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Explicit Simulations of Wrinkle Formation Due to Web Non-uniformity

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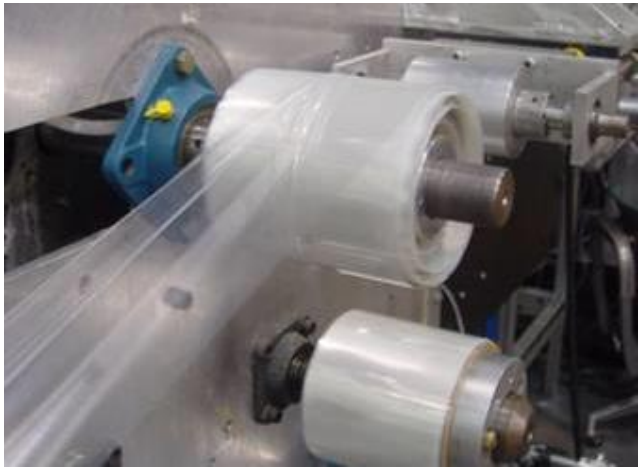
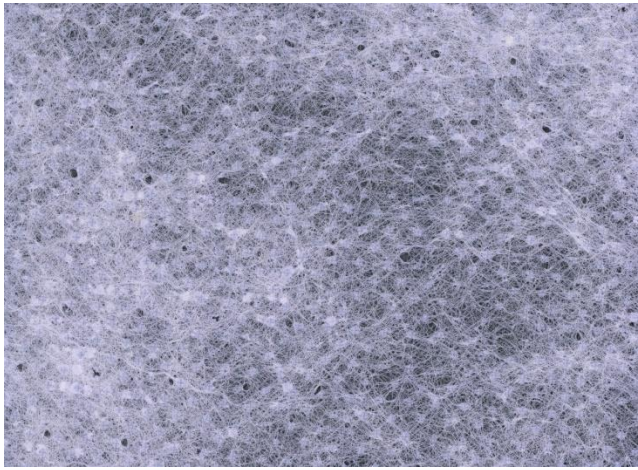
What Is a Web?

A web can be defined as a continuous, flexible strip that has a rectangular cross section where the thickness is much smaller than the width.

Paper

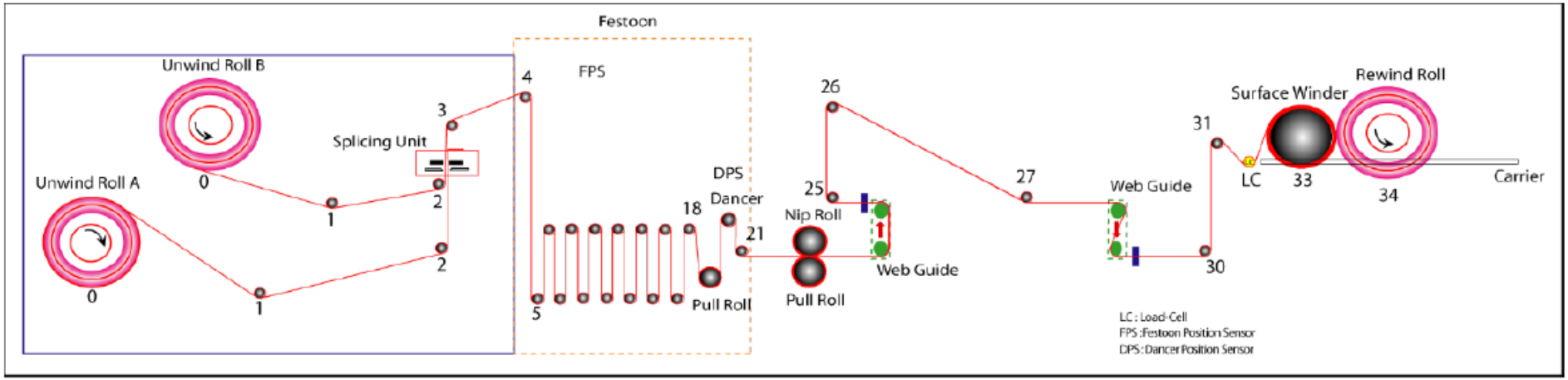


Film



Nonwoven

A Web Handling Example

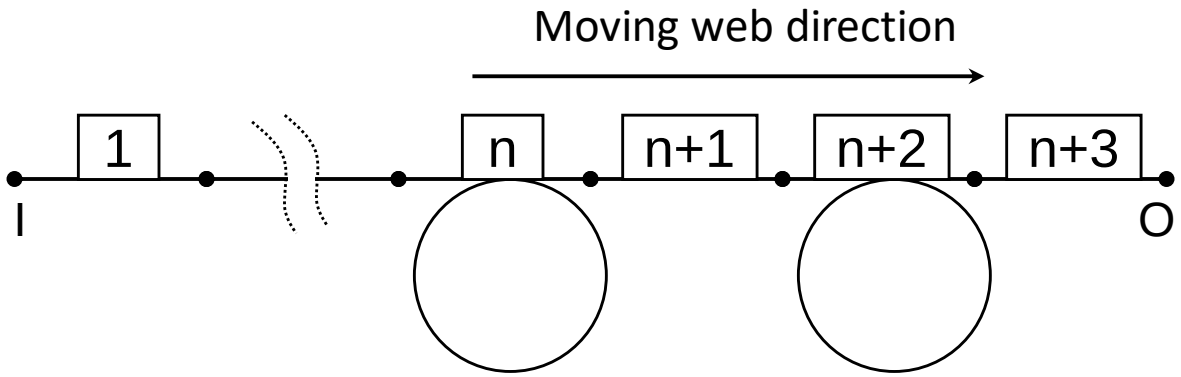


Background

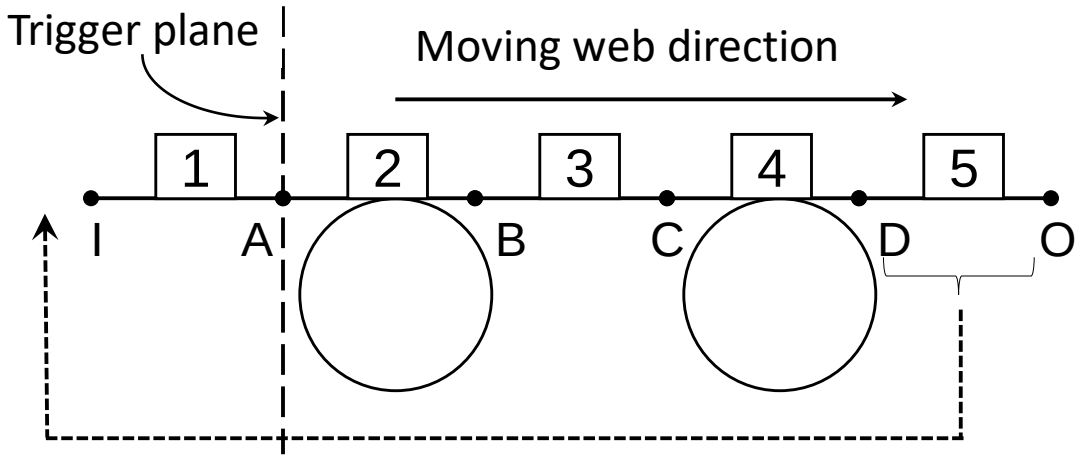
- Wrinkling correction experimentation is expensive, in terms of waste and machine down-time.
- Wrinkling of the composite web represents one of the top causes of waste and delay.
- Research is now going into the development of FEA models to understand how wrinkles form when processing particular non-woven web.
- Abaqus' periodic media analysis (PMA) is a key feature enabling this work.

Introduction of PMA in Web Handling Simulation

Traditional model



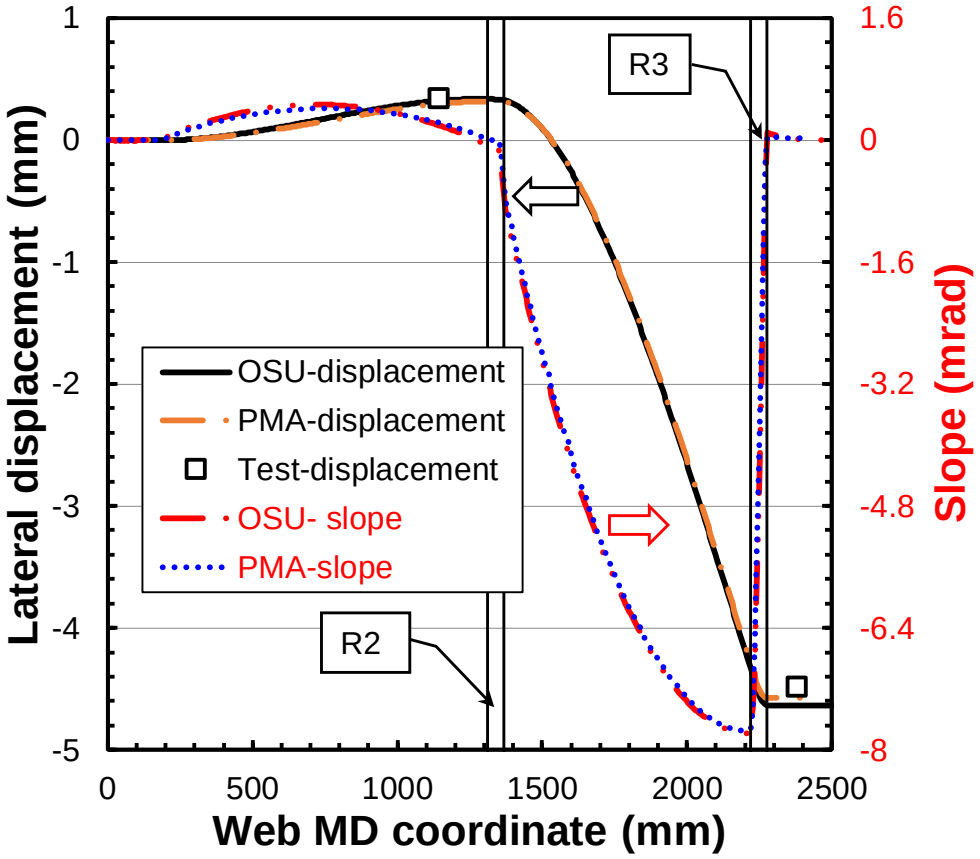
Periodic media analysis model

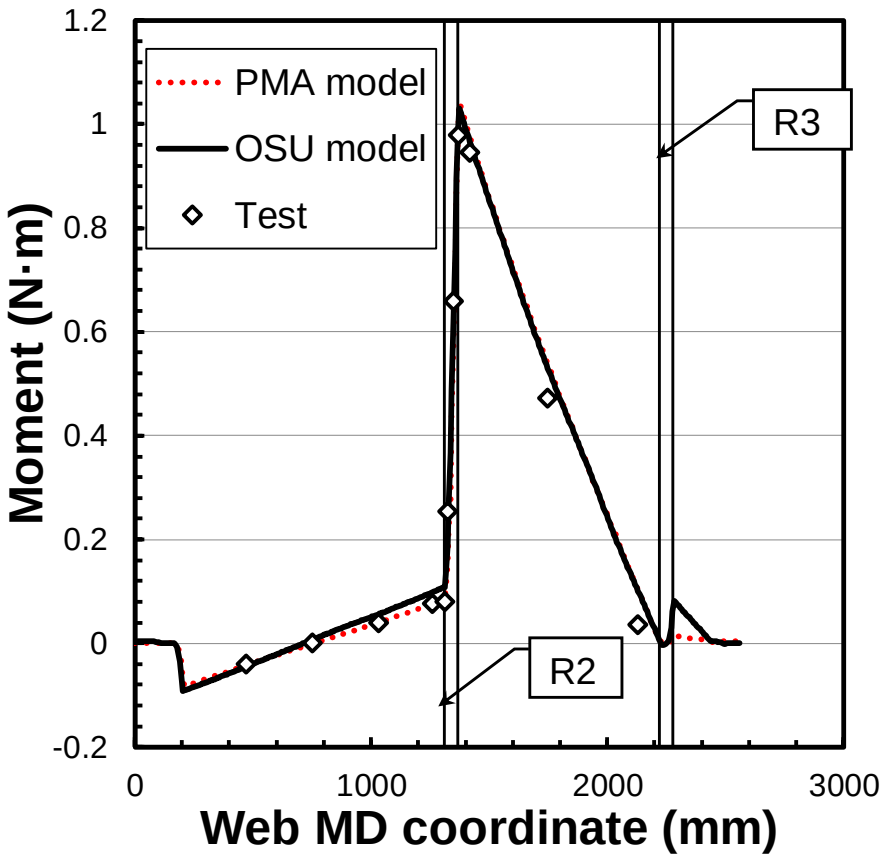


PMA Model vs. Traditional Model

	Traditional model	PMA model
Computational time	9 hours 13 minutes	5 hours 38 minutes

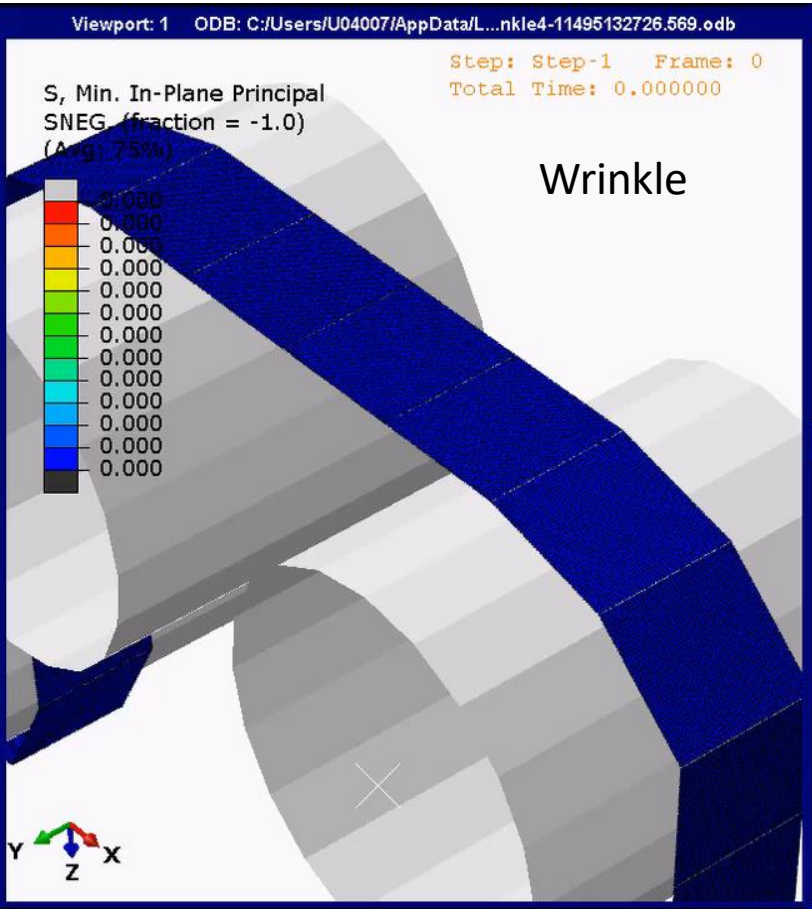
Simulation Results: Displacements, Slopes and Moments

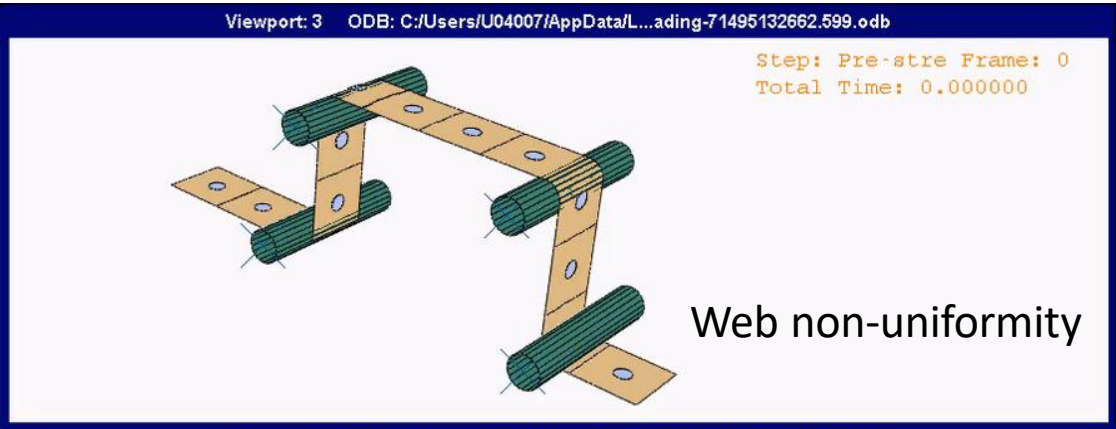




The experimental results (displacements and moments) agree with the simulation results from two models very well. Normal entry to R3 is achieved in both cases too.

PMA Model Application

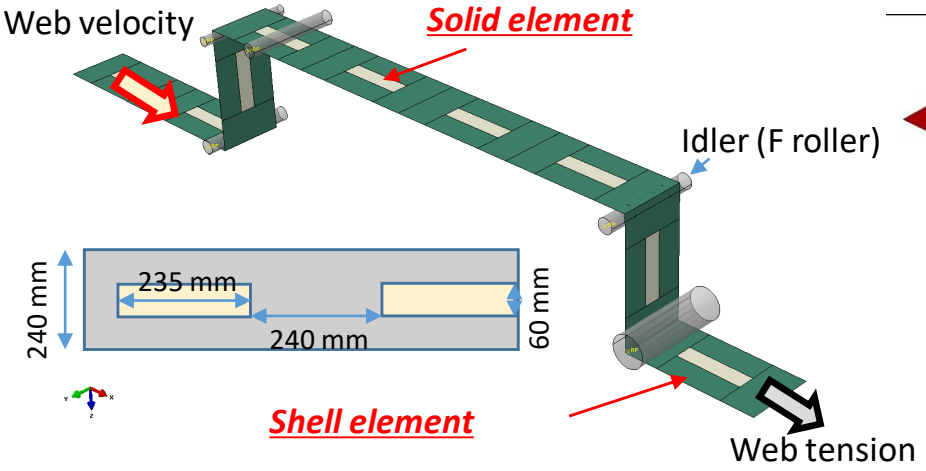


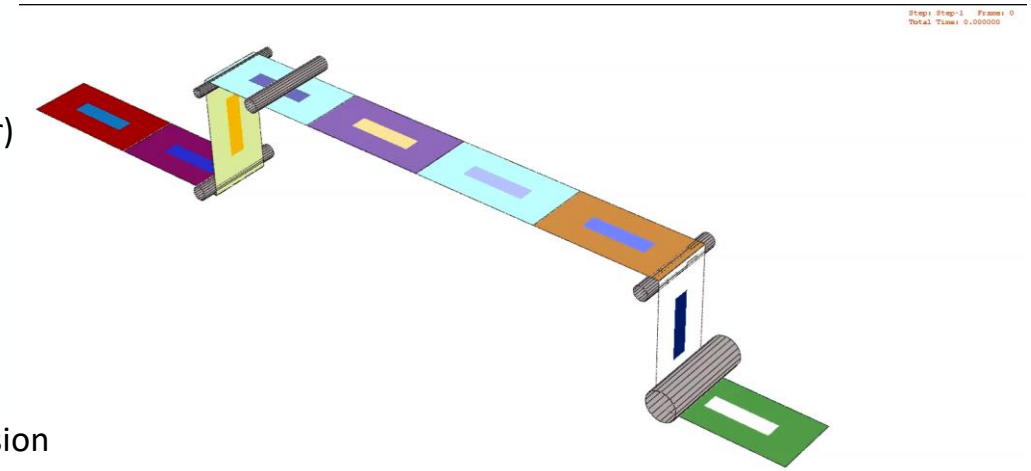


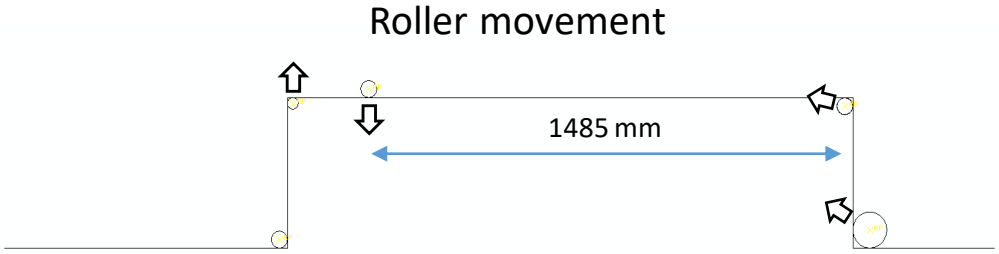
PMA models were successfully developed to study moment transfer, wrinkle formation due to roller misalignment, and web instability due to web non-uniformity.

Fu et al. 2015 International Web Handling Conference

PMA Model Set-up







Material properties

Thin web:

E_{MD}=30337 KPa; E_{CD}=3309 KPa;

υ_{MD}=2.8

Thickness=0.09 mm

Thicker patch:

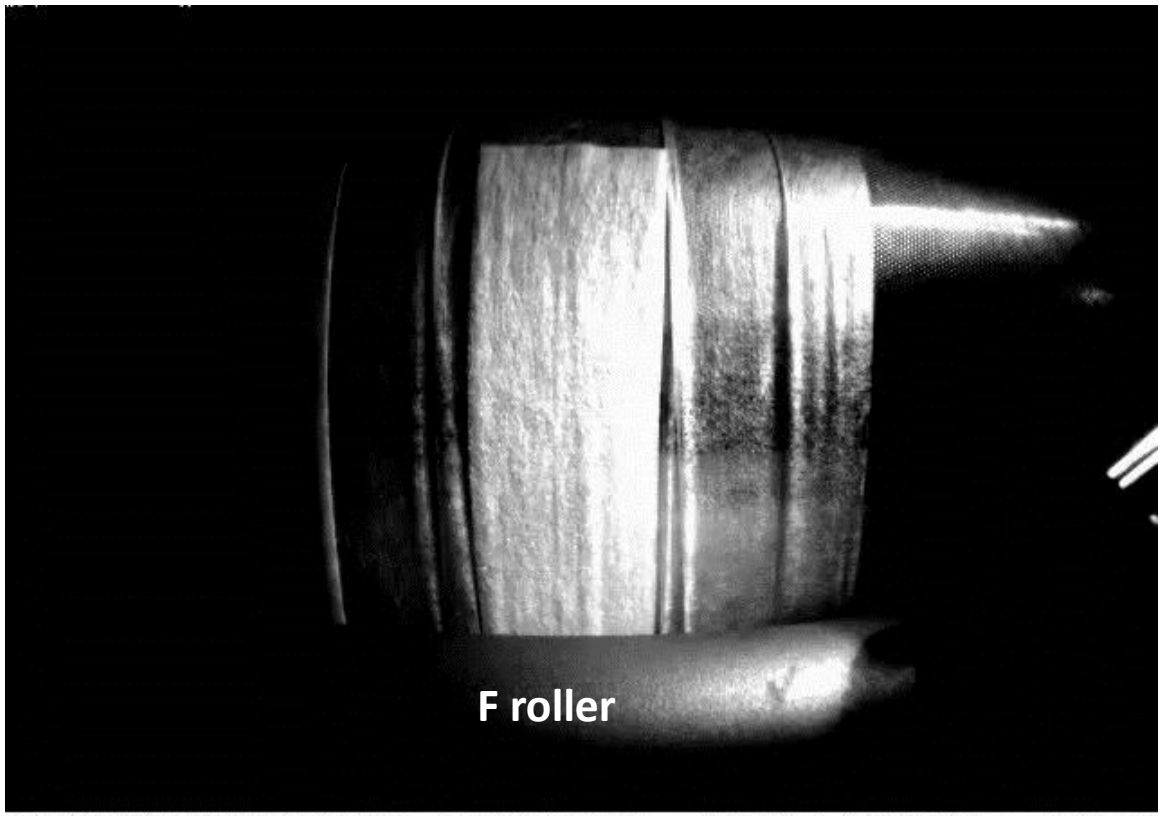
E_{MD}=13376 KPa; E_{CD}=10342 KPa;

υ_{MD}=1

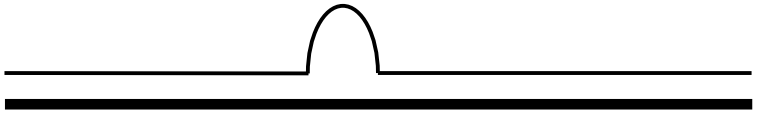
Thickness=1.7 mm

Friction coefficient= 0.4

Wrinkle Observation



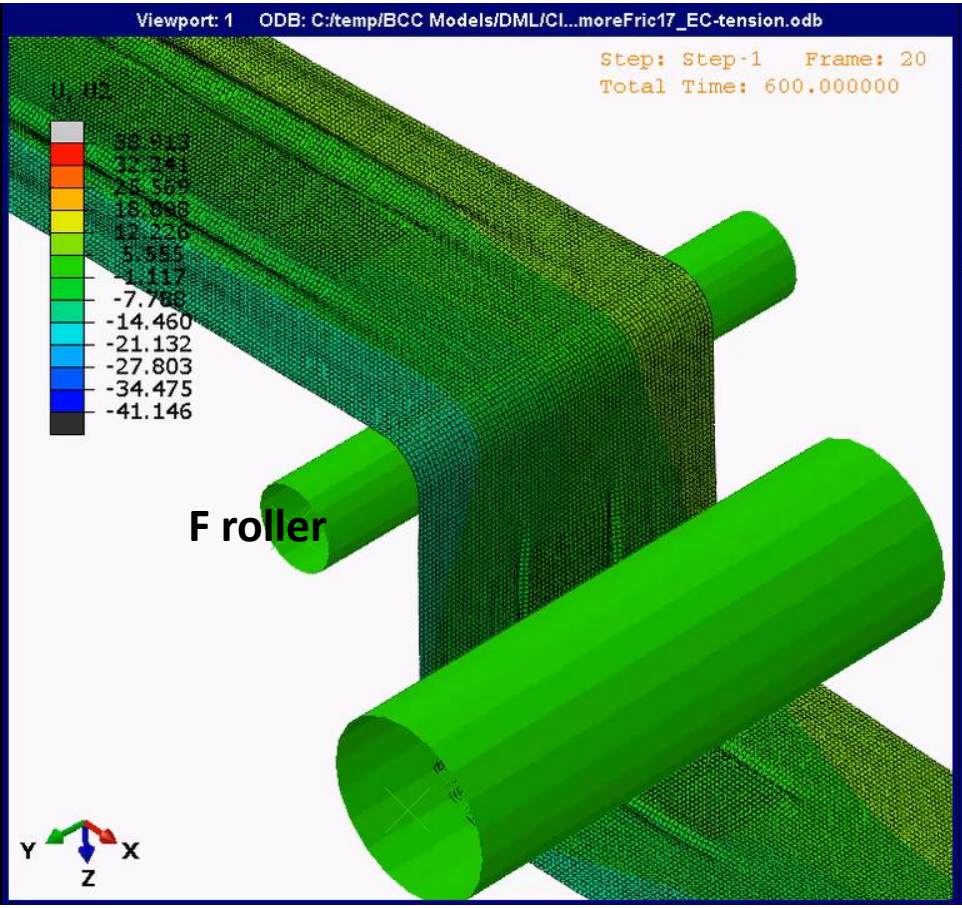
As defined by the Brown researchers, the wrinkle state *is when peaks and troughs start to form on the surface, like waves on the ocean*.
A fold occurs *when the areas on either side of the wrinkle begin to touch, forming hollow channels beneath the surface plane of the material*.
Diab et al. 2013 Proceedings of The Royal Society

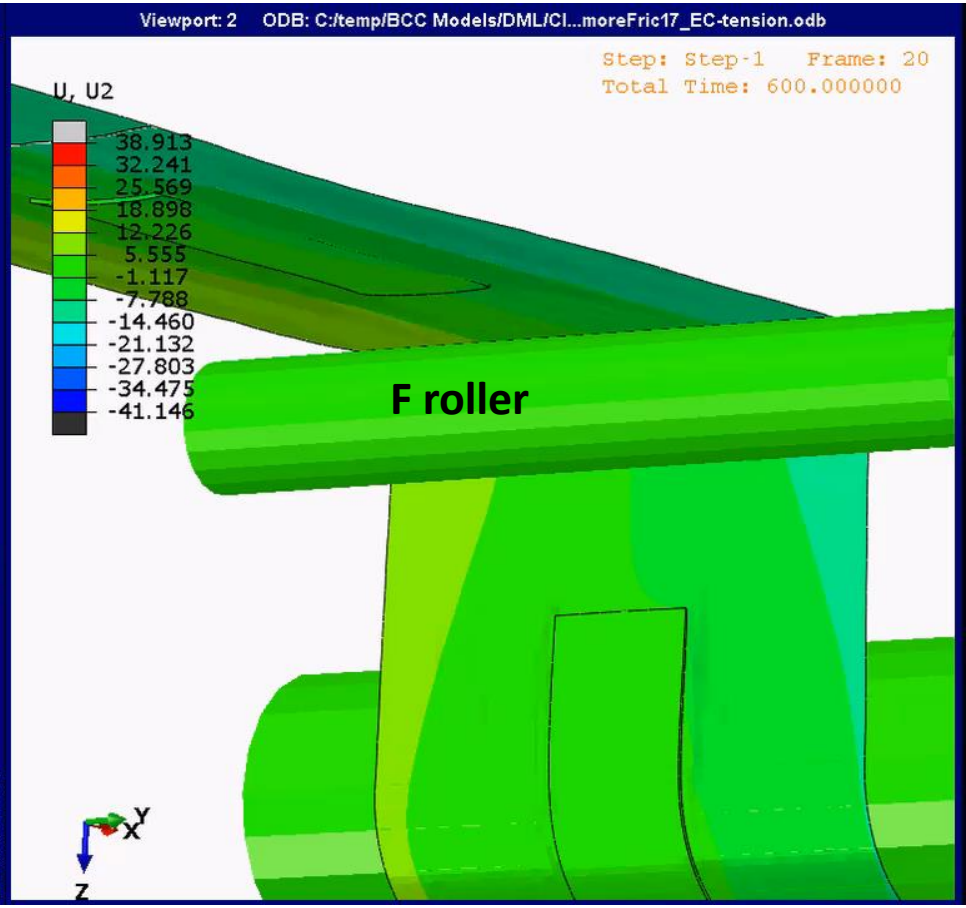


Wrinkle

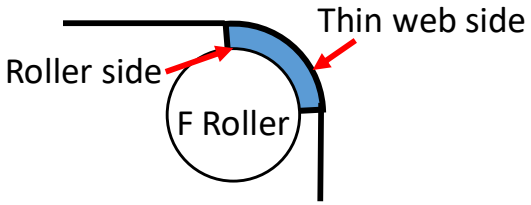
Folding

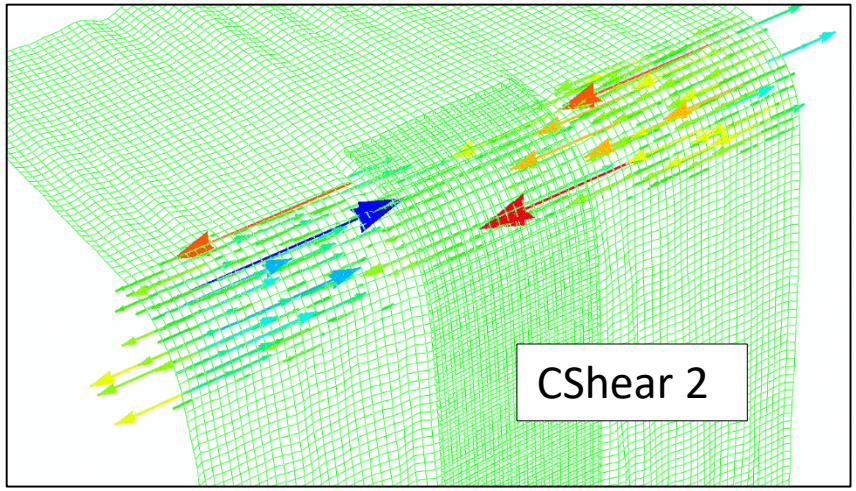
Simulation Results

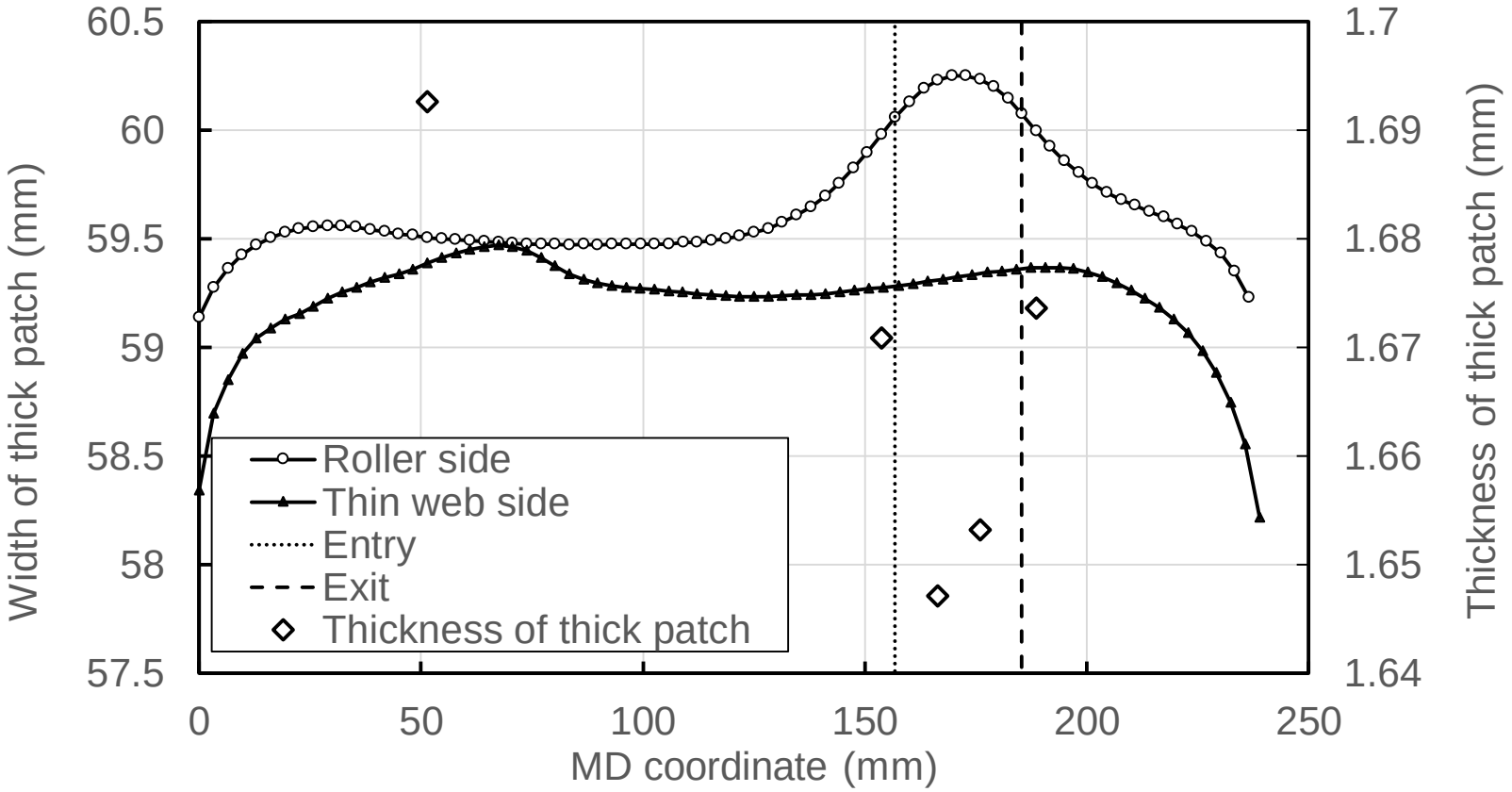




Simulation Results







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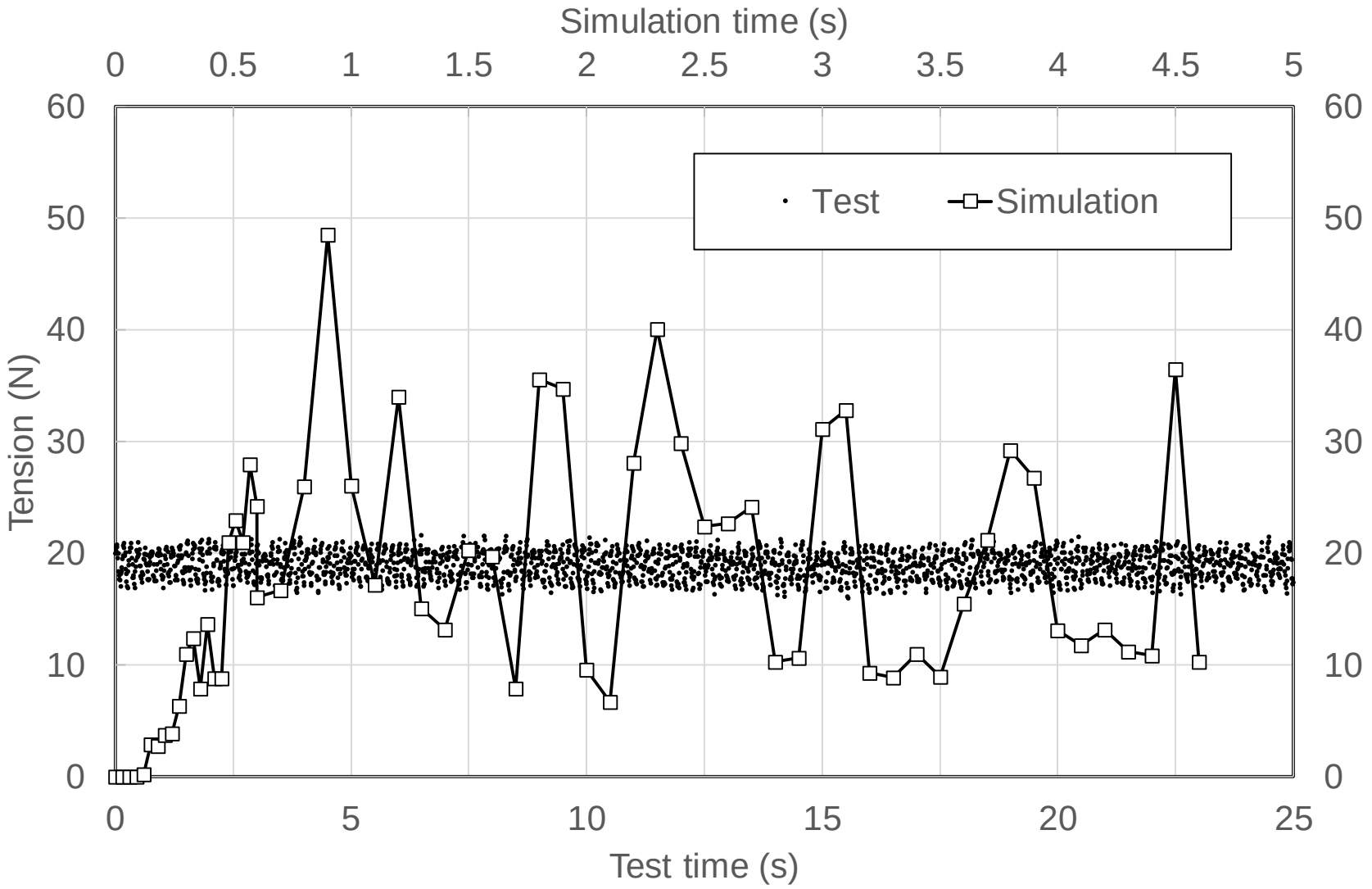

Sensitivity Study

Effects of web thickness, friction coefficient and Poisson's ratio.

	COF-F Roller	COF-else	Thin web thickness (mm)	Thin web Poisson's ratio	Thick patch Poisson's ratio	Wrinkle
1	*0.4*	*0.4*	*0.09*	*2.8*	*1*	***Yes***
2	0.4	0.4	0.1	2.8	1	**No**
3	0.4	0.2	0.09	2.8	1	**Yes**
4	0.3	0.2	0.09	2.8	1	**No**
5	0.35	0.2	0.09	2.8	1	**Yes**
6	0.34	0.2	0.09	2.8	1	**Yes**
7	0.33	0.2	0.09	2.8	1	**Yes**
8	0.33	0.2	0.09	1.8	1	**No**
9	0.34	0.2	0.09	1.8	1	**No**
10	0.4	0.2	0.09	1.8	1	**No**
11	0.4	0.2	0.09	1.8	0.9	**No**
12	0.4	0.2	0.09	1.8	0.85	**Yes**

Summary and Conclusion

- Simulation models can capture wrinkle formation due to web structure non-uniformity.
- Mechanical root causes of wrinkles on non-woven materials may not be the same as those on film/metal webs. It appears that “wrinkles” on non-wovens may be a combination of wrinkle and folding.
- Solid elements are used to model thick material sections because they accurately portray ZD compression. Shell elements are used to model thin sections of the web.
- The friction coefficient is a key factor affecting wrinkle formation: wrinkles occur within higher friction coefficients.
- Wrinkles are sensitive to thickness non-uniformity: which increases their likelihood.
- The difference in Poisson’s ratios between thin web and thick sections of the web affects wrinkle formation: larger differences tend to generate more wrinkles.