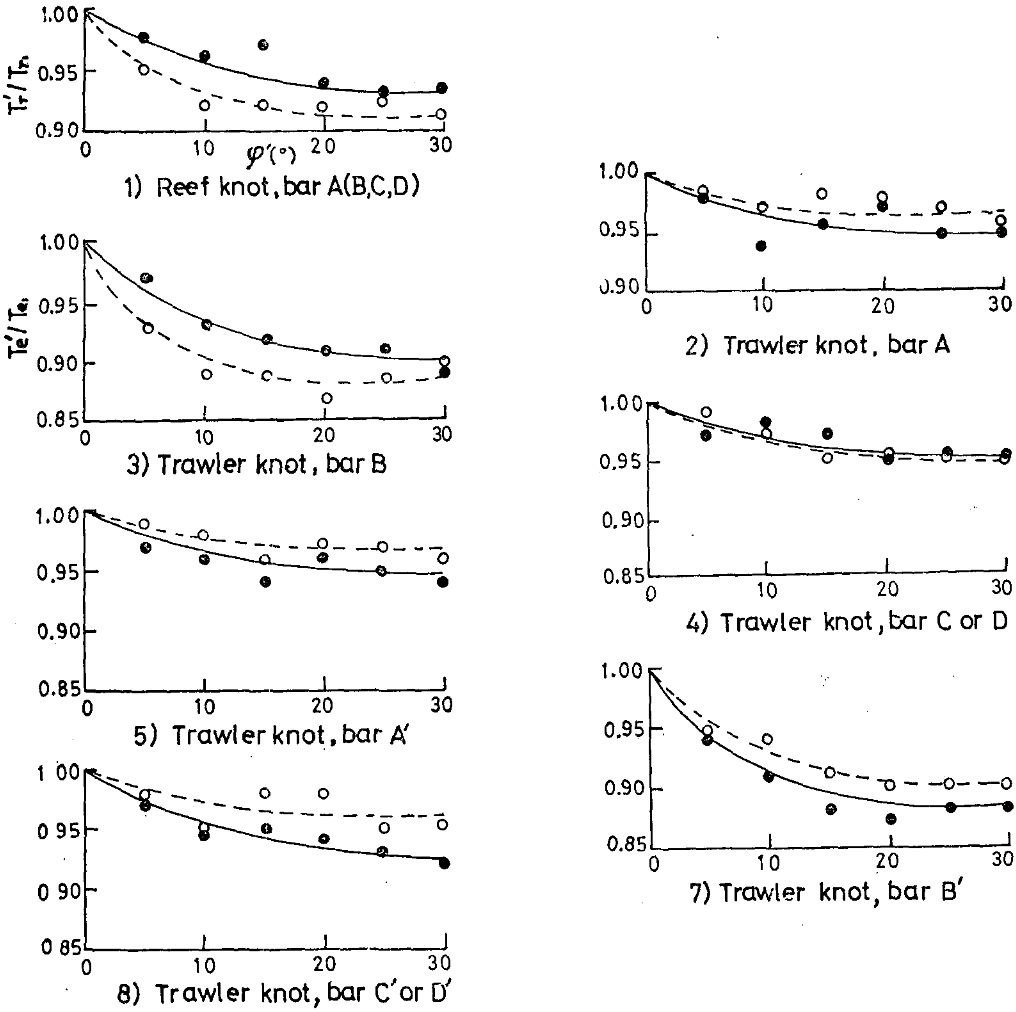

Fig. 3. Variation of knot strength with φ'.
T_r', T_e': Knot strength at φ'. T_{r0}', T_{e0}': Knot strength at $\varphi=45°$ and $\varphi'=0°$.
○----- : Nylon 23tex×5×3, ●—— : Cotton 30tex×5×3.
A', B', D': indicate that the sides opposite to those of bars which was given to φ in Fig. 1 stand at φ'.

The knot strength T of knotted netting with meshes closed lengthwise or breadthwise was expressed, in the previous paper,[6] as

$$T=\frac{T_0}{1+\mu\frac{s}{\rho}e^{-\theta\rho}} \quad (7)$$

The variation of T with φ or φ' is considered to be due to that in slight range of s, ρ and θ. The variation of s, ρ and θ can be roughly seen from Fig. 1 without measuring.

With increasing φ, the reef knot seems to show no change in the value of ρ and to increase gradually in the value of s but slightly. The value of θ by which the extent of the loss of tension in the compressing netting twine is decided, is regarded to decrease gradually with increasing φ, although it looks as if it increases gradually in Fig. 1. This is why by pulling the knot at gradually increased φ, i. e., by pulling the knot towards its breadthwise direction, the compressing twine gradually becomes free from the tightening by another one in the vicinity of the tip opposite to the one which it compresses, and so the loss of tension in it comes to decrease gradually. Consequently, the value of θ comes to decrease gradually with increasing φ. These variation in the values of s, ρ and θ probably led to the almost linear decrease of the reef knot strength.

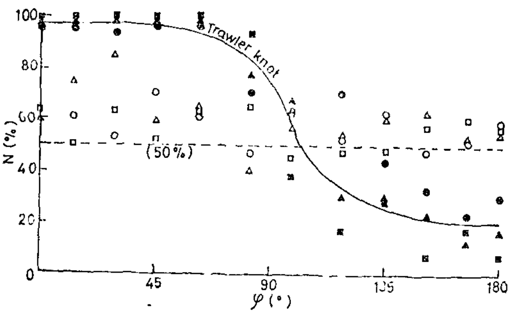

Fig. 4. The number of knots broken from bar A or B, or both in percent. (N).
○●: Polyethylene 42tex (4×3, 5×3, 6×3), △▲: Nylon 23tex(5×3, 6×3, 8×3), □■: Polyester 30tex(7×3, 8×3, 10×3). ○△□: Reef knot, ●▲■: Trawler knot.

On the occasion of the trawler knot, the breakage shifts from the tip of bar A to that of bar C at $\varphi=100°$ (Fig. 4). Therefore, it seems that at φ between 0° and 100° the trawler knot strength varies with s, ρ and θ on the tip of bar A, and at φ between 100° and 180° with s, ρ and θ on the tip of bar C. That is, the tip of bar A seems to have too much smaller value of θ than the tips of the other three bars not to break first. With increasing φ, the value of θ on the tip of bar A seems to increase gradually and that on the tip of bar C seems to decresse gradually. Thus, the tension in the netting twine compressing the tip of bar A seems to decrease gradually and that in the netting twine compressing the tip of bar C to increase gradually. These variation in tension will have the tip of bar A strengthened gradually and that of bar C weakened gradually. At $\varphi=100°$ the tip of bar A and that of bar C will become in strength each other. As φ increases above 100°, both the tip of bar A and that of bar C seem to become stronger by the increase in the value of θ on them. Consequently, the trawler knot seems to increase gradually in the value of θ with φ in addition to the slight decrease in the value of s and so to increase almost linearly in strength.

The increase of φ' seems to cause merely an increase in the value of s and a decrease in the value of θ, and so the knot strengths seem to decrease.

In view of the above results, the knot strength of knotted netting may be expressed by Equation (7), disregarding its shape and the direction of tensile loads acting on it.

Fig. 5 shows the ratio of the knot strength in simultaneous break of four bars to that in non-simultaneous break. At each value of φ both the reef knot and the trawler knot seem to be stronger in the simultaneous break than in the non-simultaneous break. The reef knot seems to have more values of φ and frequency in the simultaneous break than the trawler knot. The simultaneous break is considered to occur when the frictional forces on the four tips of the

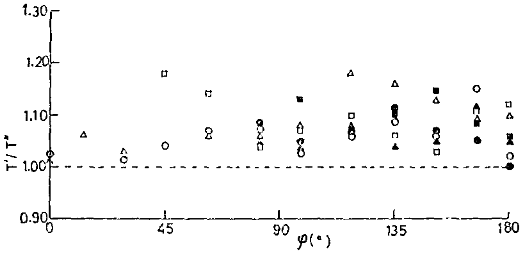

Fig. 5. Ratio of the knot strength in simultaneous break of four bars (T') to that in non-simultaneous break (T''). ○, ●, △, ▲, □, ■: Shown in Fig. 4.

knot become equal one another. It can be therefore seen that the knot given at any value of φ has the maximum strength in the equality of the frictional forces on the tips.

SUMMARY

1) The variation of the reef knot strength T_r and the trawler knot strength T_e with the angle φ between the adjacent bars are given by

$$T_r = T_{ro} - k_r\varphi$$

and

$$T_e = T_{eo} + k_e\varphi,$$

where T_{ro} and T_{eo} are values of T_r and T_e at $\varphi=0°$ respectively, and k_r and k_e constants decided by the fibre materials of netting twines (φ is 0° when the knot is pulled lengthwise).

2) The variation of the reef knot strength T_r' and the trawler knot strength T_e' with the angle φ' between any one bar and the plane made by the other three bars may be expressed by

$$T_r' = T_{ro}'e^{-c\varphi'}$$

and

$$T_e' = T_{eo}'e^{-c\varphi'}$$

where T_{ro}' and T_{eo}' are values of T_r' and T_e' at $\varphi'=0°$ ($\varphi=45°$) respectively, and c is the coefficient of attenuation.

3) Knot strength of knotted netting may be expressed by the expression derived in the previous paper, disregarding its shape and the direction of tensile loads acting on it.

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REFERENCES

1) Tauti M. (1931): The decrease of the strength of cords at the knot. J. Imp. Fish. Inst., 26, 41-51.

2) Miyamoto H. (1956): *Gyogugyohogaku* (Fishing gears and methods). 1st ed., p. 85, Kinbara shuppan, Tokyo. (In Japanese)

3) Honda K. (1953): in "*Kasenbinran*" (Chemical fibres handbook. ed. by K. ATSUGI et al.). 1st ed., p. 526, Maruzen, Tokyo. (In Japanese)

4) Shimozaki Y. (1957): Fish. Tech. Ser., 3, 77-79.

5) Kusaka T. and K. Kanda (1962): in "*Suisanhandobuku*" (Fisheries handbook, ed. by M. UDA et al.). 1st ed., Touyo Keizai Shimbosha. Tokyo. (In Japanese)

6) Kim. D. A(1976): Studies on strength of netting (1). The decrease in strength of netting twines by knotting. This bull., 9(1), 1—7.