Time-dependency of flexural properties in biaxially oriented polypropylene laminates

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State of the art

Problem statement

Results

Conclusions

ORIENTED POLYMERS

Uniaxial orientation

- ⊕ High properties along **ONE** direction
- ⊖ **Large** property **GAPS** between the stretched and not stretched directions

Biaxial orientation

- ⊕ Good properties along **TWO** directions
- ⊕ **Limited** property **GAPS** between the two directions

BIAXIALLY ORIENTED POLYPROPYLENE (BOPP)
Simultaneous or sequential stretching:

- Molecular orientation changes
- Crystallinity degree changes
- Melting point changes

TIME-DEPENDENCY ANALYSIS

EXPERIMENTAL PART

BOPP laminate level

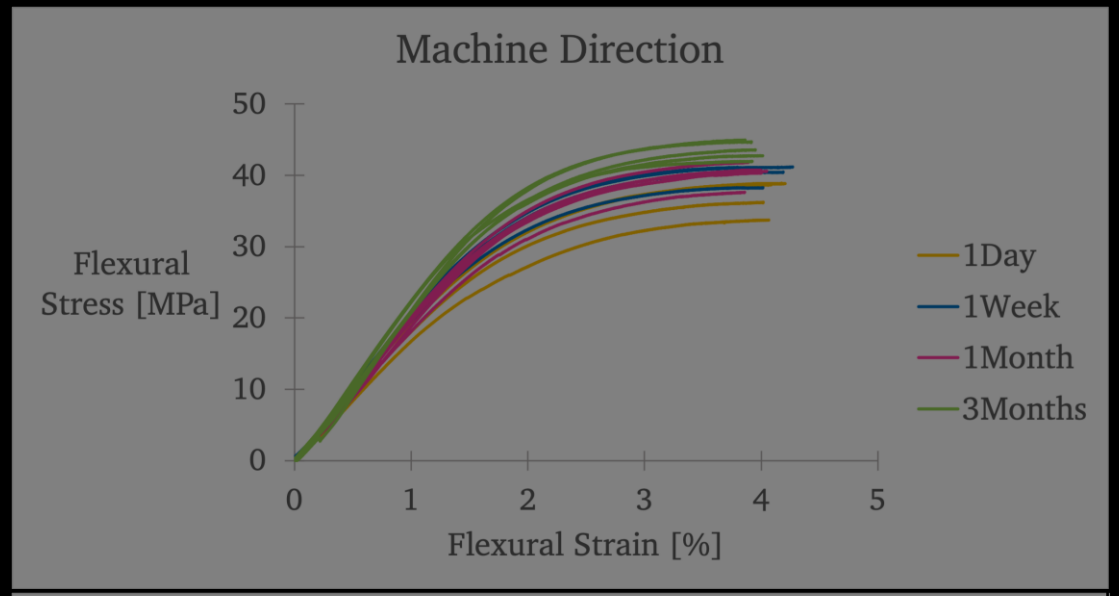
Materials	BOPP films
Hot compaction	125°C 60 seconds dwell time 39 bar
Characterization at different time slots	3-point bending test Drop weight impact test Differential Scanning Calorimetry

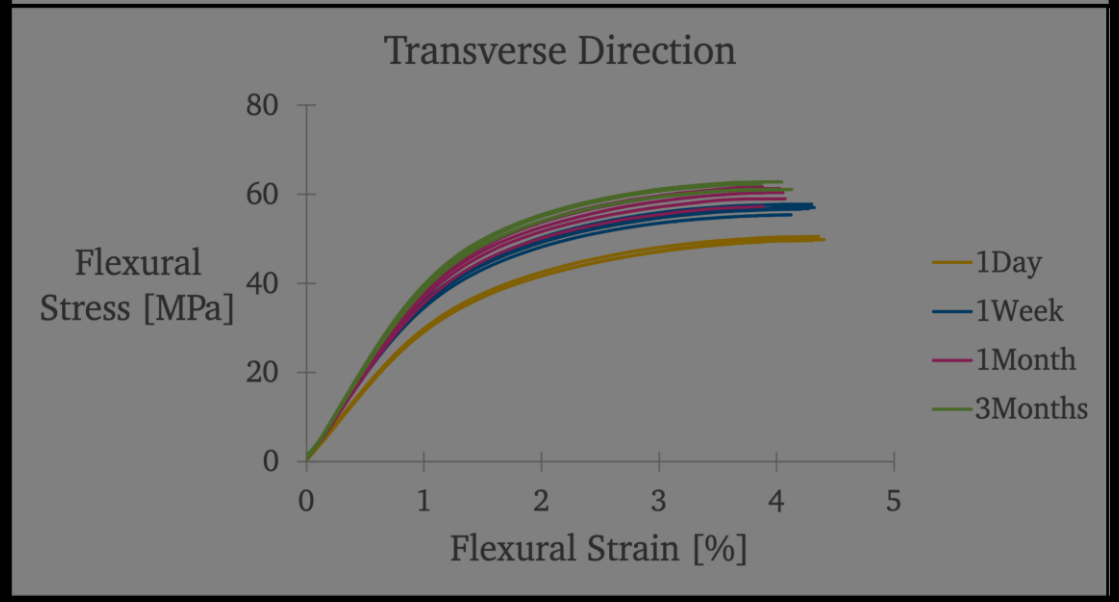
Suitcase shell level

Materials	
Characterization at different time slots	3-point bending test Tensile test Annealing at 40°C and 60°C Differential Scanning Calorimetry

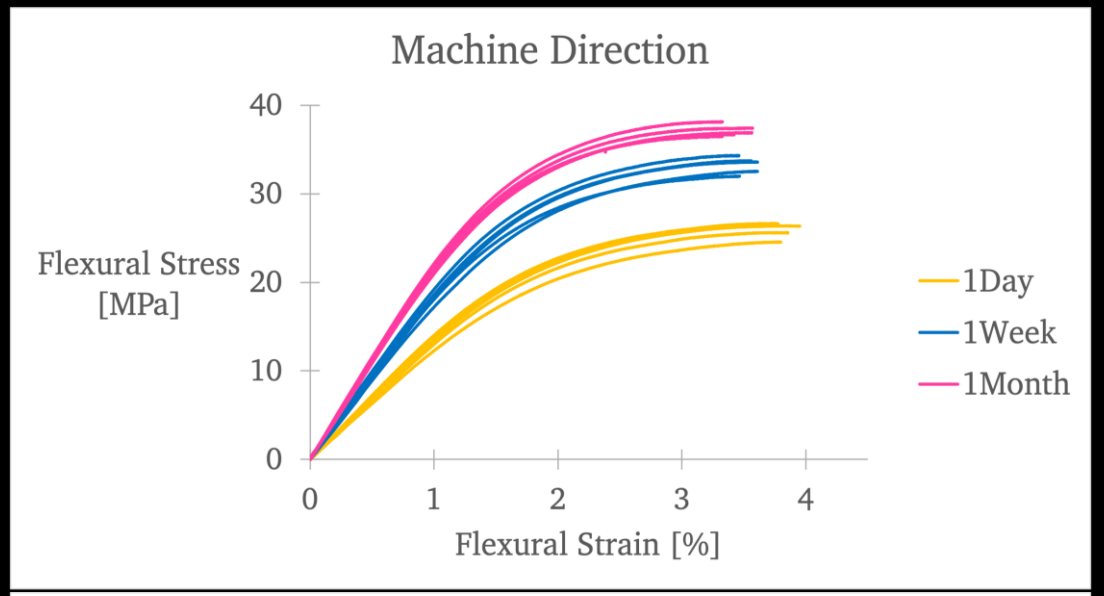
Three-point bending test results

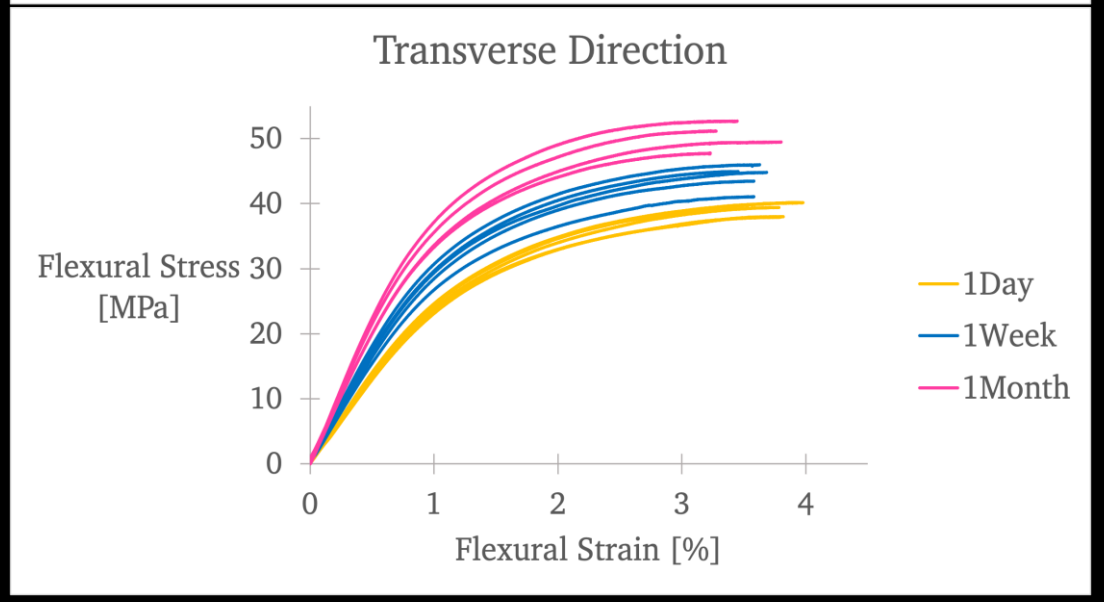
Laminate level



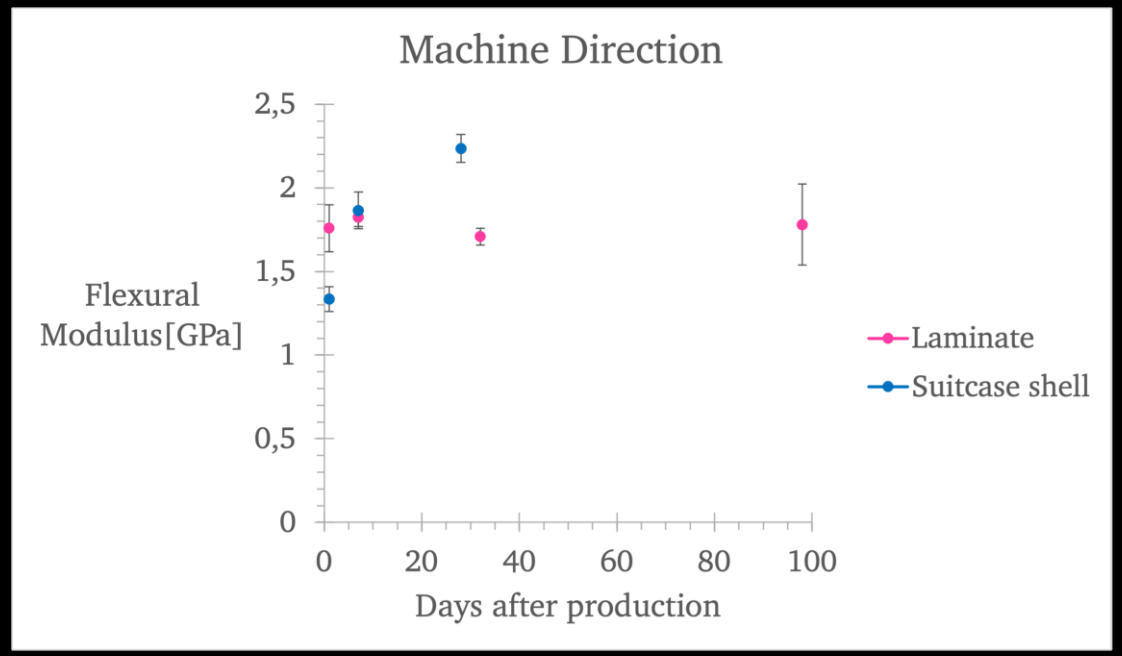


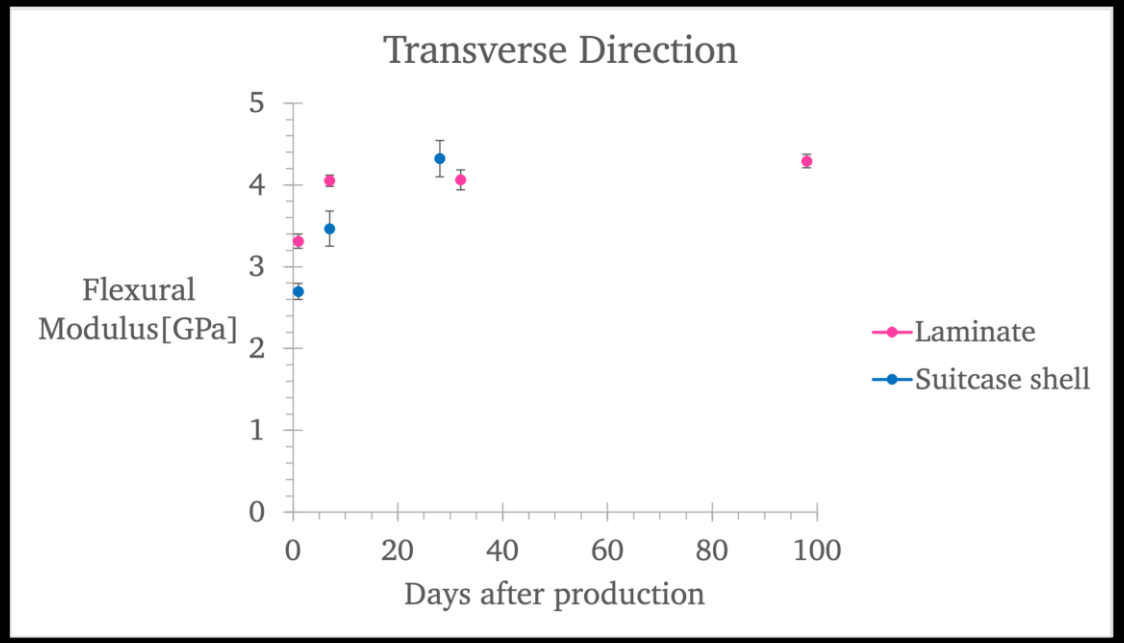
Suitcase level





Three-point bending test results





Gaps between timeslots statistically analyzed

Laminate level

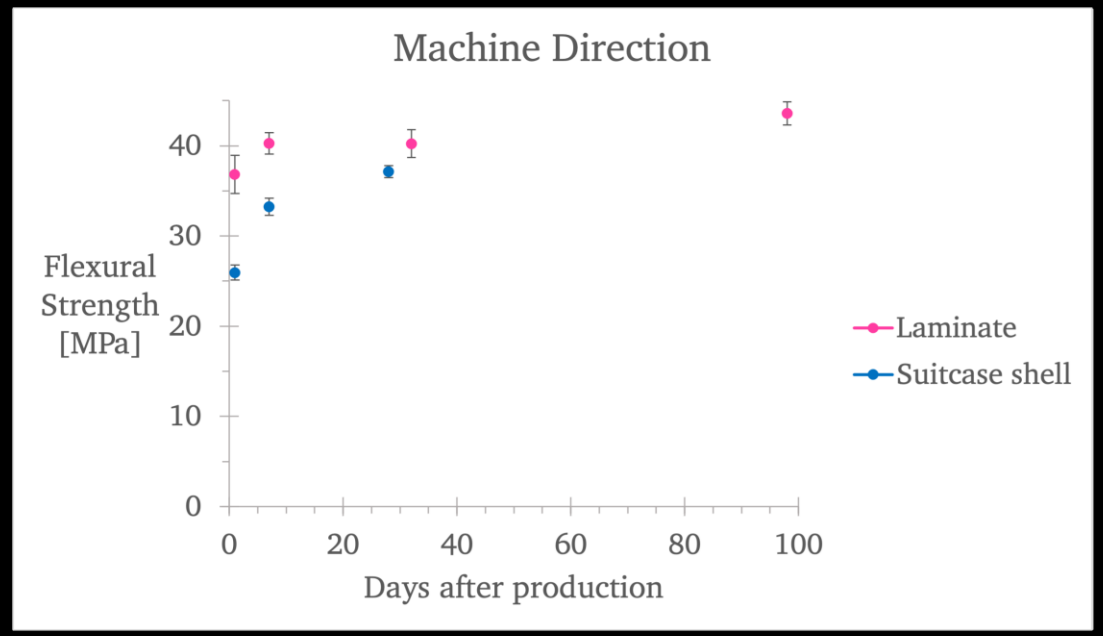
- MD: No significant difference
- TD: +30% in 3 months
- Stabilization between 1 week and 1 month

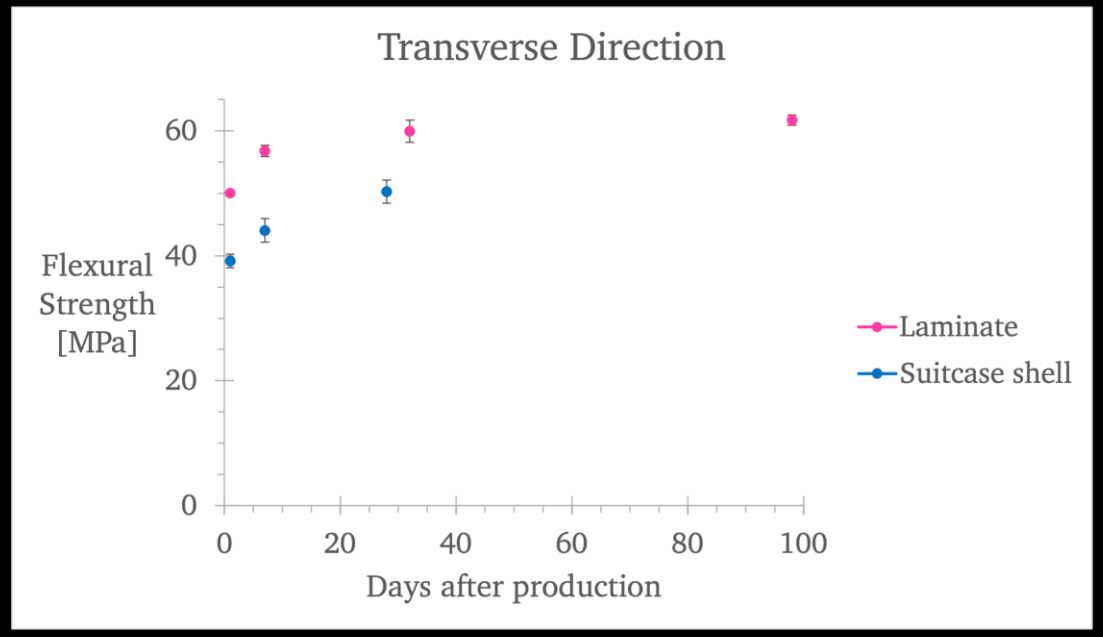
Suitcase level

- MD: +68% in 1 month
- TD: +60% in 1 month
- Slower stabilization
- Influence of storage condition
- Influence of thermoforming process

MD = Machine Direction; TD = Transverse Direction

Three-point bending test results





Gaps between timeslots statistically analyzed

Laminate level

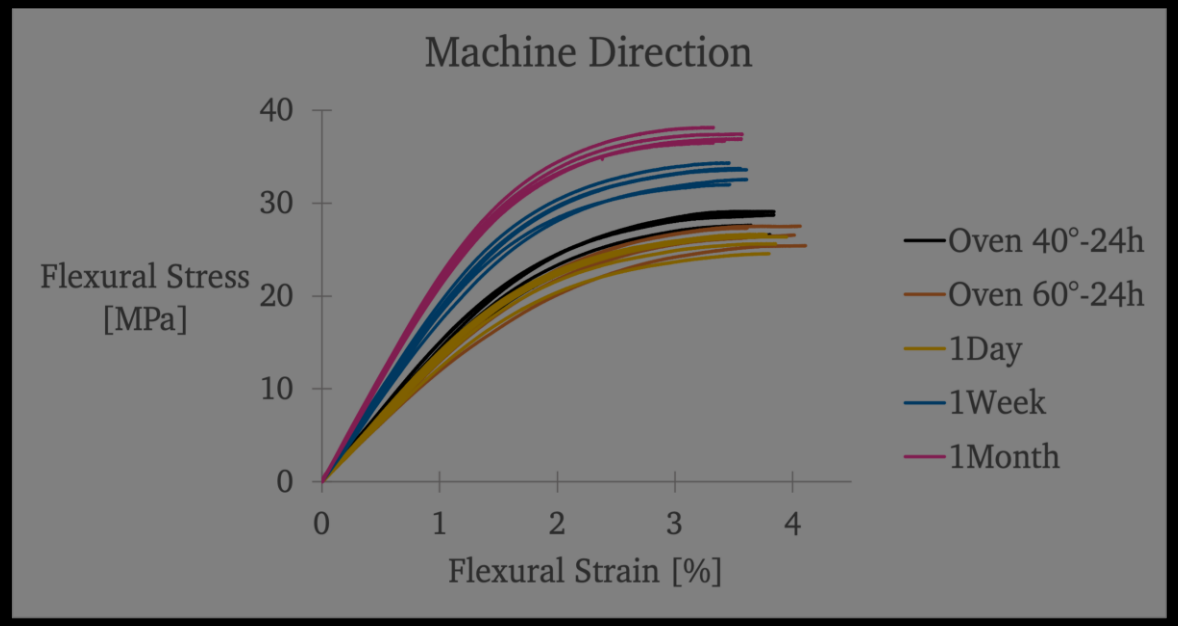
- MD: +18% in 3 months
- TD: +21% in 3 months
- Stabilization between 1 week and 1 month

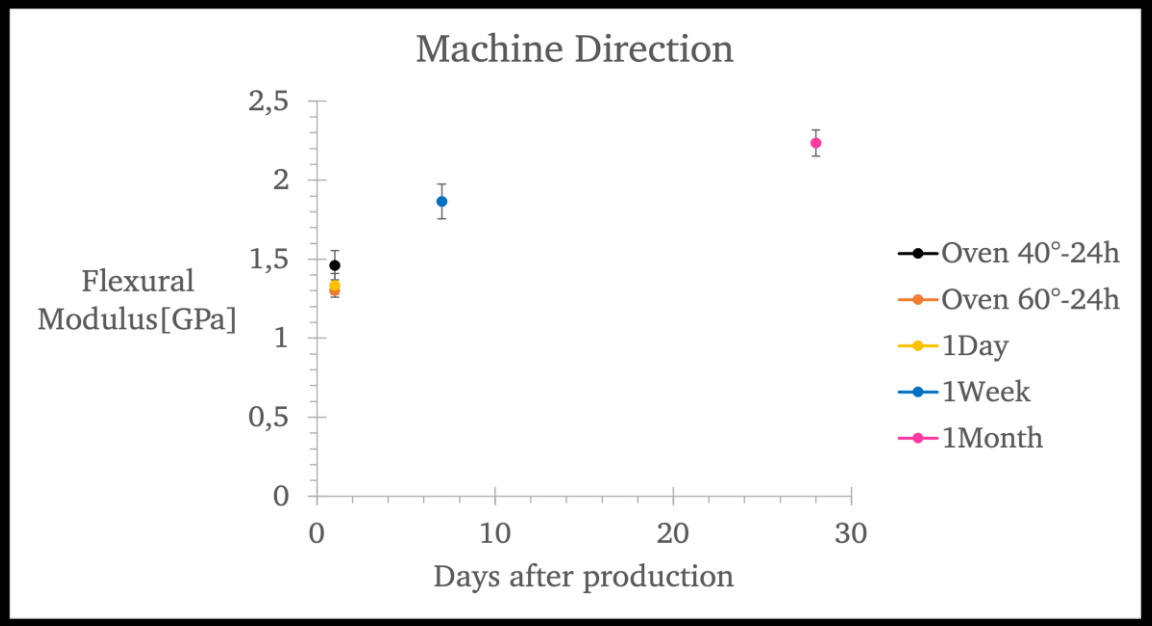
Suitcase level

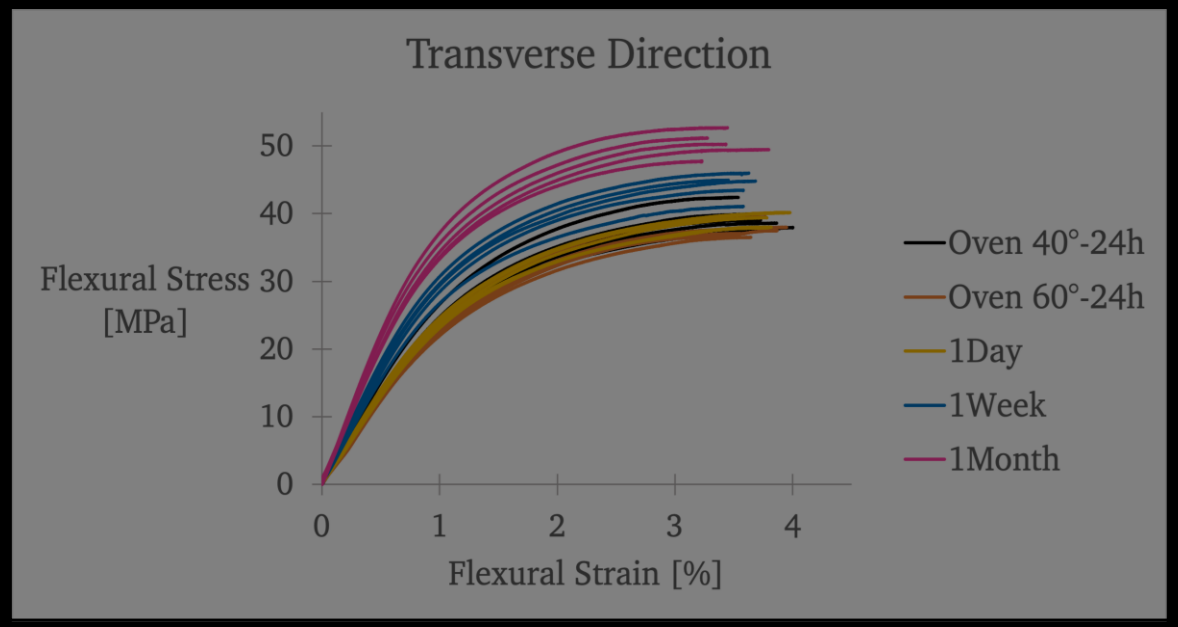
- MD: +43% in 1 month
- TD: +28% in 1 month
- Slower stabilization
- Influence of storage condition
- Influence of thermoforming process

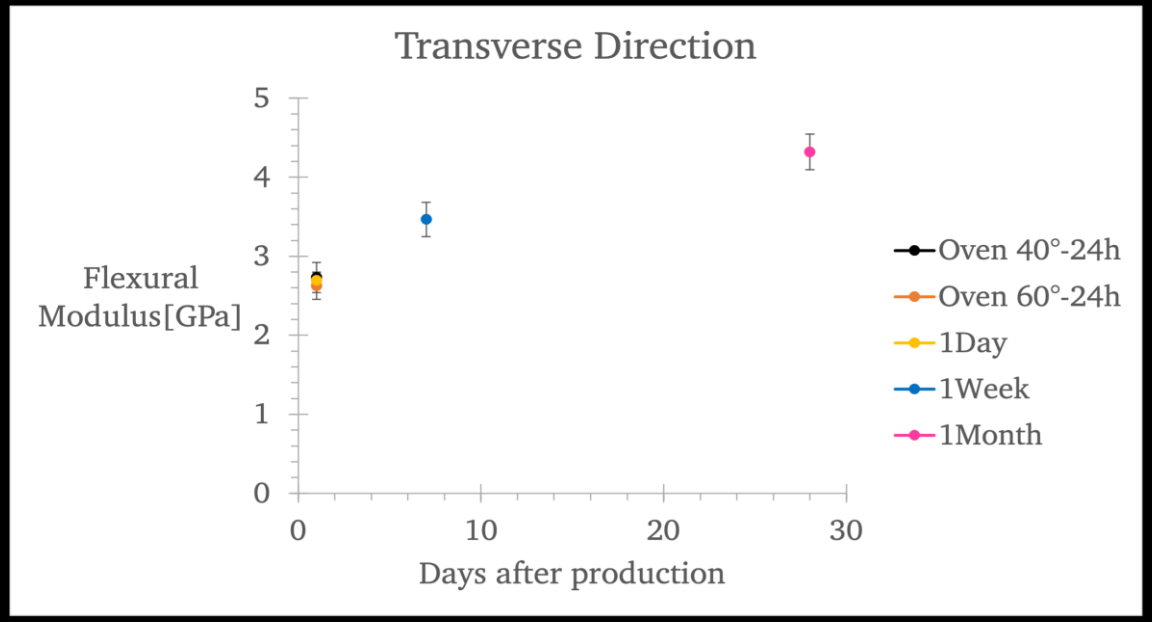
MD = Machine Direction; TD = Transverse Direction

Annealing treatment – suitcase level

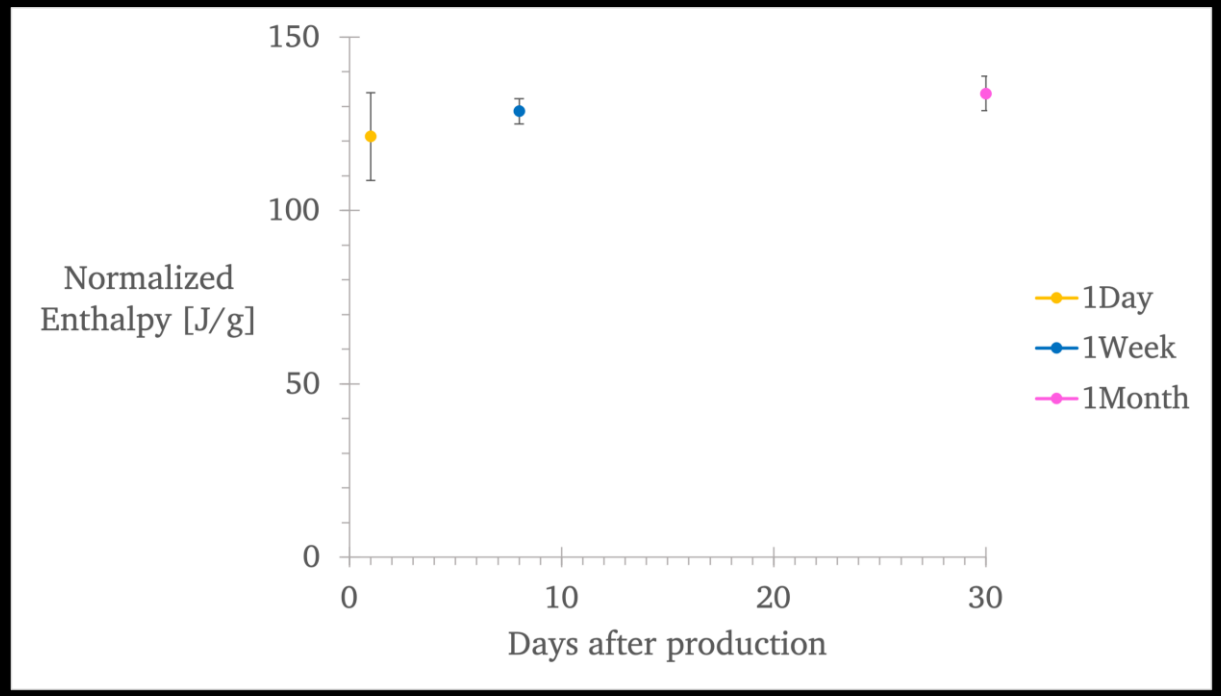




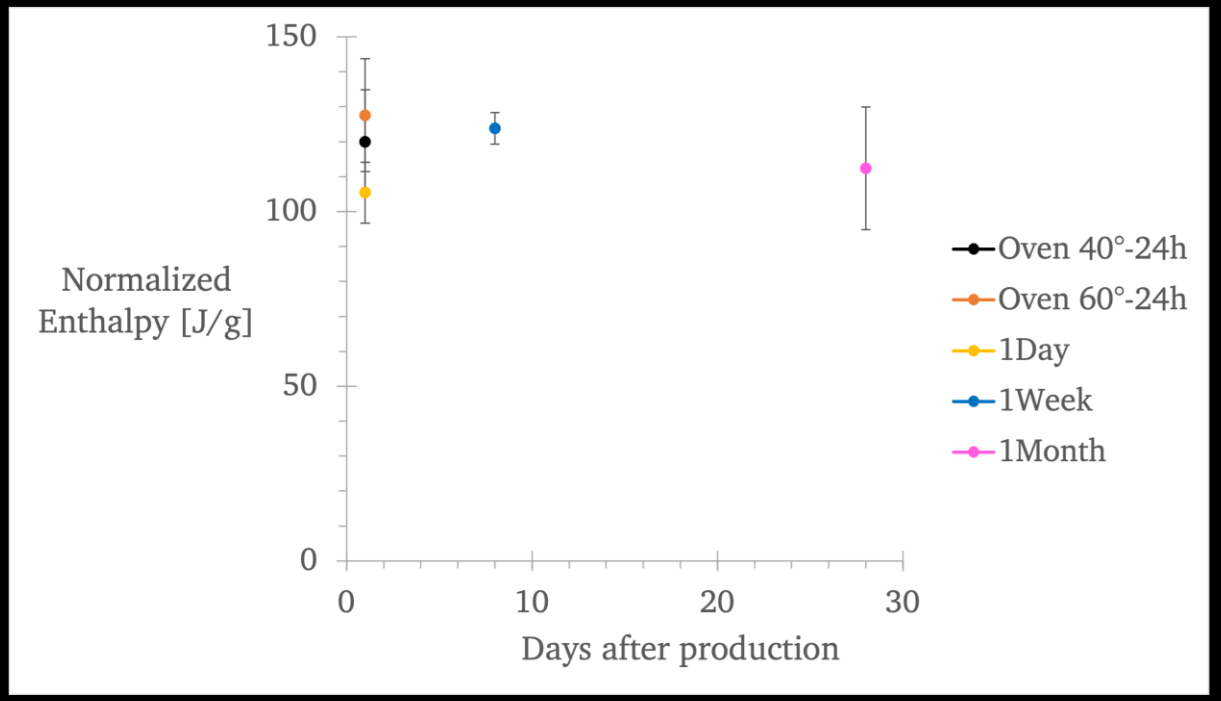




DSC analysis



Laminate level

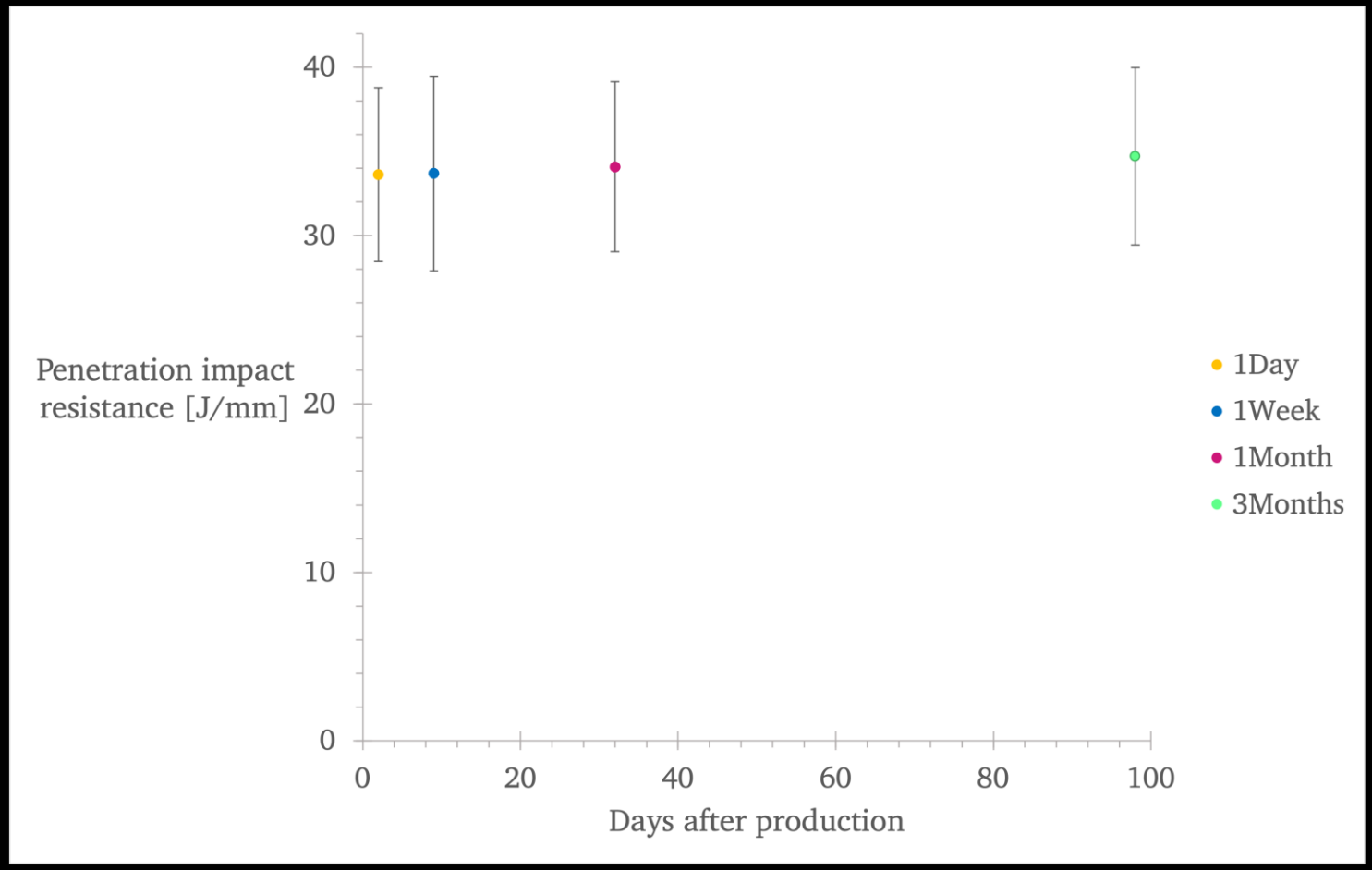


Suitcase level

- No change in crystalline phase
- Amorphous phase is responsible of mechanical properties time-dependency

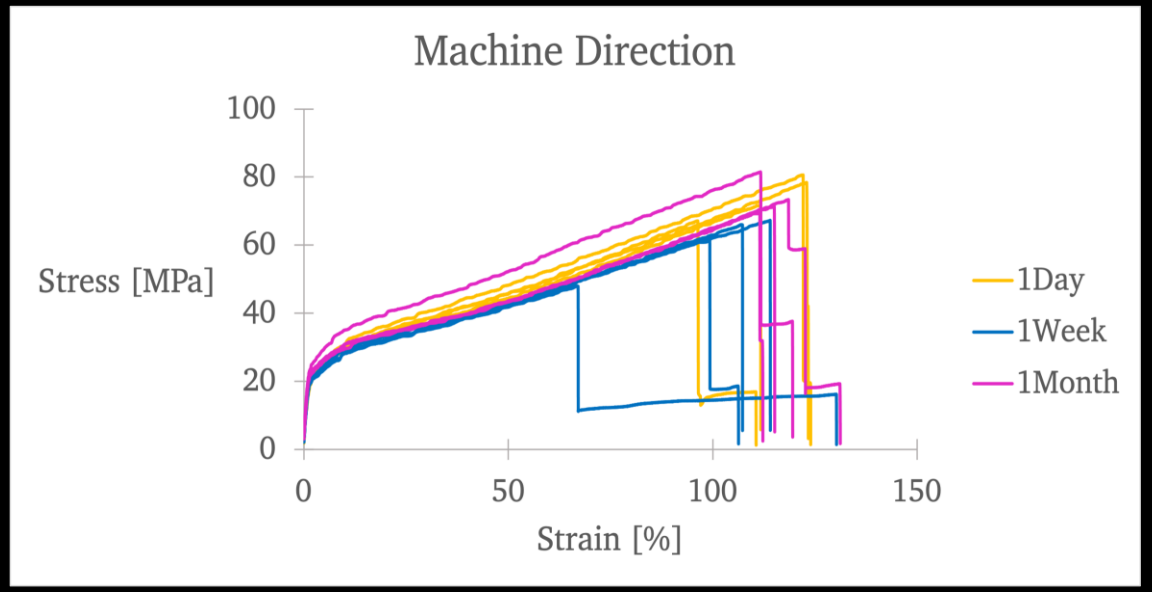
- Crystallinity change between 1 Day - 1 Week

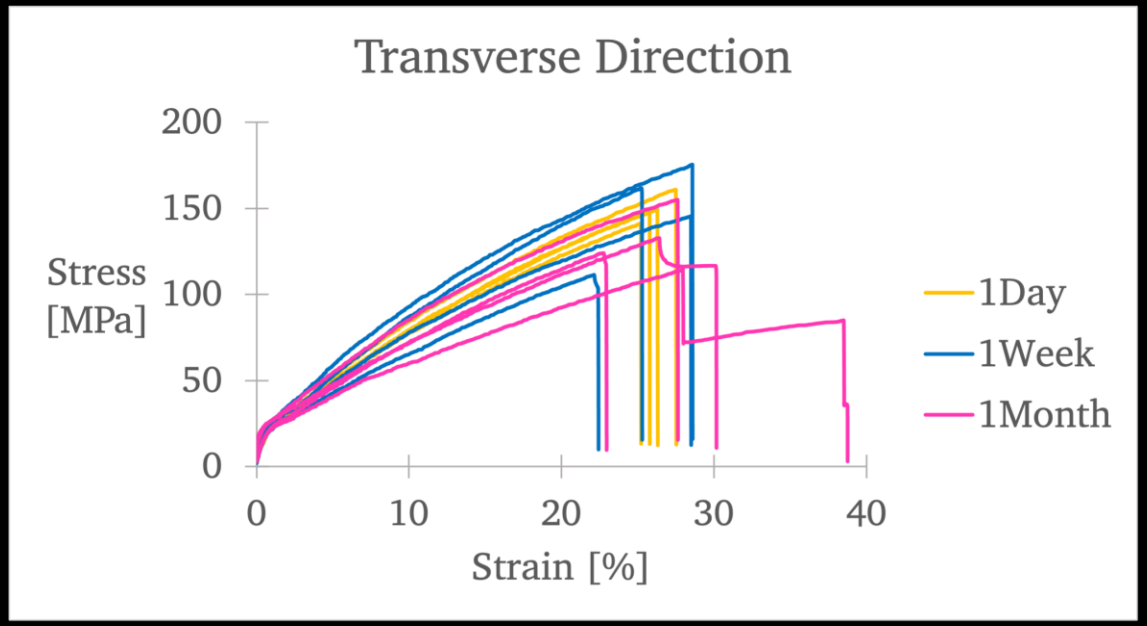
Impact test results – laminate level



Impact tests can be performed at any time after the production

Tensile test results – suitcase level





Gaps between timeslots statistically analyzed

No significant gaps

- Elastic modulus
- Failure stress
- Failure strain

Significant gap between 1 week and 1 month

- Yield point
- Resilience

No enough data points between 0.1% - 0.3% of the strain

Cutting process

CONCLUSIONS

Time-dependency analysis

Laminate level

Impact resistance is **NOT AFFECTED** by time

Flexural properties are **TIME-DEPENDENT**

Ideal testing time: ANYTIME

BETWEEN ONE WEEK AND ONE MONTH

Suitcase level

Crystallinity degree is **NOT AFFECTED** by time

Flexural properties are **TIME-DEPENDENT**

Ideal **Samsonite** testing time:
AT LEAST AFTER ONE MONTH

Annealing

Temperature does **NOT ACCELERATE** the time-dependency behavior

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