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MECHANICS

Spinning a strong yarn

A ball of yarn is a continuous length of a few hundred metres, but is made up of fibres that are no more than centimetres long — so how does the yarn hold together and transmit forces over its length? This question has been asked since at least the time of Galileo and the short answer is friction, but a full mathematical model is lacking. In a paper to appear in *Physical Review Letters*, Antoine Seguin and Jérôme Crassous report experiments and calculations that show how twisting yarn strengthens it, in a way that can be captured by a single dimensionless number.

For their experiments, Seguin and Crassous made simplified yarns by interleaving two bundles of threads, which they then twisted together. To test the strength of the yarns, they pulled them apart. Yarns that were twisted only a few full revolutions came apart with relatively little applied force, by the threads sliding away from each other. However, the force required to separate the threads increased exponentially if the number of revolutions was increased, and for nine or more revolutions the yarns failed by individual threads snapping rather than sliding apart.

Credit: GK Hart/Vikki Hart/Stone

The maximum force values for a variety of experimental yarns, along with simulations, were all given by an exponential function of a dimensionless number that involves the twist, friction coefficient and length and radius of the threads. Seguin and Crassous used a mathematical model of yarn to explain the origin of this dimensionless number in terms of force balance along the threads. They also extended the calculation to staple yarns, which are yarns made of short fibres that are oriented randomly, rather than neatly twisted.

Although twisting a yarn prevents its fibres from sliding apart, it also puts strain on the individual fibres. For a given twist, the strain is larger for thicker fibres, so from their calculations, Seguin and Crassous could determine an optimal geometry for a yarn, in terms of twist and fibre thickness. The optimal geometry agreed with measured values on a commercial yarn.

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ORIGINAL ARTICLE Seguin, A. & Crassous, J. Twist-controlled force amplification and spinning tension transition in yarn. *Phys. Rev. Lett.* (in the press)
RELATED ARTICLES Seguin, A. & Crassous, J. "Twist-Controlled" force amplification & spinning tension transition in yarn. Preprint at https://arxiv.org/abs/2110.04206 (2021)