Tensile Strength Properties of Polyethylene Netting Twines Under Exposure to Out-door and Artificial UV Radiation

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Photodegradation of three types of polyethylene twines namely, polyethylene fibrillated tape twine, polyethylene flat tape twine and polyethylene monofilament twines were studied by exposing them to sunlight and a rtificial UV radiation. The percentage residual strength varied in the samples, the monofilament with the highest residual strength followed by fibrillated tape twine and flat tape twine. A plot of the difference between the breaking strengths of the fibrillated tape twine and the monofilament twines against any given period of exposure exhibited a linear relationship.

High density polyethylene fibres developed by Ziegler in West Germany in the early 1950's find extensive application in fishing industry. Of late, this material has surpassed other materials that were earlier used for fishing. Enormous quantity of high density polyethylene (HDPE) is used in the country for the fabrication of trawl nets. HDPE twines with its high wet knot breaking strength, extensibility, high abrasion resistance combined with low cost factor makes it an ideal material for trawl gear. Klust (1973) reports that at present polyethylene is used most commonly for bottom trawls as they out-weigh in technical and economic advantages over other synthetic netting materials.

Sunlight is a powerful agent which deteriorates polymers and HDPE is no exception to this. Baltenas *et al.* (1966) applied differential thermal analysis for the study of the structural changes occurring in polyethylene during oxidative ageing due to ultraviolet radiation. The study of Winslow & Hawkins (1967) on the degradation of polyethylene has shown that photolysis results in chemical changes which have a predominant effect on the physical properties especially the mechanical strength.

The measure of photo-oxidation in polyethylene was found to correlate with the degree of loss in physical properties during weathering (Newland & Tamblyn, 1967). Rapid technological advances in weather resistant polymers have generated a great interest in test methods which combine the chemical techniques for an understanding of the degradation reactions and physical measurements to monitor the changes in the mechanical properties. The accelerated UV tests permit a realistic extrapolation of mechanical properties which aid in predicting the serviceability.

Materials and Methods

A study was undertaken to compare the photo-degradation of three types of polyethylene, namely, polyethylene monofilament twine (0.5 mm dia), polyethylene fibrillated tape twine (0.75 mm dia.) and polyethylene flat tape twine (0.75 mm dia). The twines were subjected to natural sunlight and artificial UV radiation. The twines were tied to a rectangular wooden frame kept vertically in a north-south direction on the roof top and exposed to sunlight. Marine atmospheric conditions prevailed at the test-site. The samples were exposed to artificial UV radiation in a UV irradiation chamber, the design of which and the arrangement of samples were already reported (Meenakumari *et al.,* 1985). The periods of exposure were read from a digital elapsed time indicator connected in series with the UV light source. During the course of the experiment the inside temperature of the chamber was 30° ± 2°C and R.H. 75–85%. Periodically, twines were retrieved and tested for the reduction in tensile strength, in accordance with IS: 5815 (Part IV, 1971).

Results and Discussion

The initial breaking strengths of the twines were: polyethylene fibrillated tape twine 10.00 kg, polyethylene flat tape twine 8.23 kg and polyethylene monofilament twine 4.95 kg. With the onset of degradation triggered by the solar energy, the percentage residual tensile strength varied in the samples, the monofilament with the highest residual strength followed by fibrillated tape twine and flat tape twines.

A plot of the difference between the breaking strengths of the fibrillated tape twine and the monofilament twine (D_t) against any given period of exposure exhibited a linear relationship (Figs. 1 & 2) which by the method of least squares was found to be $D_t = 5.25 - 0.0115\ t$ for outside exposure and $D_t = 5.12 - 0.00384\ t$ for artificial UV exposure, where t is the period of exposure

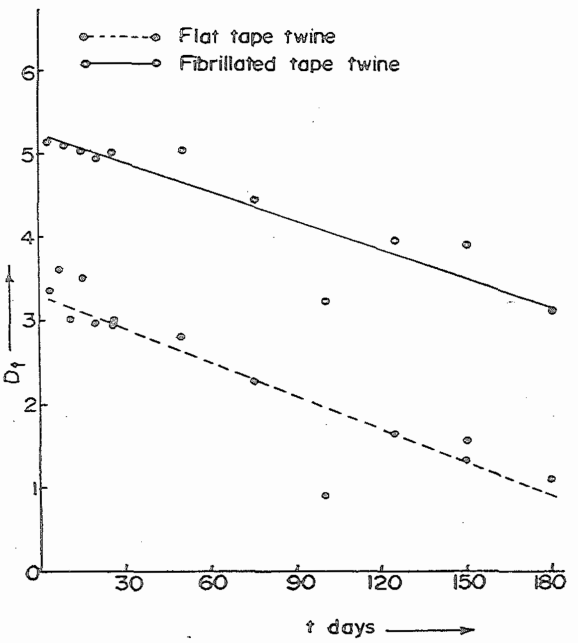

Fig. 1. Plot of the difference between the breaking strengths of the fibrillated tape twines and flat tape twines against the monofilament twines (out-door exposure).

in days. A comparison of flat tape twine with monofilament showed $D_t = 3.32 - 0.0133\ t$ for out door exposure and $D_t = 2.61 - 0.007736\ t$ for artificial UV exposure. This shows that the flat tape twines deteriorates faster than the fibrillated tape twine and monofilament is the least affected of the three on exposure to either UV radiation or out door.

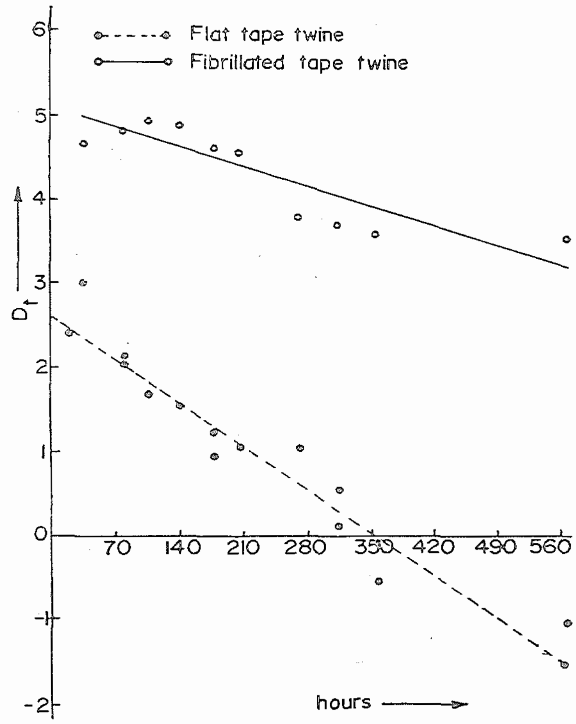

Fig. 2. Plot of the difference between the breaking strengths of the fibrillated tape twine and flat tape twines against the monofilament twines (artificial UV radiation).

The correlation between D_t and t were highly significant, r exceeding 0.9 in magnitude in all the cases (r is $-^{ve}$ as the breaking strength decreases with exposure time). A further insight into the photolytic degradation of polyethylene was obtained by the test of applicability of Tauti's equation (Tauti, 1929),

$$\log\left(\frac{T}{T_o - T}\right) = -(K \log e)\ t + \text{a constant}$$

where T is the breaking strength of the material after exposure for t hours; T_o is the initial breaking strength and K is the coefficient of deterioration (Figs. 3 & 4). Following the method of least squares, the constant and K in Tauti's equation were evaluated (Table 1).

The r values for the two samples were highly significant for fibrillated tape twine and flat tape twine as it exceeded 0.83 in magnitude while the monofilament twine gave a value of r = 0.75 which signifies that the rate of deterioration of monofilament twine is lower in comparison to the other two.

Table 1. *Test of applicability of Tauti's equation to tensile strength data*

	Equation for the linear plot	K
Out-door exposure		
Fibrillated tape twine	$\log\left(\frac{T}{To-T}\right) = -0.009869t + 2.05$	0.000946
Flat tape twine	$\log\left(\frac{T}{To-T}\right) = -0.008545t + 1.63$	0.000821
Monofilament twine	$\log\left(\frac{T}{To-T}\right) = -0.003294t + 1.63$	0.000316
UV exposure		
Fibrillated tape twine	$\log\left(\frac{T}{To-T}\right) = -0.002144t + 1.40$	0.00494
Flat tape twine	$\log\left(\frac{T}{To-T}\right) = -0.002959t + 1.03$	0.00681
Monofilament twine	$\log\left(\frac{T}{To-T}\right) = -0.001926t + 1.46$	0.00443

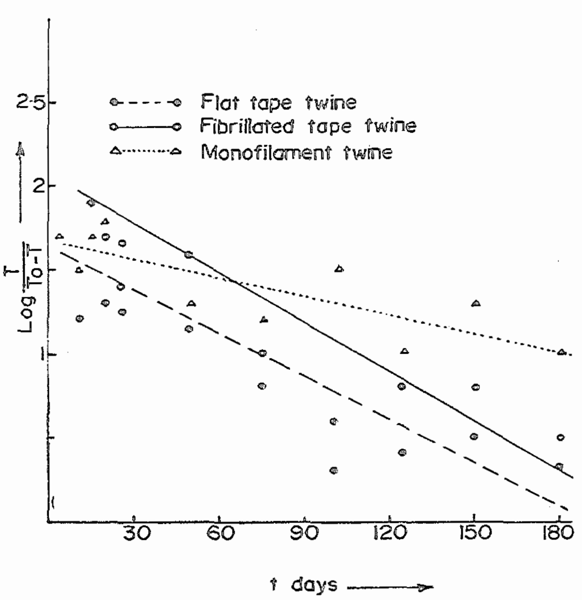

Fig. 3. Tauti's plot for flat tape, fibrillated tape and monofilament netting twines (out-door exposure)

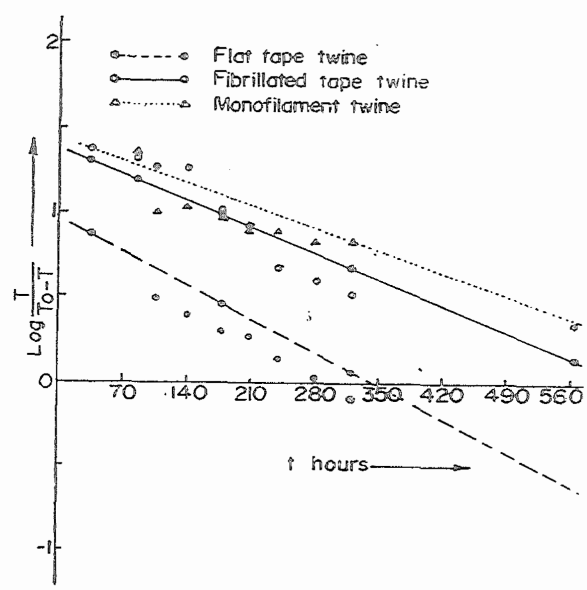

Fig. 4. Tauti's plot for flat tape, fibrillated tape and monofilament netting twines (artificial UV radiation).

The degradation of synthetics exposed to atmosphere is dependent upon several factors such as the intensity of UV radiation, relative humidity and temperature. The ultraviolet radiation which promotes primary photochemical process is perhaps the most important factor responsible for the degradation of polymers by weathering. Greathouse & Wessel (1954) have reported that two years of continuous exposure in England and six months exposure in India or Florida renders polyethylene useless. This is to be expected as the total energy received as UV light on the earth's surface varies, and even for the same location the summer to winter variations are reported (Newland & Tamblyn, 1967) to be of the order of 600%. Because of the complexities involved in the weathering action by atmospheric factors, a reliable prediction of the service behaviour of polymers by out-door tests meet with difficulties. Chain-scissioning and crosslinking also take place in certain critical actinic regions. Controlled accelerated exposure tests do provide results of practical reliability highly needed for the quick evaluation of relative stability of different brands of HDPE flooding in the market.

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