Quality Assessment of Polyester Chips and Yarn by TMS-2

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Synopsis

Penetration in polyester chips of different manufacturers and yarn (undrawn and drawn) was studied between 323 and 423 K on a thermomechanical system (TMS-2) using a penetration kit. It was observed that the penetration of the probe varied in the case of chips from manufacturer to manufacturer. The undrawn and drawn yarns from different batches and also within the same batch showed a clear variation in penetration curve, which may be attributed to the degree of crystallization. The same technique can be utilized for an assessment of the quality of yarn in continuous production and for differentiating the manufacturing process of polyester chips.

INTRODUCTION

Synthesis of polyester chips and melt spinning of these chips into various types of yarn is becoming increasingly common in India. Compared to its availability, the demand for chips, yarn, and staple fiber is very high. The quality of the yarns produced in different batches and from different manufacturers must be kept consistent. The various physical tests of chips, including denier, % elongation, tenacity of yarn, and carboxyl end groups, viscosity, oxidation, etc., are the usual tests performed for routine quality control. In this paper, we describe a modern and sophisticated technique, the use of a thermomechanical system (TMS-2) for studying thermal behavior of chips and yarn using penetration kit. The added advantage of TMS-2 is that it also records the temperature of crystallization and glass transition (T_g) of chips and yarn. The same technique can be used for the rigorous quality control of the chips and yarn (undrawn and drawn) by performing their thermal analysis from different batches in the continuous production.

EXPERIMENTAL

All analyses were carried out on the thermomechanical system (TMS-2) (Perkin-Elmer).

Penetration Study

Zero setting for the recorder was adjusted without sample, with a weight of 2 g on weight tray. A thin transverse section (3.5 mm) of polyester chip was placed in a quartz sample tube under penetration probe, and zero adjustment was repeated. In all experiments, the thickness and length of the sample were

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TABLE I
Penetration Study of Polyester Chips from Different Manufacturers

Sample	T_g (K)	Penetration (mils)
A	354	3.5
B	351	3.1
C	349	2.3
D	352	0.25

kept constant. The chip samples were heated with the following setting:
(1) Heating range—323–423 K
(2) Heating rate—2.5 K/min
(3) Chart speed—10 mm/min
(4) Penetration range—5 mils/full scale of recorder
With the same setting, chip samples A, B, C, and D of different manufacturers were analysed (Table I).

Penetration Study of Undrawn and Drawn Yarn

The zero setting was adjusted without sample and with a weight (2 g) on the weight tray. Zero adjustment on recorder chart was carried out with sample by adjusting with fine vernier. The sample (undrawn yarn 3.5 mm length) was heated with the following setting. In all experiments the length of the sample was kept constant.
(1) Heating range—323–423 K.
(2) Heating rate—2.5 K/min.
(3) Chart speed—10 mm/min.
(4) Penetration range—2.5 mils/full scale of recorder.
Penetration of various undrawn and drawn yarns from different batches and within the same batch was studied (Table II).

TABLE II
Penetration Study of Undrawn and Drawn Yarn on TMS-2

	Glass transition temperature (K)		Penetration (mils)	
Batch	Undrawn yarn (550 D)	Drawn yarn (150 D)	Undrawn yarn (550 D)	Drawn yarn (150 D)
I	354	353	0.62	0.17
I	353	352.5	0.63	0.24
I	352	351.5	0.56	0.25
I	353	352	0.48	0.28
II	351	350.5	0.60	0.21
II	352	352	0.55	0.23
II	351	350	0.50	0.14
II	352	351	0.53	0.17
III	350	350	0.61	0.25
III	352	352	0.56	0.11
III	353	352.5	0.49	0.30
III	350	350	0.52	0.17

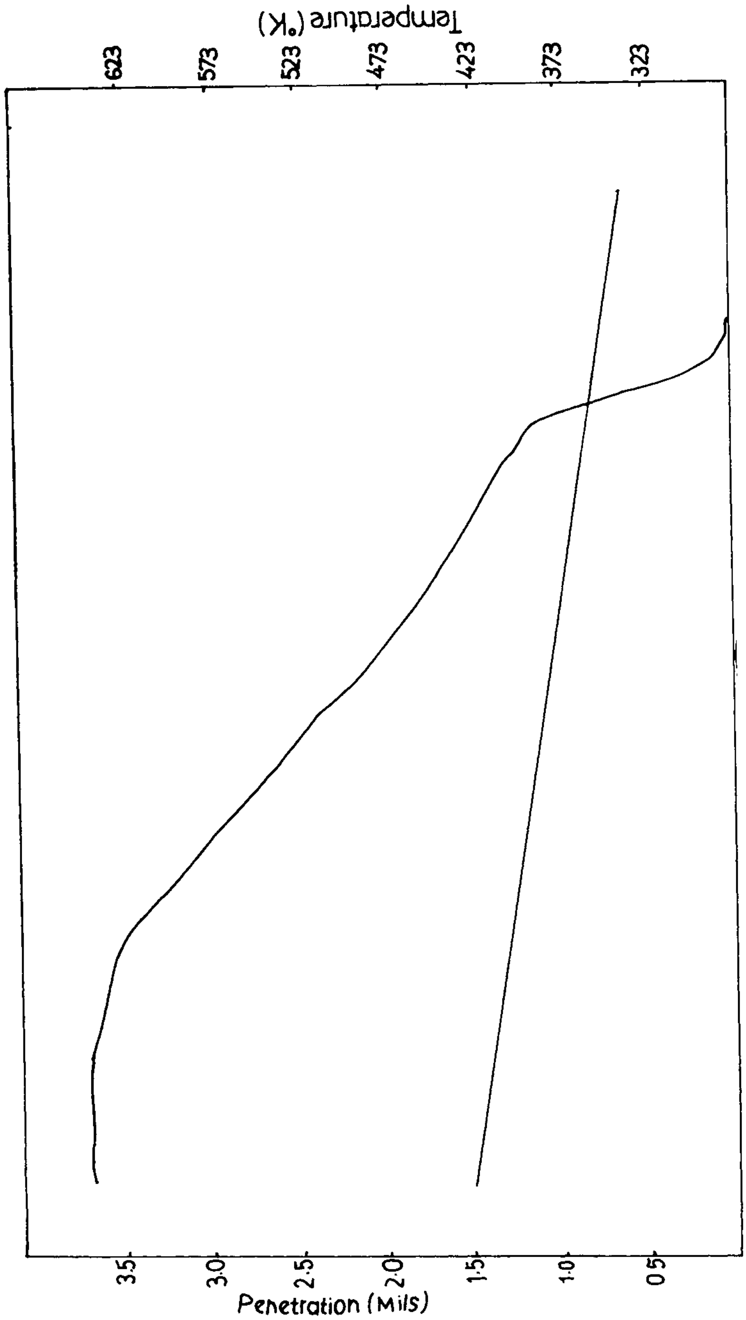

Fig. 1. TMS-2 graph of sample A.

DISCUSSION

Synthetic polyester chips and yarns (undrawn and drawn) exhibit a variety of physical properties, which derives from the differing orientation of the molecules that constitute the material. To study the physical properties such as T_g and crystallization of chips or yarn, the thermomechanical system plays a vital role in displaying the graphical explanation of transition temperatures. Thus, polyester chips of different manufacturers were tested on TMS-2 with a penetration probe (Table I). Penetration in chip samples A (Fig. 1), B, and C were recorded as 3.5, 3.1, and 2.3 mils with a zero weight of 5 g. However, the sample D could not display any penetration with a zero weight of 5 g. Little penetration (0.25 mils) (Fig. 2) was observed only after increasing the weight up to 25 g on the weight tray. It clearly indicates that the quenching process for sample D must have been different as compared with A, B, and C. The glass transition temperature of the chips (Table I) also showed a relation towards the penetration. It is observed that, in case of samples C, B, and A, increase in glass transition temperature leads to gradual increase in the penetration of the probe.

Out of four chips sample, sample A was melt-spun into undrawn yarn (550 D) and was analyzed on TMS-2. The undrawn yarn showed a typical curve (Fig. 3) with penetration (0.62 mils) and T_g (354 K). It may be

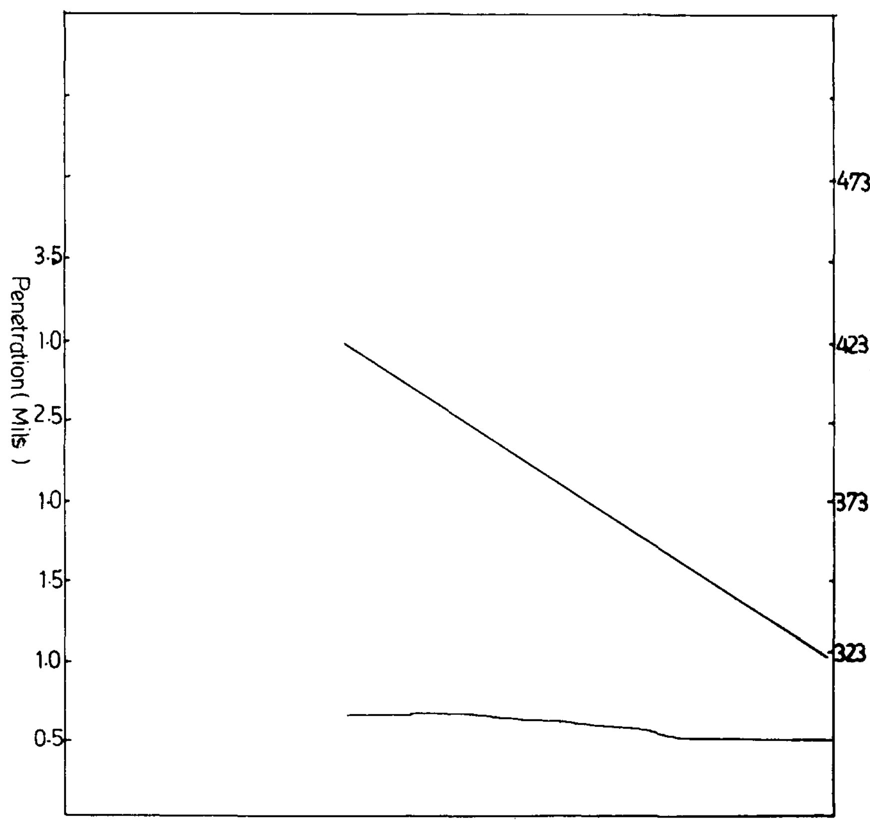

Fig. 2. TMS-2 graph of sample B.

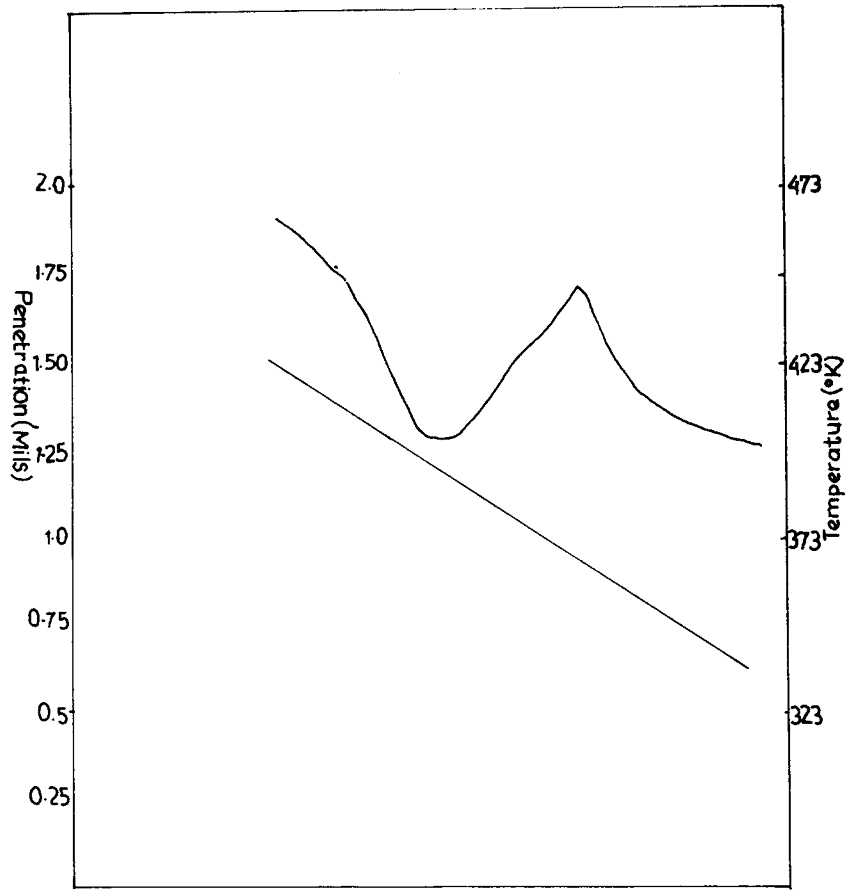

Fig. 3. TMS-2 graph of undrawn PE yarn indicating high crystallinity.

attributed to its nonoriented nature which generally elongates upon softening or when the crystal–crystal phase occurs and shrinks upon crystallization. Thus, different undrawn yarn samples of the same denier from different batches and also within the same batch in continuous production were tested on TMS-2. The results, tabulated in Table II, clearly shows variation in penetration of different samples of the undrawn yarn of same denier. From Figures 3 and 4, it was observed that the sharpness of the curves depends upon the nature of the yarn. The initial sharp curve in a few cases indicates the crystallization (Fig. 3), i.e., the undrawn yarn is slightly stretched after melt spinning. However, in a few cases (Fig. 4) the curve is not prominent, indicating the lesser amount of crystallization. The initial curve was then followed by another curve, due to shrinkage upon softening. The variation of the penetration of the probe observed in the different sample of undrawn yarn may be due to the variation in crystallization occurring due to defective winding or quenching process.

The penetration study was further continued by testing the drawn yarn on TMS-2 to see the effect of stretching. While stretching, the degree of orientation introduced by the alignment of crystalline regions is an important factor

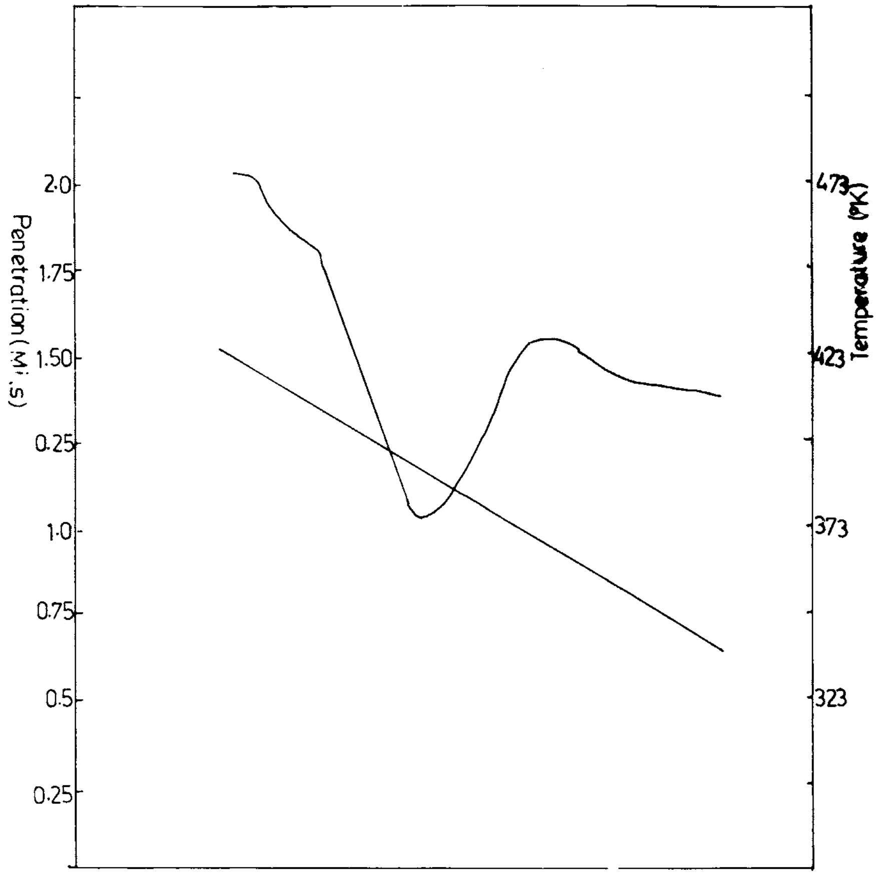

Fig. 4. TMS-2 graph of undrawn PE yarn indicating low crystallinity.

in determining the potential of yarn. If the degree of alignment is uncontrolled, e.g., stretching ratio (SR) to produce yarn of specified properties, it results in the yarn of substandard grade. The higher the SR, the higher will be the orientation, and, consequently, the yarn will possess high breaking strength, low elongation, and high tenacity. It will be reverse when the stretching ratio is lower. Hence, to achieve the optimum SR is a crucial stage in industry, to get effective alignment of the molecules in the crystalline region.

Thus, when the drawn yarn (150 D), obtained from the undrawn yarn (550 D, average penetration 0.56 mils, T_g = 352 K) with stretching ratio 3.66, was loaded on TMS-2, the recorder showed an immediate movement in the positive direction (hump-like) to give a penetration of 0.25 mils (Fig. 5). It may be attributed to its oriented nature, which generally shrinks when the temperature reaches to a softening temperature, i.e., T_g (352 K). However, the second sample collected from the same batch after 1 h was loaded to give a penetration of 0.24 mils (Fig. 6). Similarly different yarn samples with the same denier from the same batch were tested to study the proper alignment of

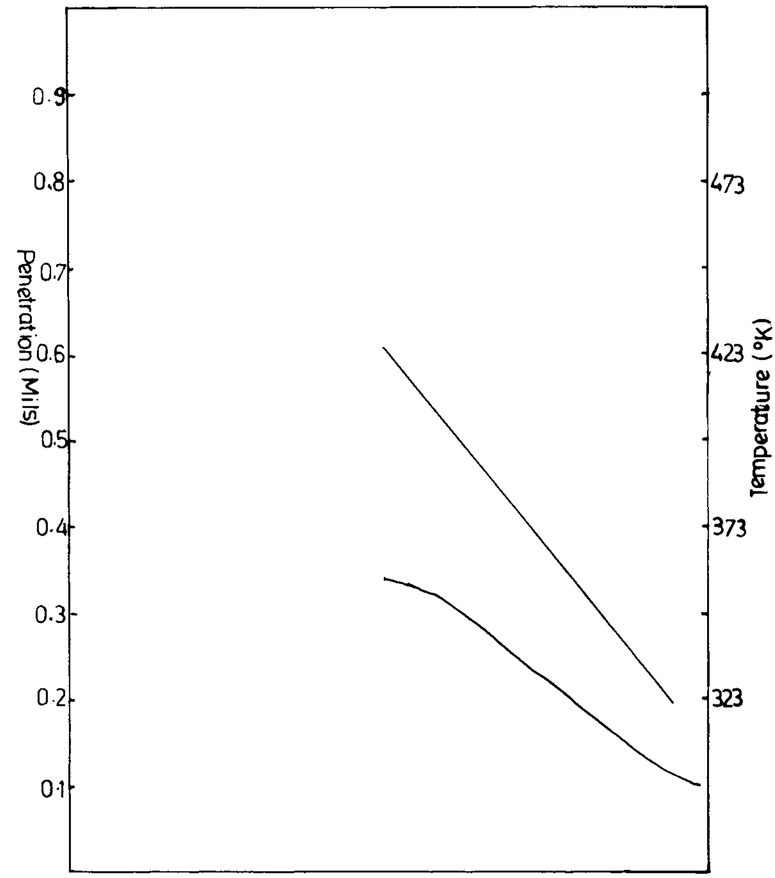

Fig. 5. TMS-2 graph of drawn PE yarn at the beginning of production.

molecules in the yarn (Table II). The samples from different batches were also analyzed on TMS-2. The results are shown in Table II. However, it was observed that the variation in penetration of probe in yarn samples with 150 denier were found in the range 0.1–0.3 mils; the variation observed in the drawn yarn may be due to variation in the degree of crystallization in undrawn yarn. Thus from the above results it was observed that the samples from batch to batch as well as within the batch showed variation in the penetration of the probe in undrawn and drawn stages. The variation in penetration shows that the yarn is unevenly aligned. It can create problems during dyeing of the fabric produced from it. However, these defects could be rectified by the use of TMS-2 by applying it during running production, to check the quality of yarn. Results clearly indicate that the yarn of the same denier exhibits uneven penetration on TMS-2. Hence, to get a yarn of uniform nature, a thorough study of the internal structure of yarn on TMS-2 is essential at least after 0.5 h. Once the variation in the penetration of the probe in yarns ceases, the parameters in the plant can be fixed for production of a yarn having good quality and uniformity.

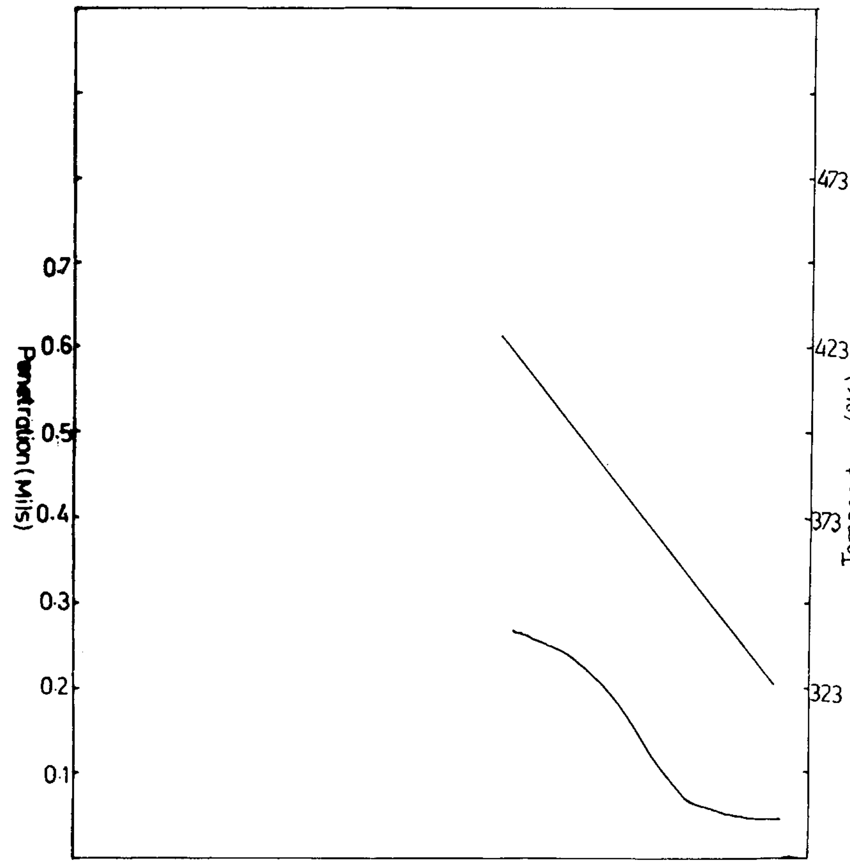

Fig. 6. TMS-2 graph of drawn PE yarn after 1 h of production.

CONCLUSIONS

The penetration study using a thermomechanical system (TMS-2) can be widely applied as a tool for quality control of polyester chips and yarn. An added advantage of this system is that it can be applied at any stage during the manufacture of chips and yarn in undrawn and drawn stages. From the results obtained for chips, it can be said that the chips of different manufacturers showed variation inpenetration, and thus on this basis they can be differentiated from each other. The variation in penetration may be due to difference in crystallinity of chips, which may be due to difference in the quenching process of chips of a different manufacturer.

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