# Improved Level and Control of Stiffness

A joint action of 18 mills, converters and suppliers supported by Wageningen UR Paper and Board

Robin Sinke
Wageningen UR Paper and Board

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## Introduction - Wageningen UR Paper and Board

**Wageningen University**
location: **Wageningen**

**8 research centers**
location: **Wageningen,** Lelystad, Ijmuiden, The Hague

Agrotechnology and Food Innovations: **Paper and Board Research**

## Introduction - research themes paper and board

- Fibre Raw Materials: Fibre quality and choice related to processing and end product requirements
- Fibre Processing: Reduced energy consumption during fibre processing and in the total paper production line
- Papermaking Chemistry: Synthesis of new or more effective chemicals based on natural raw materials
- End Product Quality: Insight in product requirements based on converting and consumer demands, enhancing end product performance and development of packaging
- By-stream Upgrading / Processing: Creating commercial value for by-streams from pulp and paper production processes

## Project motivation

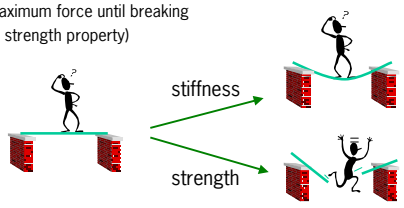
'Optimisation Stiffness of Paper and Board'

- Stiffness is one of the most important quality parameters for a lot of paper and board applications
- Workshop and discussions with industry 2001
  - Miscommunication about stiffness
  - Great variety in analysis methods, norms and standards
  - Significant influence of climate conditions
  - How to optimise and control stiffness?

Centre of Competence Paper and Board
Project in co-operation with Centre of Competence Paper and Board

## Background: what is stiffness?

- Differences between strength and other properties
  - stiffness vs. strength
    - stiffness: resistance against deformation
    - strength: maximum force until breaking
    - (e.g. SCT is strength property)



## Background: what is stiffness?

- Stiffness is a construction property, e.g. multilayer board, box
- The way and kind of load on construction determines the material specifications:
  - modulus of Elasticity, E
  - thickness, d
- Important to distinguish between different kinds of stiffness
  - Bending stiffness ~ $E \cdot d^3$
  - Tensile stiffness / Compression stiffness ~ $E \cdot d$
  - Torsion stiffness

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## Requirements

- Application determines specifications:
  - processability
  - practical use
  - use in construction, possibility of stacking etc.
- Often compromise between stiffness, strength and optical properties
- Requirements in daily practice
  - customer wants 'fit for purpose'
- Climate conditions (temperature and humidity influences)
  - practical climate conditions: -20 - 70°C (or higher), 10 - 95% R.H. (transport, storage and user conditions)
  - standard measurements at 23°C, 50% R.H.

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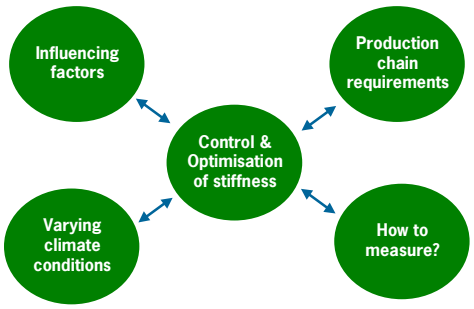
## Requirements

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## Participants

- Paper and board mills and customers
- Suppliers of chemicals, fibre raw materials, measuring equipment and paper
- Wageningen UR Paper and Board
- Centre of Competence Paper and Board

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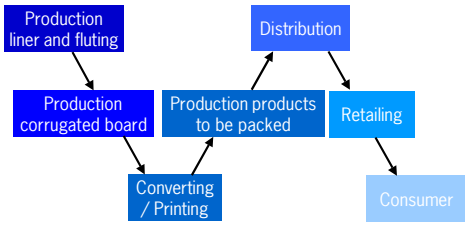
## Chain optimisation

- The production chain of board material to end product use
- Example: corrugated board chain

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## Chain optimisation - challenges

- Different viewpoints from producers and customers
- Most important issue: communication with customers
- Different, but inter-related chains for corrugated board, solid board and folding box board
- Start for better communication and further optimisation in the production chain in the future

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## Optimisation of Stiffness

- Differences issues for board industry vs. graphic paper industry

board: stiffness primary issue
(increasing importance due to deteriorating raw material and higher demands)

graphic paper: stiffness side issue (with tolerance value range)
(strength and surface properties more important)

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## Optimisation of Stiffness - issues

- Optimisation research - topics
  - stiffness improvement
    (partly: thickness improvement)
  - stiffness at high humidity conditions

by
- use of starch / chemicals / glues
- use of filler materials
- construction of multilayer board
- improved selection of fibre raw materials

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## Optimisation of Stiffness - influence of humidity

- Relevance
  - daily use of packaging in different climate conditions
  - variations from 10 - 95% R.H. (at varying temperature)
  - bad performance resulting in high product losses
- Todays practice
  higher strength and stiffness at standard climate conditions
  *through*
  higher grammage, increased use of starch, stronger cover papers etc.
  *resulting in*
  higher costs, increased tonnage of packaging material

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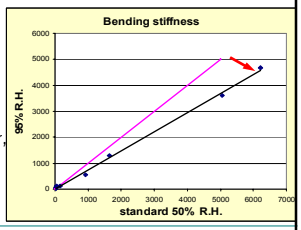
## Optimisation of Stiffness - influence of humidity

- *Higher initial stiffness ⇒ higher stiffness at high humidity*
- Example
  decrease of bending stiffness to 73%
  of original value from 50% R.H. to 95% R.H.

comparable results for
tensile strength and SCT

Regardless of the type of paper!
(70 - 1000 grams, single-/multilayer, virgin/recovered fibres)

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## Optimisation of Stiffness - two cases

- **Stiffness: methods, conditions and applications**

- **Determining aspects of laminating paper**

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## Optimisation of Stiffness - case 1

- ***Stiffness: methods, conditions and applications***

- Determining aspects of laminating paper

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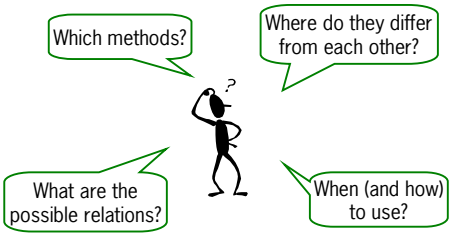
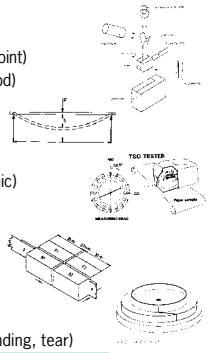
## Stiffness – methods, conditions and application



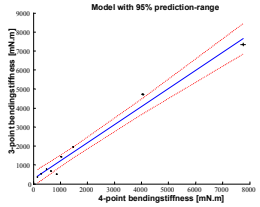

## Stiffness methods

- Principles
  - Bending: static (2-point, 3-point, 4-point) dynamic (resonance method)
  - Tensile: static (tensile test) dynamic (TSO/TSI ultrasonic)
  - Compression: SCT, RCT
  - Others: burst strength (tensile, bending, tear)




## Correlations between methods

- Paper and board samples
  - from 70 grams graphic paper to 2000 grams board
- Direct correlations between several measurement methods
- Limitations




## Measurement and environmental conditions

- Measurement conditions
  - Measurements performed according to ISO standards
  - Personal influence may be affecting results
- Environmental conditions
  - Laboratory condition 23°C/50 % RH
  - Moisture is affecting all strength properties

## Results

- Possibilities for improved communication
- Fitness for use
- Prediction of approximate stiffness levels for different methods
- Awareness of moisture content and other environmental conditions

## Optimisation of Stiffness - case 2

- Stiffness: methods, conditions and applications

- ***Determining aspects of laminating paper***

## Determining aspects of laminating paper

- Laminating paper for solid board
- Requirements:
  - Optical: brightness, shades, opacity, dot count
  - Processing: friction coefficient, dennison wax test, porosity, water absorption, tensile strength
  - Endproduct (board): stiffness, strength
  - Endproduct (box): box compression

  and others?

## Model

- Theoretical bending stiffness for a symmetrical 3-layer model

  $S_{endproduct} = f(E_{bending,\ board};\ d_{board};\ E_{tensile,\ paper};\ d_{endproduct})$

- Question:
  - Is there a relation between the theoretical bending stiffness and stiffness measured in practice?
- If so:
  - Which testing methods predict the best?
  - Which aspects have the greatest influence?
  - Which are determining aspects of laminating paper and board?
  - How can these aspects be optimised?

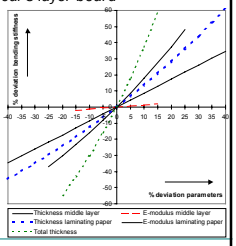
## Experiment

- Conditions
  - 13 liners tested
  - Varying grammage and properties
  - Each liner laminated on both sides of a standard board (400 g/m$^2$)
  - On a full industrial laminating machine with constant speed and sizing
  - Liners, board and laminated board tested on different properties with several testing methods

*Laminating machine at Coldenhove Papier*

## Results

- Theoretical formula gives a good description of practice
- Limiting conditions e.g:
  - Laminating papers should be < 50% of the thickness of the board
  - Correlation with practice only for symmetrical 3-layer board
- Determining aspects:
  - Laminating paper: thickness
    E-modulus tensile
  - Board: thickness
    (E-modulus bending)




*Sensitivity analysis (model prediction) for laminated paper and board*

## Conclusions

- Model is easy to use (with the right precautions)
- Close co-operation positive
  - however, clients and competitors within one project can cause sub-optimal situations
- Possibility for determining price / quality ratio, also further down the production chain.
- Model has been extended already for prediction of stiffness of non-symmetrical multi-layer board

## General conclusions

'Optimisation Stiffness of Paper and Board'

- Innovations in process- and product optimisation by:
  - multidisciplinary approach: exchange of expertise
  - co-operation with customers
  - co-operation with and between suppliers
  - activities performed by all participants
  - outsourced co-ordination
- Integral approach leads to a relatively cheap way of actual optimisation and control of process and product

## General conclusions

- Results
  - increased level of knowledge on mechanical paper properties
  - awareness of applicability of stiffness measurement methods
  - decreased amount of stiffness measurements
  - step towards improved chain communication
  - possibilities, impossibilities and requirements for stiffness control
  - improved stiffness control of solid board
  - insight in significance of humidity influences

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## Questions?

### Thank you for your attention

More information:

***www.paperandboard.nl***

Contact: Robin Sinke, Tel.: +31 317 475310, E-mail: robin.sinke@wur.nl


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