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Evaluation and optimization of the peel performance of a heat sealed topfilm and bottomweb undergoing cool processing

2021 Member Conference

iapri

Packaging Technology and Science
An International Journal

PAPER SUBMITTED TO IAPRI PEER REVIEW STREAM | Open Access

Evaluation and optimization of the peel performance of a heat sealed topfilm and bottomweb undergoing cool processing

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First published: 21 February 2021 | https://doi.org/10.1002/pts.2562

Funding information: Agentschap Innoveren en Ondernemen, Grant/Award Number: TETRA nr. 180224; Bundesministerium für Wirtschaft und Energie, Grant/Award Number: IGF project no. 243 EBR/1

Structure

Introduction

Optimization peel performance

Evaluation peel performance – cool processing

Conclusions

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Introduction

- Closure of food packages is crucial to guarantee food safety and food quality → Heat conductive sealing

- Cool processing to extend shelf life

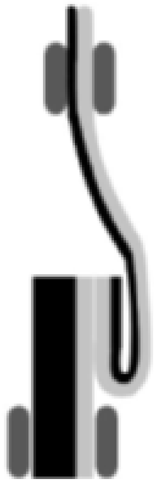
- Expectations consumers + population ageing → need for convenient packaging: 'easy peel'

Introduction

- Objectives
  - Develop and validate a method to **optimize** peel performance during and after cool processing
  - **Evaluate** the relation peel performance – cool processing

- Materials: commercial films
  - Topfilm: PET/PE-EVOH-PE (peel) 12/45
  - Bottomweb: PET/PE 250/35

- Seal characterization:
  - 180° peel test < 4h after sealing



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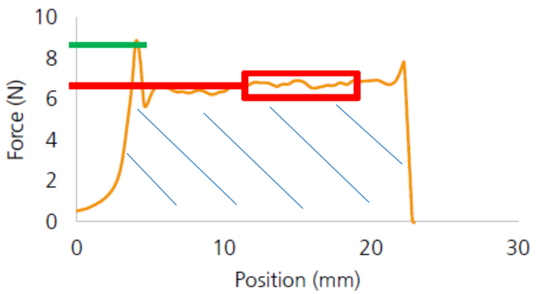
Optimization

- Design of experiment approach (6 steps)[1,2]
  1. A design space is defined based on preliminary tests

Process parameters (x)	Range
Seal temperature (upper jaw – lower jaw is kept at 50 °C)	130 → 180 °C
Seal time	1.0 → 3.0 s
Seal pressure	1 → 4 $N.mm^{-2}$
Processing temperature	-18, 4 and 23 °C

Responses (y)
Average peel strength ($N.mm^{-1}$)
Maximum peel strength ($N.mm^{-1}$)
Peel energy (J)



  2. An experimental design is proposed: I-optimal design with 24 runs[3]

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1: D'huys et al, 2019 - 2: Bamps et al, 2019 – 3: Goos et al, 2011

Optimization

3. Experimental work: in duplo + samples *DURING* and *AFTER* cool processing are tested

	Process parameters (x)				Responses (y)					
					DURING cool processing			*AFTER* cool processing		
	Seal temperature (°C)	Seal time (s)	Seal pressure ($N.mm^{-2}$)	Processing temperature (°C)	Average peel strength ($N.mm^{-1}$)	Maximum peel strength ($N.mm^{-1}$)	Peel energy (J)	Average peel strength ($N.mm^{-1}$)	Maximum peel strength ($N.mm^{-1}$)	Peel energy (J)
1	155	2.0	2.5	-18	1.1	1.2	0.34	0.8	0.8	0.20
					1.1	1.2	0.33	0.7	0.8	0.18
2	180	1.0	4.0	4	1.0	1.0	0.26	0.7	0.7	0.17
					1.0	1.0	0.27	0.8	0.8	0.20
3	155	1.0	1.0	4	0.8	1.0	0.21	0.2	0.3	0.02
					0.3	0.7	0.10	0.6	0.7	0.13

→ 24

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Optimization

4. Response surface models are fitted to obtained data

Example: model for maximum peel strength *DURING* processing

$$Maximum\ peel\ strength = -4.598 + 0.028 * Tseal + 0.468 * tseal + 0.244 * pseal + Match\ Tprocessing[-18 \rightarrow 0.082; 4 \rightarrow 0.042; 23 \rightarrow -0.124] + 0.009 * Tseal * tseal - 0.212 * tseal^2 + 0.009 * Tseal * pseal + 0.124.tseal.pseal + 0.032 * pseal^2 + Tseal * Match\ Tprocessing[-18 \rightarrow 0.008;\ 4 \rightarrow -0.007;\ 23 \rightarrow -0.002] + tseal * Match\ Tprocessing[-18 \rightarrow -0.044; 4 \rightarrow 0.118; 23 \rightarrow -0.074] + pseal * Match\ Tprocessing[-18 \rightarrow -0.014; 4 \rightarrow -0.129; 23 \rightarrow 0.143]$$

Only significant terms!

First order – second order - interactions

5. Optimal peel performance is defined.

For this concept: maximum = average = 0.5 $N.mm^{-1}$, maximize peel energy

Seal temperature, time and pressure are predicted to achieve optimal responses at 23 °C

Responses *DURING* and *AFTER* cool processing at -18 and 4 °C are predicted

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Optimization

6. Validation: 5 samples are sealed at optimal seal temperature, time and pressure + tested *DURING* and *AFTER* cool processing

Processing temperature	Average peel strength ($N.mm^{-1}$)		Maximum peel strength ($N.mm^{-1}$)	
	Predicted value	CI measured	Predicted value	CI measured
-18 °C *DURING*	0.80	[1.02, 1.24]	0.99	[1.17, 1.25]
-18 °C *AFTER*	0.54	[0.56, 0.67]	0.62	[0.62, 0.68]
4 °C *DURING*	0.47	[0.94, 1.04]	0.63	[0.97, 1.07]
4 °C *AFTER*	0.48	[0.60, 0.77]	0.47	[0.68, 0.77]
23 °C	0.45	[0.51, 0.62]	0.58	[0.60, 0.66]

➔Confidence intervals (=CI) follow the trend of predicted values
Trend = *DURING* cool processing peel strength increases at −18°C BUT also at 4°C increased peel strength is measured.
AFTER: no impact of cool processing.

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Evaluation

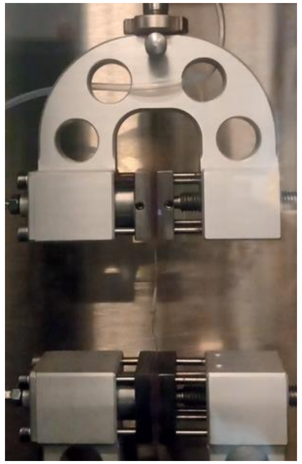
DURING: peel strength increases (23 < 4 < -18 °C): Why?

Peeling = bending + elongation + fracture

Films are characterized *DURING* -18, 4 and 23 °C

The following tests are discussed in the paper

- 3-Point flexural test bottomweb
- Tensile test topfilm
- Tensile test LDPE film



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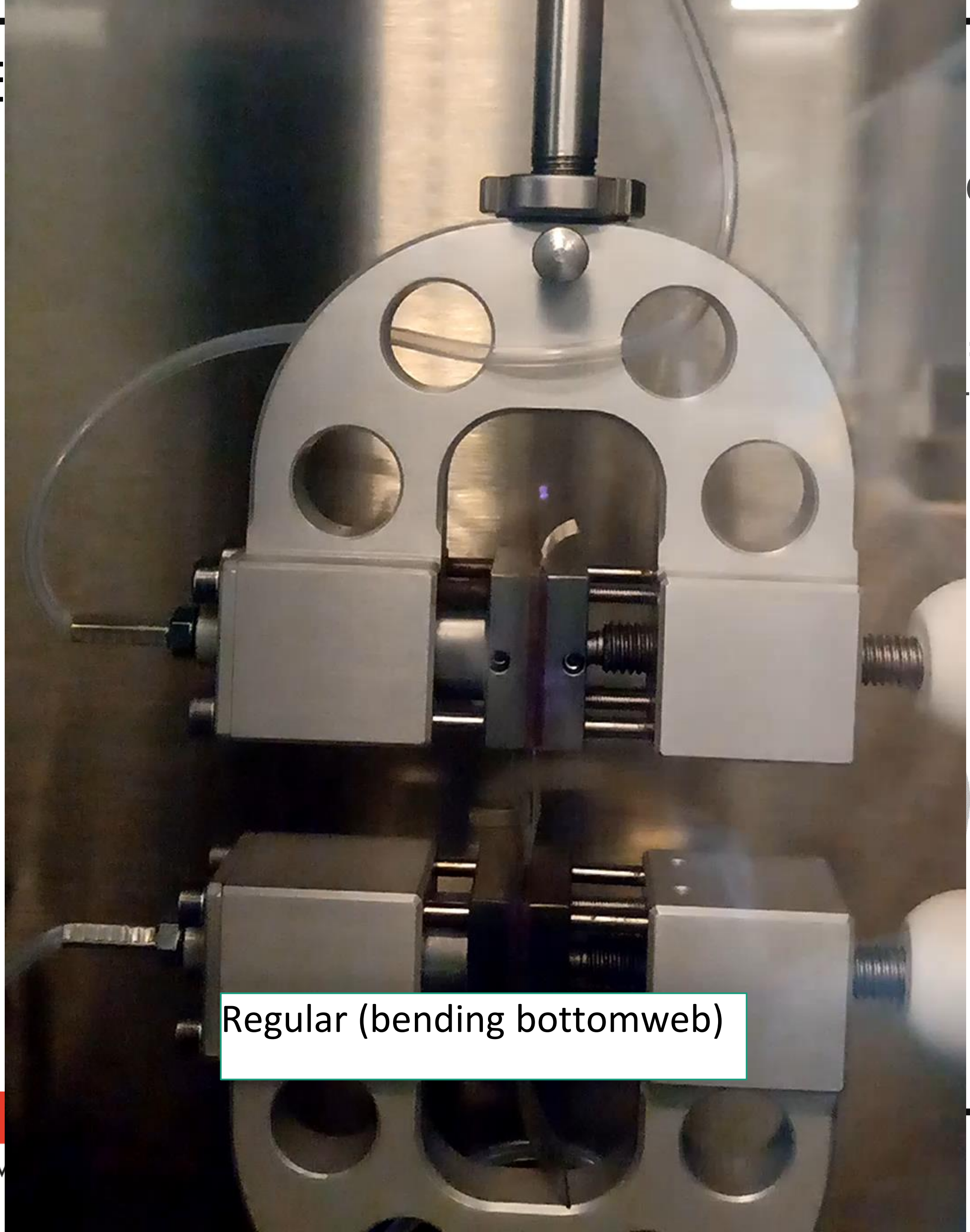
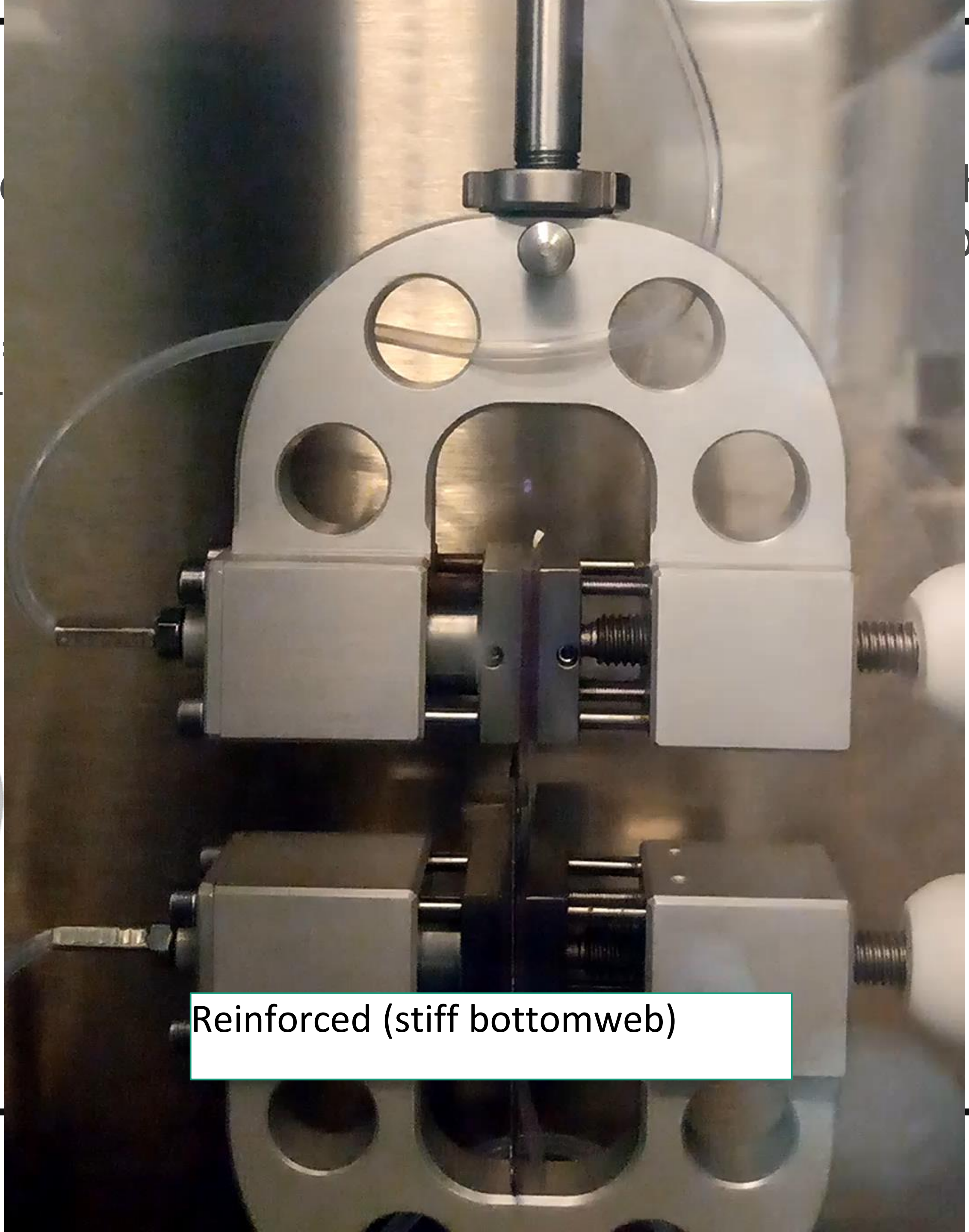
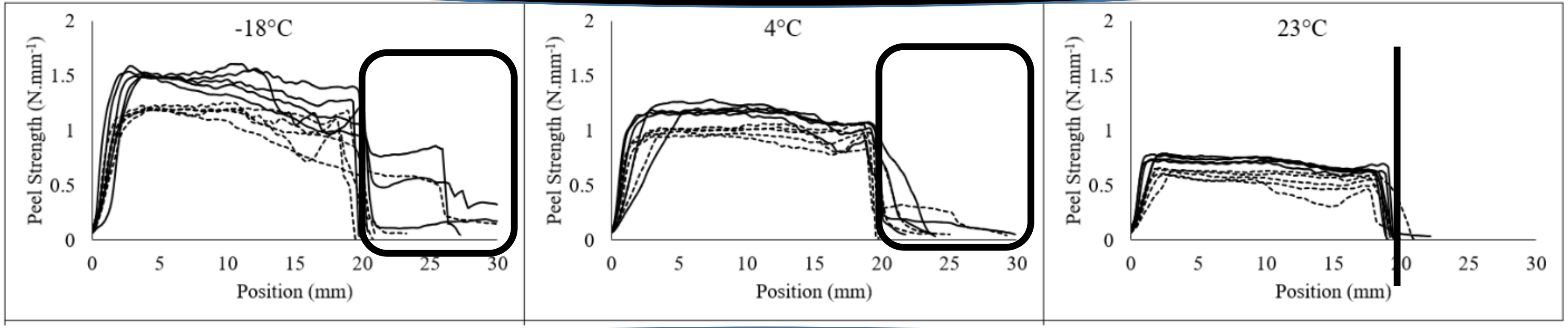

Regular (bending bottomweb)


Reinforced (stiff bottomweb)

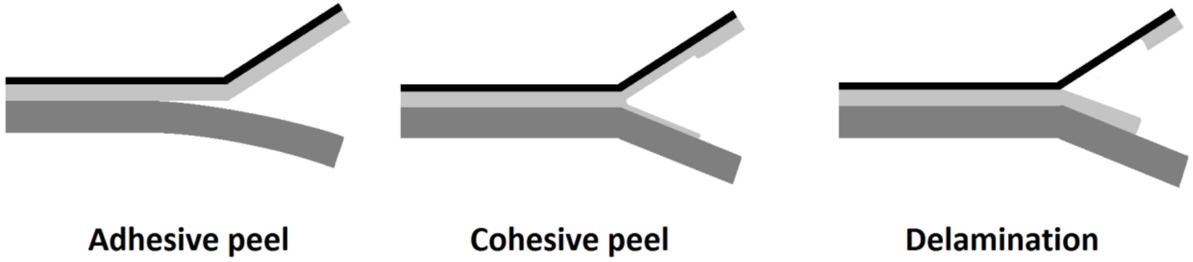
Evaluati

▪ Seal

Less sharp decrease of strength *DURING* -18 and 4 °C
→ seal failure mechanism



23 °C: full cohesive peeling
DURING -18 and 4 °C: partially delamination occurs



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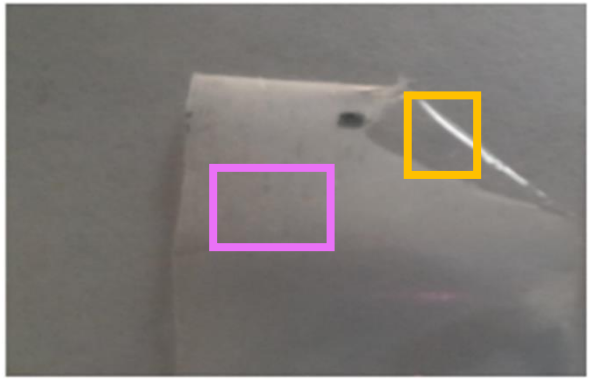
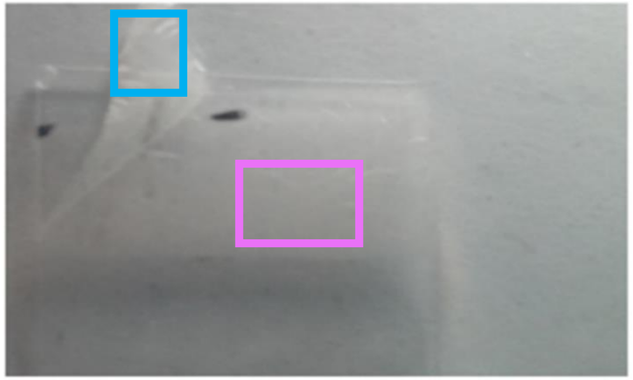
Evaluation

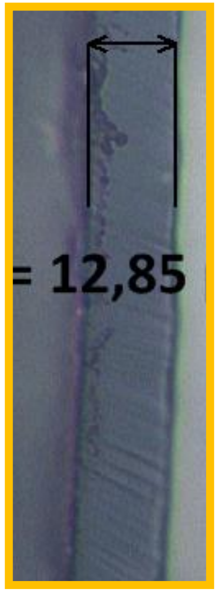
- Seal failure mechanism
  - Cross sections

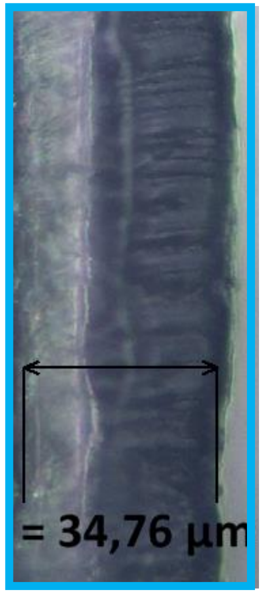
Topfilm



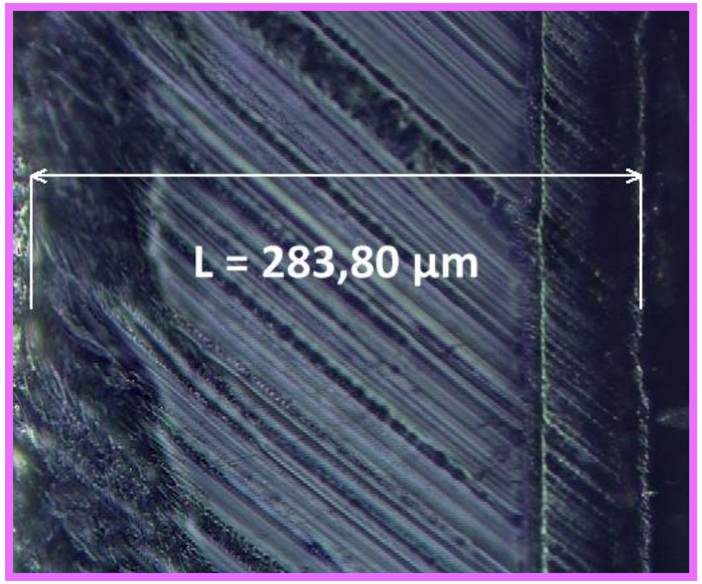
Bottomweb







Delamination (undesired)



Cohesive peel

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Conclusions

- Method to optimize peel performance
  - *AFTER* cool processing: no impact of processing temperature
  - *DURING* cool processing: Peel strength increased at low temperature

- Evaluation peel performance – cool processing
  - Increase in peel strength related with seal failure mechanism
  - Minor impact of bending bottomweb on peel strength

Thank you
for your attention!

Questions?

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