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Citation: Bigoni, Davide, Kirillov, Oleg, Misseroni, Diego, Noselli, Giovanni and Tommasini, Mirko (2016) Flutter and dissipation instabilities in structures subject to friction follower forces. In: 24th International Congress of Theoretical and Applied Mechanics (ICTAM2016), 21st-26th August 2016, Montreal, Canada.

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## FLUTTER AND DISSIPATION INSTABILITIES IN STRUCTURES SUBJECT TO FRICTION FOLLOWER FORCES

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**Summary** Flutter and divergence instabilities are theoretically and experimentally analyzed in elastic structures with internal and external damping. Despite of the fact that only the former (and not the latter) was believed to be a destabilizing effect, it is theoretically demonstrated that the external damping plays a role similar to internal damping, so that both yield a pronounced destabilization paradox (in the Ziegler sense). This finding and other features of the Beck and Pflueger columns are substantiated by an experimental campaign in which the follower forces are obtained via dry friction with a newly designed experimental apparatus.

### INTRODUCTION

Flutter and divergence instabilities may occur in elastic structures subject to tangential follower loads and well-known examples are the Ziegler double pendulum and the Beck and Pflueger columns [1, 2]. A key point in these mechanical frameworks is the realization of the follower force, which has been long debated and often considered of impossible practical realization, as discussed in detail by Elishakoff [3].

The controversy about the realization of the force was definitively solved by Bigoni and Noselli [4], who showed how to realize a follower tangential force in the Ziegler pendulum via Coulomb friction. Their idea, sketched in Fig. 1, was to provide the follower force through a wheel of negligible mass mounted at the end of the Ziegler double pendulum and constrained to slide against a frictional plane.

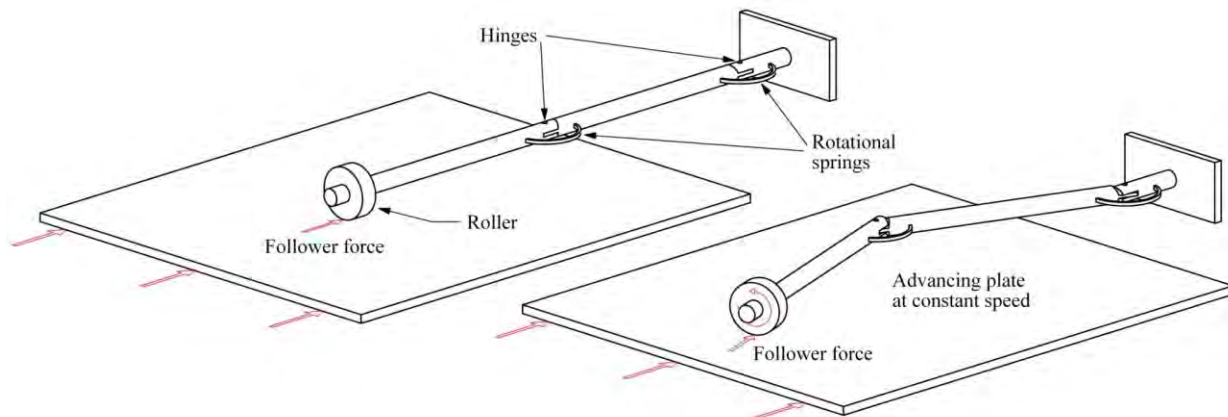


Fig. 1 Sketch of the experimental setup to realize a follower tangential force in the Ziegler double pendulum (figure adapted from [4])

### THE EXPERIMENTAL REALIZATION OF THE BECK'S COLUMN

The experimental realization by Bigoni and Noselli was found unsuitable for the analysis of the Beck and the Pflueger columns, because if the ellipse of inertia of the cross-section of the rod to be tested is elongated, lateral torsional buckling occurs and if the ellipse of inertia of the cross-section of the rod is a circle, flexure involves large deformation, too large to produce the force necessary to flutter. Therefore, a new apparatus has been designed, following the scheme reported in Fig. 2 and realized.

The new experimental setup allows the first realization of follower tangential forces on elastic structures and allows a systematic investigation of flutter, divergence, and dissipation-induced instabilities. In these experiments, internal and external damping play a chief role, so that the effects associated to these two types of damping have been thoroughly

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investigated. From theoretical point of view it is shown that external damping plays a destabilizing role qualitatively similar to internal damping [5], a feature previously not believed, and which is now also experimentally confirmed.

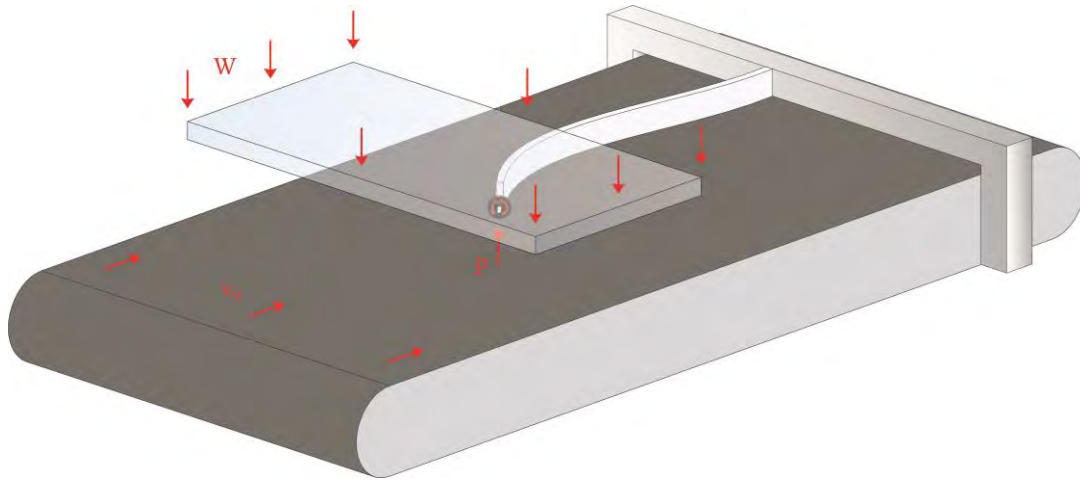


Fig. 2 Sketch of the experimental setup to realize a follower tangential force in the Beck's column

The experimental realization of the follower force also permits the investigation of the so-called „Ziegler destabilization paradox“, where the critical force for flutter instability decreases by an order of magnitude when the coefficient of internal damping becomes infinitesimally small. This instability is important since it represents an example of dissipation-induced instability (in the sense explained in [6]) and the experimental setup allows for the first systematic investigation of this instability.

## CONCLUSIONS

A theoretical framework and an experimental setup have been proposed for the investigation of flutter and divergence instabilities in elastic continuous structures, in the presence of internal and external damping. Results confirm theoretical results that were demonstrated a long time ago, but never experimentally verified and pave the way to the realization of self-oscillating mechanisms of completely new design.

## ACKNOWLEDGEMENT

The authors gratefully acknowledge financial support from the ERC Advanced Grant „Instabilities and nonlocal multiscale modelling of materials“ FP7-PEOPLE-IDEAS-ERC-2013-AdG (2014-2019).

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