CHAPTER VI
RASCHEL KNOTLESS NETTING

6.1. Introduction

Knotless nets have been known for a long time and as the name implies are nets devoid of knots, the twines being joined at the mesh corners by an interlacing of the adjacent mesh bars. Introduction of chemical fibres for fishing brought the idea of welding or gluing synthetic fibres together to form netting. Stamping or molding finished net sheets have been unsuccessfully tried (Brandt, 1964).

The knotless net was invented in 1922 by the Nippon Seimo Co.Ltd. and was first introduced in the Japanese fishery (Nippon Seimo, 1959). This type of knotless netting is made of twines consisting of only two yarns. Meshes are formed by interlacing the yarns of two twines, once or several times. By increasing the number of interlacing of the twines at the joining points, the shape of the mesh may be changed from rhomboid to hexagonal. This method of making knotless netting is known as the Japanese twisted type, and the technique stimulated efforts elsewhere to develop production techniques for new types of knotless netting.

Consequent to these efforts, another type of knotless netting was introduced into fisheries around 1951. The manufacture of this type of netting was based on the Raschel technique popular in curtain-making for about a century and hence this type of knotless netting came to be known as Raschel.
knotless netting. This method has been developed in Germany in 1950 (Viswanathan, 1972), from where it spread quickly to other European countries and the U.S.A.

The bars of the meshes are built up by one or two knitted stitches made by looping of yarns referred to as looped threads (Damiani, 1964). Besides, additional loops for strengthening are provided by another set of yarns referred to as laid-in-threads or swing threads. In the most popular type of Raschel knotless netting, a thread is formed by three ends - two laid-in-threads and one looped, entwined together. The laid in threads are in an almost rectilinear position, while the looped threads follow a more complicated path. (Fig. 6.1)

The Raschel technique of knitting is done by special machines (Reichel, 1960). It not only makes the connections to form meshes but also knits the mesh bars. Therefore the Raschel machine operates quite differently from knotting machines, in that it produces, per unit time, not a certain number of connections but a certain area of netting which is not influenced by the mesh size (Brandt, 1964). There is no uniformity of opinion as yet regarding the mesh size above which the production of knotless Raschel nets are no more profitable. But, the output of Raschel machines increase with increasing strand size because the number of stitches per centimeter for building up the bar decreases with increasing strand sizes. This contradicts the widespread opinion that this technique is profitable only for the production of small-meshed netting. Apparently, the
possibilities of the Raschel technique for producing heavy, large-meshed netting are gaining popularity in many countries.

The Raschel type knotless netting has characteristics of both the knotted as well as that of the Japanese twisted types and various combinations are possible depending on the choice of yarns used for looped and laid-in-threads and the method of interlacing of the threads (Nakamura, 1971). According to Damiani (1964), the more complex the structure of joints, the stronger and more durable they are, according to whether only the looped threads or also the laid-in-threads are entwined and depending upon the number of binding points. But a comparison of twine strength lost in the joints between knotted and Raschel knotless nettings was not possible due to the difference in the construction of the joints (Mugaas, 1964).

Advantages of knotless netting

Knotted netting has some principal disadvantages for fishing nets. An important factor is that knotting causes a significant decrease in the breaking strength (Klust, 1982). Another disadvantage is that the protruding knots are more susceptible to abrasion. In knotted netting a substantial proportion of the length of netting yarn goes into the knots, increasing the weight but not the useful area of the netting and this portion increases with decreasing mesh size and increasing diameter of the netting yarn.
Contrary to these unfavorable characteristics of knotted netting, the knotless netting claims many advantages. But the presence of at least two different construction techniques, twisting and Raschel, permit a wide range of modifications regarding the connections and twine, causing the advantages to vary quantitatively with each type of netting. The validity of these advantages also vary for different types of fishing gear.

All the essential advantages claimed by knotless variety are mainly due to the absence of knots. One significant advantage is that, since less twine is used to make the meshes for the same area, knotless netting would be lighter. This reduction in material used, greatly reduces the bulk, making it easier to handle the gear. In certain instances a saving of up to 50 percent by weight of material is noted. This in turn translates into a reduced production cost. Another important advantage is the low resistance offered by the knotless netting to the flow of water, making it possible to increase towing speed or the gear size.

The loss in strength, when knotted, is about 18 to 20 percent for natural fibres and 30 to 40 percent for synthetic fibres (Klust, 1982). But in knotless nets, as the fibres undergo practically no sharp bending, there is no reduction in strength and as a result, correspondingly lighter twine can be used.
Yet another benefit of avoiding knots is that since there is no tightening of knots, as in knotted nets, the meshes undergo no change and is almost 100 percent constant throughout its life (Nippon Seimo, 1959). The damage caused by abrasion of knots as a result of friction with the bottom of the operating area, against the boat's side or with other gear parts, can also be reduced in knotless nets.

The absence of interstices of knots considerably reduces the adherence of dirt and micro-organisms, so that knotless nets are much less fouled and need less washing. Other advantages such as causing relatively less damage to fish collected in the cod end, convenience and perfection in dyeing and quicker drying are also attributed to the knotless netting.

**Specification of Raschel knotless netting**

Even though the Raschel type knotless netting was introduced to fisheries during the early fifties, its production in India began only in 1964 (Lal, 1969). The properties and mode of specification of the Raschel type of knotless netting produced in India by four different production units have been studied in detail by Gopalan Nayar and Radhalakshmi (1981).

The popular 210 denier nylon multifilament yarn is used as looped as well as laid-in-threads. When used as looped threads, it is paired with either the same denier or heavier denier yarn laid-in-threads. Samples with 210 denier yarn as
laid-in-threads and finer yarns as looped threads are also made. Use of finer denier yarns for looped threads is advantageous, since increase in weight by looping of yarns is reduced.

For specifying a knotless netting the quality numbers combined with dimensions of the netting are denoted. The first digit of the quality number expresses the first digit of the denier size of looped thread yarn, the second digit denotes the first digit of the denier size of laid-in-thread yarn and the last two digits, the size of mesh in mm (Gopalan Nayar and Radhalakshmi, 1981). In samples where more than one multifilament yarn was used for laid-in-thread, a third digit was incorporated before denoting the mesh size, to indicate the size of the second laid-in-thread yarn.

Raschel denier of the netting which is indicative of the weight is derived by adding the denier size of the laid-in-threads with four times that of the looped threads, since when looped threads stitch the bars, four times the length is utilized for the formation. A Raschel netting is economical by weight if the Raschel denier is nearer, equal to or is less than the resultant denier of the knotted equivalent. The sum total of the strength of laid-in-threads and looped threads gives the strength of Raschel netting. Laid-in-threads are in an almost linear position and hence the strength can be equated to the linear strength of the basic yarn. Loop ed threads follow a complicated path and hence there is a 25 percent reduction in strength by looping (Tani, 1964).
A recent development in the field of knotless netting has been the introduction of braided knotless netting. But it is yet to be introduced into fishing on an industrial scale. In this type, the bars are real braids consisting of three or four strands, which are braided together with the strands of the neighbouring bars, thus forming the joints. All threads run diagonally through the netting. It is possible that this type of knotless netting will prove superior to the other types of knotless netting (Klust, 1982).

6.2. Objectives

The acceptance of knotless webbing by the fishermen for the construction of different parts of the gear operated in the backwaters is an interesting phenomenon, since the introduction of this netting was done by the fishermen themselves and was not the result of any scientific study highlighting the advantages of this type of net for any specific gear or parts of a particular gear. Preliminary studies have shown that local fishermen have selected the knotless netting mostly in stake nets and Chinese nets where a large number of small sized meshes are required, especially in the codend region. Hence the preference for knotless netting could have been a labour saving measure. Advantages such as uniform mesh size, reduced bulk and cost benefits could have also helped in the change from the knotted to knotless netting.

Twines in knotted netting are supposed to be
exchangeable if they have equal knot strength in wet condition. However, there are cases where, for special reasons in respect of certain fishing gear, other properties such as diameter, stiffness, visibility etc. have also been taken into consideration. But this well known practice of substituting twines in knotted netting cannot be applied to knotless Raschel netting because netting strength depends not only on the property of the twines, but also on the strength of the particular type of Raschel connection (Brandt, 1964). Hence the exchangeability of knotted and knotless netting, or of knotless nets made of different systems is based on the mesh strength, and an exchange is possible between netting of different constructions if the mesh strength in wet condition is more or less equal.

Therefore, it was the objective of this study to evaluate through basic studies, the properties of the Raschel Knotless netting used by the local fishermen, in order to ascertain whether the replacements made by them are actually advantageous in terms of mesh strength and reduction in material, affecting a lowering in the cost of fabrication of the gear.

6.3. Materials and method

The experiments were carried out in order to study the mesh strength in relation to different number of meshes in width and also with different mesh sizes, for Raschel knotless netting. The samples selected were similar to those employed by the local fishermen and had quality numbers 2 2 2 1 6, 2 2 2 2 0 and
A sample of knotted netting of 210x2x3 specification, which was replaced by the knotless netting was also tested for comparison. The length of panels were fixed at 200 mm and the number of meshes in width ranged from 1 to 4.

The tests were conducted in the ZWICK 1484 Universal Testing System and the procedure followed was a modification of the proposal for measuring netting strength cited by Brandt and Carrothers (1964). Strips of netting having 3, 4, 5 and 6 meshes in width were taken, so as to have an extra column of meshes at either sides and an extra row of meshes at the top and bottom. This was to avoid the effect of any knot loosening that might be caused if tension was applied to meshes at the edge. Instead of hooks mentioned in the proposal of Brandt and Carrothers (1964), pins, similar to those employed for mesh strength experiments by Wijngaarden (1959), were used in the present experiment for the attachment of the nettings.

To estimate the extent of reduction in material that can be achieved by substituting knotted netting with knotless, weights of knotted nettings, of specification 210x2x3 and dimensions of 100 x 100 meshes, were ascertained for mesh sizes 10, 14, 18, 22 and 26 mm. This was compared with the weights of knotless nettings of same dimensions and of quality numbers 2 2 2 1 0, 2 2 2 1 4, 2 2 2 1 8, 2 2 2 2 2 and 2 2 2 2 8, used to replace the knotted nettings.
Different methods are adopted for the calculation of the weight of netting. Radhalakshmi (1964) put forward a method for estimating the weight of netting based on the theory of Kawakami (1964) that the weight per unit length of a twine is proportional to the square of its diameter and that the length of twine required for knot is proportional to its diameter. Japanese workers Hachii and Nose (1987 a, b) have developed equations for finding the weight in air of nylon netting. For the present study a more direct method suggested by Fridman (1988) was followed.

\[ W_n(g) = L_t \cdot \text{Rtex} \cdot 10^{-3} \]

Where \( W_n \) is the weight of netting in grams

\( L_t \) is the total length in meters of yarn or twine used in a netting panel and

\( \text{Rtex} \) is the linear density of the final netting yarn or twine.

The total length in meters of yarn or twine (\( L_t \)) that goes into a netting panel, including that used in knots, was estimated from

\[ L_t = E_y \cdot \left( \frac{A_f}{m_1} \right) \cdot 10^{-3} \]

Where \( E_y \) is the knot correction factor

\( A_f \) is the fictitious area of the netting panel and

\( m_1 \) is the mesh length

In usual conditions, Fridman (1988) recommends an \( E_y \)
of 2.4 for knotted nettings and 2 for knotless nettings.

The fictitious area \( A_f \) is an unrealizable conceptual area of netting, when it is considered to be fully stretched in both horizontal and vertical directions simultaneously.

\[ A_f = \frac{A_n}{E_1 E_2} \]

Where \( A_n \) is the actual working area of the netting panel and is the product of horizontal and vertical hung lengths.

\( E_1 \) and \( E_2 \) are the primary and secondary hanging coefficients respectively.

Rtex for the netting yarn in knotted netting was calculated from the runnage values, given in IS 4401 (1981) and for knotless netting the increase in length, by four times, of the looped thread due to looping and the length of laid-in-thread was also considered (Gopalan Nayar and Radhalakshmi, 1981).

6.4. Results and discussion

Kondo (1960) suggests that breaking strength of the netting is proportionate to the number of meshes on the width side and to the number of yarns in the netting yarn for a given yarn size and has no relation to mesh size and length. His experimental samples included cotton and synthetic knotted
nettings. The applicability of his assumption was checked for the knotless netting in the present work. A comparison was also made with a representative knotted equivalent. Table 6.1 gives the strength of netting of different mesh sizes for Raschel knotless type and for the knotted sample. Even though there is no direct proportionality between the number of meshes on the width side and mesh strength, the relation was linear (Fig 6.2) with the formula

$$Y = a + bx$$

where $Y$ is the strength of the netting

$a$ and $b$ are constants and

$x$ is the number of meshes on the width side.

with a high correlation coefficient (Table 6.2). In the case of knotted netting also, the correlation between the number of meshes on the width side and mesh strength was linear as in the case of knotless, with a correlation coefficient of 0.9998.

To ascertain the influence of mesh size on mesh strength, the Chi-square statistic was applied (Fisher and Yates, 1957). A 3 x 4 contingency table was formed in which one attribute was the mesh size having the classification 16, 20 and 24 and the other attribute, strength, having four classes, 50-100, 100-150, 150-200 and 200-250. The Chi-square worked out to 1.473 having degrees of freedom six. This was not significant at 5 percent level indicating that mesh strength was independent of mesh size.

The knotted netting registered higher strength in all
cases than the Raschel knotless nettings. But Brandt (1964) based on mesh strength studies with both knotted and knotless nettings of different constructions, has stated that in all cases, the mesh strength of Raschel knotless netting was higher than that of knotted nettings made of the same fibre material. The reason for the reduced strength registered by Raschel knotless netting used to replace the knotted netting by the local fishermen was due to the fact that the knotless netting was selected on the basis of total nominal denier of the knotted netting they replaced, rather than on its resultant equivalent. Hence to arrive at the knotless equivalent for knotted netting, the following steps are suggested after Gopalan Nayar and Radhalakshmi (1981).

To find the knotless equivalent for 210x2x3 knotted netting, first its resultant denier, which is the weight in grams of 9000 m of netting twine, was ascertained in the following manner.

\[
\text{Weight of 1 m of single yarn in the twisted form} \times \text{Number of single yarns in the netting yarn} \times 9000 = 1450
\]

The mesh strength of a 210x2x3 knotted netting sample was then experimentally determined and was found to be 8541 gf.

The Raschel denier (Rden) equivalent to obtain this strength was worked out using the equation.

\[
\text{Rden} = 4X + Y
\]
Where \( X \) is the denier of the looped thread and 
\( Y \) is the denier of the laid-in-thread.

Since the knotted twine to be replaced had a resultant

denier of 1450, the above equation becomes

\[
4X + Y = 1450 \quad \text{(6.1)}
\]

And the mesh strength of Raschel netting (\( R_{\text{ms}} \)) was calculated using the equation

\[
R_{\text{ms}} = (t \times s_1 \times s_2 \times X) + (t \times s_2 \times Y)
\]

Where \( t \) is the tenacity in g/denier of 210 denier

multifilament yarn available in India (IS 4401 1981).

\( s_1 \) is the percentage of strength retained after

looping and

\( s_2 \) is the percentage of strength retained after

wetting.

Since the looped thread losses 25 percent strength due

to looping and 20 percent by wetting and the laid-in-thread

losses 20 percent strength by wetting, the above relationship

becomes

\[
\left(6.5 \times \frac{75}{100} \times \frac{80}{100} \times X\right) + \left(6.5 \times \frac{80}{100} \times Y\right) = (3.9X + 5.2Y)\times 100
\]

For obtaining equal strength as that of the knotted

this should be equal to 8541 gf. Hence

\[
(3.9X + 5.2Y) \times 100 = 8541 \text{ gf} \quad \text{(6.2)}
\]
Subtracting equations (6.2) from (6.1), the value of $X$ was found to be 193.5

Substituting the value of $X$ in equation (6.1), the value of $Y$ was found to be 676.15.

From the above it becomes evident that to make a substitution of knotted 210x2x3 netting with knotless netting, the denier for looped thread should be 193.5 and for laid-in-thread, the denier should be 676.15, which would have resulted in a total Raschel denier of 1450. However, in practice, the knotless netting of quality number 2 2 2, used for replacing knotted netting of 210x2x3 has as its looped thread a yarn of 210 denier and as laid-in-threads 2 yarns of 210 denier each, resulting in a total Raschel denier of only $(4 \times 210) + 420 = 1260$. Hence the reduction in mesh strength in comparison with the knotted nettings.

Due to the above mentioned reason, it was found that on an average, knotless nettings of 2 2 2 quality number, recorded 25 percent lesser strength than nettings of knotted 210x2x3 specification. But this reduction in strength neither affected the performance nor the longevity of those parts in which knotless nettings were used in gears such as stake nets or Chinese nets. This was evidenced by the absence of any abnormally high incidence of breakage of these parts. It was, therefore, apparent that the strength of knotless webbings used
for substitution was more or less sufficient for the respective parts.

The replacement also results in a saving of material. The weight of knotted and knotless webbings of standard dimensions was worked out for different mesh sizes and was also compared with the observed values (Fig. 6.3). To test the significance of the difference between the calculated and observed values, Students t-test was applied. The t values were 0.0468 and 0.0595 for 8 df in the case of knotted and knotless webbings respectively, indicating that the difference was not significant at 5 percent level. Irrespective of the mesh size, it was found that about 30 percent saving of material by weight could be achieved by replacing knotted with Raschel knotless netting (Table 6.3).

Considering all the above aspects, the substitution of knotted netting with knotless netting in certain gears operated in the backwaters can be said to be advantageous and a step in the positive direction.
FIG. 6.1 LAID-IN-THREADS AND LOOPED THREADS FORMING A BAR IN RASCHEL KNOTLESS NETTING.
1 and 3 LAID-IN-THREADS
2 LOOPED THREAD
FIG. 6.2 RELATION BETWEEN THE NUMBER OF MESHES ON THE WIDTH SIDE AND MESH STRENGTH.

FIG. 6.3 COMPARISON OF THEORETICAL AND OBSERVED WEIGHT OF KNOTTED AND KNOTLESS NETTING.
### TABLE 6.1 STRENGTH OF NETTINGS OF DIFFERENT MESH SIZES.

<table>
<thead>
<tr>
<th>Type</th>
<th>Specification</th>
<th>Mesh size (mm)</th>
<th>Mesh strength of panels with different number of meshes in width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22216</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Knotless</td>
<td>68.83</td>
<td>127.14</td>
<td>170.34</td>
</tr>
<tr>
<td>22220</td>
<td>60.51</td>
<td>117.58</td>
<td>160.96</td>
</tr>
<tr>
<td>22224</td>
<td>73.88</td>
<td>145.41</td>
<td>183.97</td>
</tr>
<tr>
<td>Knotted</td>
<td>210 x 2 x 3</td>
<td>20</td>
<td>85.41</td>
</tr>
</tbody>
</table>

### TABLE 6.2 CORRELATION COEFFICIENT OF STRENGTH WITH NUMBER OF MESHES IN WIDTH.

<table>
<thead>
<tr>
<th>Material</th>
<th>Nylon knotless</th>
<th>Nylon knotted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specification</td>
<td>22216</td>
<td>2220</td>
</tr>
<tr>
<td>Mesh Size</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>No. of meshes in width</td>
<td>1,2,3,4</td>
<td>1,2,3,4</td>
</tr>
<tr>
<td>Corr. Coeff.</td>
<td>0.989160</td>
<td>0.997121</td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
</tr>
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</table>
TABLE 6.3 WEIGHT OF KNOTTED AND KNOTLESS NETTINGS OF DIMENSION 100x100 MESSES FOR DIFFERENT MESH SIZES.

<table>
<thead>
<tr>
<th>Type Specification</th>
<th>Mesh size (mm)</th>
<th>An (Sq.mm)</th>
<th>Af (Sq.mm)</th>
<th>Ey (m)</th>
<th>Lt (m)</th>
<th>Rtex (g)</th>
<th>Calculated Weight (g)</th>
<th>Observed Weight (g)</th>
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<tbody>
<tr>
<td>10.00</td>
<td>433012.70</td>
<td>1000000</td>
<td>2.4</td>
<td>240.0</td>
<td>159.5</td>
<td>38.28</td>
<td>40.26</td>
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</tr>
<tr>
<td>14.00</td>
<td>848704.89</td>
<td>1960000</td>
<td>2.4</td>
<td>336.0</td>
<td>159.5</td>
<td>53.59</td>
<td>57.35</td>
<td></td>
</tr>
<tr>
<td>Knotted 210x2x3</td>
<td>18.00</td>
<td>1402961.15</td>
<td>3240000</td>
<td>2.4</td>
<td>432.0</td>
<td>159.5</td>
<td>68.90</td>
<td>74.40</td>
</tr>
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<td>22.00</td>
<td>2095781.47</td>
<td>4840000</td>
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<td>528.0</td>
<td>159.5</td>
<td>84.22</td>
<td>91.00</td>
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</tr>
<tr>
<td>26.00</td>
<td>2927165.85</td>
<td>6760000</td>
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<td>624.0</td>
<td>159.5</td>
<td>99.53</td>
<td>107.50</td>
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<td>280.0</td>
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</tr>
<tr>
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<td>360.0</td>
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<td>60.98</td>
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<tr>
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<td>6760000</td>
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<td>520.0</td>
<td>138.6</td>
<td>72.07</td>
<td>64.75</td>
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