

Study of Wet Scroll

How paper curls and uncurls

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4 Conclusion

Background Information

When a piece of semi-transparent sulfuric acid paper (Tracing Paper) is gently placed on the surface of water, it may quickly curl up into a roll and then slowly unfold.

- specially processed
- increased light transmittance and hydrophobicity
- hereinafter referred to as paper for simplicity

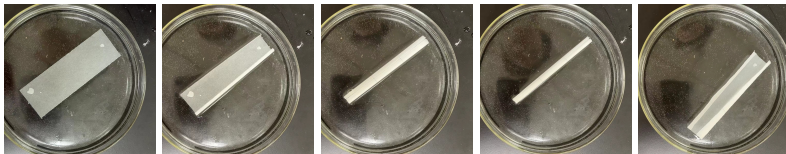


Figure 1: Changes of paper strips over time

Research Gaps

- studied the basic properties of paper ([Alava and Niskanen, 2006](#)) and ([Van der Reyden et al., 1993](#))
- explained the diffusion of water in paper ([Dano and Bourque, 2009](#))
- explained the change in curvature of paper ([Reyssat and Mahadevan, 2011](#))
- GAP1: no simple and effective experimental approach
- GAP2: surface tension has not been considered

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Theoretical Modeling

- transport problem of water in paper
 - Fick's second law of diffusion
 - second-order differential equation and boundary conditions
 - linear relationship between paper width and water content
- mechanical analysis
 - consider paper as a homogeneous elastic material
 - gravity can be neglected
 - torque balance equation and force balance equation
- assume that paper strip cannot roll into a cylinder

Experimental Measuring

- place a paper strip on water surface
- use a camera to record the changes
- use Tracker software to measure the width of paper strips

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Comparison: experimental and theoretical results show similar variation tendency.

Initially, the width of the paper decreases as paper curls, then it increases as paper uncurls, and finally, the width becomes slightly larger than the initial width, which is a result from expanding after absorbing water.

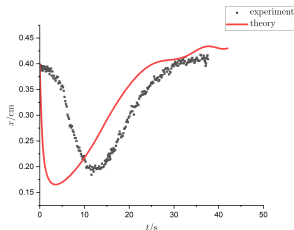
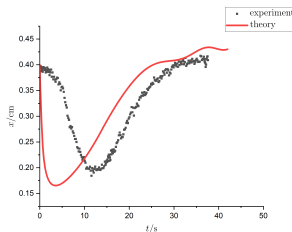


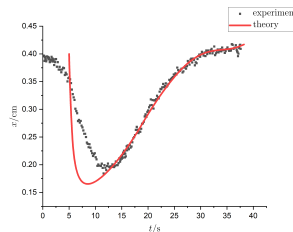
Figure 2: Changes in paper width(x) over time(t) in water

Introducing relaxation time τ : the second half of curves fit very well.

After introducing a relaxation time $\tau = 5$ seconds, the second half of experimental and theoretical curves, but there are still differences in the short period after the paper strip is placed on the water surface.



(a) original



(b) modified

Figure 3: Figure(b) is obtained by shifting the theoretical curve in Figure(a) to the right by $\tau = 5$ s.

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Conclusion

What's in this presentation:

- a new method to measure the motion of paper strips
- improvements to [Reyssat and Mahadevan \(2011\)](#)'s theory
- comparison between the experimental and theoretical results
- introduction of relaxation time τ

Some problems remain:

- relaxation time needs explanation
- another case remains unsolved: the case where paper strips can roll into a cylinder

References

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Thanks!