

A high-fidelity model for coupling flow and mechanical deformation of the porous paper web

CPS Agreement Number: 29332

LLNL/LBNL/Agenda 202020

Project Period: Oct 2015 – Sep 2016

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U.S. DOE Advanced Manufacturing Office Program Review Meeting

Washington, D.C.

June 14-15, 2016

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Project Objective

- Develop a scalable model to be used by the pulp and paper manufacturing industry to help reduce the energy required during the drying process of paper manufacture.
- Provide insights to inform the designs of more energy efficient processes and equipment.
- Leverage the HPC capability at LLNL/LBNL to understand the complex water removal process at the press section



Relevant scientific expertise

- LLNL – developed simulation tools, the Geocentric and GEOS codes. The Geocentric code is a massively-parallel finite-element / finite-volume code designed primarily for tightly-coupled poromechanical problems. It simulates either single-phase or multi-phase flow in a deformable porous medium. The GEOS code that is a multi-physics computational platform has recently been developed to simulate coupled flow and mechanical processes.
- LBNL – expertise in developing pore scale modeling capability called Chombo-Crunch which has been applied to wide variety of flow and transport problems in resolved porous media including reactive transport related to carbon sequestration, mesoscale resolution of flows in hydraulic fracturing, electrochemical transport in battery electrodes and large scale turbulent flows
- Agenda 2020 – a member funded Member-funded 501(c)(3) organization, with the mission to Promote the development of advanced manufacturing technologies that promise transformational impact on the paper and forest-based industries

National Impact

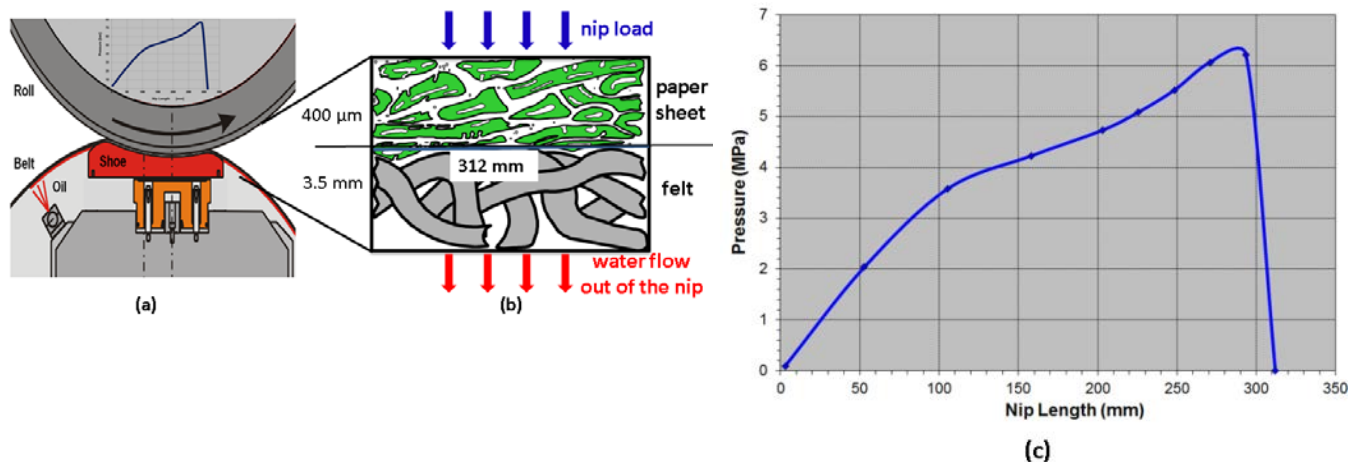
- There are 359 pulp and paper mills in 40 U.S. states, employing 370,000 person
- In 2010, U.S. pulp and paper manufacturers used 400 trillion Btu of energy for paper drying to produce 83 million tons of paper and paperboard
- 10% improvement in solids entering dryer section translates into 20% drying energy saving, or 80 trillion Btu, worth approximately \$250 million

Technical Innovation

- The exact mechanism of “Rewet” is not known. In the recent Drier Web Roadmap, it was ranked one of the most challenging technical barrier to significantly improve the web solid content from 45-55% to up to 65%
- This project will develop and apply tools to model and simulate the flow of moisture from/to the porous pulp medium (dewatering/rewetting) during the pressing process focusing on the critical paper web/press felt separation phase.

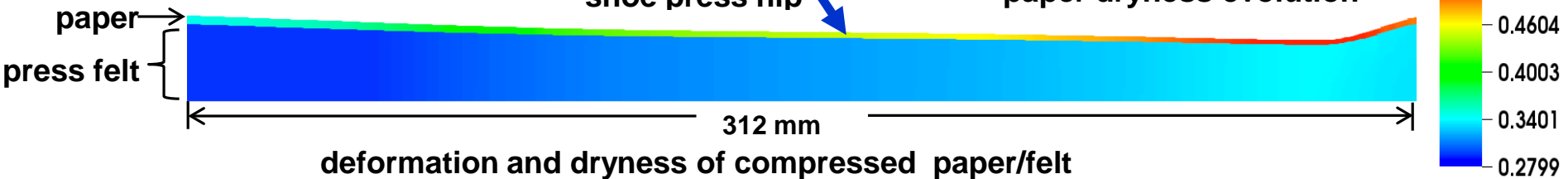
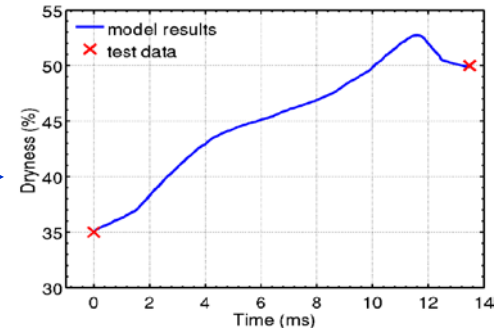
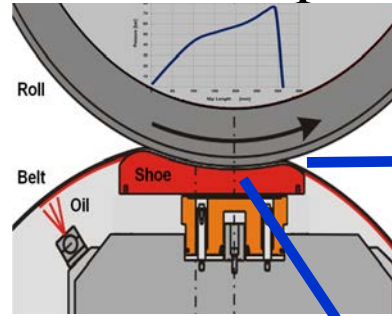
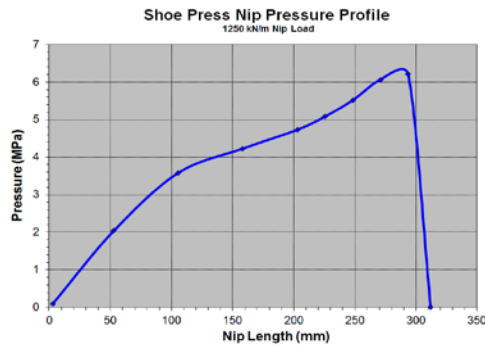
Technical Approach

- LLNL will develop a continuum simulation framework to couple mechanical deformation and two-phase flow models
- LBNL will develop a pore-scale single-phase flow model
- Agenda 2020 member companies (made up of paper companies and supplier companies) will collaboratively define the scope of the modeling framework and provide data to verify and validate the model



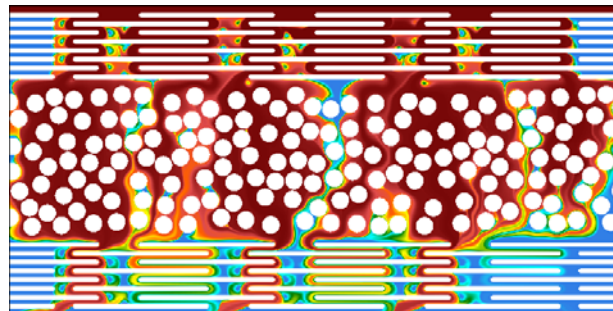
Results and Accomplishments

- Continuum model is completed



- Single phase pore scale model is 70% complete with data provided by Agenda 2020.

2D pore-scale felt model using geometry obtained from constructive solid geometry (velocity data shown)



3D pore-scale felt model using geometry reconstructed from image data (pressure data shown)
 $K \sim 7.732 \times 10^{-11} \text{ m}^2$

