

Draw Resonance Phenomenon In Glass Ribbon Forming Process

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Abstract

The production processes of glass and polymers often comprise a draw stage wherein the molten material is stretched without tool contact until it sufficiently cools. Stability of this step is crucial as primary dimensional attributes of the final product are established here. In the present work, we study the draw resonance effect which corresponds to ribbon width and thickness variations after the draw speed exceeds a critical value. From the mathematical point of view, this problem corresponds to stability of free surface flow. While this phenomenon is well studied considering a 1D formulation (see, e.g., [1]), we address a 2D case which introduces additional computational complexity due to the need to resolve a free surface. We will discuss equations for extensional flow in thin films and their implementation in COMSOL, a moving mesh approach for free surface modeling, and eigenvalue solver setup for a linear stability study in COMSOL. The results of the linear stability analysis are compared to explicit transient solutions and published results obtained by other methods [2]. The flexibility of COMSOL in terms of adding and coupling equations allows extending the basic model with more advanced physics, such as the influence of heat transfer on the ribbon stability. The described approach gives a useful tool to get a better understanding of the draw resonance phenomenon in a real process. Nevertheless, it could be used for analysis of other free surface flow instabilities.

Reference

- [1] J.S. Lee et al., Kinematic waves and draw resonance in film casting process, *Journal of Non-Newtonian Fluid Mechanics*, Vol. 101, Pages 43-54 (2001).
- [2] I. Kwon et al., Stability windows for draw resonance instability in two-dimensional Newtonian and viscoelastic film casting processes by transient frequency response method, *Journal of Non-Newtonian Fluid Mechanics*, Vol. 240, Pages 34-43 (2017).

Figures used in the abstract

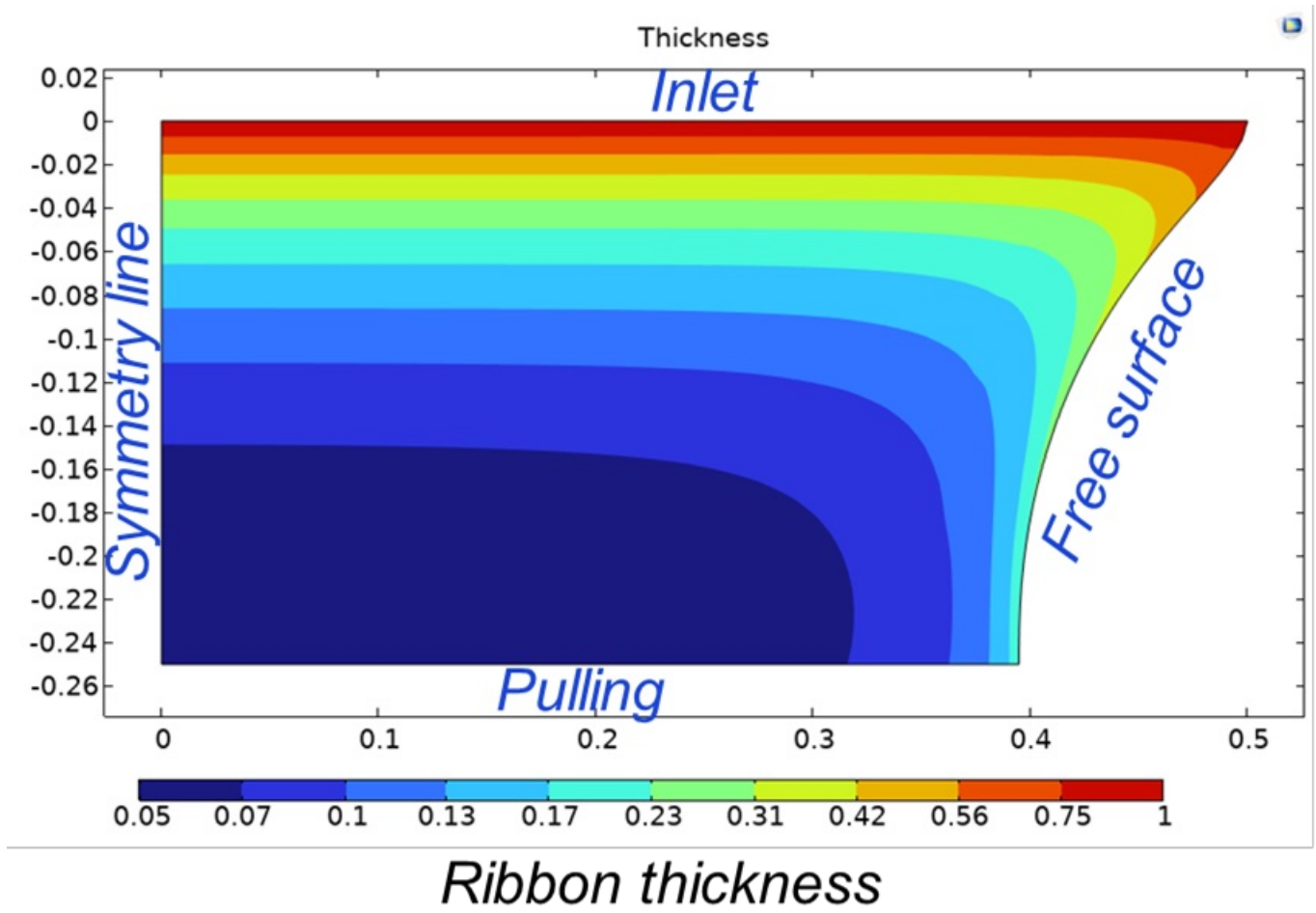


Figure 1 : Thickness distribution in isoviscous ribbon which is stretched by a factor of 20. Labels show boundary conditions on the corresponding edges.

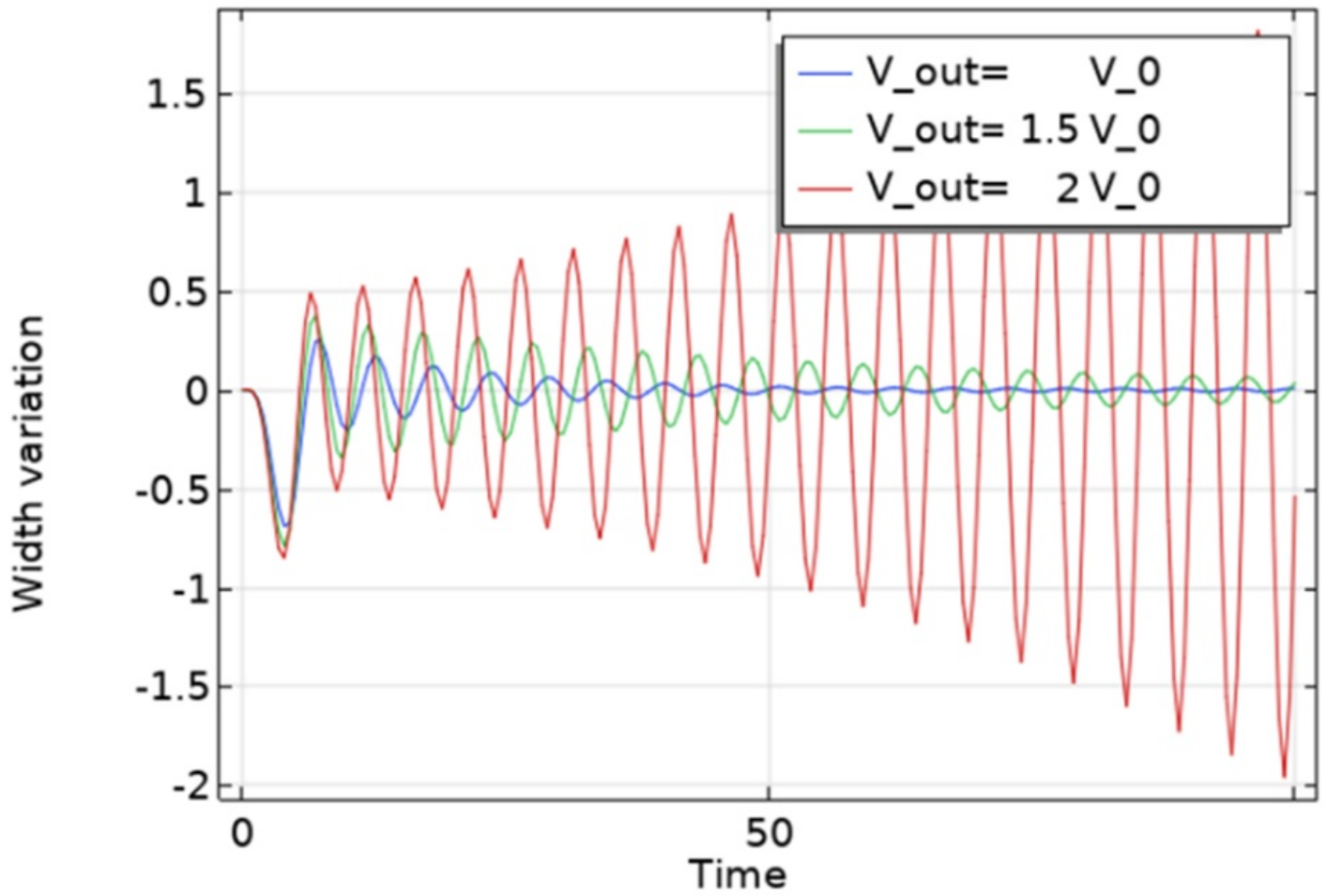


Figure 2 : Width response to a draw speed perturbation calculated with a transient model. At lower speeds the perturbation decays, while at high speed an instability occurs.