To be presented as poster at the 6th European Coating Symposium ECS 2005, September 7–9, 2005, University of Bradford, UK

Numerical investigation of the linear response of a viscous liquid sheet

N. Alleborn, H. Raszillier
Lehrstuhl für Strömungsmechanik, Universität Erlangen-Nürnberg, Cauerstr. 4, D-91058 Erlangen, GERMANY

Abstract

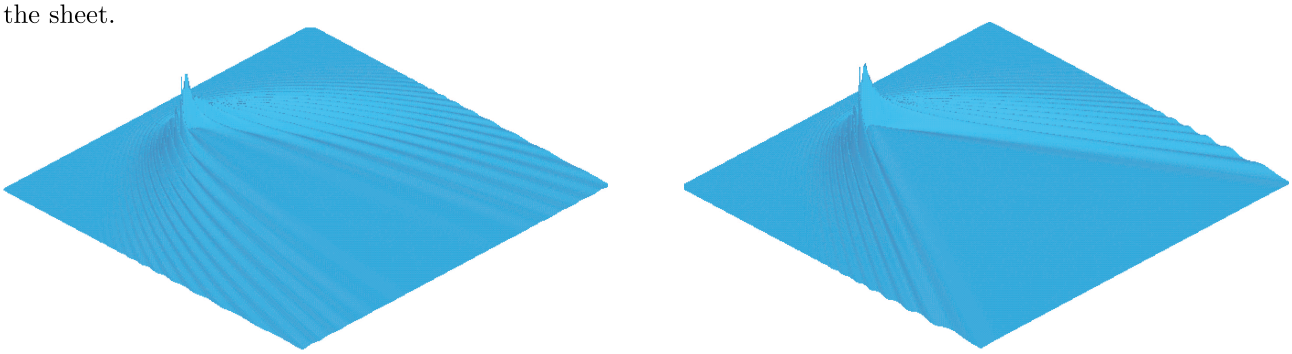
Thin viscous liquid sheets, as used e.g. in the curtain coating process, are sensitive to external disturbances, such as pressure fluctuations along their interfaces. The paper to be presented investigates the propagation of such disturbance signals in a uniform thin viscous liquid sheet of infinite extent which is in contact with a passive ambient medium. The disturbances are induced by local external pressure perturbations moving with constant velocity $\vec{V}$ along the sheet. The tool of analysis is the Fourier-Laplace transformation of the linearized perturbation equations, and the inverse Fourier-Laplace transform

$$\eta_{v,s}(\vec{x},t) = -\frac{1}{2\pi}\int d\vec{k}\, e^{i\vec{k}\cdot\vec{x}}\ \frac{1}{2\pi i}\int_{c-i\infty}^{c+i\infty} d\omega\ e^{\omega t}\ \frac{k\,\tilde{\mathcal{P}}(\vec{k},\omega)}{D_{v,s}(k,\omega)}\,, \quad c>0\,, \tag{1}$$

for the reconstruction of the signal, the amplitude of the interface deflections[2]. The response is determined by the shape of the disturbance, $\mathcal{P}(\vec{x},t)$, and by the intrinsic response properties of the viscous sheet, codified in its two dispersion functions

$$D_v(k,\omega) = \Gamma^2 k^3 + (k^2+l^2)^2\coth(k) - 4k^3 l\coth(l)\,, \tag{2}$$
$$D_s(k,\omega) = \Gamma^2 k^3 + (k^2+l^2)^2\tanh(k) - 4k^3 l\tanh(l)\,, \tag{3}$$

with $\vec{k}$ the two-dimensional wave vecter, $k=|\vec{k}|$, and $l^2 = k^2+\omega$, and with the characteristic number $\Gamma = \sqrt{\gamma H/(2\rho\nu^2)}$, which determine the singularities of the Fourier-Laplace integrand. Symmetric (varicose) and antisymmetric (sinuous) disturbances are investigated in the long time limit by numerical signal evaluation[1]. Fig. 1 shows for illustration in the rest frame of the perturbation source the varicose and sinuous response of the sheet to a localized pressure perturbation moving with the dimensionless velocity $V=2\Gamma$ with respect to the sheet.



(a) (b)

Figure 1: Propagation of disturbances for a moving external pressure profiles $P_s(\vec{x},t)$, $\Gamma=100, V=2\Gamma$ (shown in the rest frame of disturbance): Numerical results for a varicose disturbance (left, dispersion function eq. (2)), and eq. (3) for a sinuous disturbance (right, dispersion function eq. (3)).

The support of the Deutsche Forschungsgemeinschaft (DFG) is gratefully acknowledged.

References

1. N. Alleborn and H. Raszillier. Linear response of a viscous liquid sheet. In W. Gutkowski and T.A. Kowalewski, editors, *21st International Congress of Theoretical and Applied Mechanics — ICTAM04, Abstract Book and CD–Rom Proceedings*. Published by IPPT PAN, 15–21 August 2004.
2. Alleborn N., Raszillier H.: Linear Response of a Viscous Liquid Sheet to Oscillatory External Pressure Perturbation in the Long Wave Approximation — Varicose Excitation. *Acta Mechanica*, **170**:77–119, 2004.