Laboratoire de Physique et Mécanique Textiles

ensisa

UNIVERSITÉ HAUTE-ALSACE

Quelques mystères des structures tricotées

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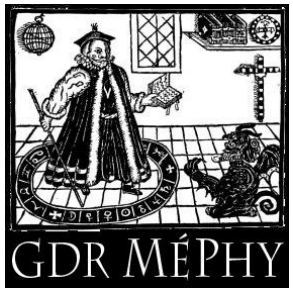
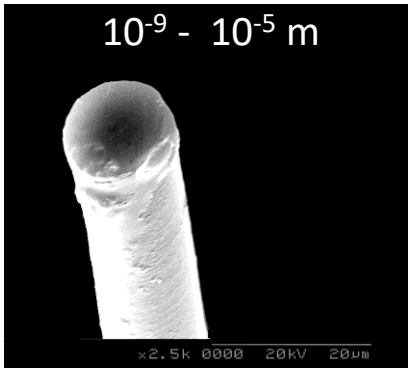
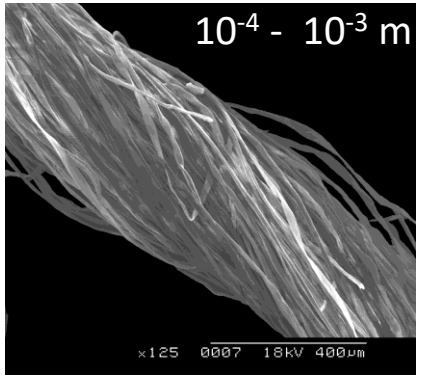


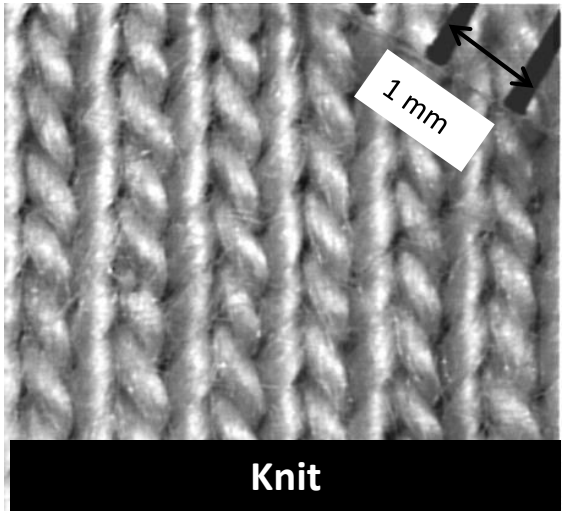
1. Multi-scale structure

Nanofibre - Fibre



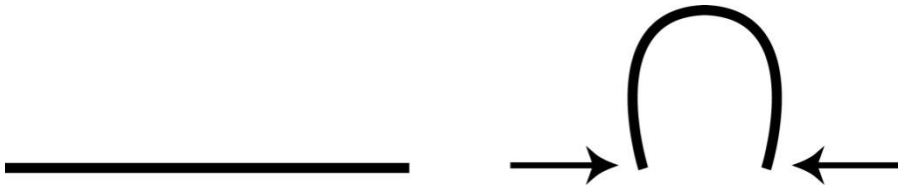
Yarn



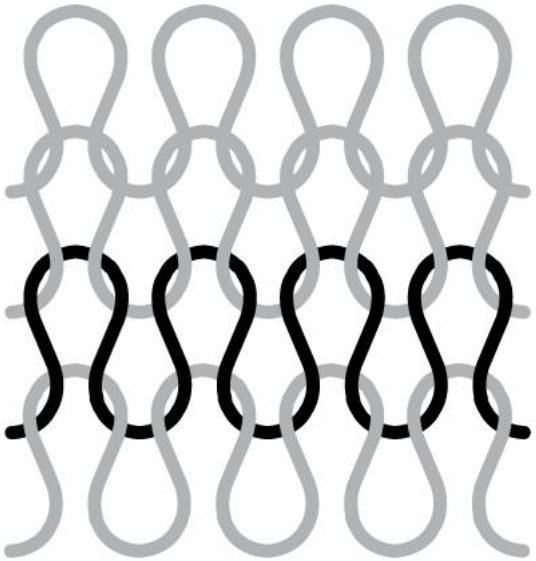


A knitted fabric?

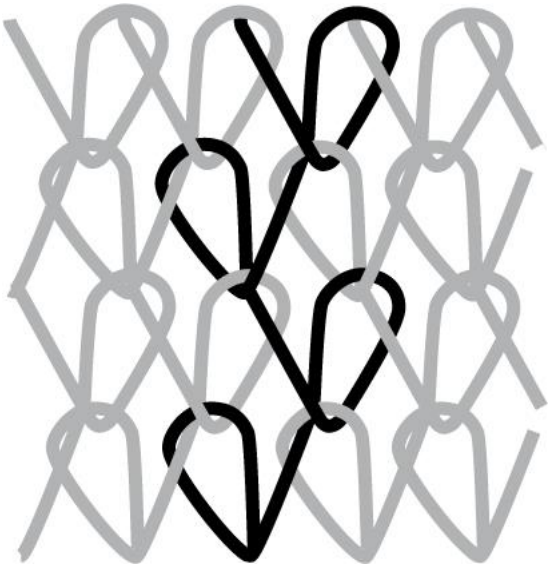
= a fabric with loops



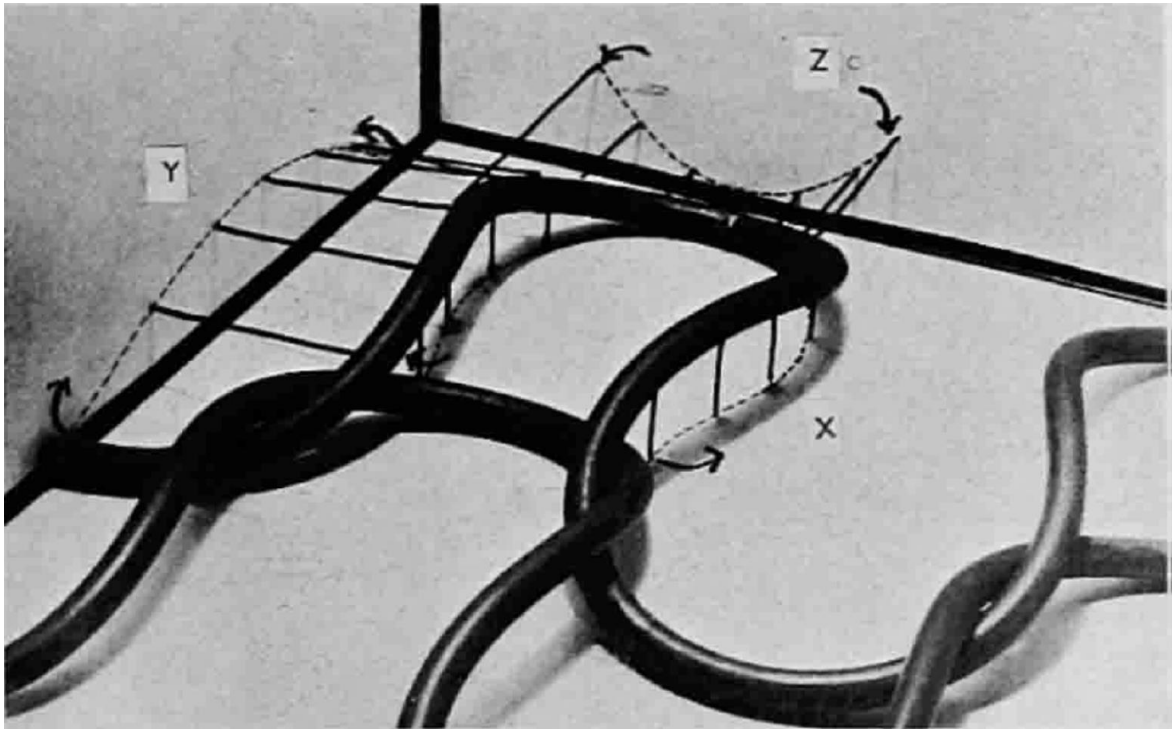
Weft knit



Warp knit

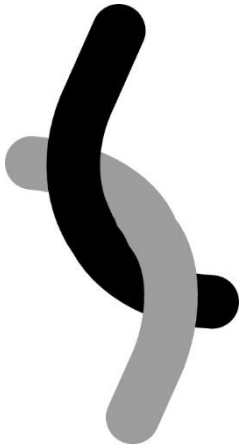


A knitted fabric?



Doyle PJ., Journal of the Textile Institute Proceedings. 1952;43(1):P19-P35.

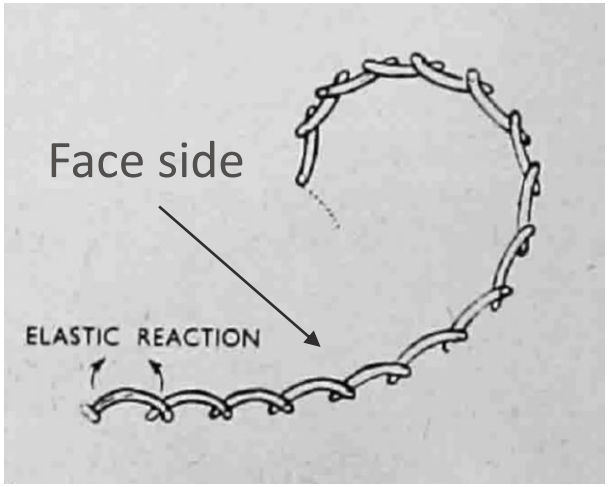
Quater-loop symmetry



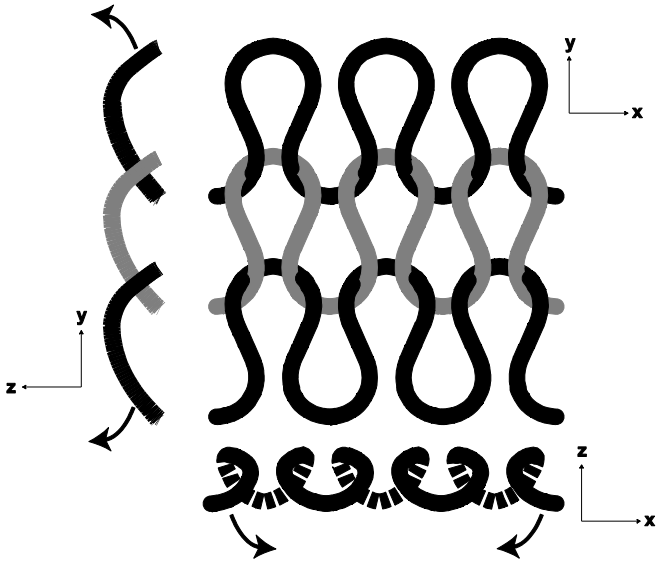
→ Mechanical behaviour:

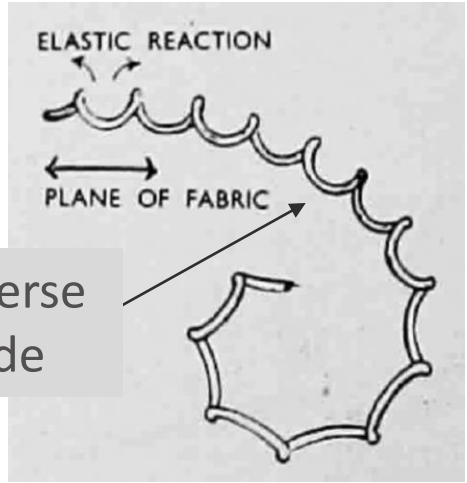
- Yarn bending rigidity
- Interyarn friction

Curling effect (roulottage)



Course-wise

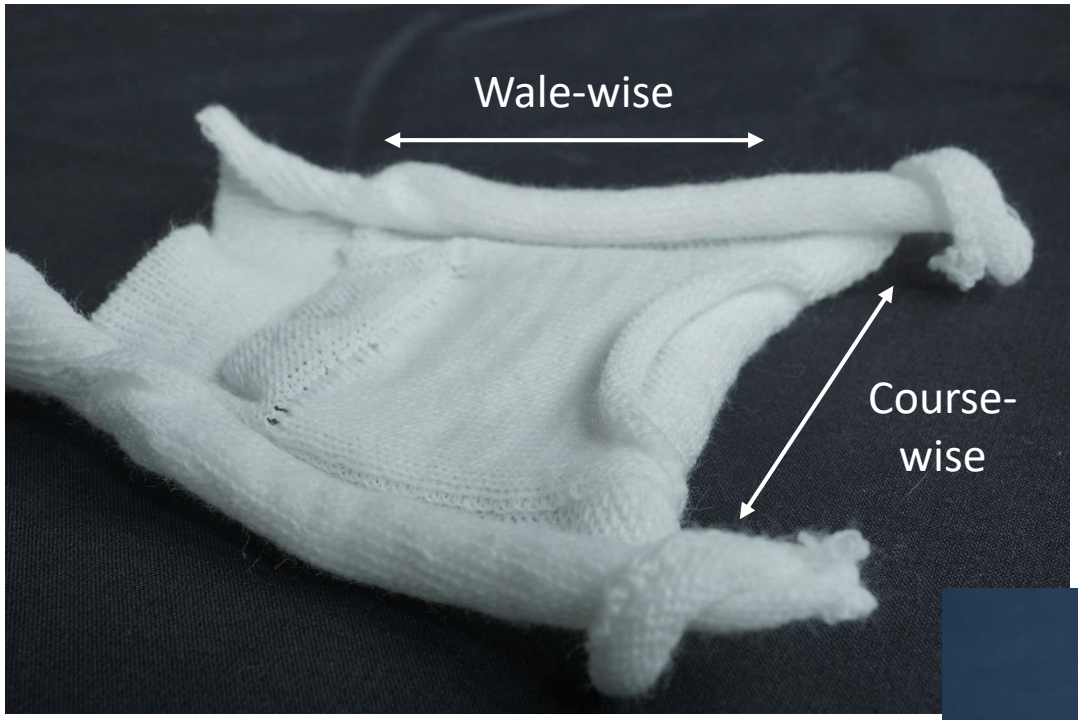




Wale-wise

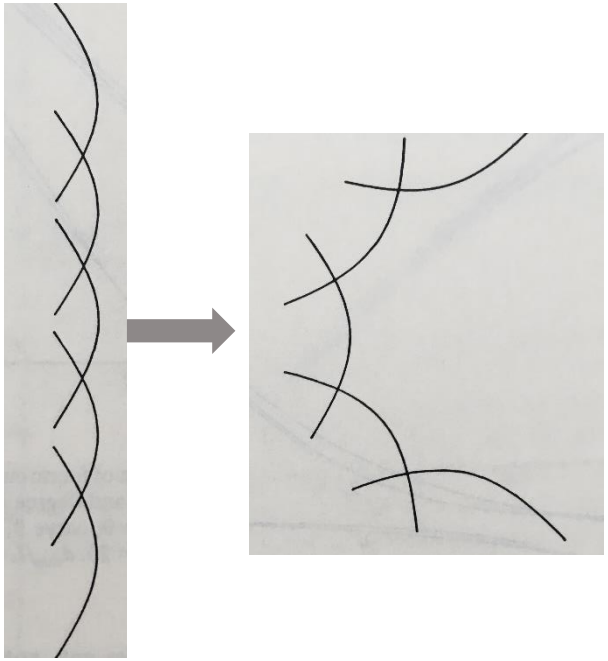
Doyle PJ., Journal of the Textile Institute Proceedings. 1952;43(1):P19-P35.

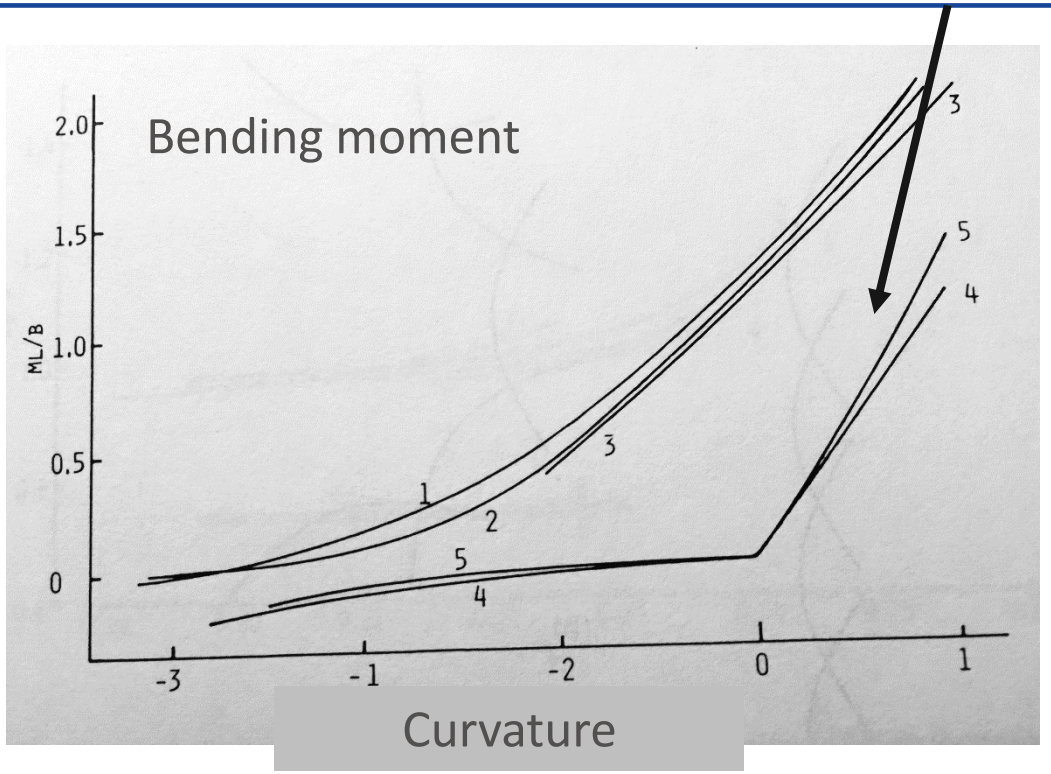
Curling effect (roulottage)



Curling effect (roulottage)

Yarn compression (jamming)





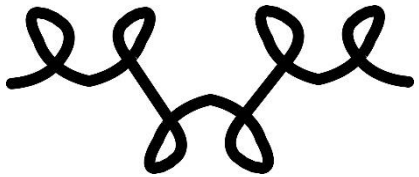
- Is stronger in course-wise (higher bending stiffness) [1]
- Is lower for small stitch length and high fabric thightness (structure blocking) [2,3].

1. Hamilton RJ, Postle R., Text Res J. 1974.
2. Doyle PJ., Journal of the Textile Institute Proceedings. 1952
3. Basiri MR, Najar SS, Yazdan-Shenas ME, Najafizadeh MM, The Journal of The Textile Institute. 2010.
4. R. Postle, G.A. Carnaby and S. de Jong , The Mechanics of Wool Structures, Ellis Horwood, Chichester U.K., 1987

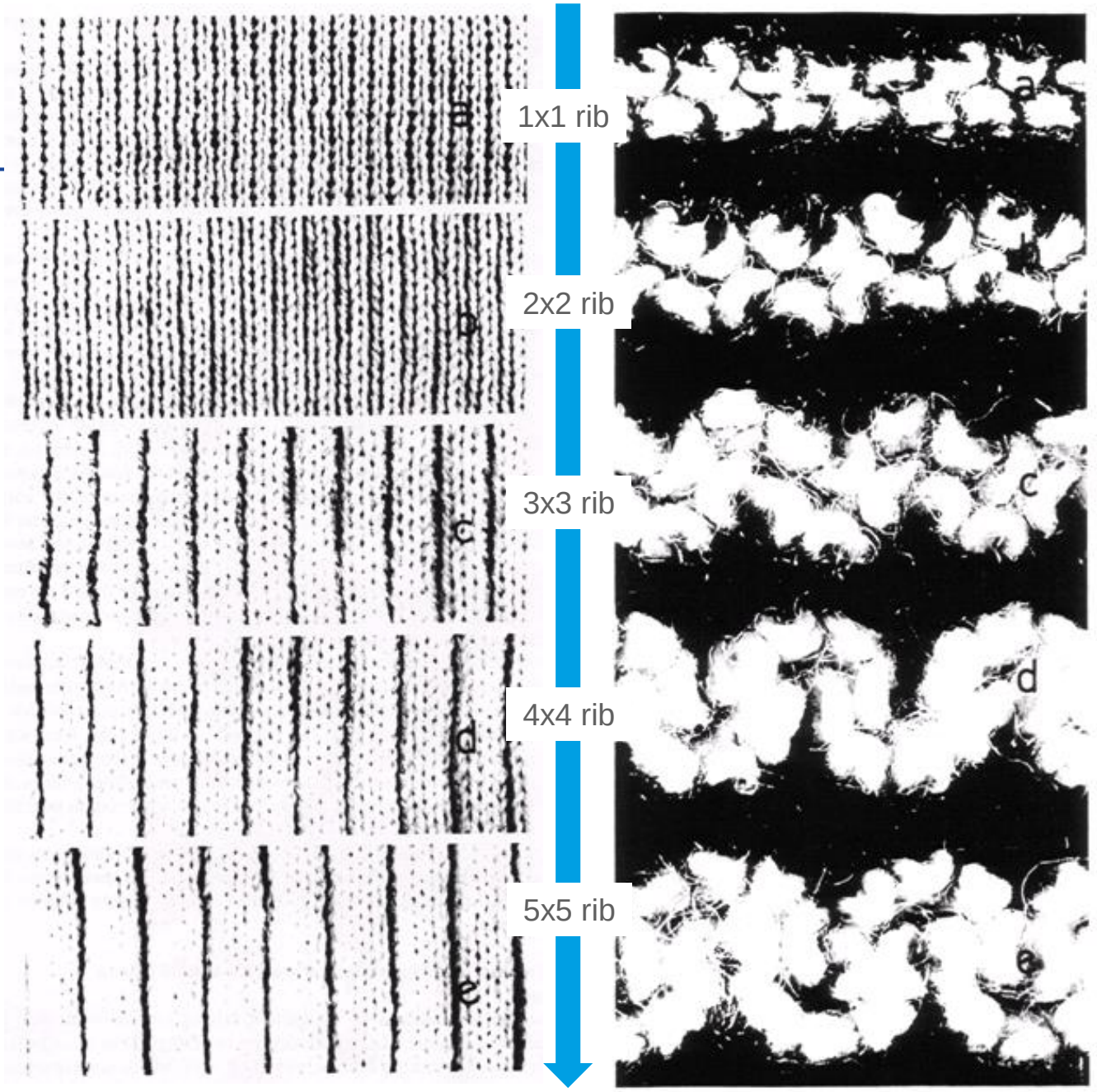
Jersey

Face stitches

1X1 rib



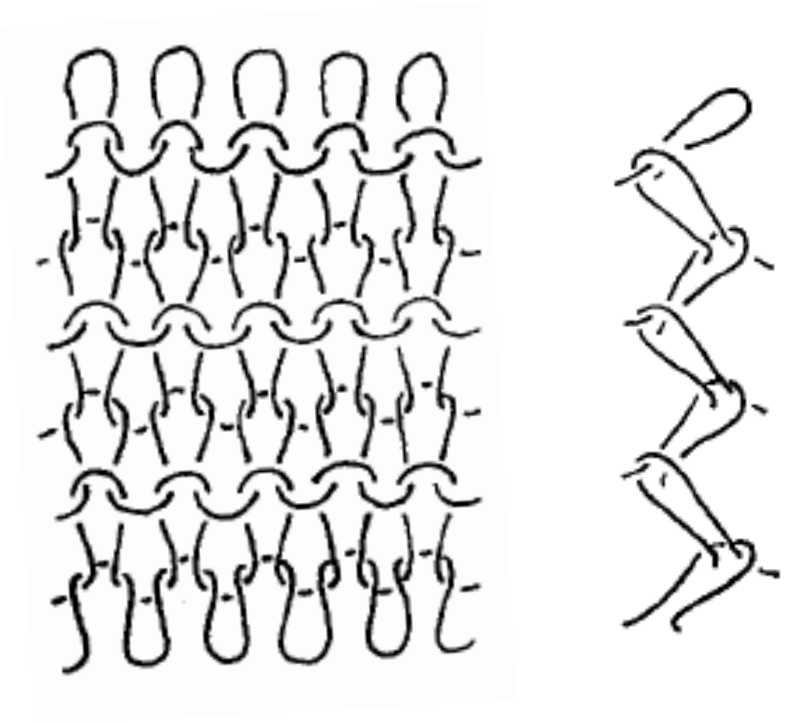
Face and reverse stitches



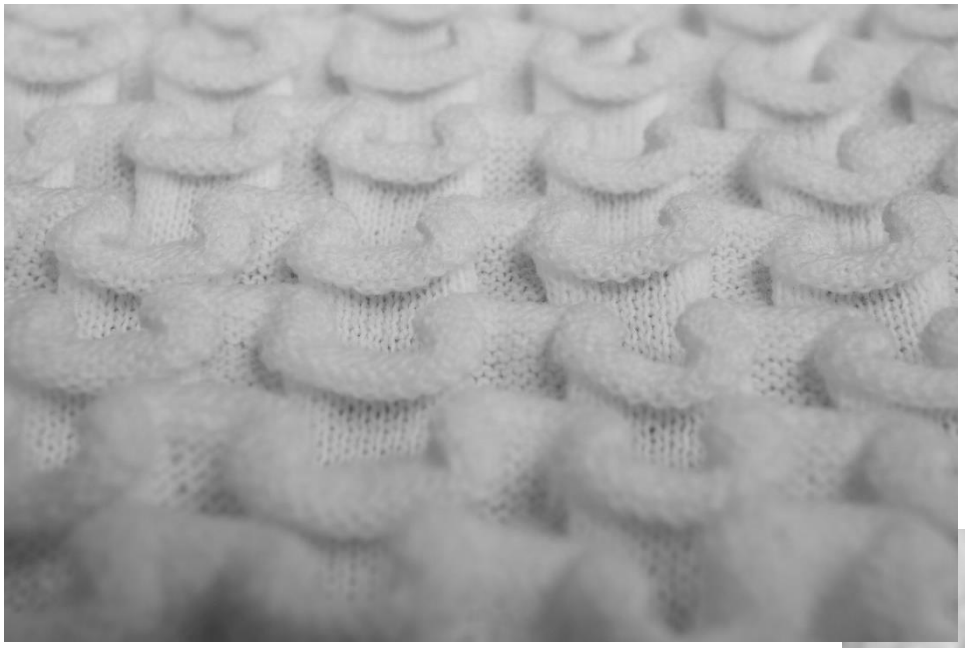
R. Postle, G.A. Carnaby and S. de Jong , The Mechanics of Wool Structures, Ellis Horwood, Chichester U.K., 1987

Curling effect (roulottage)

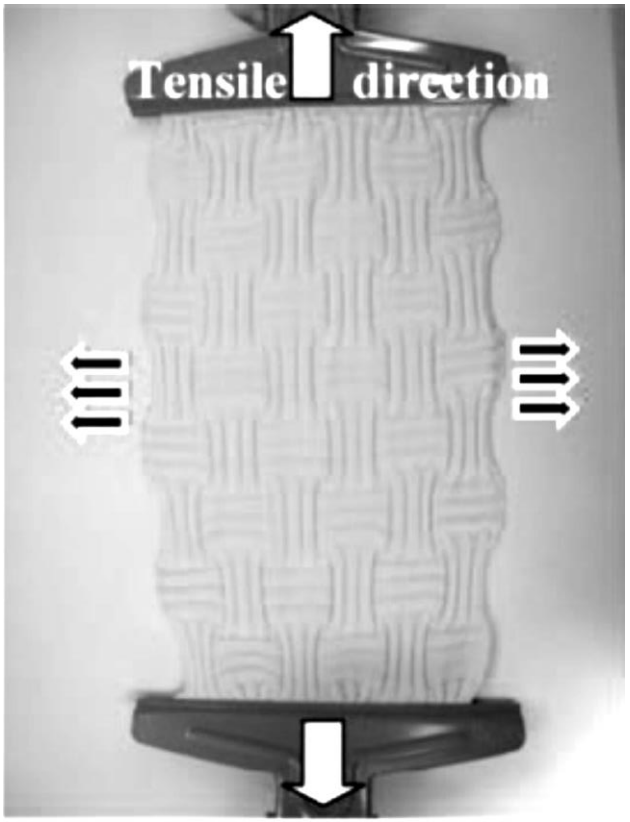
Links-links structure (point mousse)



Curling effect (roulottage)



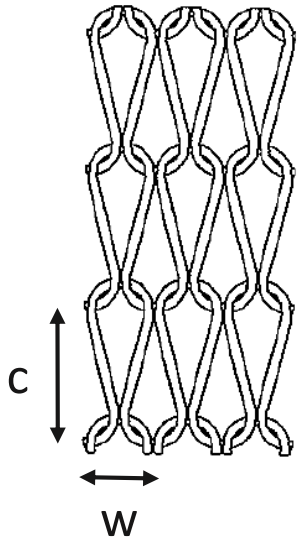
Curling effect (roulottage)

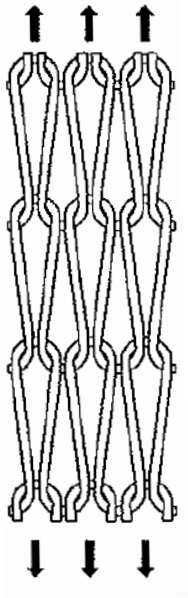


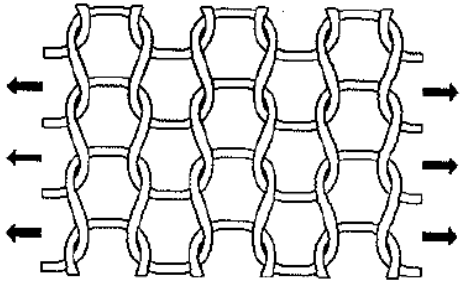
Liu Y, Hu H, Lam JKC, Liu S., Text Res J. 2010.

Hu H, Wang Z, Liu S., Text Res J. 2011.

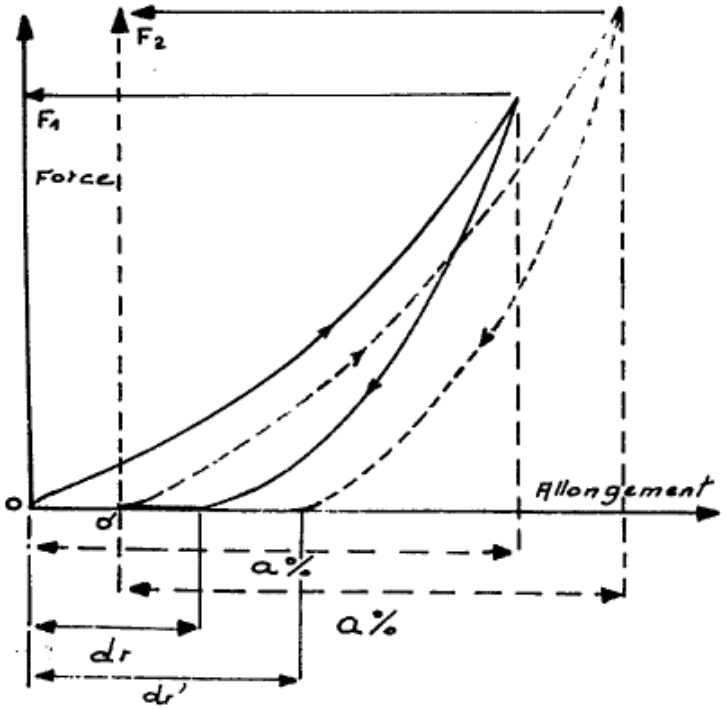
Knitted fabric extensibility







Raz S. Flat Knitting Technology, 1993.



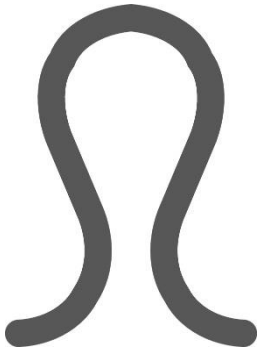
Consequences on fabric geometry and mechanical behaviour

Knitted fabric characteristics

Doyle PJ., Journal of the Textile Institute Proceedings. 1953;44(8):P561-P78.

Munden DL., Journal of the Textile Institute 1959;50(7):T448-T71.

Stitch length



→ Independant of fabric state

Natural shape of the loop

- minimum energy conditions,
- Independant of yarn properties and stitch length

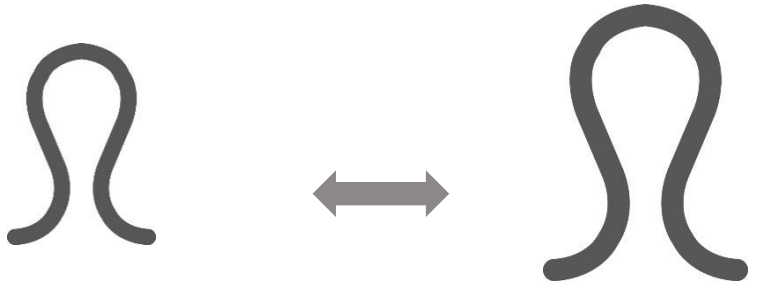
→ Relaxation

Geometry of single jersey fabrics

Munden's laws (after fabric relaxation):

→ Number of wales/cm : W

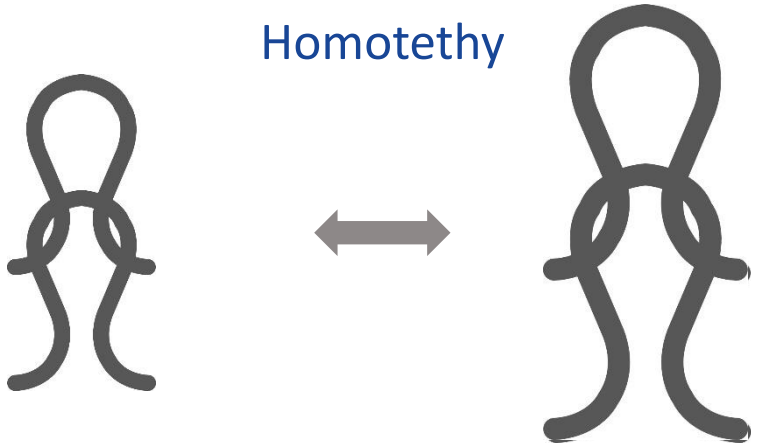
$$W = \frac{K_w}{L}$$



→ Number of courses/cm : C

$$C = \frac{K_C}{L}$$

Homotethy



L is the stitch length,

K_c, K_w are constants.

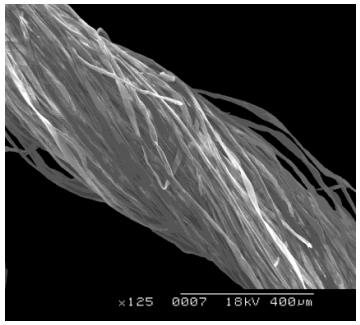
Munden DL., Journal of the Textile Institute 1959;50(7):T448-T71.

Geometry of single jersey

Munden's laws (after fabric relaxation):

K_c and K_w depend on:

- Yarn (material, structure)



- Cover factor or fabric tightness $= \frac{d}{L}$ with d yarn diameter

	K_c	K_w
jersey	5.3 – 5.7	4.0 – 4.1

1. ITF-Maille. Géométrie des tricots: application à la mise en fabrication, Troyes, 1976.
2. R. Postle, G.A. Carnaby and S. de Jong , The Mechanics of Wool Structures, Ellis Horwood, Chichester U.K., 1987

Geometry of jersey and ribs

Munden's laws (after fabric relaxation) extensions:

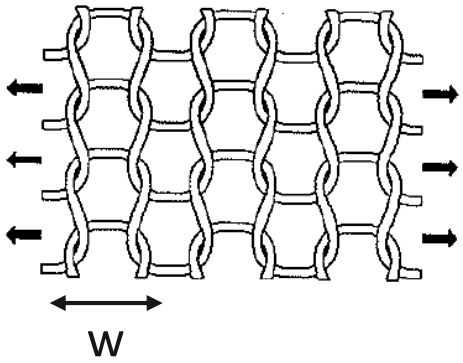
	K_w	K_c
jersey	4.0 – 4.1	5.3 – 5.7
1x1 rib	6.1 – 6.8	4.5 – 5.2
2x2 rib	7.4 – 8.2	4.8 – 5.8
3x3 rib	8.9 – 11.4	4.9 – 5.8
4x4 rib	10.9 – 17.0	5.0 – 5.6
5x5 rib	34.0	5.0

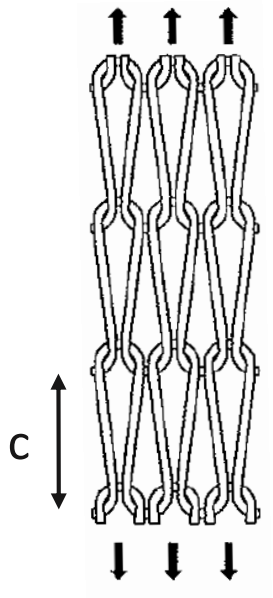
with W wales/cm/side

1. ITF-Maille. Géométrie des tricots: application à la mise en fabrication, Troyes, 1976.
2. R. Postle, G.A. Carnaby and S. de Jong , The Mechanics of Wool Structures, Ellis Horwood, Chichester U.K., 1987
3. Bueno M-A. Chapter 4 : Structure and mechanics of knitted fabrics. In: Professor Peter Schwartz AU, editor. Structure and mechanics of fibre assemblies. CRC Press ed. Cambridge: The Textile Institute and Woodhead Publishing Limited; 2008. p. 84-115.

Maximum elongation of knitted fabrics

Jersey





For course-wise traction

$$w_{max} = L - 2d \quad \Rightarrow \quad \varepsilon_c = K_w\left(1 - \frac{2d}{L}\right) - 1$$

And $\frac{1}{25} \leq \frac{d}{L} \leq \frac{1}{15}$ from Chamberlain , 1926

$$\Rightarrow \quad 250\% \leq \varepsilon_c < 300\%$$

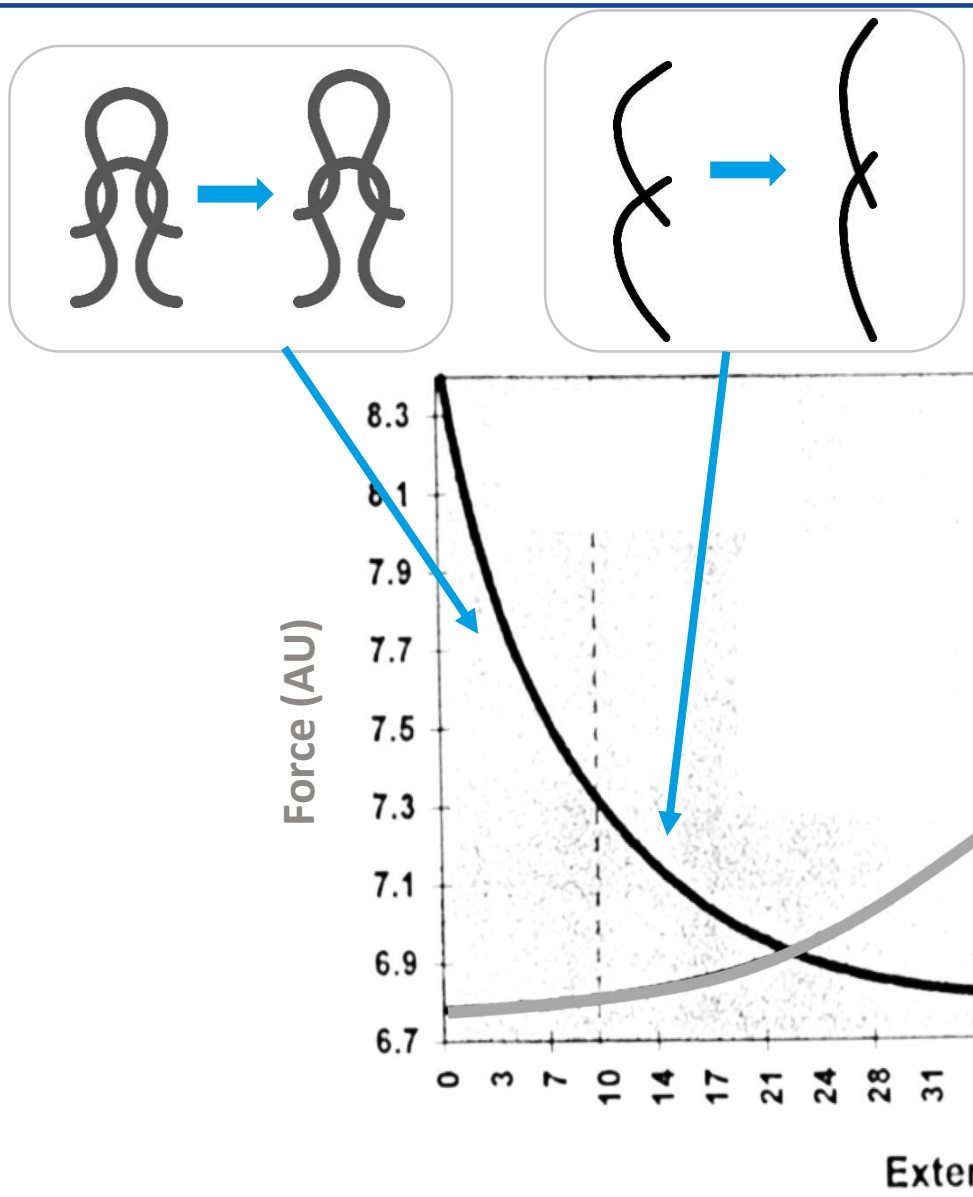
For wale-wise traction

$$c_{max} = \frac{L}{2} - 3d \quad \Rightarrow \quad \varepsilon_w = K_c\left(\frac{1}{2} - \frac{3d}{L}\right) - 1$$

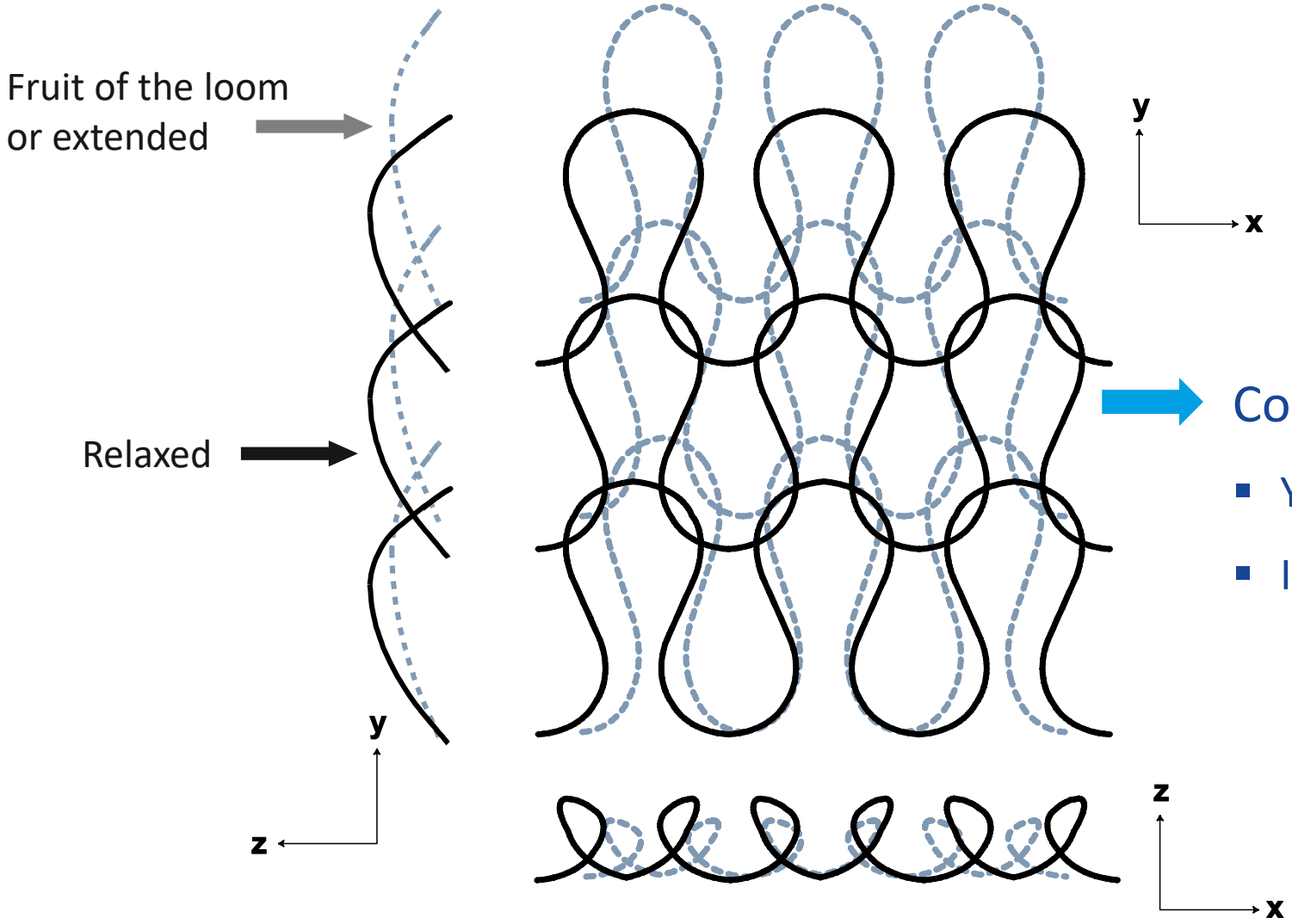
$$\Rightarrow \quad 60\% \leq \varepsilon_w \leq 120\%$$

Chamberlain J., Hoisery Yarns and Fabrics, 1926.

Tensile behaviour of knitted fabrics



Yarn and history influence on relaxed state

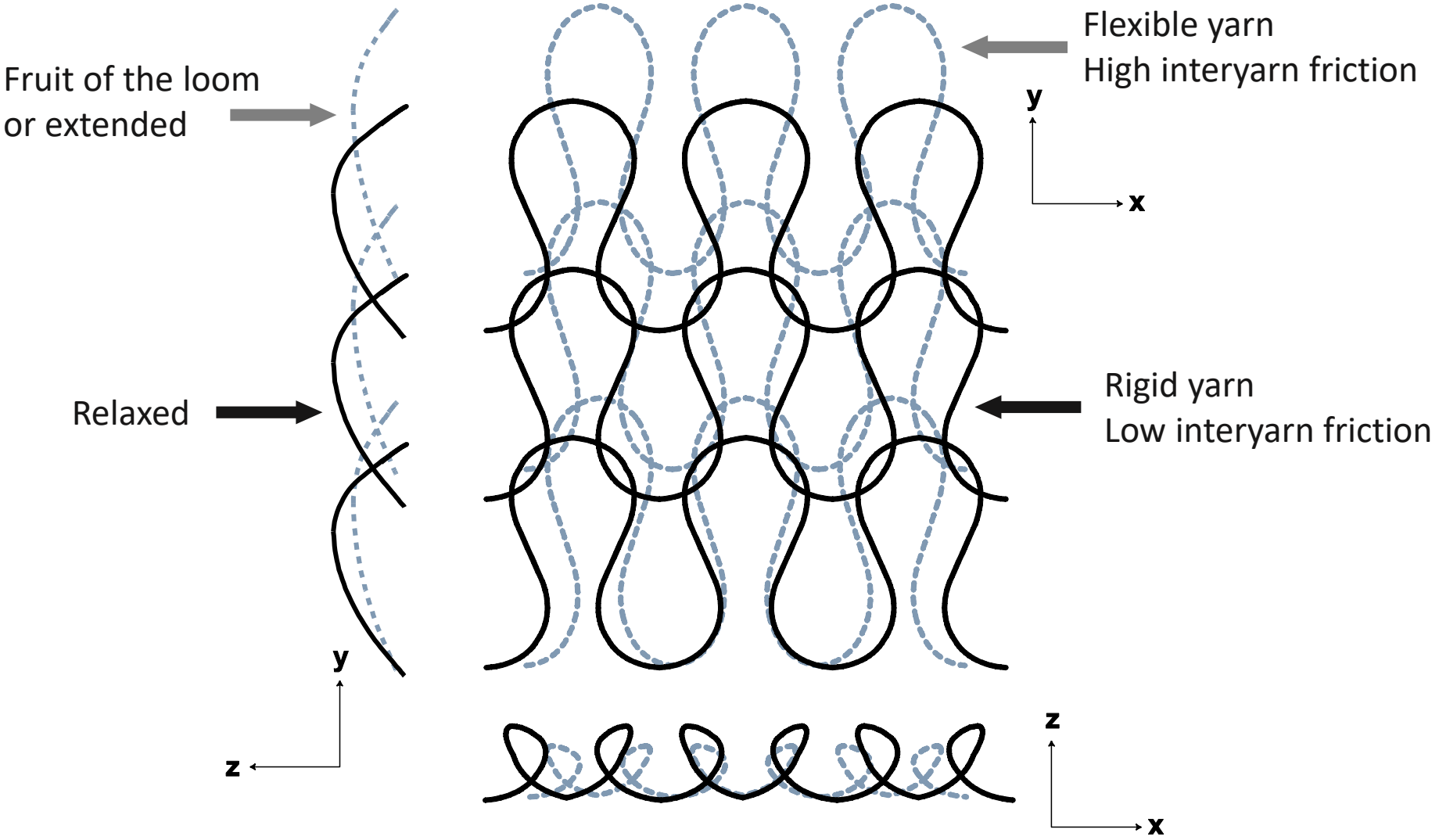


Competition:

- Yarn rigidity
- Interyarn friction

Bueno MA, Renner M, Nicoletti N., Text Res J., 2004.

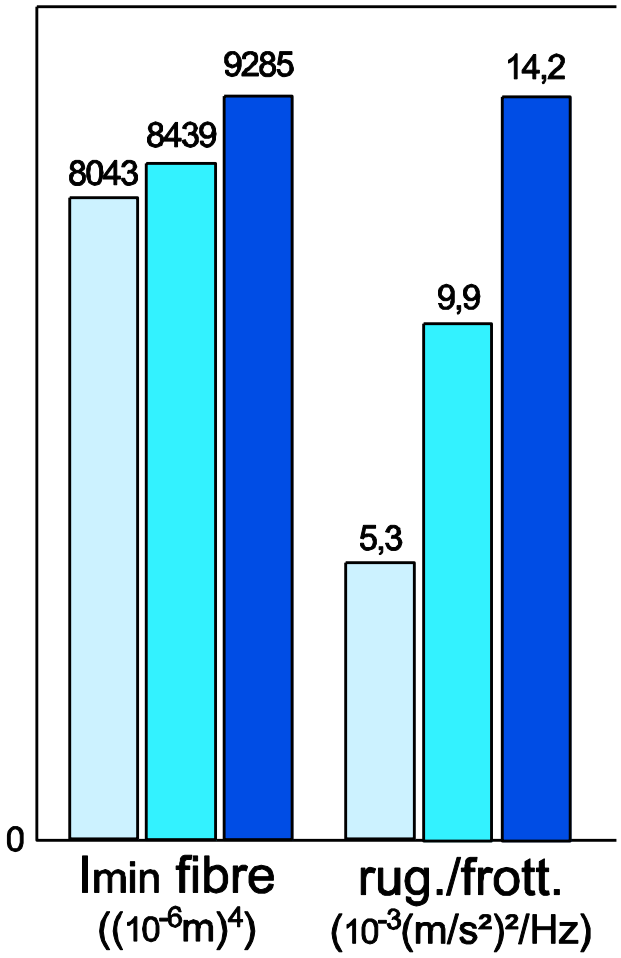
Yarn properties influence on relaxed state



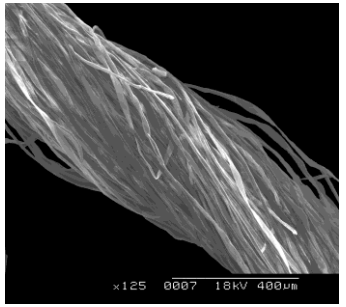
Bueno MA, Renner M, Nicoletti N., Text Res J., 2004.

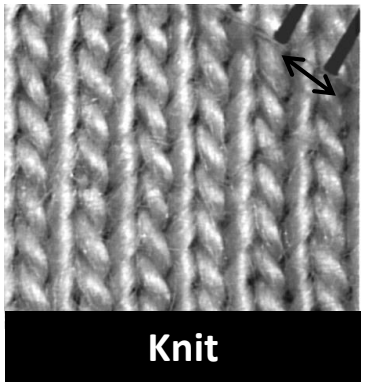
Fibre influence on relaxed state

Bending rigidity $B = E.I$



Yarn

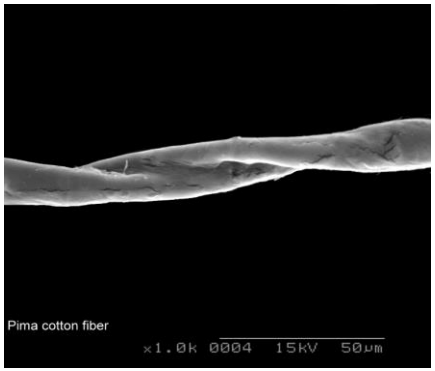




Bueno M-A, Aneja AP, Renner M., Journal of Materials Science. 2004.

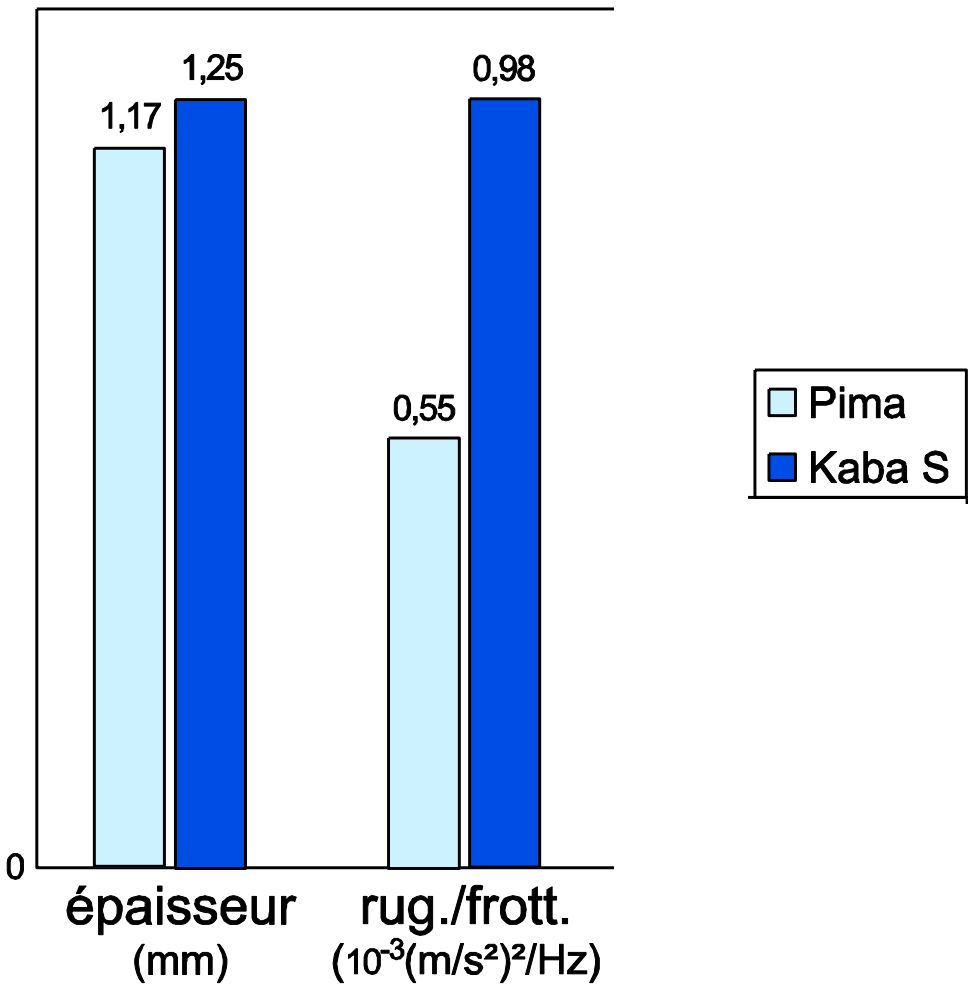
Fibre influence on relaxed state

Bending rigidity $B = E.I$



Kaba S fibre coarser than

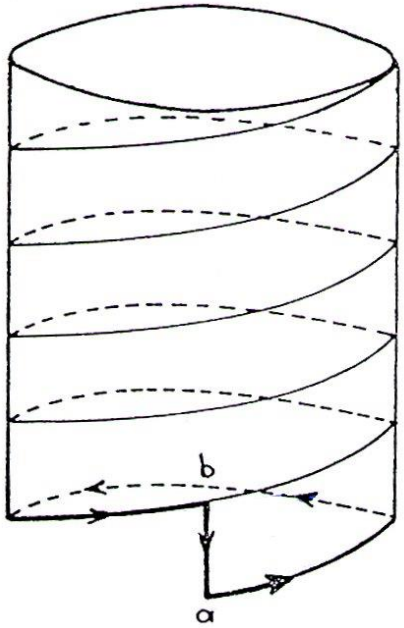
Pima cotton fibre



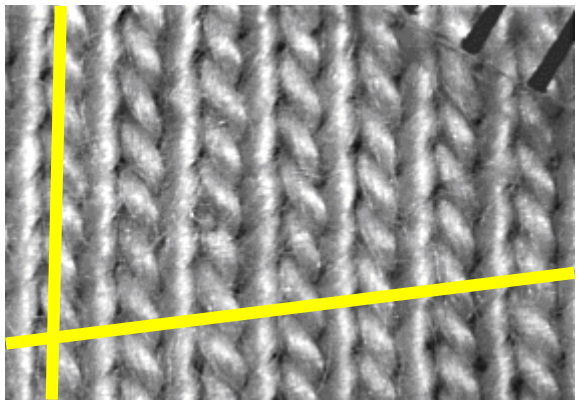
Bueno M-A, Renner M, Pac M-J., Journal of Materials Science. 2002.

Spirality and inclination

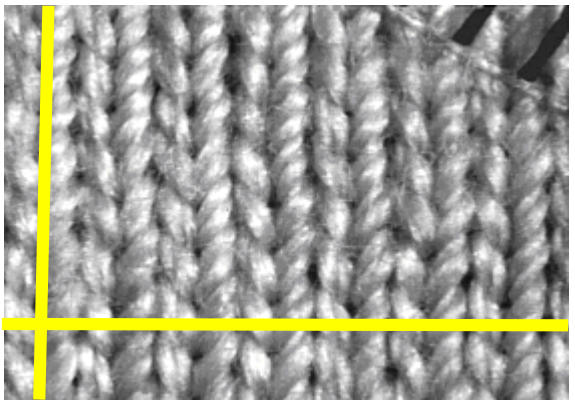
With circular knitting machine



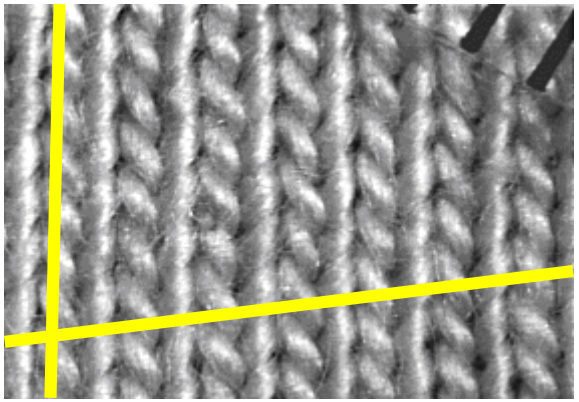
Courses are not perpendicular to wales



?



Spirality and inclination



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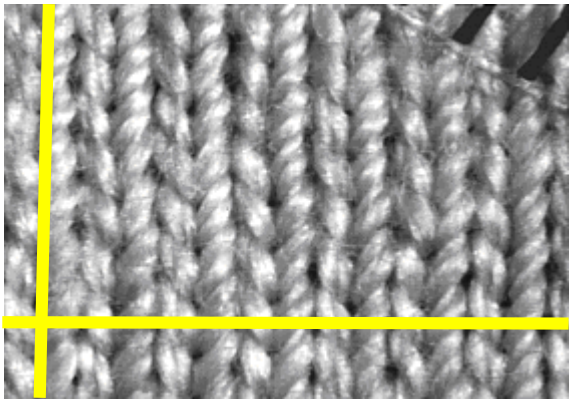
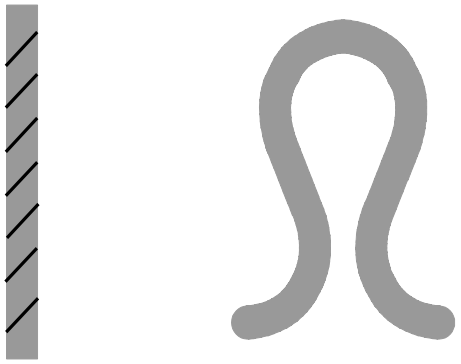


- Stitch 3D shape
- Yarn moment of torsion

Z-twist yarn

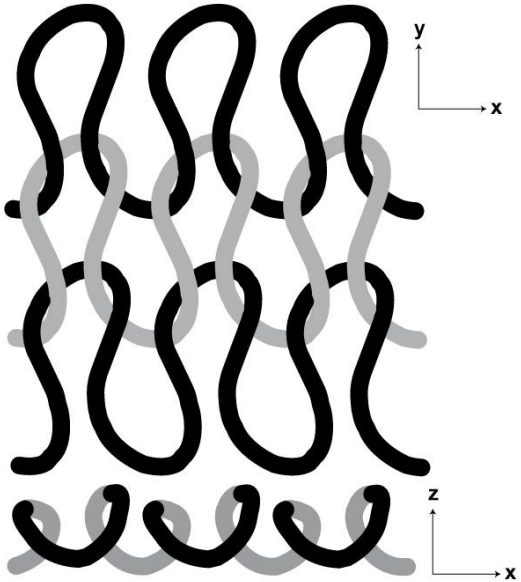


+ ¼ to ½ turn

- ¼ to ½ turn

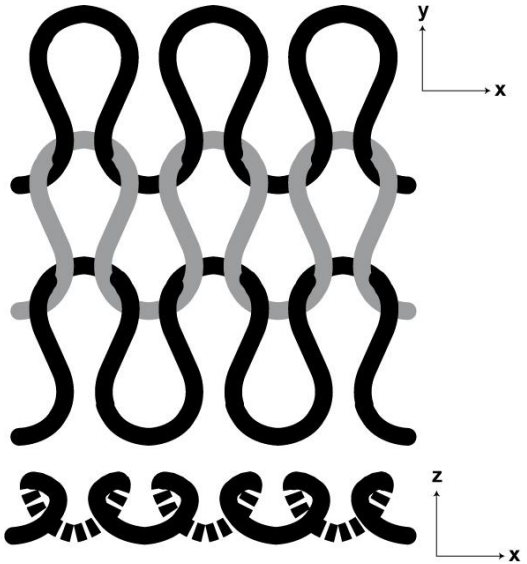
Doyle PJ., Journal of the Textile Institute Proceedings. 1952.
Leaf GAV., Journal of the Textile Institute Transactions. 1960.
Postle R, Munden DL., J Text I., 1967.

Spirality and inclination

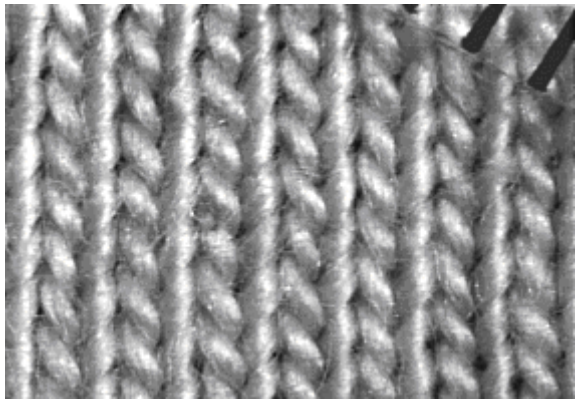


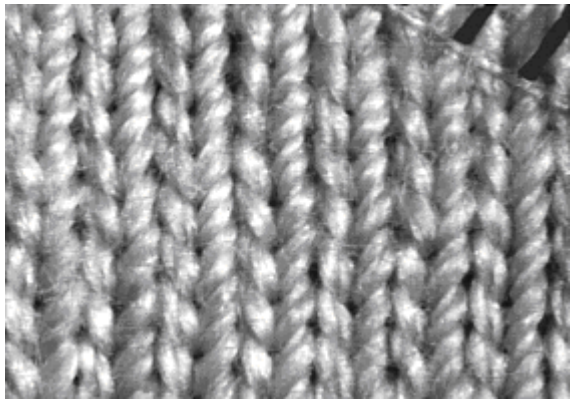
Unbalanced yarn

No quater-loop symmetry



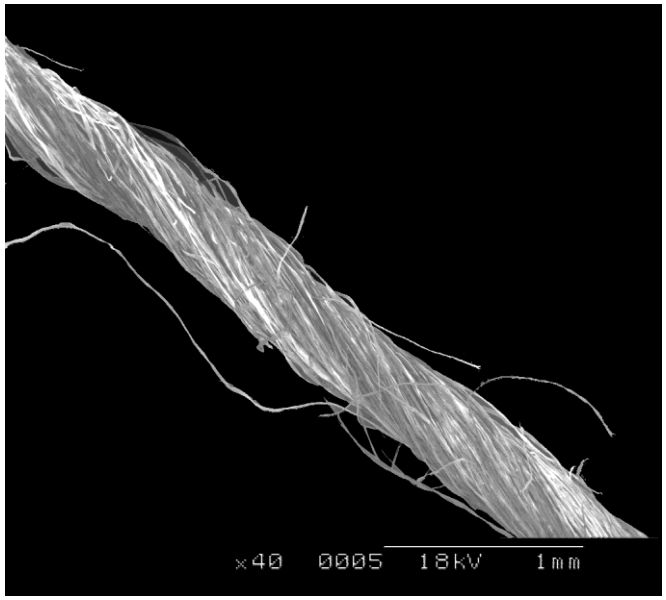
Balanced yarn



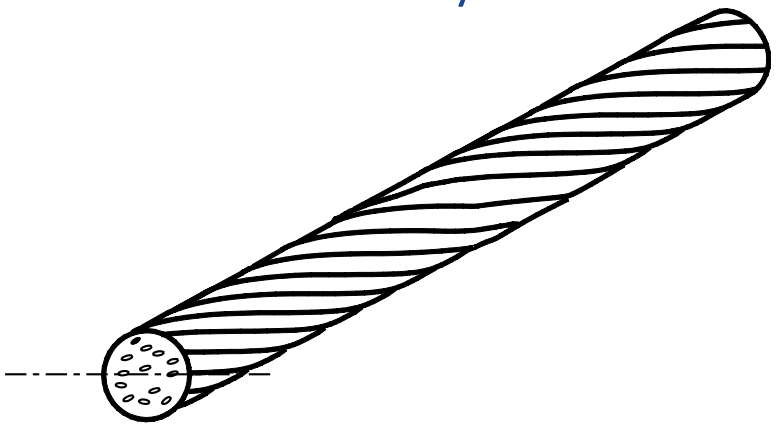


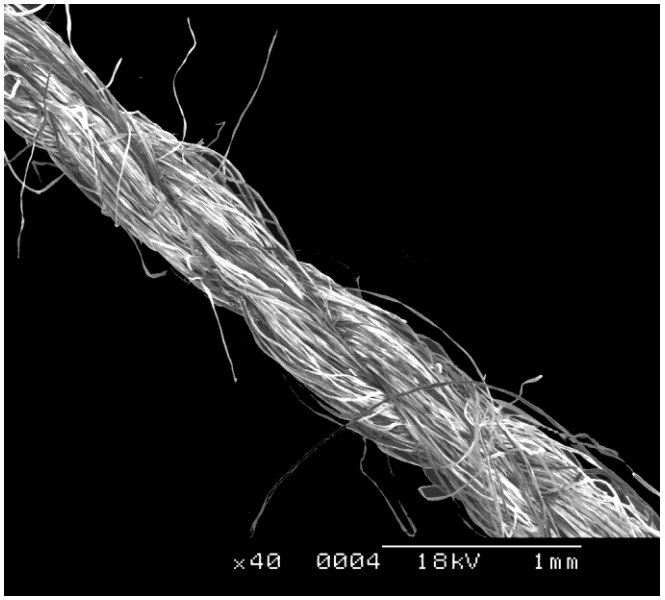
Bueno M-A, Renner M, Pac M-J., Journal of Materials Science. 2002.

Spirality and inclination

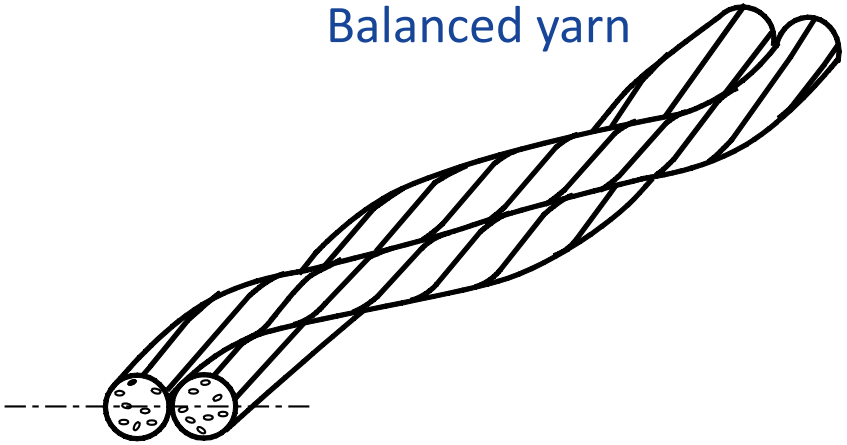


Unbalanced yarn



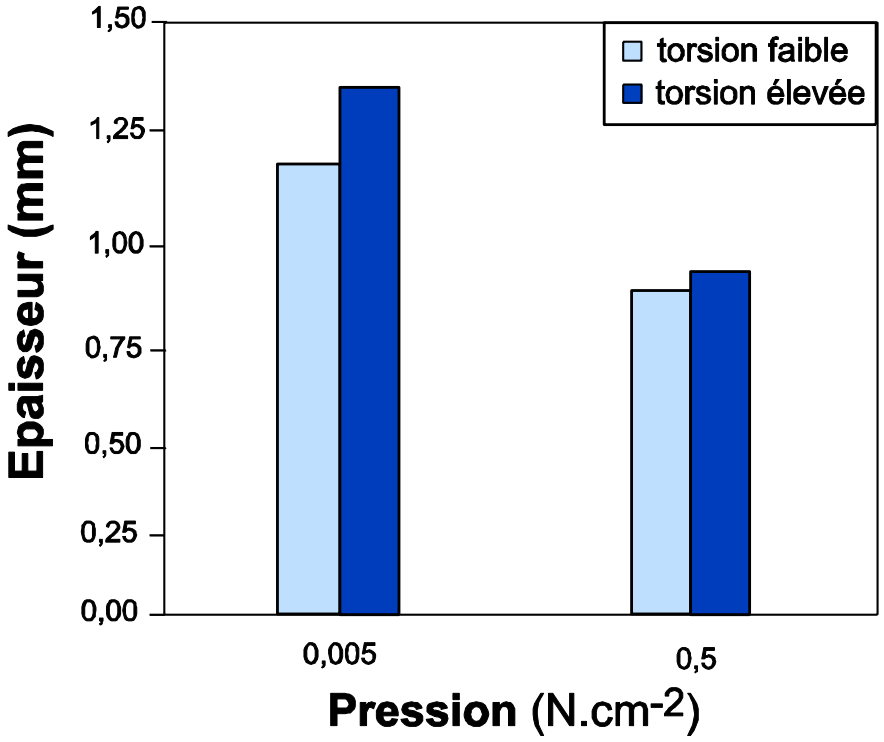


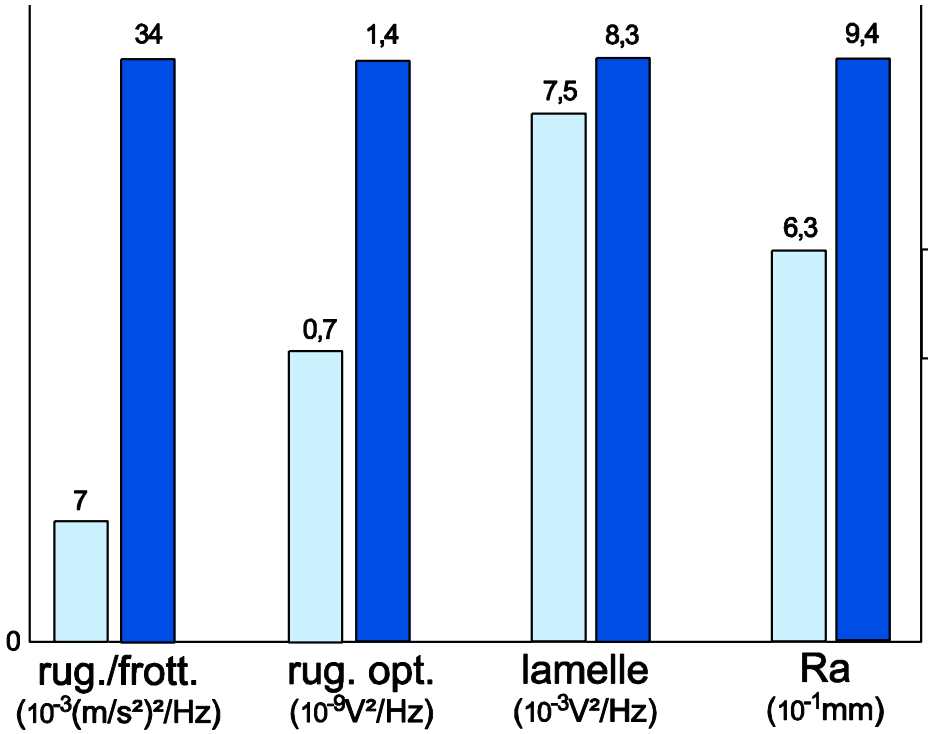
Balanced yarn



Bueno M-A, Renner M, Pac M-J., Journal of Materials Science. 2002.

Spirality and inclination



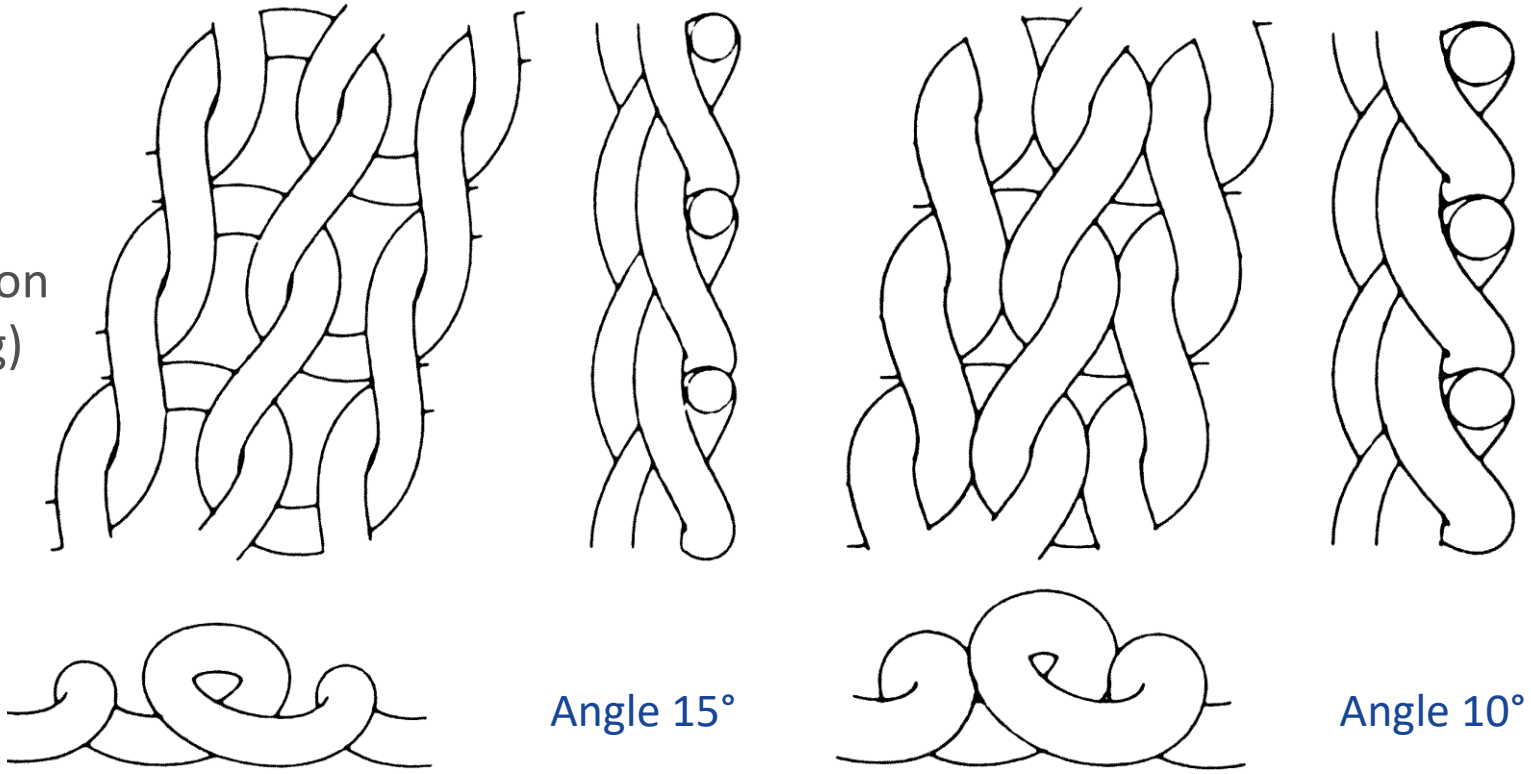


Pensé-Lhéritier A-M, Guilabert C, Bueno M-A, Sahnoun M, Renner M., Food Qual Prefer., 2006.

Spirality and inclination

From [1]

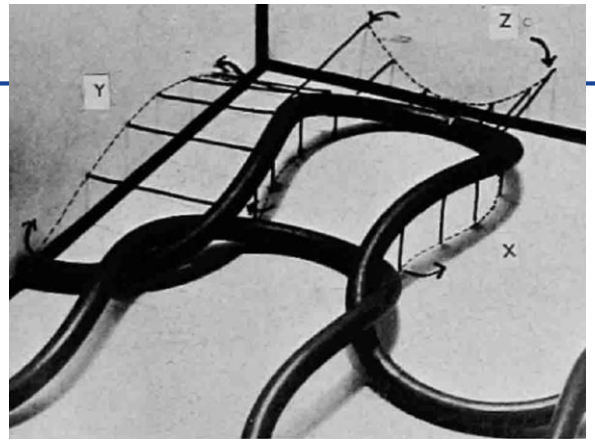
Yarn compression (jamming)



- Increase with yarn twist factor
- Increase when cover factor decrease.

1. Hepworth B., Melliand Textilberichte. 1993.
2. Tao J, Dhingra RC, Chan CK, Abbas MS. Text Res J. 1997.
3. Carnaby GA. Spirality The Journal of The Textile Institute. 1973
4. Prementas., Indian J Fibre Text. 2003.

To summerize



Mechanical conditions:

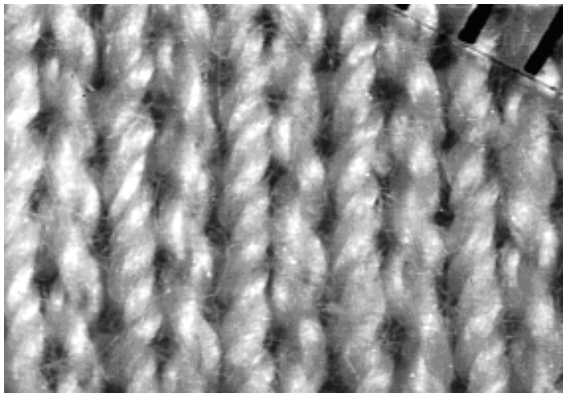
large displacements + friction

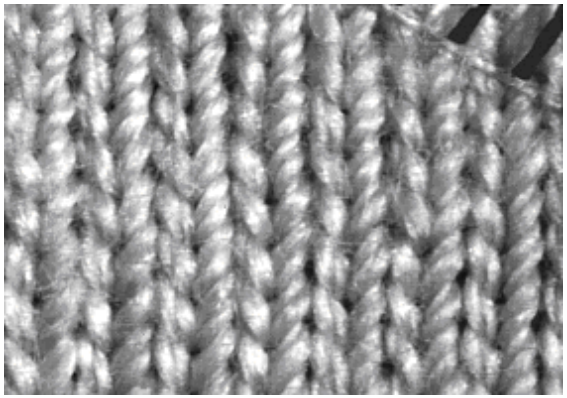
The most important experimental features necessary for predicting geometry and mechanical behaviour are:

Feature	Easy or difficult to obtain
Stitch length	+
Interyarn friction	-
Yarn bending rigidity	--
Cover factor → yarn diameter	--

To summarize

Same yarn different cover factor





yarn mass per unit length

$$d = \sqrt{\frac{4 \cdot t_y}{\pi \cdot \rho_f \cdot \phi \cdot 10^5}}$$

fibre density

yarn porosity

R. Postle, G.A. Carnaby and S. de Jong:

→ Yarn compression index

R. Postle, G.A. Carnaby and S. de Jong , The Mechanics of Wool Structures, Ellis Horwood, Chichester U.K., 1987

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