20th European Mechanics of Materials Conference - EMMC20
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

Kirchhoff Knots: a new analytical model for loose and semi-tight regimes

Florence Bertails-Descoubes[1], Thibaut Métivet[2], Sébastien Neukirch[3], Victor Romero[4]

[1] Univ. Grenoble-Alpes, INRIA, CNRS, Grenoble INP, LJK, 38000 Grenoble, France, France.
florence.descoubes@inria.fr
[2] Univ. Grenoble-Alpes, INRIA, CNRS, Grenoble INP, LJK, 38000 Grenoble, France, France.
Thibaut.metivet@inria.fr
[3] Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, F-75005 Paris, France, France.
sebastien.neukirch@cnrs.fr
[4] Univ. Grenoble-Alpes, INRIA, CNRS, Grenoble INP, LJK, 38000 Grenoble, France, France. victor.romero-gramegna@inria.fr

Paper ID: 288
Symposium S7: Mechanics of soft materials and structures

Abstract

We revisit existing models of elastic trefoil knots based on the Kirchhoff theory for thin elastic rods. We substantially improve the accuracy of previous analytical models by accounting for higher order terms. In addition, we analyse the transition from loose to semi-tight knots, which reveals a dependency upon the thickness of the rod, and show that this transition to a semi-tight knot can be properly covered by simply considering extensibility in the tails of the open trefoil knot. By comparing our results to fully 3D simulations, we show that our improved analytical model for Kirchhoff knots remains valid for a large range of parameters, from extremely loose to moderately tight knots. Finally, we carefully confront various 1D rod simulators of the literature (based on the Reissner, or extensible/inextensible Kirchhoff models) against our theory, and provide key invariant quantities to refine the analysis. Overall, our model can serve to verify accurately experimental and numerical results of knots produced in a wide tying range.

Keywords:

Kirchhoff thin elastic rods Trefoil knots Contact