Effect of Sunlight and UV Radiation on Mechanical Strength Properties of Nylon Netting Twines

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The tensile strength properties of nylon netting twines of two specifications, viz. 210/1/2 and 210/2/3, were studied on exposure to natural sunlight and artificial ultraviolet radiation. Tauti's equation, which relates to the microbial deterioration of cotton twines, was found applicable to the present data from which the coefficients of deterioration (K) were evaluated in each case. The significance of sample-to-sample variation in the rate of deterioration of nylon twines was tested by covariance analysis.

The fishing industry, especially in the context of expansion of fishing activities in the extended exclusive economic zone, utilizes large quantities of a variety of synthetic twines for fabricating fishing nets. The deteriorating action of sunlight usually occurs when the net is in operation, taken to and from the fishing ground, and kept for drying. The serviceability of netting is affected when a change in mechanical properties, notably a reduction in tensile strength, occurs. The solar energy received in the tropics being considerably more than in temperate countries, there is need to study the deterioration of the strength of synthetic twines in the tropics. The strength of synthetic twines on exposure to UV light has not so far been evaluated in detail. Hence the present study to assess the quality of the commercially available undyed nylon twines, in which UV absorbers are said to be incorporated, but in which the type of stabilization is unspecified by manufacturers.

Materials and Methods

The study was made on nylon twines of two specifications, viz. 210/1/2 and 210/2/3, obtained from three different commercial sources: firms A, B and C. The twines were subjected to natural and artificial UV radiation and the results compared. For subjecting to natural UV radiation, the twines were tied to a rectangular frame held vertically and kept in a north-south direction on the roof top where sunlight falls directly on the twines during the whole day. Marine atmospheric conditions prevailed at the test site. The twines were exposed for 3, 10, 15, 20, 25, 50, 75, 100, 125, 150 and 180 days.

Simultaneously, the samples were exposed to artificial UV radiation in a UV irradiation chamber (Fig. 1). In the centre of the chamber, two 30 W ultraviolet germicidal tubelights, each of 90 cm length and 2.5 cm diam, were fixed vertically. The ultraviolet

output at 253.7 nm was 8.3 W and at a distance of 1 m, the output was 85 μW cm^{-2}. The twines were held 20 cm away from the light source, tied loosely to two circular rings provided at the upper and lower sides of the chamber as shown in the figure and exposed for 80, 105, 140, 180, 205, 235, 280 and 325 h . The periods of exposure (h) were calculated from an elapsed time indicator connected to the circuit, with a 5-digit hour counter. During the exposure of twines in the chamber, the inside temperature of chamber was $30 \pm 2°$C and RH 75-85%.

The exposed twines were retrieved at the defined intervals and were tested for breaking strength on a tensile strength testing machine in accordance with IS: 5815 (Part IV): 1971. Tensile strength measurements for each set of twines were made on 15 samples and the average value was taken.

Results and Discussion

Assessment of deterioration is usually made on the basis of the measurement of the viscosity of fibre in a suitable solvent under standard conditions[1], weight loss determination[1], or loss in strength[2]. Several research workers have shown that Nylon 66 absorbs light strongly in the region of wavelength 250 nm (ref. 3). In fishing nets, as the residual strength of the twine provides a direct measure of the serviceability, the tensile strength of the twine was recorded as a function of exposure to UV radiation and natural sunlight. From this, loss in strength at any defined period can be calculated.

Tauti's equation[4]:

Log $T/(T_0 - T) = -(K \log e) t + $ constant

where T_0 is the breaking strength of twine exposed to seawater when the rotting has not yet started; T, the breaking strength of twine exposed to seawater for t days; t, the number of days of exposure of the twine; and K, the coefficient of rotting, was applied to study

the rotting course of a twine exposed to seawater[5]. In the present context, as the materials were subjected to UV radiation instead of immersion in seawater, the symbols T_0, T, t and K have the following definitions:

T_0 is the breaking strength of twine before exposure to UV radiation; T, the breaking strength of twines exposed to UV radiation for a period of t days/hours; t,

the period of exposure; and K, the coefficient of deterioration.

Tauti's equation was fitted to the data for each sample, separately for samples exposed to natural and artificial UV radiation and also separately for the two specifications. The equations were fitted by regressing $\log T/(T_0 - T)$ on t; and the slopes, $-K \log e$ and constants were estimated by the method of least squares. The correlation coefficients between the variables were found to be highly significant (Table 1) for all the twine samples showing that Tauti's equation fitted the data well. Thus, the fraction of retained strength to the strength lost in the logarithmic scale appears to be proportional to t in the range of exposure periods. The fitted regression lines drawn on the scatter diagram are shown in Figs 2 and 3. From the
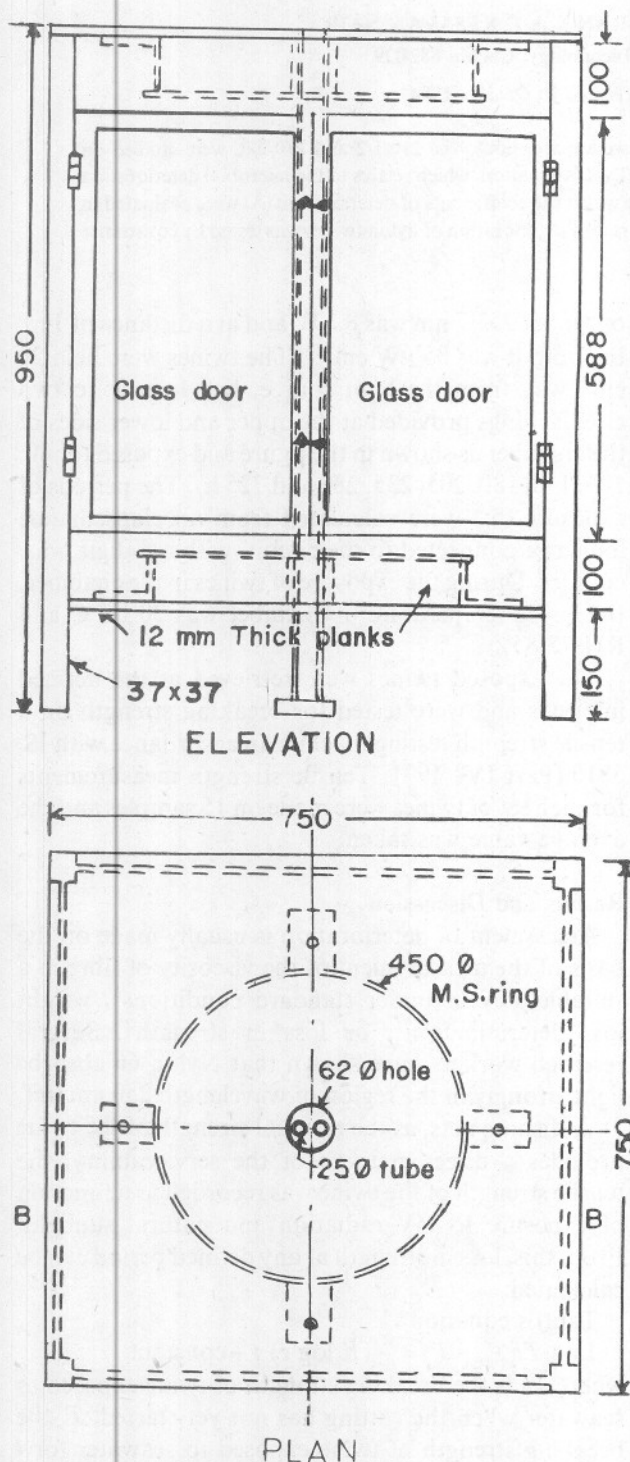

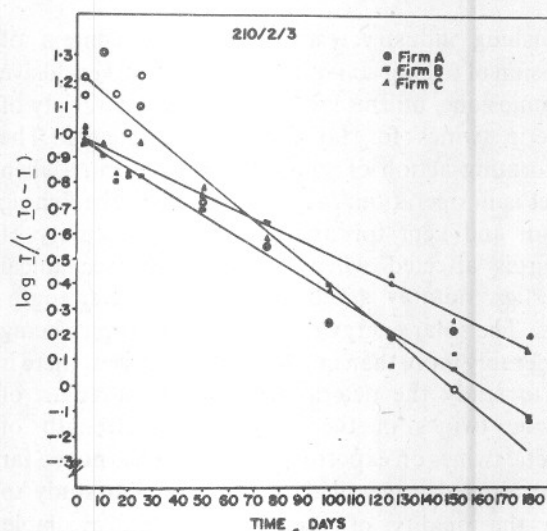Fig. 1—UV irradiation chamber (scale, 1:10 and all dimensions in mm)

Fig. 2—Plot of $\log T/(T_0 - T)$ on t (under natural exposure) with the fitted regression lines for 210/2/3

Table 1—Values of K and Constant in Tauti's Equation

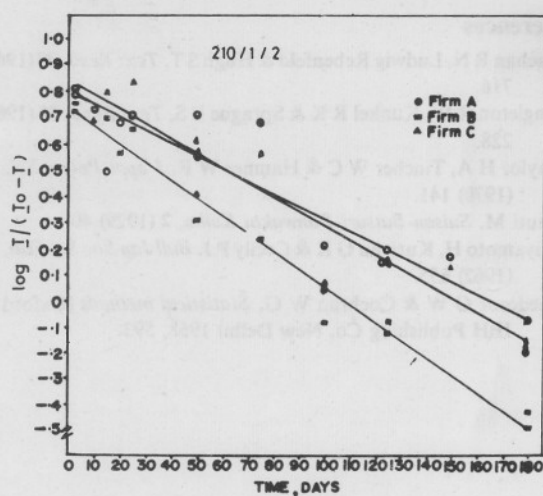| Firm	Sample	$K \log e$	K	Constant	Correlation coefficient r
Samples exposed to natural sunlight for t days					
A	210/2/3	0.008420	0.01939	1.2459	−0.9533**
B	210/2/3	0.006098	0.01404	0.9825	−0.9833**
C	210/2/3	0.005001	0.01152	0.9942	−0.9681**
A	210/1/2	0.004940	0.01138	0.8079	−0.9164**
B	210/1/2	0.006889	0.01600	0.7450	−0.9867**
C	210/1/2	0.005626	0.01296	0.8470	−0.9329**
Samples exposed to artificial ultraviolet radiation for t h					
A	210/2/3	0.002245	0.005170	1.1064	−0.9610**
B	210/2/3	0.001978	0.004553	0.4245	−0.8136**
C	210/2/3	0.002679	0.006168	0.6042	−0.9117**
A	210/1/2	0.002235	0.005145	0.5963	−0.9681**
B	210/1/2	0.002041	0.004700	0.2080	−0.8773**
C	210/1/2	0.002661	0.006127	0.6754	−0.9571**

**Significant at 1% level.

Fig. 3—Plot of log $T/(T_0 - T)$ on t (under natural exposure) with the fitted regression lines for 210/1/2
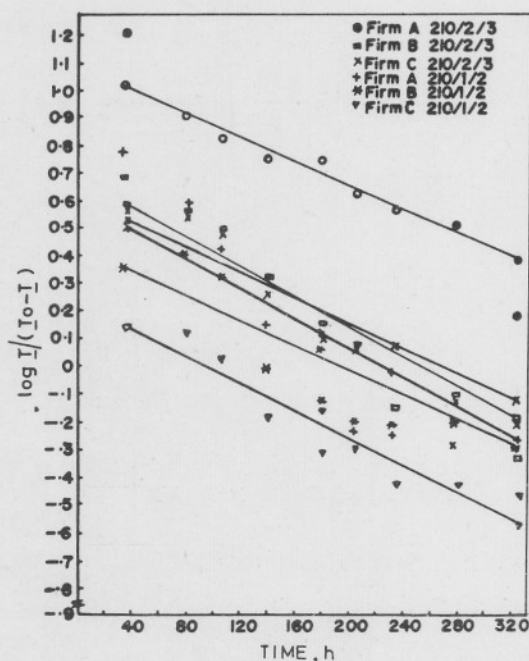

Fig. 4—Plot of log $T/(T_0 - T)$ on t (under artificial exposure) with the fitted regression lines for 210/2/3 and 210/1/2

slopes of the equations, the K values were calculated. The values of K and constants are given in Table 1. The values of constants depend on the initial strength of the samples. The difference in K values may be due to the differences in the strength of the material or treatments given to samples.

Comparison of the K values obtained for the different samples and specifications under natural exposure was made by analysis of covariance[6]. The homogeneity of residual variances was tested by using Bartlett's test. The test statistic (computed as 10.7)

which is distributed as a χ^2 (with 5 df, here) was not found to be significant ($p > 0.05$). The F-test for comparison of slopes was, therefore, carried out and this was found to be highly significant ($F = 4.49^{**}$; df $= 5,53$), showing that there was difference in slopes and therefore in K. Grouping according to specification was then made and analysis applied separately to the two groups. The difference in slopes was found to be highly significant for the specification 210/2/3 ($F = 9.93^{**}$; df $= 2,26$), showing that the coefficients of deterioration varied from sample to sample. But the analysis of covariance applied to 210/1/2 did not reveal any significant difference in the slopes and hence in the K values ($F = 2.48$; df $= 2,26$), showing that the coefficient of deterioration remained more or less the same for this specification.

Application of Bartlett's test for homogeneity of variances to the residual variances showed that the variances were homogeneous with $\chi^2 = 5.81$ ($p > 0.05$) for 210/2/3 and 3.97 ($p > 0.10$) for 210/1/2 with 2 df for each. But for 210/2/3, the value is close to 5.99, the χ^2 value corresponding to 5% level. The scatter diagrams along with the fitted straight lines corresponding to the two specifications 210/2/3 and 210/1/2 are shown in Figs 2 and 3 respectively. The equality of slopes 210/1/2 is exhibited by the parallel nature of the straight lines.

The K values obtained under UV exposure were compared and analysis of covariance was carried out. The test statistic for homogeneity of variance worked out to 6.11 ($p > 0.25$) for 5 df, which is not significant, showing that the residual variances are homogeneous. The F-test for comparison of slopes showed that there was no significant difference in the slopes ($F = 0.67$; df $= 5,48$) and therefore the K values did not differ significantly. Thus the coefficient of deterioration is found to be the same, regardless of specifications and of firms. The scatter diagrams with the fitted equations are shown in Fig. 4. The lines are almost parallel showing the equality of the slopes and therefore the deterioration coefficients. The K values for the two specifications from the same firm are almost the same. Table 1 shows that the difference in K values of the two specifications of the same firm is less than the difference in the K values of the three firms for a given specification.

When the materials were subjected to exposure to artificial light in the laboratory, the coefficient of deterioration remained the same ($K \simeq 0.005$) regardless of the specifications and of the firms. Between the two specifications of a given firm, the coefficient of deterioration did not show any difference and was almost the same.

When the materials were subjected to natural exposure the coefficient of deterioration varied between 0.011 and 0.019. Though the effects of the
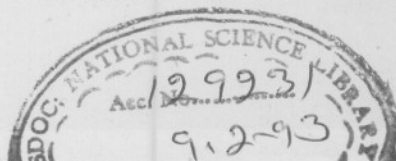
other factors outside the study on each material are assumed to be the same, as all materials were exposed simultaneously, the action of some of those factors with these materials might have caused the difference.

Acknowledgement

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