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KNITTABILITY OF ALL-WOOL YARNS ON A 28 GAUGE SINGLE JERSEY MACHINE

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ABSTRACT

The knittability of a range of yarn linear densities was determined from knittability curves of tightness factor versus the number of yarn breakages, during the knitting of plain single jersey fabrics. From a statistical analysis of the results it was found that a 35 tex yarn gave the highest knittability.

The investigation also included the effect of tucking in accordion fabrics on the knitting performance. The straight and alternate accordion structure could be knitted at the tightest knitted stitch length and produced fabrics with the lightest mass per unit area.

INTRODUCTION

With the development of higher machine speeds and fine gauge knitting machines, the problems encountered in the knitting of wool yarns have increased. The difficulty in commercially producing sufficiently fine, strong and regular wool yarn appears to be the limiting factor.

Table I indicates some of the formulae that have been proposed by different workers[1–5] for determining a suitable yarn linear density for knitting on circular (latch needle) single jersey knitting machines, and the yarn linear densities thus calculated for use on a 28 gauge machine. The term 'gauge' in the formulae refers to needles per inch.

In a survey of yarn counts employed on various weft knitting machines, Hunter[3] plotted the resultant yarn tex against machine gauge (needles per inch) for data collected from the technical literature and other sources and suggested that a 17 tex yarn was an average worsted yarn for a 28 gg single jersey machine.

Other workers[6–8] have also determined which yarn linear densities are most suitable for double jersey machines.

Knapton[9, 10] investigated the knittability of wool on an experimental plain jersey machine and employed the term Ty (the torque required to knit the yarn at a constant machine speed) as a measure of knitting performance. The lower the value of Ty, the lower are the knitting tensions, and therefore the better the knittability of the yarn. His experiments covered a range of yarn linear densities from 21 tex to 76 tex and he found that a tightness factor of 14,5 gave the overall best knitting conditions. Hunter[11] reported similar conclusions when knitting two-ply wool yarns into 1 x 1 rib structure. He found that the minimum

TABLE I

FORMULAE DERIVED FOR CALCULATING YARN LINEAR DENSITIES SUITABLE FOR SINGLE JERSEY CIRCULAR KNITTING MACHINES

SOURCE	FORMULAE	YARN	SUITABLE YARN LINEAR DENSITY FOR 28 gg MACHINE (tex)
Shinn[1]	$\frac{9454}{(\text{Gauge})^2}$	Cotton	12
Chamberlain[2]	$\frac{10850}{(\text{Gauge})^2}$	Worsted	14
Hunter (encountered at Leicester Polytechnic)[3]	$\frac{11071}{(\text{Gauge})^2}$ and $\frac{22142}{(\text{Gauge})^2}$	Worsted	14 and 28
Anon[4]	$\frac{10628}{(\text{Gauge})^2}$	Acrilan	14
Wignall[5]	$\frac{22500}{(\text{Gauge})^2}$	Not Specified	29

knitting force required coincided with a tightness factor of about 13 — 14.

Recently Sasaki *et al*[12] established a method of evaluating the knittability of a yarn *before knitting*. They produced an apparatus which simultaneously measured what they considered the four most important physical properties.

1. Unwinding resistance of the yarn off the cone.
2. Yarn to yarn friction.
3. The friction between yarn and knitting needle, and
4. The bending moment of the yarn.

In a previous report Robinson *et al*[13] described a method of assessing the knittability of a yarn on a double jersey machine. Use was made of knittability curves relating the number of yarn breakages to machine tightness factor in order to determine the knittability of a yarn. This report deals with:

(a) the validity of the knittability test method[13], for use on a 28 gg single jersey machine;

(b) determination of a suitable yarn linear density (for wool) for use on a 28 gg single jersey machine; and
(c) to investigate the effect of tucking (in accordion fabrics) on the knittability of fine worsted yarns on a Jacquard knitting machine.

EXPERIMENTAL

(a) KNITTABILITY OF ALL-WOOL YARNS IN PLAIN SINGLE JERSEY FABRICS:

A nominal 22 tex all-wool hosiery yarn was waxed, and then knitted into plain single jersey fabric on a 28 gg Bentley JSJ knitting machine fitted with trip tape positive feed. The machine settings employed were similar to those employed under industrial conditions for commercially acceptable knitting performance, with one exception that the fabric tightness was varied to determine the optimum tightness for good knittability.

Knitting details:

Machine	: Bentley JSJ
Gauge	: 28 (needles per inch)
Diameter	: 66 cm (26")
Yarn input tension	: 3 cN
No. of feeders used	: 4 (experimental purposes only)
Machine speed	: 14 r/min.
Structure	: Plain
Take-down tension	: Medium

The yarn was divided into four lots and each lot dyed to a different shade. The yarn was knitted at various fabric tightness values for 250 machine revolutions using a different shade at each of the four feeders and repeated a further three times so that each shade of yarn was knitted at each feeder, thus eliminating any discrepancies due to feeder differences. Therefore, in total, 4 000 courses (1 000 revolutions of the machine) were knitted. The fabrics were examined, the number of yarn breakages of each shade of yarn noted and the results converted to the number of yarn breakages per 100 000 m of yarn knitted.

For the purpose of determining the characteristics of the knittability curve the experiment was repeated for a series of fabric tightness values (different course lengths) as recorded by a Uniwave course length meter. The yarn tension was kept constant at 3 cN and every precaution was taken to ensure that yarn breakages recorded were directly related to the yarn characteristics and not caused by machine faults (e.g. damaged needles). The physical properties of the yarns were measured.

(b) OPTIMUM YARN TEX (ALL-WOOL) FOR USE ON A 28 GG SINGLE JERSEY MACHINE:

Yarns:

Eight different yarn linear densities were chosen ranging from 18 tex to 34 tex. Yarn below 18 tex were considered too weak and irregular. Seven of the yarns, all produced at SAWTRI, were spun with less than one yarn breakage per 100 spindle hours and the eighth yarn was an imported commercial yarn. These eight yarns were waxed and electronically cleared before knitting.

Knitting:

The knitting details were exactly the same as those for part (a) and the experiment was repeated for all eight yarn linear densities (18, 19, 20, 22, 24, 28, 32 and 34 tex). Each lot was knitted for 250 machine revolutions, which therefore gave 1 000 courses of fabric per yarn lot. The number of yarn breakages were recorded and converted to number of yarn breakages per 100 000 m of yarn knitted. The cause of the breakages was carefully analysed and only those due to yarn characteristics were recorded (see Table IV). In the case of the 28, 32 and 34 tex yarns only three tightnesses were knitted due to shortage of yarn. The fabric mass per unit area was determined in all cases.

(c) EFFECT OF TUCKING IN ACCORDION STRUCTURES ON THE KNITTABILITY OF FINE WORSTED YARNS

It was decided to knit a simple *two colour* Jacquard check design with selective tucking. Fig. 1(e) shows the fabric appearance and (a), (b), (c) and (d) are full designs showing the different tucking arrangements, viz. — —

(a) No tucking
(b) Selective accordion
(c) Straight accordion, and
(d) Alternate accordion.

Knitting details:

The knitting details and yarns used were as described in part (a) with the exception that 16 feeds were employed for the Jacquard knitting. Each structure

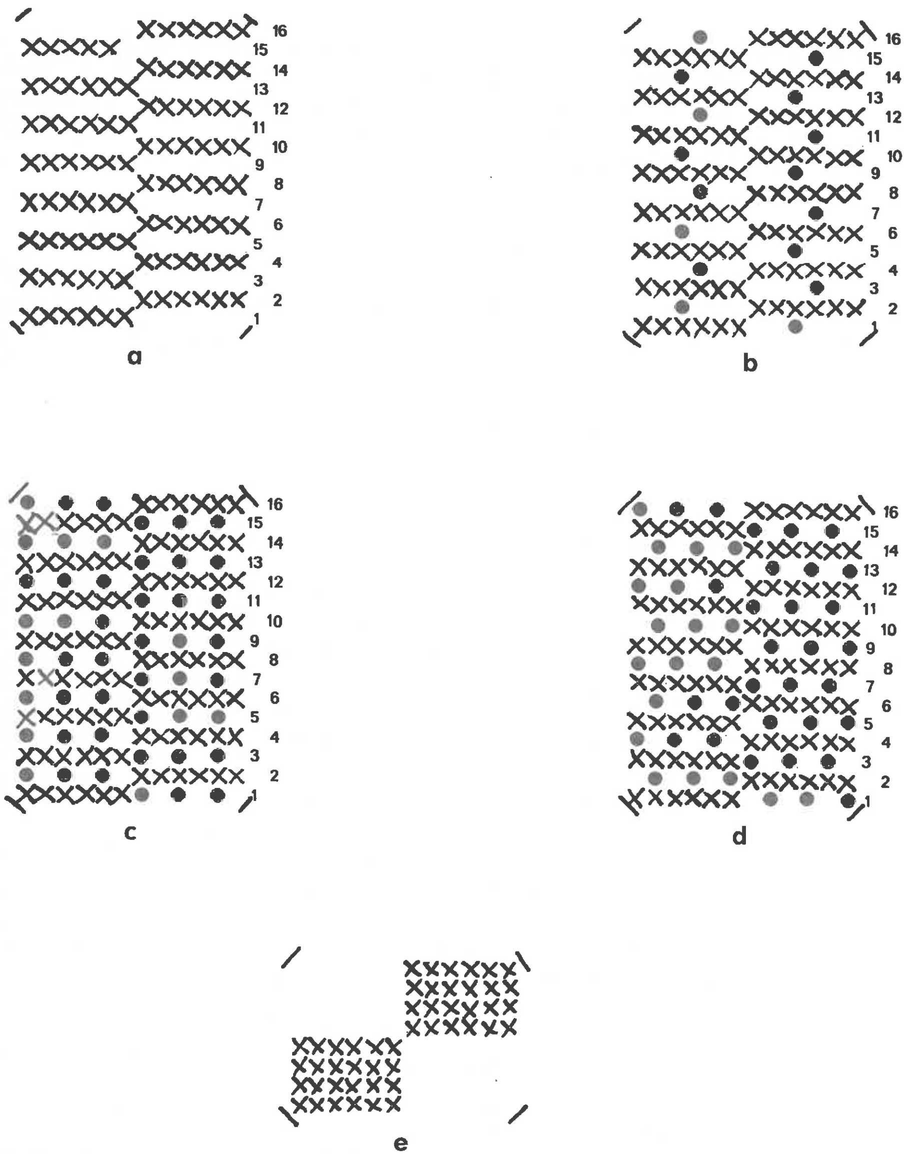

Fig. 1 (a), (b), (c), and (d) are diagrams of the different structures knitted and (e) is the fabric appearance was knitted at different tightnesses for 250 revolutions of the machine (2 000 courses). This was repeated with each shade of yarn being knitted at each feeder to eliminate any feeder discrepancies. The number of yarn breakages was then recorded as in part (a) and (b). The smallness of the pattern repeat allowed positive feed to be employed.

General:

The width of the fabric off the machine and the fabric mass per unit area were determined. The average course length was measured on a HATRA course length metre over the repeat of the pattern and the knitted stitch length (ℓ_k) calculated by using the formula[14] :

$$\ell_k = \frac{g.L_T. - m.N}{(k + t).g.N}$$

where L_T = the total length of yarn in the pattern repeat in one machine revolution.
n = the number of needles in the width of the pattern repeat.
N = the total number of needles in the machine.
g = the gauge of the machine in needles per cm .
m = the number of needles *missing* in the Structural Knit Cell.
k = the number of needles *knitting* in the Structural Knit Cell.
t = the number of needles *tucking* in the Structural Knit Cell.

RESULTS AND DISCUSSION

(a) KNITTABILITY OF ALL-WOOL YARNS IN PLAIN SINGLE JERSEY FABRICS:

Table II shows that the four yarn lots differed only slightly in their linear density and physical properties.

TABLE II

SOME PHYSICAL PROPERTIES OF THE DYED YARNS

Dye Lot	Yarn Linear Density (tex)	Breaking Strength (cN)	Extension (%)	Irregularity (CV in %)	Friction (cN)
1	23,3	129	12,3	21,0	17
2	22,9	121	9,4	21,4	20
3	22,7	124	9,9	21,9	22
4	22,7	124	11,3	21,7	19

Table III gives the number of yarn breakages which occurred at the various tightnesses for each yarn lot and Fig 2 shows the curve obtained when the number of holes formed (yarn breakages) during knitting were plotted against the fabric tightness. From Fig 2 it can be seen that the rate of increase in the number of yarn breakages accelerated as the tightness factor increased, and eventually approached infinity. As expected, these results show the same trends as those obtained in a previous report[13] on double jersey knitting, and indicate that the proposed method of test can be adapted to single jersey knitting as well as to double jersey knitting.

TABLE III

NUMBER OF YARN BREAKAGES PER 100 000 m OF YARN KNITTED AT VARIOUS TIGHTNESSES

Stitch Length (ℓ) (cm)	Tightness $= \frac{\sqrt{tex}}{\ell}$	No. of yarn breakages				
		Dye Lot				Average
		1	2	3	4	
0,2748	17,1	81	0	16	0	24
0,2659	17,7	83	33	33	17	42
0,2570	18,3	104	86	86	52	82
0,2482	18,9	215	322	304	143	246
0,2393	19,6	1021	1189	910	650	943
0,2304	20,4	2721	3223	5713	2374	3508

(b) OPTIMUM YARN TEX (ALL-WOOL) FOR A 28 GG SINGLE JERSEY MACHINE:

Physical Properties of Yarns:

Some physical properties of the yarns are shown in Table IV and the differences in breaking strength, extension and irregularity between the yarns are very noticeable. The imported yarn appeared to have the worst overall properties and this was probably due to it being the only dyed yarn. The relatively high friction of this yarn indicated that it was not effectively waxed. The physical properties of the yarns generally improved with increasing linear density, with the exception of the 22 tex yarn which had better overall properties than the 24 tex, and the 32 tex yarn which was better than the 34 tex yarn.

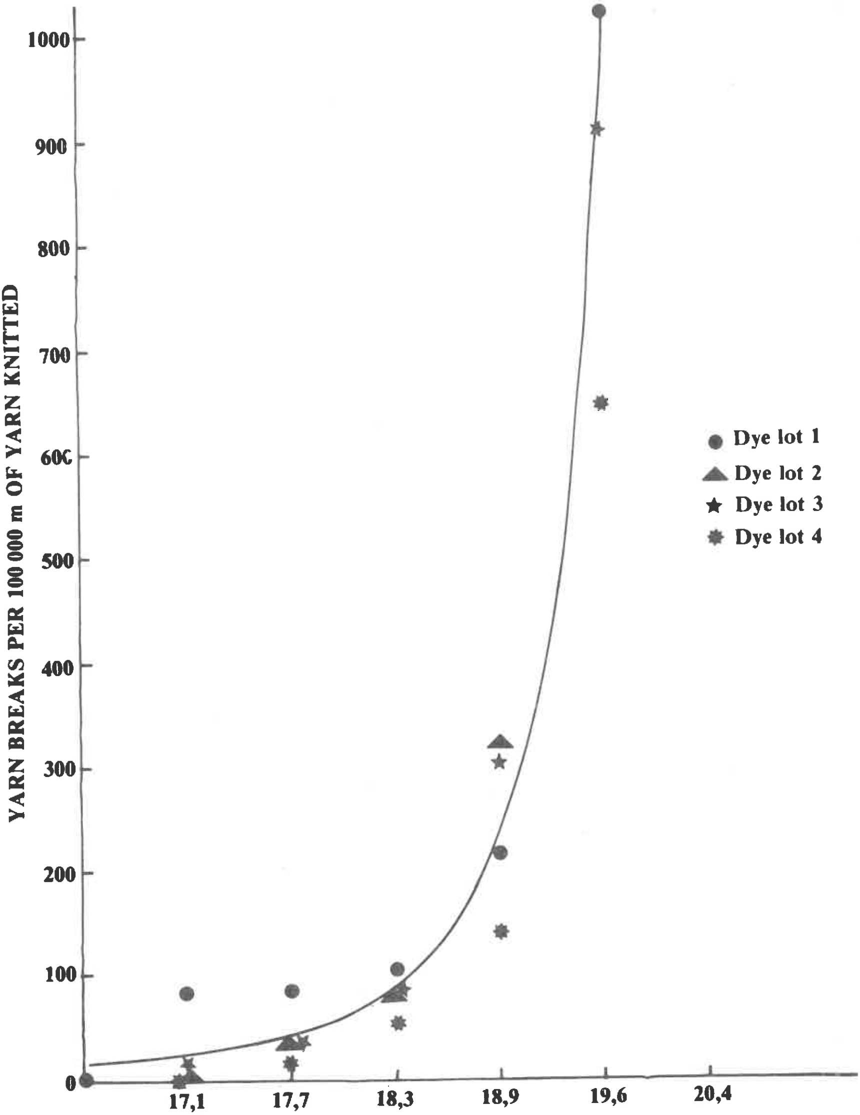

Fig. 2 Knittability curve showing the relationship between yarn breaks per 100 000 m of yarn knitted and tightness factor (single jersey 28 gg) for a yarn of linear density 23 tex.

TABLE IV
SOME PHYSICAL PROPERTIES OF THE YARNS

Yarn Linear Density (tex)		Breaking Strength	Extension	Irregularity	Friction
Nominal	Mean	(cN)	(%)	CV (%)	(cN)
18	17,6	105	10,8	21,8	13
20	19,7	116	11,7	19,5	13
22	21,7	139	14,2	18,3	13 — 14
24	24,2	141	13,6	18,8	13 — 14
28	27,0	186	15,7	18,2	12 — 13
32	31,8	218	18,9	17,0	9
34	32,1	203	14,9	18,2	15
19 (Foreign)	18,3	101	7,8	21,3	25

Knittability:

Table V shows the number of yarn breakages at the different tightnesses for the different yarn linear densities, as well as fabric mass per unit area. The knittability of all the yarns (Fig 3) followed similar curves as in Fig 2 and from these curves the knittability factor[13] was determined for each yarn.

The *knittability factor* of a yarn on a particular gauge of machine is defined as the tightness factor ($\frac{\sqrt{\text{tex}}}{\ell}$) at which the yarn knits at 100 yarn breakages per 100 000 metres of yarn knitted determined from a knittability curve showing the relationship between yarn breakages and MTF.

In Fig 4, the knittability factors are plotted against the mean yarn linear densities. From a quadratic regression analysis it was shown that the equation $y = 0{,}584\ x - 0{,}0084\ x^2 + 10{,}28$ had the best fit, and that the slope of the curve became zero (maximum knittability) at 35 tex. This indicates that 35 tex is the most suitable linear density for a wool yarn knitted on this machine. However, the optimum yarn to use for commercial purposes would obviously depend on the required mass per unit area of the fabric as determined by its end use. For example, the 28 tex and 32 tex yarns produced fabrics with a mass per unit area of 150 and 165 g/m^2 (after dry relaxation) respectively when knitted at a tightness factor of 14,5.

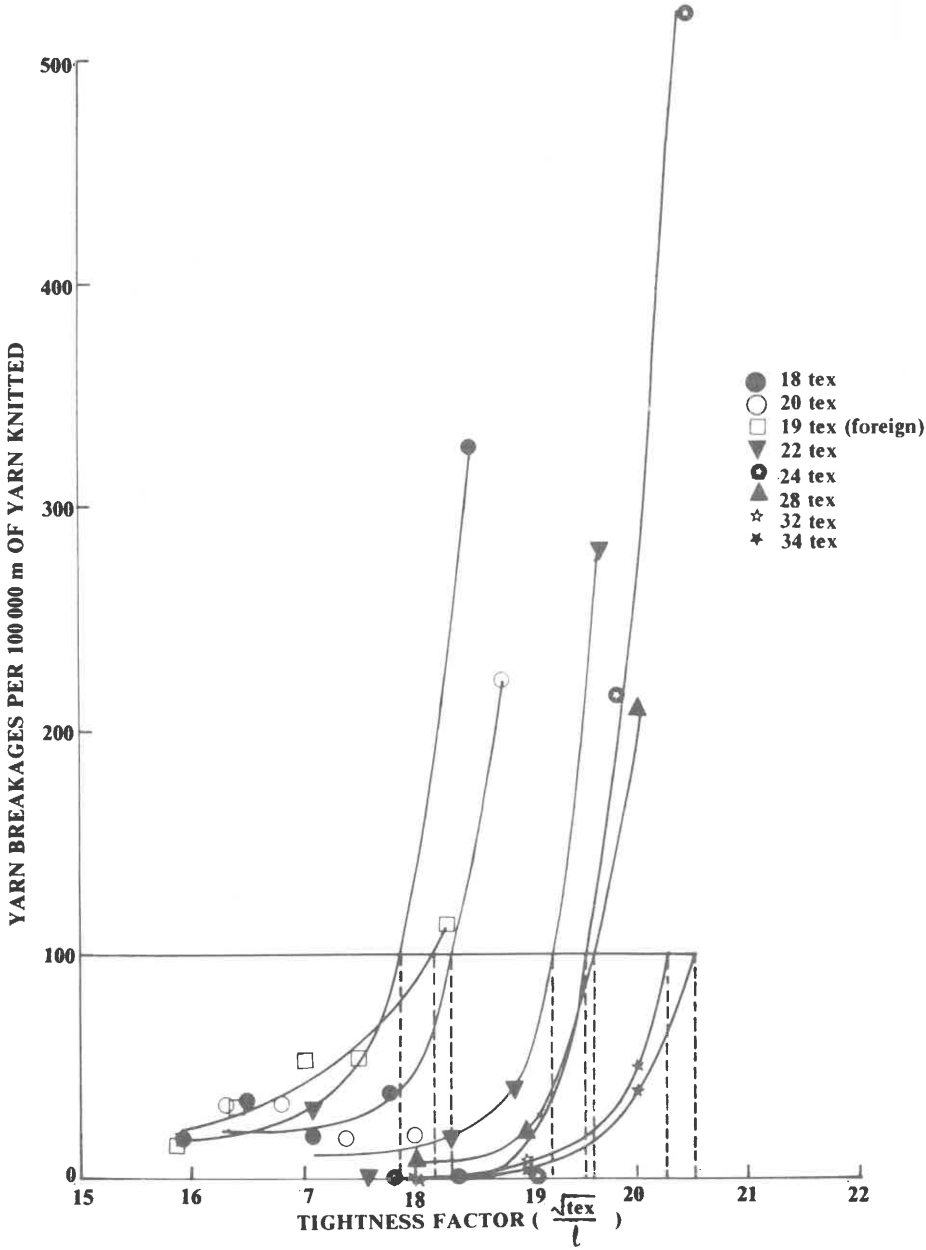

Fig. 3 Yarn breakages per 100 000 m of yarn knitted for the various tightness factors of the different yarn linear densities knitted.

The finer yarns of the series (less than 20 tex) produced fabrics which were sleezy and accentuated the irregularity of the yarn and therefore these yarns were considered unacceptable.

(c) EFFECT OF TUCKING IN ACCORDION STRUCTURES ON THE KNITTABILITY OF FINE WORSTED YARNS:

Table VI shows the number of yarn breakages per 100 000 m of yarn knitted and the mass per unit area of the four different structures knitted at the various tightnesses.

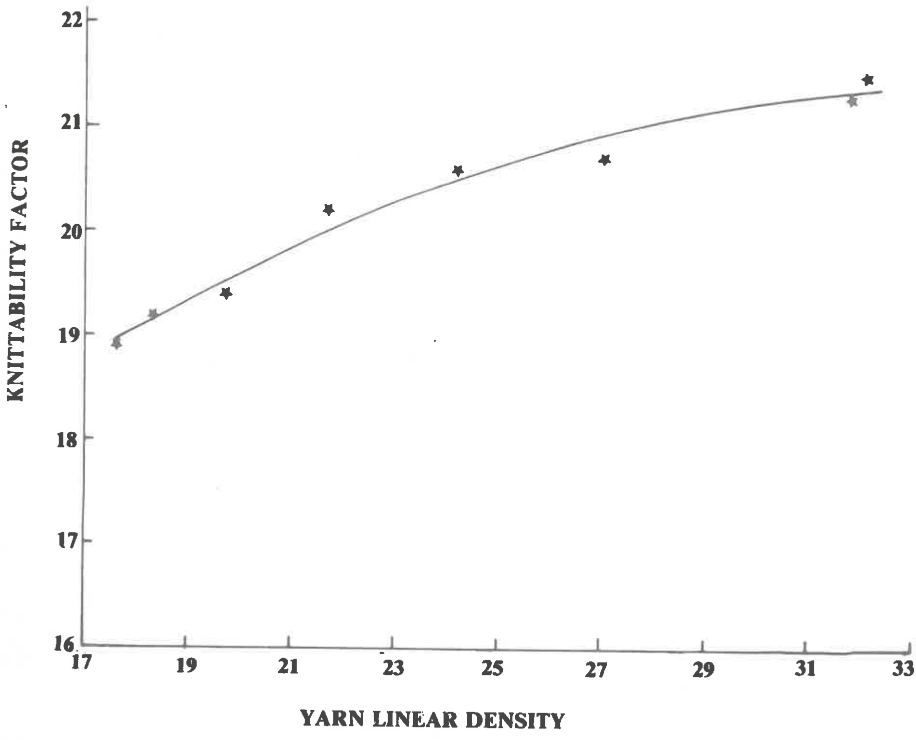

Fig. 4 Knittability factors for the different yarn linear densities.

TABLE V

THE EFFECT OF FABRIC TIGHTNESS ON THE KNITTABILITY (NUMBER OF YARN BREAKAGES PER 100 000 m OF YARN KNITTED) OF ALL-WOOL YARNS OF VARIOUS LINEAR DENSITIES

Yarn Linear Density (tex)	Fabric Mass per Unit Area (g/m²)	Course Length (m)	Tightness Factor $\left(\frac{\sqrt{tex}}{l}\right)$	Number of Yarn Breakages per 100 000 m of Yarn Knitted	Knittability Factor
18	116	6,00	15,9	17	17,9
	120	5,79	16,5	34	
	125	5,59	17,1	18	
	134	5,38	17,8	37	
	136	5,18	18,5	328	
20	132	6,20	16,3	32	18,4
	135	6,00	16,8	33	
	139	5,79	17,4	17	
	150	5,59	18,0	18	
	160	5,38	18,8	223	
22	149	6,20	17,1	32	19,2
	154	6,00	17,6	0	
	155	5,79	18,3	17	
	170	5,59	18,9	37	
	172	5,38	19,7	279	
24	170	6,20	17,8	0	19,6
	170	6,00	18,4	0	
	176	5,79	19,1	0	
	190	5,59	19,8	214	
	193	5,38	20,5	520	
28	181	6,63	18,0	8	19,7
	188	6,27	19,0	16	
	198	5,97	20,0	209	
32	196	7,09	18,0	0	20,3
	197	6,70	19,0	7	
	208	6,38	20,0	47	
34	203	7,30	18,0	0	20,5
	210	6,93	19,0	7	
	229	6,58	20,0	38	
19 (Foreign)	115	6,20	15,9	16	18,2
	120	6,00	16,4	33	
	128	5,79	17,0	52	
	140	5,59	17,6	54	
	153	5,38	18,3	112	

TABLE VI

RESULTS OBTAINED FROM KNITTING THE DIFFERENT ACCORDION FABRICS AT VARIOUS TIGHTNESSES

Design (see Fig 1)	Positive Feed Setting	Average Course Length (m)	Knitted Loop Length (cm)	Total Number of Yarn Breakages			Fabric Mass (g/m^2)
				Dye Lot 1	Dye Lot 2	Average	
(a)	0	4,02	0,266	9	6	8	215
	- 1	3,90	0,255	38	83	67	220
	2	3,80	0,246	428	572	500	232
No Tucking	- 3	3,64	0,232	1140	1587	1363	233
	- 4	3,52	0,221	2258	2287	2273	234
(b)	1	4,18	0,252	34	30	32	184
	0	4,06	0,243	137	107	122	198
Selective	- 1	3,93	0,233	519	694	607	201
Accordion	- 2	3,84	0,266	937	1851	1394	205
	- 3	3,77	0,221	3322	4733	4028	210
(c)	4	4,26	0,238	12	65	39	172
	3	4,14	0,230	60	72	66	181
Straight	2	4,05	0,224	117	321	219	187
Accordion	1	3,95	0,217	886	1645	1266	195
	0	3,86	0,211	2189	7487	4838	214
(d)	4	4,23	0,236	30	17	24	170
	3	4,14	0,230	115	66	91	176
Alternate	2	4,04	0,223	309	613	461	186
Accordion	1	3,93	0,216	1972	2455	2214	187
	0	3,86	0,211	5738	11140	8439	197

Knittability:

It was interesting to note that the positive feed mechanism was ineffective in controlling the yarn consumption when knitting Jacquard fabrics. From the table it can be seen that, at the positive feed setting of zero, the average course length measured for the structures differed, except for the alternate and straight accordion structures which were the same. These two structures had the same course length because the same amount of tucking occurred in each structure and therefore it was expected that they should knit similarly.

The knittability curves of the yarns (Fig 5) differed between the structures, and these appeared to depend upon the amount of tucking in the structure. The knitted stitch length was used as a measure of tightness since all the yarn breaks occurred at the knitted stitches. The straight and alternate accordion structures had almost similar knittability and could be knitted at the *tightest* knitted stitch length. This was probably because of the extra yarn which was available from the tuck loops for "robbing back" to occur. The selective accordion could be knitted slightly tighter than the no-tuck structure, but a longer knitted stitch length was necessary than for the straight and accordion structures because there were less tuck loops from which to "rob back".

Furthermore, at a given average course length, the straight and alternate accordion fabrics were the lightest in mass per unit area, followed by the selective accordion whereas the heaviest was the no-tuck fabric. However, the opposite was the case when the knittability was compared at different mass per unit areas, i.e. at the same mass per unit area the no tuck structure exhibited the best knittability followed by the selective accordion and finally the straight and alternate accordions. It must also be mentioned that the pattern definition on the face side of the no tuck fabric was better than that of the tuck fabrics since the tuck loops in the accordion fabrics could be seen on the face side of the fabric.

SUMMARY AND CONCLUSIONS

An investigation has been carried out using a method of assessing the knittability of yarns (previously found to be successful on a double jersey machine) on a 28 gauge single jersey machine. An attempt was made to find the optimum linear density of yarn for use on a 28 gg single jersey machine using a range of yarn linear densities from 18 to 34 tex and a study of the effect of knitting different types of tucking in accordion fabrics on the knittability of a yarn was carried out.

The method developed at SAWTRI for determining the knittability of yarns has been found equally applicable to single jersey machines. This method was then used to determine the most suitable yarn linear density (all-wool) to be

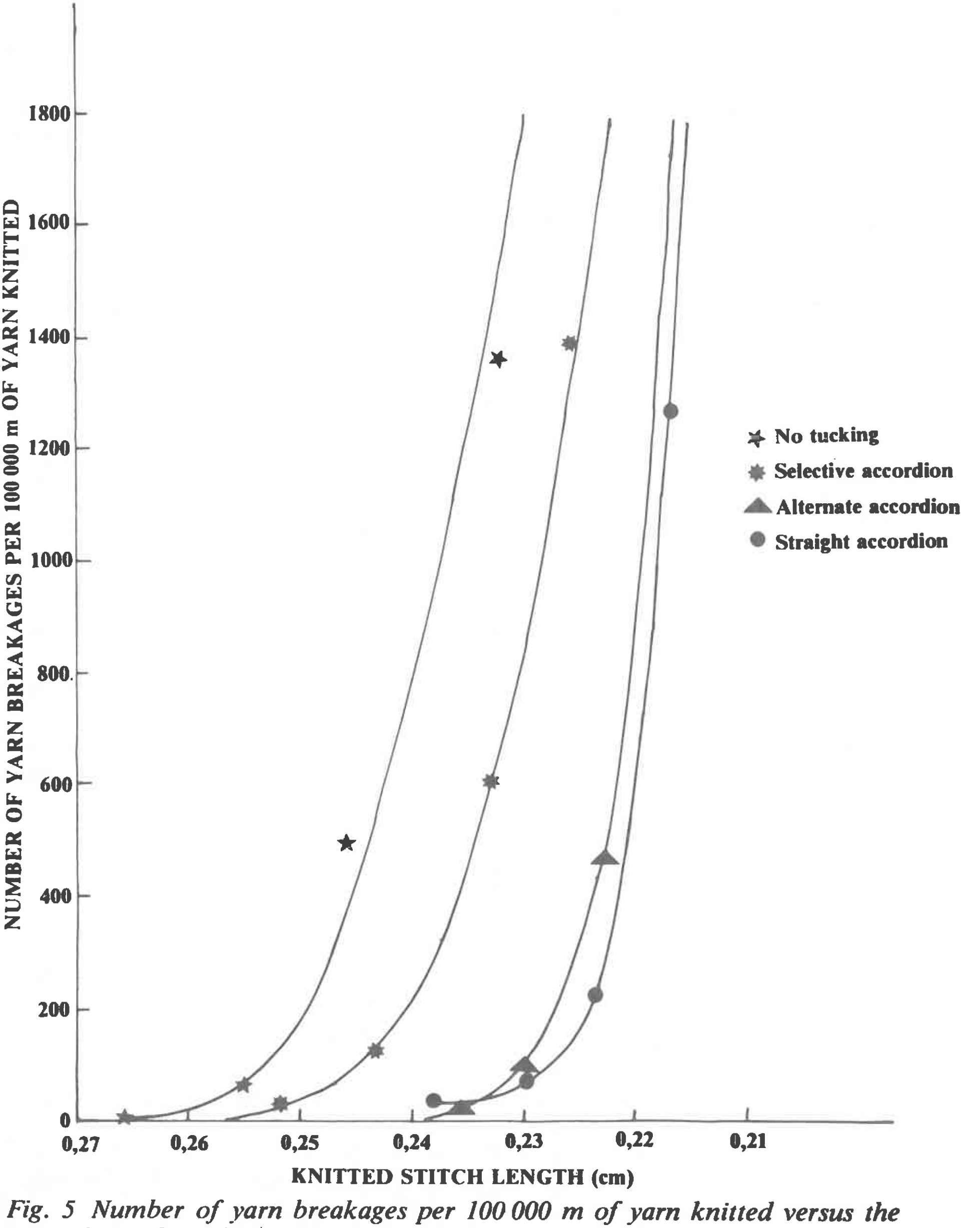

Fig. 5 Number of yarn breakages per 100 000 m of yarn knitted versus the knitted stitch length for the different accordion fabrics.

knitted on a 28 gg single jersey machine. It was found that a 35 tex yarn knitted best, however, depending on the end use, the yarn linear densities can be chosen according to the fabric mass per unit area required.

The straight and alternate accordion structures when knitted at the tightest stitch length produced fabrics with the lowest mass per unit areas. It appeared that the tuck loop provided yarn from which the knitted loops could "rob" and therefore the greater the number of tuck loops, the tighter the structure could be knitted. However, for fabrics of similar mass per unit area the no-tuck fabrics knitted the best followed by the selective accordion and straight and alternate accordion fabrics. The no-tuck structure produced the best pattern definition on the face side of the fabric.

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