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Effect of Blend Ratio on the Quality Characteristics of Recycled Polyester/Cotton Blended Ring Spun Yarn

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Abstract
This study investigates the effect of the blend ratio on recycled blended yarn quality characteristics. Ring-spun yarns of linear density of 23.6, 29.5 and 39.4 tex were produced from five blend proportions of recycled polyester and cotton (0:100, 33:67, 50:50, 67:33 and 100:0). Increasing the recycled polyester content increases the tenacity, elongation at break and hairiness and decreases unevenness, thin places, thick places and neps, while a decrease in linear density increases the tenacity, elongation at break, unevenness, thin places, thick places, neps and hairiness. Statistical analysis reflects that both the blend ratio and linear density have a significant difference on the tenacity, elongation at break, thin places, thick places, neps and hairiness. However, with reference to unevenness, a significant difference is reported only for linear density and not for the blend ratio. The ratio of recycled polyester has a significant influence on the overall quality of recycled polyester/cotton blended yarn. The blending of recycled polyester and cotton can be optimised to meet various end-use requirements.

Key words: *sustainability, blending, recycled polyester/cotton ratio, ring spun yarn, yarn characteristics.*

Introduction

Sustainability, a buzzword, was defined by Brundtland (formerly known as the World Commission on Environment and Development) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. To improve the sustainable use of materials, the focus has to be shifted towards circular material flow (reuse, recycle) rather than conventional liner flow that relies on extraction, use and disposal in landfills [2]. The growing awareness of environmental conservation has resulted in the recycling of post-consumer polyethylene terepthalate (PET) bottles using mechanical and chemical recycling processes [3]. Mechanical recycling is basically a melt extrusion process and typical process steps include cutting, shredding, contaminant separation, floating, washing, drying, extrusion and pelletising. Chemical recycling aims at the reduction of plastic polymers into various levels like oligomers or monomers by reaction with certain chemical agents.

The blending of various fibers is a widely practiced means of obtaining desirable combinations of properties. Blending natural and man-made fibres has the typical advantage of the combination of both fibre components such as comfort, durability and easy care properties. Cotton/polyester fibre blending is one of the most common practices in the textile/apparel industry. Typically cotton/polyester blends display higher durability and easy care (higher breaking strength, abrasion resistance, crease resistance) properties than 100% cotton and less pilling, easy spinning and better evenness than 100% polyester [4]. The blending of recycled PET has opened up new avenues in the development of a sustainable future.

Researchers, Abbasi M, Mojtahedi MRM and Khosroshahi A [5], Joo Hyung Lee, Ki Sub Lim, Wan Gyu Hahm and Seong Hun Kim [6], Andrzej Pawlak, Mirosław Pluta, Jerzy Morawiec, Andrzej Galeski and Mariano Pracella [7], Scheirs [3], Prasad S. Upasani, Ashwin K. Jain, Ninad Save, Uday S. Agarwal and Anil K. Kelkar [8] successfully studied the blending of recycled PET flakes with virgin PET chips. Masoud Frounchi, Mahmood Mehrabzadeh and Reza Ghiaee [9] studied the effect of reprocessing poly ethylene terephthalate (PET) and revealed that an increase in recycled PET content decreases the mechanical properties during the blending of virgin and recycled PET blending. Sun Young Lee, Jong Sung Won, Jae Jung Yoo, Wan-Gyu Hahm and Seung Goo Lee [10] showed that chemical-recycled(CR) PET draw texturized yarn had better crimp, a more stable structure, and higher elongation at break than mechanical recycled (MR) PET draw texturised yarn.

The inherent nature of the recycling process produces fibers with a short length, non-uniformity, unopened/partially opened and more imperfections. These limitations enable the production of coarser yarn counts only, and the production of medium and fine count yarns is yet to be explored. However, ring, rotor and friction spinning have been successfully employed for the production of recycled PET yarns. Rotor spinning is one of the most widely used spinning techniques for the production of recycled yarns. Duru P.N and Babaarslan O [11] produced 29.5 tex polyester/waste OE rotor yarns on a laboratory-type spinning machine and showed that an increase in the opening roller speed negatively affects yarn strength and positively affects unevenness and hairiness values.

Merati A.A., Okamura M [12] successfully produced medium count (30, 40, 50, 60 & 70 tex) yarns from recycled

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fibres of acceptable appearance and tensile properties using friction spinning. A modified friction spinning machine was used for the production of two-component and three-component yams in which recycled fibres in the yarn core are completely covered by virgin cotton fibers. The results reveal that 51/49 cotton/RF two-component appearance is similar to that of 100% cotton yarn and that 30-tex three-component core yarn possesses higher tensile properties (strength and elongation) than those of equivalent 100% cotton yarn.

Abdurrahman Telli1, Nilgün özdil2 [13] made an attempt to produce 29.5 tex yarns using a ring spinning system (carded). This study reveals that an increase in recycled-PET content decreases the tensile strength of PET/recycled-PET blended yarns and increases the tenacity of recycled-PET/cotton blends. The evenness, number of IPI faults (thin places, thick places and neps) and hairiness values of 100% recycled PET yarns are worse than for 100% PET yarns, but no significant difference is observed for these properties. Other studies conducted on the comparison of yarns produced from recycled fibers and virgin fibers [14] reflect that the tenacity and elongation values of yarns obtained from recycled fibres differ marginally, however, such processes appear to be economically advantageous in the long run [15].

Few studies have been reported in the literature on the characterisation of woven and knitted fabrics developed from recycled PET content. Yeon Joo Choi and Seong Hun Kin [16] characterized mechanically recycled PET, chemically recycled PET, PET-nylon 6 blend and virgin PET knitted fabrics. Inoue Mari, Yamamoto Shinji [17] studied the performance and durability of woven fabrics, including recycled PET fibres in various blend proportions. However, the effect of the blend ratio on the yarn quality characteristics of recycled PET-cotton blended yarn is not yet reported. An attempt was made in this to study to explore the effect of the blend ratio of recycled polyester and cotton on ring spun yarn properties.

Materials and methods

Materials

Sankara 6 cotton and mechanically recycled polyester (India) were used in the production of yarns. The properties of the cotton and recycled polyester fibres are given in ***Table 1***. Cotton fibre properties were measured using a Premier High Volume Instrument (Premier Evolvics pvt. Ltd, India) where for recycled polyester the fibre length, single fibre tenacity and elongation at break (%) were measured using a Trutzschler Length meter (Trützschler GmbH & Co. KG, Germany) and Texttechno Favigraph Fibretest (Textechno H. Stein GmbH & Co. KG, Germany). Fineness values of recycled polyester were calculated by measurement of the diameter of the fibre and further conversion to dtex.

Method

Spinning

The process steps include carding, first drawing, second drawing, rove-preparation and ring-frame. Two different slivers (100% cotton and 100% polyester) were produced on a carding machine with the fibres mentioned in ***Table 1.*** Five blend proportions of recycled polyester and cotton (0:100, 33:67, 50:50, 67:33 and 100:0) were used in the first draw frame, and then further in a second draw frame, roving frame and ring frame. The conditions of spinning included a Rieter G 30 ring frame, 10000 rpm spindle speed, 42 mm ring diameter, a ISO 90 traveller, 5.5 mm light grey clips, shore hardness of top roller covers for feeding and exit rollers 80 and 70, respectively, a breaking draft and a total draft of 1.17 and 20, respectively. Besides 100% cotton and 100% recycled polyester yarns, blended yarns of blend proportion of 33:67, 50:50 and 67:33 were produced in three linear densities i.e., 23.6, 29.5 and 39.4 tex using the same twist coefficient (α_t = 34.5). The yarns produced were conditioned under standard atmospheric conditions (65 % RH and 25°C).

Testing

Yarn linear density was calculated as per ASTM D1907-01; tensile properties (tenacity and elongation at break)

Table 1. *Fibre properties.*

Fibre property	Cotton	Recycled polyester
Mean length, mm	27.1	34.2
Fineness, dtex	1.77	1.86
Tenacity, cN/tex	27.45	29.64
Elongation at break, %	7.1	18.3

Table 2. *Properties of recycled blended yarns.*

Blend ratio	Linear density, tex	Tenacity, cN/tex	Elongation at break, %	Unevenness, %CVm	Thin places, -50%	Thick places, +50%	Neps, +200%	Hairiness, > 3mm/km
100% cotton	23.6	9.1	7.4	12.6	64	169	605	175
	29.5	13.8	8.1	13.8	79	181	715	181
	39.4	15.2	9	14.4	85	200	791	186
33:67 recycled polyester: cotton	23.6	9.8	9.1	12.1	59	152	521	189
	29.5	14.2	14.4	13.5	61	160	550	182
	39.4	15.4	15.1	14.7	77	188	676	193
50:50 recycled polyester: cotton	23.6	10.2	10.2	11.9	51	143	456	194
	29.5	14.8	16.8	13.3	54	155	567	182
	39.4	15.5	17.4	14.9	73	176	578	197
67:33 recycled polyester: cotton	23.6	11.1	11	11.5	48	138	398	205
	29.5	15.4	19.5	12.9	50	134	461	180
	39.4	15.7	20.3	15.3	68	167	482	209
100% recycled polyester	23.6	11.8	12.8	11.1	41	117	344	211
	29.5	15.9	21.4	12.5	44	115	374	218
	39.4	16.1	22.9	15.8	61	152	396	226

Table 3. *Statistical analysis (α = 0.050).*

Process variable	Tenacity, cN/tex		Elongation, at break, %		Unvenness, %CVm		Thin places, –50%		Thick places, +50%		Neps, +200%		Hairiness, >3 mm/km	
	F value	P value	F value	P value	F value	P value	F value	P value	F value	P value	F value	P value	F value	P value
Blend ratio	11.574	0.002	14.260	0.006	0.248	0.903	31.792	<0.001	62.089	<0.001	42.209	<0.001	12.616	0.002
Linear density	267.653	<0.001	18.965	0.003	32.334	<0.001	54.078	<0.001	73.876	<0.001	15.655	0.002	4.734	0.044

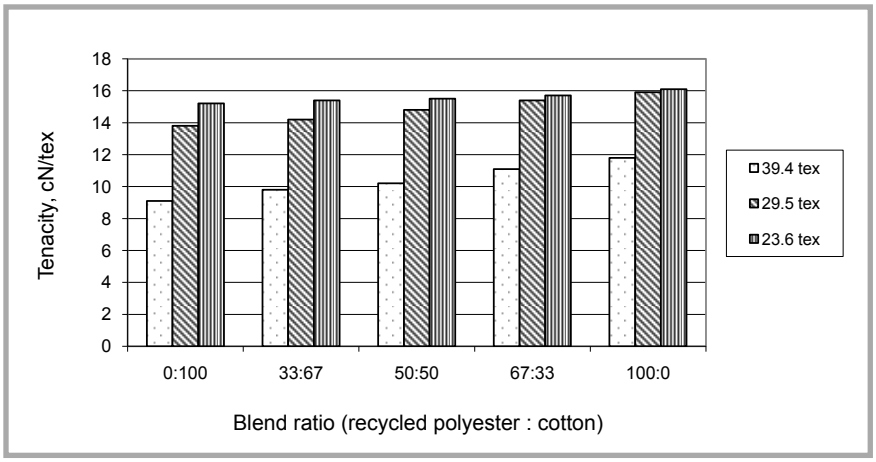

Figure 1. *Blend ratio vs. tenacity.*

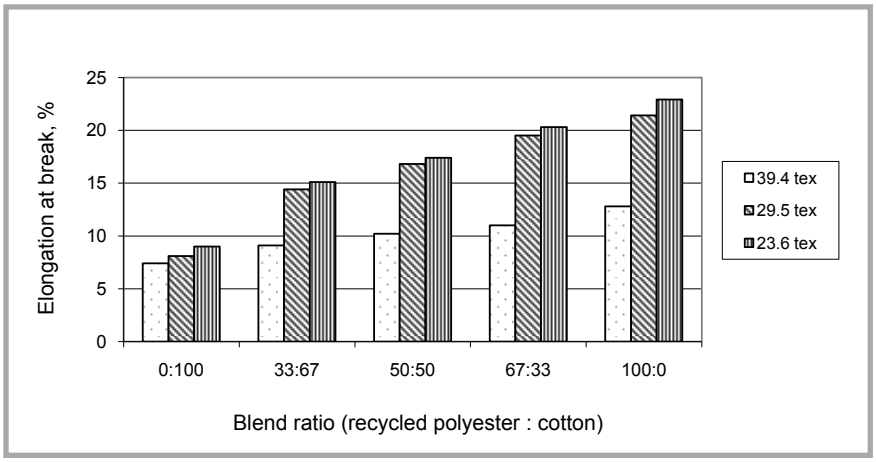

Figure 2. *Blend ratio vs. elongation at break.*

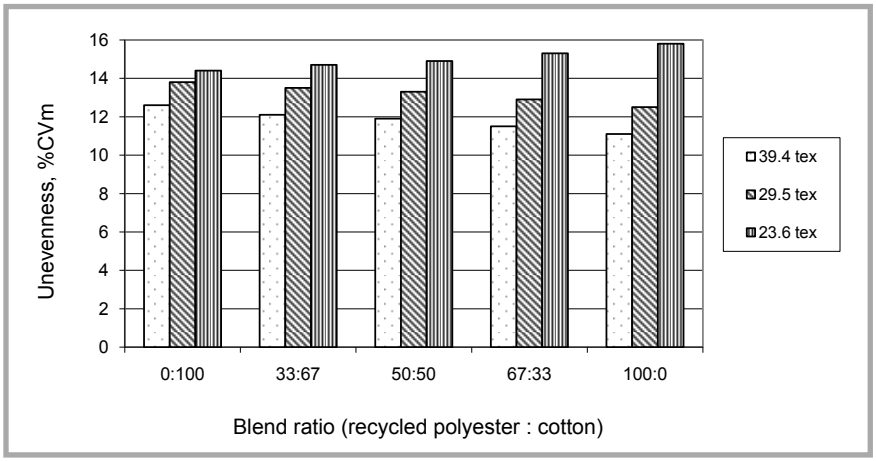

Figure 3. *Blend ratio vs. unevenness.*

were measured as per ASTM D2256-02; evenness values (thick places, thin places, neps) were measured as per ASTM D1425-96, and hairiness was measured with ASTM D 5647-01.

Results and discussion

Table 2 represents the average values of the properties tested i.e., tenacity (cN/tex), elongation at break (%), unevenness (%CVm), thin places (-50%), thick places (+50%), neps (+200%) and hairiness (> 3mm/km).

Statistical analysis

Statistical analysis of the test results was made using Sigma Plot 12.5. Yarn quality characteristics (tenacity, elongation at break, unevenness, thin places, thick places, neps and hairiness) were examined by two-way analysis of variance (ANOVA) with a confidence level of 95%. Details of the statistical significance of the yarn characteristics are shown in ***Table 3***. Statistical analysis reflects that both the blend ratio and linear density have a significant difference on tenacity, elongation at break, thin places, thick places, neps and hairiness. However, with reference to unevenness, a significant difference is reported only for the linear density amd not for the blend ratio.

Tenacity

The relationship between the yarn blend ratio, tenacity and linear density is depicted in ***Figure 1.*** The lowest and highest tenacity values are observed for 100% cotton and 100% recycled polyester yarns, respectively. An increase in recycled polyester content increases the tenacity of the yarn, irrespective of the yarn linear density observed. This trend is expected as the tenacity of the recycled polyester fibre is higher than that of cotton fibre. It is also observed that a decrease in linear density increases the tenacity of the blended yarn.

Elongation at break

Figure 2 represents the relationship between the yarn blend ratio, elongation at

break % and linear density. It is apparent that the lowest and highest elongation at break % values are observed for 100% cotton and 100% recycled polyester yarns, respectively. An increase in the recycled polyester content increases the elongation at break %, irrespective of the linear density observed, which is due to the fact that the elongation at break % of the recycled polyester fibre is higher than that of cotton fibre. It's also noted that an decrease in linear density increases the elongation% of the blended yarn.

Unevenness, thin places, thick places and neps

The relationship between the yarn blend ratio, unevenness/thin places/thick places neps and linear density is shown in ***Figures 3, 4, 5*** and ***6***, respectively. It is evident that the lowest and highest unevenness values are observed for 100% recycled polyester and 100% cotton yarns, respectively. An increase in the recycled polyester content decreases unevenness/thin places/thick places/neps of the linear densities observed, which can be attributed to the fact that the mean length of recycled polyester fiber is higher than that of cotton fiber. It is also reflected that a decrease in linear density increases unevenness/thin places/thick places/neps of the recycled blended yarn.

Statistical analysis shows that the blend ratio has no significant effect on unevenness but linear the density has on unevenness. The pairwise multiple comparison procedure using the Fisher LSD method (***Table 4***) shows that, no significant difference is observed for blend ratios of '0:100 vs. '100:0, which reflects that other blends that are within these limits also have no significant difference. ***Table 5*** reconfirms that linear density has a significant influence on unevenness.

Hairiness

The relationship between the yarn blend ratio, hairiness and linear density is shown in ***Figure 7***, which indicates that the lowest and highest hairiness values are observed for 100% cotton and 100% recycled polyester yarns, respectively. An increase in the recycled polyester content increases the hairiness and a decrease in linear density increases the hairiness of the recycled blended yarn.

Conclusions

The effect of the blend ratio of recycled polyester and cotton on the ring spun

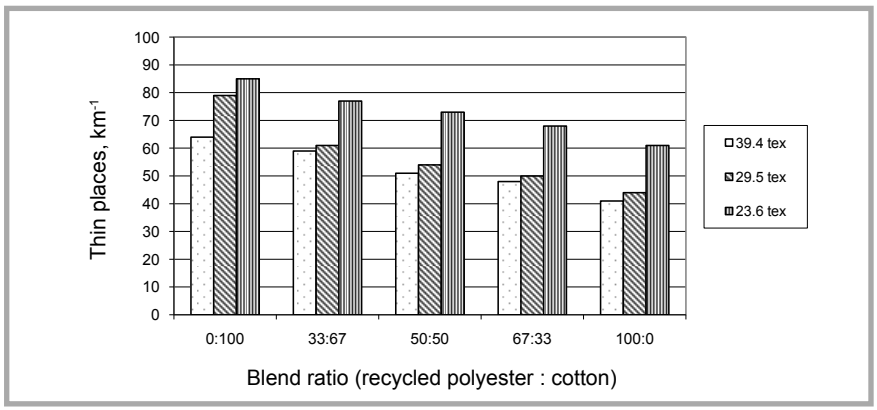

Figure 4. *Blend ratio vs. thin places.*

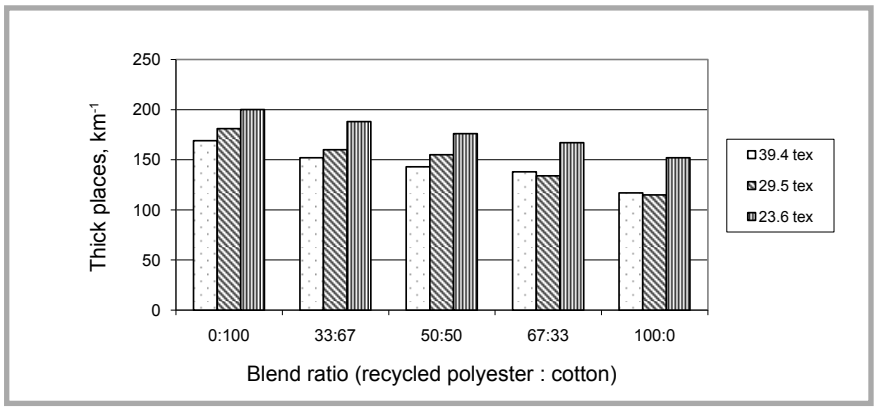

Figure 5. *Blend ratio vs. thick places.*

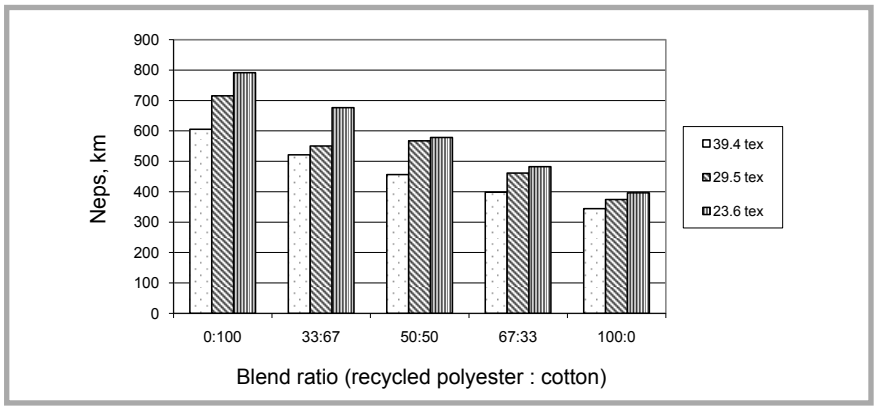

Figure 6. *Blend ratio vs. neps.*

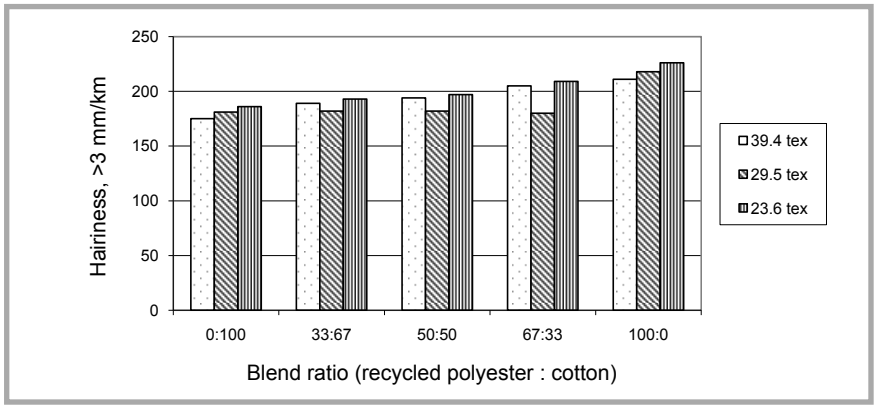

Figure 7. *Blend ratio vs. hairiness.*

Table 4. *Pair wise multiple comparison procedure using Fisher LSD method*[*]*. Comparisons for factor: blend ratio.*

Comparison	Diff of means	LSD (alpha=0.050)	P	Diff >= LSD
'0:100 vs. '100:0	0.467	1.181	0.389	No
'0:100 vs. '67:33	0.367	1.181	0.495	Do Not Test
'0:100 vs. '50:50	0.233	1.181	0.661	Do Not Test
'0:100 vs. '33:67	0.167	1.181	0.753	Do Not Test
'33:67 vs. '100:0	0.300	1.181	0.574	Do Not Test
'33:67 vs. '67:33	0.200	1.181	0.706	Do Not Test
'33:67 vs. '50:50	0.0667	1.181	0.900	Do Not Test
'50:50 vs. '100:0	0.233	1.181	0.661	Do Not Test
'50:50 vs. '67:33	0.133	1.181	0.801	Do Not Test
'67:33 vs. '100:0	0.100	1.181	0.850	Do Not Test

[*] *A result of „Do Not Test" occurs for a comparison when no significant difference is found between two means that enclose that comparison.*

Table 5. *Pair wise multiple comparison procedure using Fisher LSD method*[*]*. Comparisons for factor: linear density.*

Comparison	Diff of means	LSD (alpha=0.050)	P	Diff >= LSD
23.6 tex vs. 39.4 tex	3.180	0.915	<0.001	Yes
23.6 tex vs. 29.5 tex	1.820	0.915	0.002	Yes
29.5 tex vs. 39.4 tex	1.360	0.915	0.009	Yes

[*] *Yes indicates that significant difference exists.*

yarn characteristics was investigated in this study. It is observed that the ratio of recycled polyester has a significant influence on the overall quality of recycled polyester/cotton blended yarn. An increase in recycled polyester content increases the tenacity elongation at break and hairiness and decreases unevenness, thin places, thick places and neps, and a decrease in linear density increases tenacity, elongation at break, unevenness, thin places, thick places, neps and hairiness. Statistical analysis reflects that both the blend ratio and linear density have a significant influence on tenacity, elongation at break, thin places, thick places, neps and hairiness. However, with reference to unevenness, a significant difference is reported only for linear density and not for the blend ratio. Overall the ratio of recycled polyester has a significant influence on the quality of recycled polyester/cotton blended yarn. Recycled polyester and cotton blending can be suitably optimised to meet end-use requirements.

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