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SCHOOL OF AERONAUTICS AND ASTRONAUTICS
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The Midwest Mechanics Seminar

presents

Instabilities in solids and structures: shear bands and flutter

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Abstract

When a ductile material is subject to severe strain, failure is preluded by the emergence of shear bands, which initially nucleate in a small area, but quickly extend rectilinearly and accumulate damage, until they degenerate into fractures. Therefore, research on shear bands yields a fundamental understanding of the intimate rules of failure, so that it may be important in the design of new materials with superior mechanical performances.

A shear band of finite length, formed inside a ductile material at a certain stage of a continued homogeneous strain, provides a dynamic perturbation to an incident wave field, which strongly influences the dynamics of the material and affects its path to failure. The investigation of this perturbation is presented for a ductile metal, with reference to the incremental mechanics of a material obeying the J2–deformation theory of plasticity. The treatment originates from the derivation of integral representations relating the incremental mechanical fields at every point of the medium to the incremental displacement jump across the shear band faces, generated by an impinging wave. The boundary integral equations are numerically approached through a collocation technique, which keeps into account the singularity at the shear band tips and permits the analysis of an incident wave impinging a shear band. It is shown that the presence of the shear band induces a resonance, visible in the incremental displacement field and in the stress intensity factor at the shear band tips, which promotes shear band growth. Moreover, the waves scattered by the shear band are shown to generate a fine texture of vibrations, parallel to the shear band line and propagating at a long distance from it, but leaving a sort of conical shadow zone, which emanates from the tips of the shear band [1,2].

Flutter instability of an elastic rod subject to a follower force at one end is an example of Hopf bifurcation. This is characterized by the so-called ‘Ziegler paradox’, related to a decrease in the critical load, as connected to an increase in the viscous dissipation of the system. A new experimental apparatus is presented through which the first experimental validation of the detrimental effect of the viscous dissipation on the critical load is provided [3].

References

[1] Giarola, D., Capuani, D. Bigoni, D. (2018) The dynamics of a shear band. J. Mech. Phys. Solids, 112, 472-490.

[2] Giarola, D., Capuani, D. Bigoni, D. (2018) Dynamic interaction of multiple shear bands. Scientific Reports.

[3] Bigoni, D., Kirillov, O., Misseroni, D., Noselli, G.Tommasini, M. (2018) Flutter and divergence instability in the Pflüger column: Experimental evidence of the Ziegler destabilization paradox. J. Mech. Phys. Solids 116, 99-116.

Bio

Davide Bigoni is a mechanician working in solid and structural mechanics and material modeling, wave propagation, fracture mechanics. His approach to research is the employment of a broad vision of mechanics, with a combination of mathematical modelling, numerical simulation, and experimental validation. From 2001 Davide Bigoni holds a professor position at the University of Trento, where he is leading a group of excellent researchers in the field of Solid and Structural Mechanics. He has authored or co-authored more than 100 journal papers and has published a book on nonlinear Solid Mechanics. He was elected in 2009 Euromech Fellow (of the European Mechanics Society), has received in 2012 the Ceramic Technology Transfer Day Award (of the ACIMAC and ISTEC-CNR), in 2014 the Doctor Honoris Causa degree at the Ovidius University of Constanta and in 2016 the Panetti and Ferrari Award for Applied Mechanics (from Accademia delle Scienze di Torino). He has been awarded an ERC advanced grant in 2013. He is co-editor of the Journal of Mechanics of Materials and Structures and associate Editor of Mechanics Research Communications and in the editorial board of 8 international journals.