

Twisting Only Tilts the Fibres Away from the Load, Yet a Yarn with No Twist Has Zero Strength

— with the tilt term alone the strength falls monotonically and the maximum sits at **0** degrees — but the model peaks at **34.55** degrees with **0.381464** and gives exactly **0.000000** at **0** degrees — what rises is not the tilt but the grip between fibres — [Paper 385]

Yuuki YAMAGISHI (山岸 勇輝)
Yamagishi Complexity Torus Lab, Japan
September 2026

— *From thinking to syncing.* —

Abstract

Twisting a yarn tilts its fibres away from the load direction. A tilt reduces the resolved component, so twist ought to lower the strength—and yet a yarn with no twist has almost no strength at all. No new theorem or law is claimed. First, with the tilt term $\cos^2 \alpha$ alone the strength is maximal at 0 degrees and falls monotonically (Section 2). Second, adding the grip term $1 - e^{-k \tan \alpha}$ makes the strength at 0 degrees exactly **0.000000** (Section 2). Third, and this is the core of the paper. The maximum stands at **34.55** degrees with the value **0.381464**: a product of two monotone factors has an interior maximum (Section 3). Fourth, even at 60 degrees the strength is still **0.5734** of the maximum and does not fall below half (Section 3). Fifth, remove the grip term and the maximum disappears, returning to 0 degrees. What rises is not the tilt (Section 4). Sixth, the separator is “are the fibres continuous or of finite length” (Section 5).

Scope of this paper (scope note): No new theorem or law is claimed—the twist-angle–strength relation, the gripping length and the $\cos^2$ rule are all known in fibre science. No yarn is designed—no optimal twist count or yarn number is given. Only the mechanism by which a maximum stands at an interior point is examined, in one model. No measured value is claimed—34.55 degrees is the value of this model, not the optimal twist angle of cotton yarn itself. Only the sameness of shape is asserted. No theory of friction is built—the inter-fibre friction coefficient and the distribution of lateral pressure are not entered. Failure is not treated—whether fibres slip out or break first is not the subject. Ropes are not treated—the construction and layering of twisted rope are not the subject. Relation to earlier papers: Paper 357 showed that maximum power and maximum efficiency are different points—here two monotone factors make one interior point. Paper 363 showed that the sweet spot is three points—here the maximum is a single point. Paper 300 showed that same-root and different-root can be decided—tilt and grip are different-root by that criterion. Paper 367 showed that pushing the sensitivity down pushes it up elsewhere—here twist lowers one thing and raises another. What is added is putting a number on the strength at ten twist angles, locating the maximum at 34.55 degrees with the value 0.381464, showing that 0 degrees gives exactly 0.000000, confirming that removing the grip term destroys the maximum, and placing the separator at “continuous or finite-length fibres”.

1. Notation and the Question

Setting: write the strength of a yarn of twist angle α in the following dimensionless model.

$$S(\alpha) = \underbrace{\cos^2 \alpha}_{\text{tilt}} \times \underbrace{(1 - e^{-k \tan \alpha})}_{\text{grip}}, \quad k = 1.2$$

The first factor is the projection onto the load direction together with the strain correction; the second is the fraction of fibres that can take up force without slipping out.

Observation 1.1

the first factor decreases monotonically in α . One at 0 degrees, zero at 90—on this factor alone, no twist is strongest.

Observation 1.2

the second factor increases monotonically in α . Zero at 0 degrees, approaching one at large angles—without twist the fibres do not grip one another.

Observation 1.3

both are monotone. Not one factor has a maximum—and yet the product has an interior maximum.

Question: if twist only tilts the fibres, why is an untwisted yarn weak?

2. The Strength at Zero Degrees Is Exactly Zero

Computation 2.1: strength $S(\alpha)$ against twist angle (computed in this paper).

Twist angle [deg]	Tilt $\cos^2 \alpha$	Strength S
0	1.000000	0.000000
5	0.992404	0.098906
10	0.969846	0.184955
15	0.933013	0.256548
20	0.883022	0.312481
25	0.821394	0.352004
30	0.750000	0.374877
40	0.586824	0.372432
50	0.413176	0.314310
60	0.250000	0.218719

Observation 2.2

the first row reads 1.000000 and 0.000000 side by side. The tilt term is at its maximum and the strength is zero—the fibres point exactly along the load and not one of them takes up any force.

Observation 2.3

the middle column falls monotonically.From 1.000000 down to 0.250000——on the tilt term alone, more twist is always worse.

Observation 2.4

the right column rises and then falls.It turns between 0.374877 at 30 degrees and 0.372432 at 40——the product of two monotone factors is not monotone.

Observation 2.5

even at 5 degrees there is only 0.098906.The tilt term is 0.992404, almost untouched——the missing 90 per cent is not the fault of the tilt.

3. The Maximum Stands at 34.55 Degrees and Sixty Degrees Stays Above Half

Computation 3.1: position and value of the maximum (computed in this paper).

Quantity	Value
Twist angle of the maximum	34.55 deg
Maximum strength	0.381464
Strength at 60 deg / maximum	0.5734
Strength at 0 deg / maximum	0.000000

Observation 3.2

this is the core of the paper.The maximum stands not at an endpoint but at an interior point——though both factors are monotone, the product peaks at 34.55 degrees with 0.381464.

Observation 3.3

the maximum is flat.0.374877 at 30 degrees, 0.372432 at 40——98.3 and 97.6 per cent of the maximum, nearly the same over a 10-degree span.

Observation 3.4

even at 60 degrees there is still 0.5734 of the maximum.Although the tilt term has fallen to 0.250000——the grip term is nearly one, so the descent is gentle.

Observation 3.5

the two sides are not symmetric.A cliff on the 0-degree side, a slope on the 60-degree side——too little twist is far more dangerous than too much.

Observation 3.6

the optimal twist angle of real cotton yarn is also placed near 30 degrees.An independently known range ——the model’s 34.55 degrees does not fall outside it. This paper does not claim agreement, only sameness of shape.

4. What Rises Is Not the Tilt

Computation 4.1: with the grip term removed (computed in this paper).

Twist angle [deg]	With grip	Without grip ($\cos^2 \alpha$ only)
0	0.000000	1.000000
34.55	0.381464	0.678
60	0.218719	0.250000
Position of the maximum	34.55 deg	0 deg

Observation 4.2

remove the grip and the maximum jumps from 34.55 degrees to 0. The interior maximum disappears——what makes the maximum is the grip term, not the tilt term.

Observation 4.3

the tilt term contributes nothing to the position of the maximum. It sets only the rate of decline——“twist tilts the fibres and weakens them” cannot explain the rising side.

Observation 4.4

the shape is that of Paper 357. There power and efficiency peaked at different points——here two monotone factors make one interior point. In both, the maximum comes from a property of the product rather than from a “compromise”.

Observation 4.5

the reason zero degrees gives zero is friction. Without twist there is no lateral pressure between fibres——without lateral pressure there is no friction, and without friction a finite-length fibre pulls out.

5. Separator: Are the Fibres Continuous or of Finite Length

Observation 5.1

separator——does a fibre run from one end of the yarn to the other, or does it stop partway.

Fibre	Grip term	Optimal twist angle
Finite length (cotton, wool)	needed	interior (34.55 deg)
Continuous (silk, synthetic filament)	not needed	0 deg

Observation 5.2

this separator can be tested. Continuous-filament yarns carry almost no twist—and that is in fact the case.

Observation 5.3

the same material moves its optimum when it is cut. Chop a synthetic filament short and spin it, and twist becomes necessary—what changed is not the material but the length.

Observation 5.4

they are different-root by the criterion of Paper 300. Tilt is set by geometry, grip by friction and fibre length—a single variable, the twist angle, moves two different-root quantities at once.

Observation 5.5

to be honest— $k = 1.2$ is a constant of the model, not a measurement. The position of the maximum moves with k —what does not move is that 0 degrees gives exactly zero, and that removing the grip sends the maximum to an endpoint.

Observation 5.6

one last thing—it is not obvious that a product of two monotone factors should fail to be monotone. It is precisely because one of them is exactly zero at 0 degrees that an interior maximum stands—if the grip term retained even 0.1 at 0 degrees, the maximum would sit closer to the endpoint.

6. Roll Call and Closing

1. Strength at 0 degrees is 0.000000 (Computation 2.1): **though the tilt is maximal.**
2. The tilt term falls monotonically (Observation 2.3): **1.000000 to 0.250000.**
3. The strength turns between 30 and 40 degrees (Observation 2.4): **0.374877 and 0.372432.**
4. The maximum is 34.55 degrees, 0.381464 (Computation 3.1): **interior.**

5. The maximum is flat (Observation 3.3): **above 97.6 per cent over 10 degrees.**
6. **0.5734 of the maximum at 60 degrees** (Computation 3.1): **above half.**
7. The sides are asymmetric (Observation 3.5): **too little twist is the danger.**
8. Remove the grip and the maximum jumps to 0 degrees (Observation 4.2): **the grip makes the maximum.**
9. The separator is fibre length (Observation 5.1): **filament yarns are not twisted.**
10. **k is a model constant** (Observation 5.5): **the position moves; the zero and the jump do not.**

Closing: twisting a yarn tilts its fibres away from the load direction, and a tilt reduces the resolved component——so twist ought to lower the strength. And indeed the tilt term $\cos^2 \alpha$ falls monotonically——from 1.000000 at 0 degrees to 0.250000 at 60, without exception, so on this factor alone no twist is strongest and the maximum stands at the endpoint 0 degrees. Yet the strength of an untwisted yarn is exactly zero——in the model

$S(\alpha) = \cos^2 \alpha (1 - e^{-1.2 \tan \alpha})$ it is **0.000000** at 0 degrees. The tilt term is at its maximum of 1.000000, and not one fibre takes up any force. Even at 5 degrees there is only 0.098906, while the tilt term is 0.992404 and almost untouched, so the missing 90 per cent is not the fault of the tilt. The maximum stands at an interior point——**0.381464 at 34.55 degrees**. Both factors are monotone and the product is not. It is a flat peak, holding above 97.6 per cent of the maximum across a 10-degree span (0.374877 at 30 degrees, 0.372432 at 40), and at 60 degrees there is still **0.5734** of the maximum, above half. The sides are asymmetric——a cliff at 0 degrees, a slope at 60——so too little twist is far more dangerous than too much. What rises is not the tilt——remove the grip term and the maximum jumps from 34.55 degrees to 0, and the interior maximum disappears. The tilt term contributes nothing to the position of the maximum; it sets only the rate of decline. “Twist tilts the fibres and weakens them” cannot explain the rising side. One thing does the separating——does a fibre run from one end of the yarn to the other, or does it stop partway. For finite-length fibres (cotton, wool) the grip term is needed and the optimum stands at an interior point; for continuous filaments (silk, synthetic filament) it is not, and 0 degrees will do. Filament yarns do in fact carry almost no twist, and the same synthetic fibre, chopped short and spun, comes to require twist——what changed is not the material but the length. They are different-root by the criterion of Paper 300: tilt is set by geometry, grip by friction and fibre length. To be honest—— $k = 1.2$ is a constant of the model rather than a measurement, and the position of the maximum moves with k . What does not move is that 0 degrees gives exactly zero, and that removing the grip sends the maximum to an endpoint. One last thing——it is not obvious that a product of two monotone factors should fail to be monotone. It is precisely because one of them is exactly zero at 0 degrees that an interior maximum stands. If the grip term retained even 0.1 at 0 degrees, the maximum would sit closer to the endpoint.

References

-
1. Hearle, J. W. S., Grosberg, P., Backer, S. (1969). *Structural Mechanics of Fibers, Yarns, and Fabrics*. New York: Wiley-Interscience.

2. Gegauff, C. (1907). Force et élasticité des filés en coton. *Bulletin de la Société Industrielle de Mulhouse*.
3. Pan, N. (1992). Development of a constitutive theory for short-fiber yarns. *Textile Research Journal*.
4. Morton, W. E., Hearle, J. W. S. (2008). *Physical Properties of Textile Fibres* (4th ed.). Cambridge: Woodhead.
5. Yamagishi, Y. (2026). *The Three Hundredth Census: Whether Two Things Share a Root Is Decidable* [Paper 300]. Zenodo. 10.5281/zenodo.22171914
6. Yamagishi, Y. (2026). *Maximum Power and Maximum Efficiency Are Not the Same Point* [Paper 357]. Zenodo. 10.5281/zenodo.22697180
7. Yamagishi, Y. (2026). *A Bat Has Three Sweet Spots, and They Lie **23** cm Apart* [Paper 363]. Zenodo. 10.5281/zenodo.22697505
8. Yamagishi, Y. (2026). *Push the Sensitivity Down Somewhere and It Must Rise Somewhere Else* [Paper 367]. Zenodo. 10.5281/zenodo.22697709

— *From thinking to syncing.* —

Yuuki YAMAGISHI (山岸 勇輝)

© 2026 Yamagishi Complexity Torus Lab, Japan · Licensed under Creative Commons Attribution 4.0 International (CC BY 4.0)