Mechanisms of long-wave instabilities in shear-thinning films on porous substrates

Severine Millet*,#, R. Usha†, Valery Botton# and François Rousset‡

Laboratoire de Mécanique des Fluides et d'Acoustique (LMFA)
Université de Lyon, Université Lyon 1, INSA-Lyon, Ecole centrale de Lyon, UMR CNRS 5509
69621 Lyon, FRANCE
e-mail: severine.millet@univ-lyon1.fr, valery.botton@insa-lyon.fr - web page: http://lmfa.ec-lyon.fr/

† Department of Mathematics, Indian Institute of Technology Madras,
Chennai 600 036, INDIA
e-mail: ushar@iitm.ac.in - web page: http://mat.iitm.ac.in/

‡ Université de Lyon, CNRS
INSA-Lyon, CETHIL, UMR5008, F-69621, Villeurbanne, FRANCE
Université Lyon 1, F-69622, FRANCE
e-mail: francois.rousset@insa-lyon.fr - web page: http://cethil.insa-lyon.fr/

ABSTRACT

The physical mechanisms for the long-wave instability are considered in the case of a gravity-driven Carreau fluid film flowing down an inclined porous medium. The porous medium is assumed to be saturated with the same fluid.

In a previous paper [1], the temporal stability of a Carreau fluid down an inclined porous substrate has been analyzed in the framework of Orr-Sommerfeld eigenvalue problem. Numerical results indicate the correlation between the effects of shear thinning and permeability, both destabilizing the flow. The study is based on the assumption that the characteristic length of the pore space is very much smaller than the thickness of the film above and this reduces the boundary condition at the interface between the porous substrate and the fluid layer to a simple Maxwell - type slip condition [2].

The present work describes the phenomenology of the long-wave instability of a thin shear-thinning liquid film over a porous substrate. A small disturbance to the interface that produces a motion in the film is imposed and analysis is carried out to examine how this motion amplifies the disturbance.

The growth process is shown to be governed by different contributions including a pressure term and three inertial stresses terms. Following the analysis presented by Smith [3] for a Newtonian fluid film on a rigid inclined substrate, a complete interpretation of the physical mechanisms involved in this growth process is presented. This is done by analyzing separately the contributions of permeability and shear-thinning rheology to the different mechanisms. As a result, this study enables to clarify the origin of the overall destabilization.

REFERENCES

[1] R. Usha, S. Millet, H. Ben Hadid and F. Rousset, "Shear-thinning film on a porous substrate: Stability analysis", *Chem.Eng. Sci.*, under review.

[2] J.P. Pascal, "Linear stability of fluid flow down a porous inclined plane", *J. Phys. D: Appl. Phys.* Vol. **32**, pp. 417– 422, (1999).

[3] M. K. Smith, "The Mechanism for the long-wave instability in thin liquid film", *J. Fluid Mech.*, Vol. **217**, pp. 469–485, (1990).