Estimating strength properties online with a soft sensor

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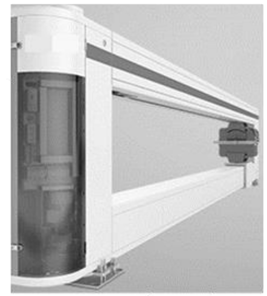
Pulp and Board Quality Measurements

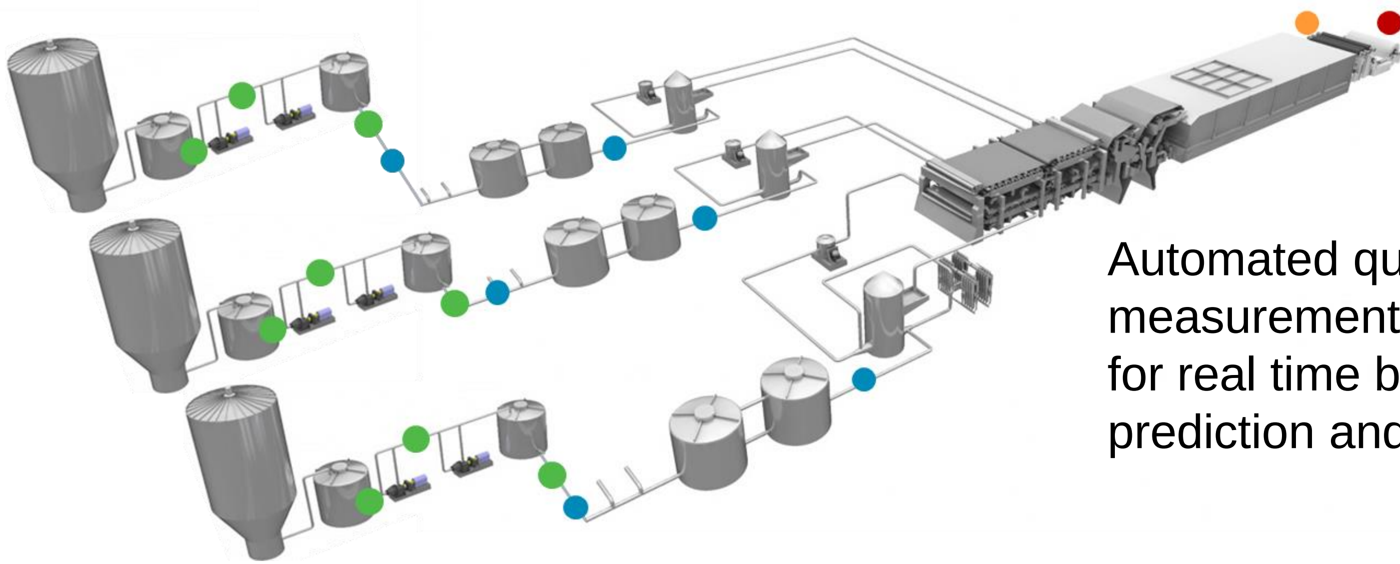
Online pulp analyzer

Automatic pulp laboratory

QCS scanner



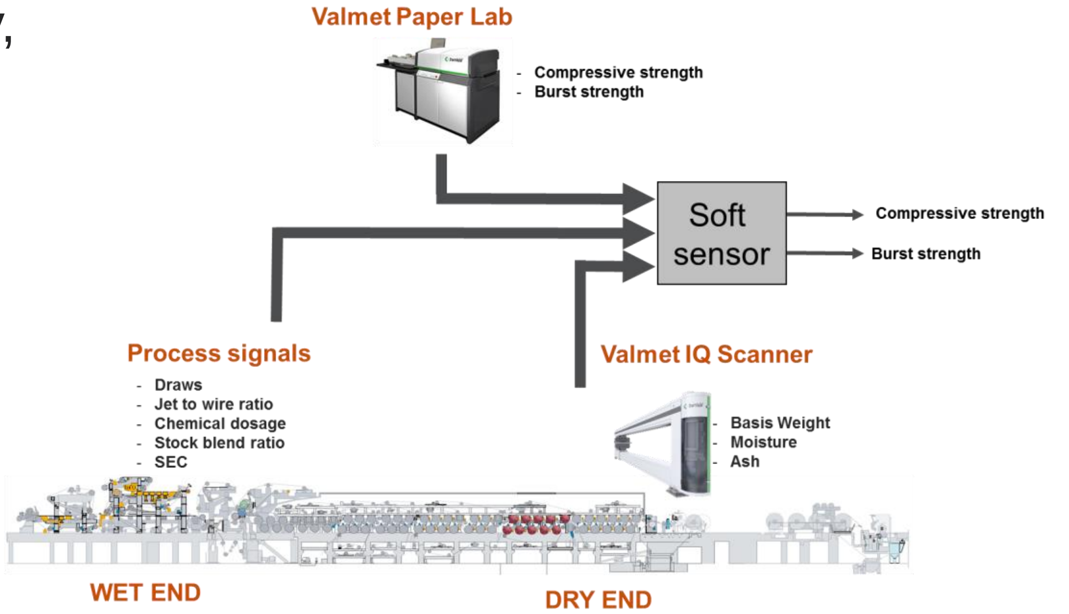
Automated paper testing laboratory



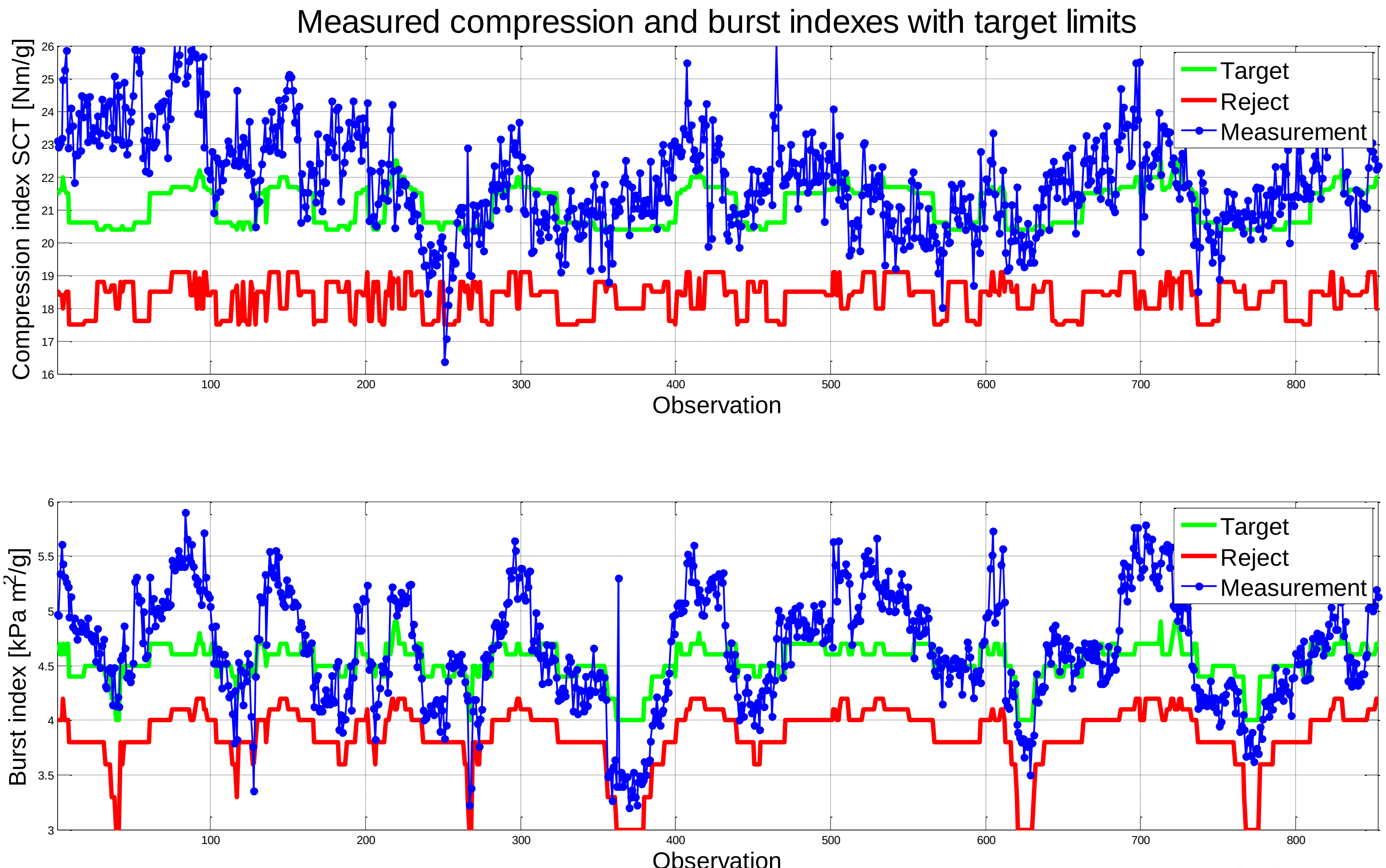
Automated quality measurements are the basis for real time board quality prediction and control

Benefit from real time quality information

- Soft sensors needed to predict future product quality, and to optimize the cost of board quality
- Measuring strength properties in traditional way the delay is significant
  - Measurement frequency is at maximum the production time of one jumbo reel
  - Slow reaction when corrections needed



Improvement potential to optimize produced quality



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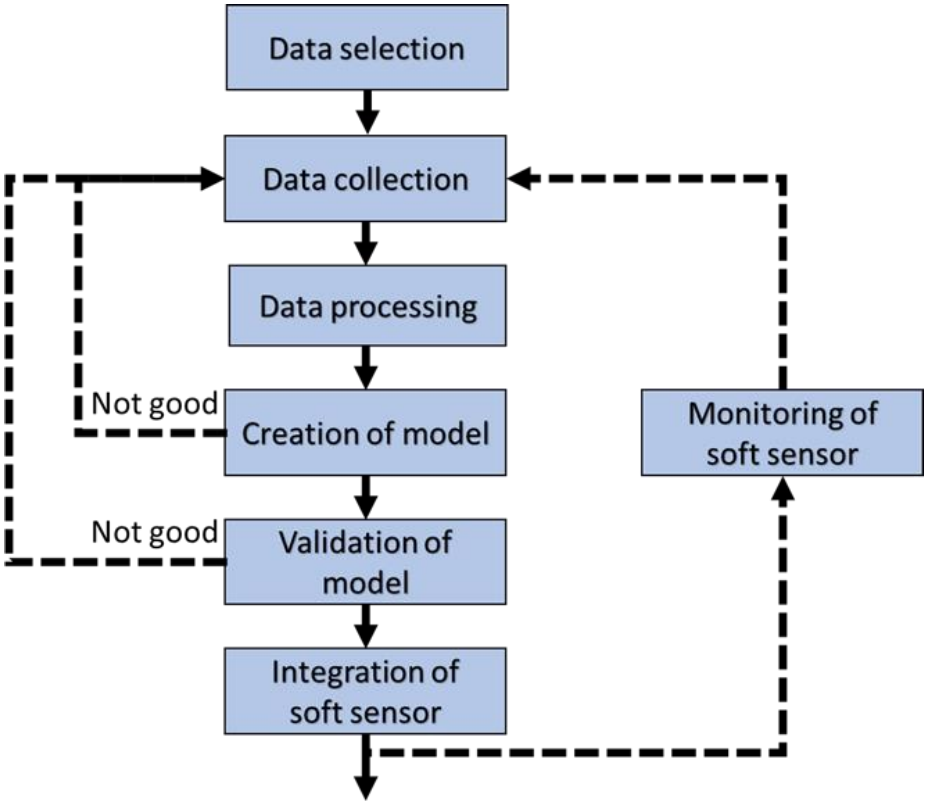
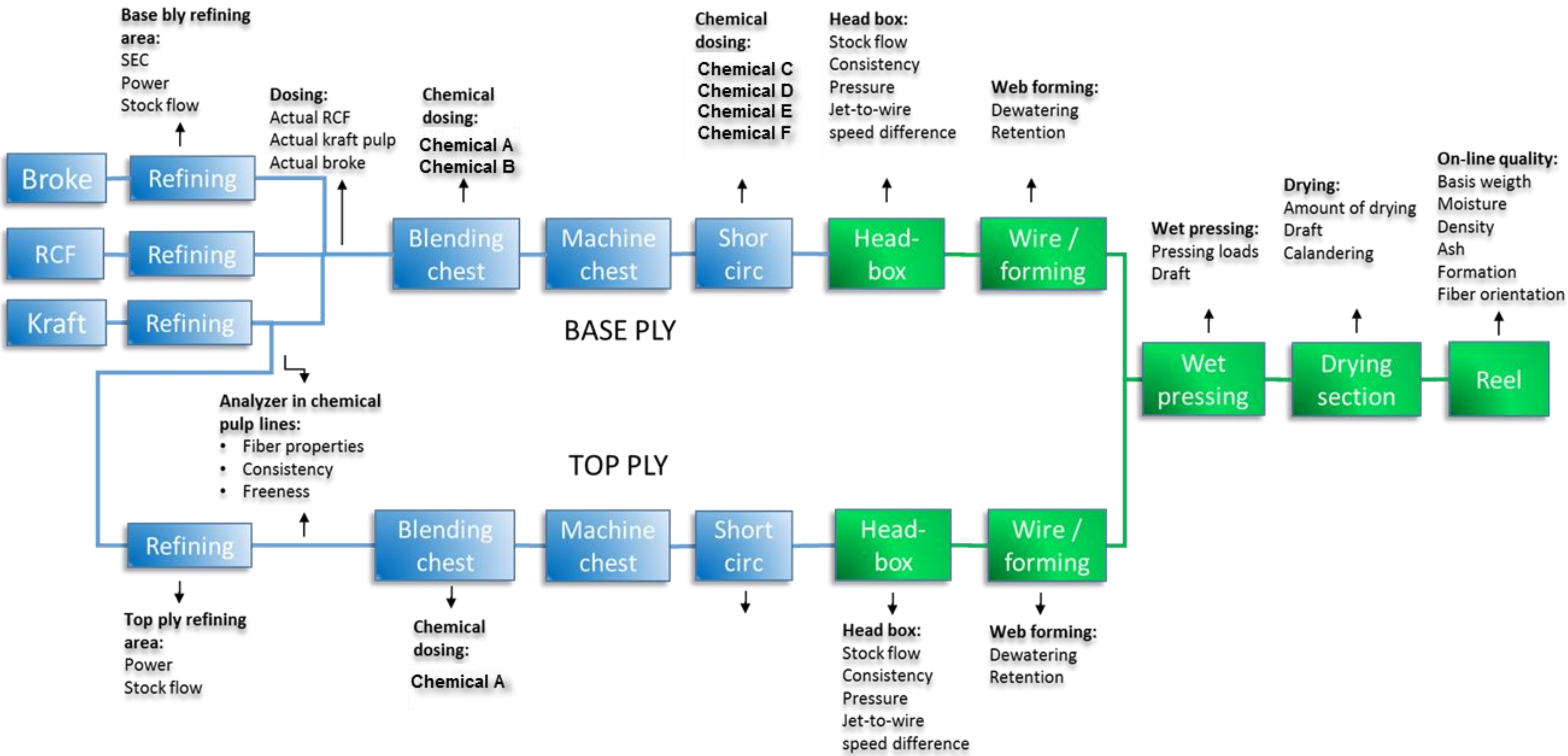
Pulp and Board Quality Soft Sensors

Soft sensor model identification process



- Soft sensors are based on empirical models
- Multivariate analysis techniques
- Desirable to have data set with many observations
- Properly clean the data
- Model inputs averaged and aligned in time
- Correlation does not necessarily equal causation
- Model validation is important
- Differences between grades can be useful for modeling

Fiber Property Soft Sensors – Mill X



- Mill X produces several grades of kraftliner board
- Data for the kraft component of the bottom and top plies of the Mill X board machine was analyzed to determine the potential for fiber property soft sensors

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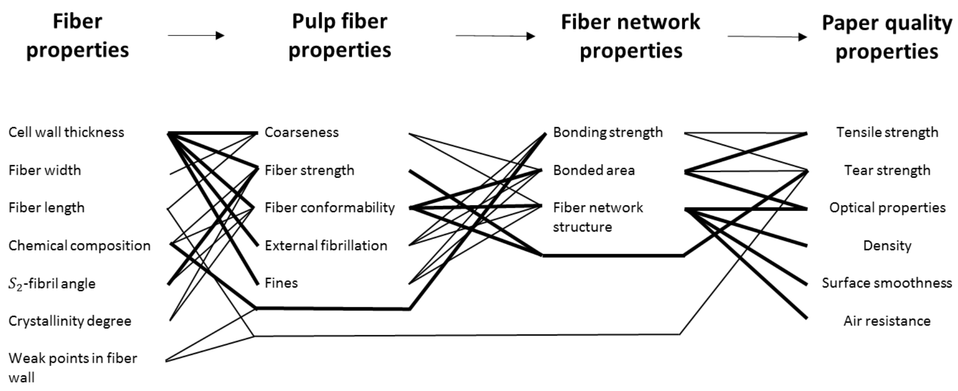
Theory behind strength properties

- The affecting factors for end products strength properties are divided into three categories:
  - Fiber strength properties
  - Fiber bonding properties
  - Fiber network properties
- It is said that roughly 80 % out of linerboard strength properites are explained by fiber properties
- Rest of the strength properties are explained with the amount of additives, process conditions etc.
- In this study case properties that can be affected in boardmaking process, are examined

Process factor	Effect on strength	Source
Pulp components	- Fiber properties	• Fellers et al (1980)
Refining	- Fiber properties - Density	• Fellers et al (1980) • Whitsitt et al (1982)
Chemicals	- Fiber bonding - Rentention	• Krogerus (2007)
Head box consistency	- Density - Orientation	• Whitsitt et al (1982)
Jet-to-wire ratio	- Orientation	• Levlin (1999)
Formerin vedenpoisto	- Formation - Retention	• McDonald et al (1998)
Wet pressing	- Density	• Pikulik et al (1998) • Seth et al (1979)
Size pressing	- Density	• Whitsitt et al (1982)
Draw differences	- Drying shrinkage	• Kajanto (2008) • Whitsitt et al (1982)

Theory behind strength properties



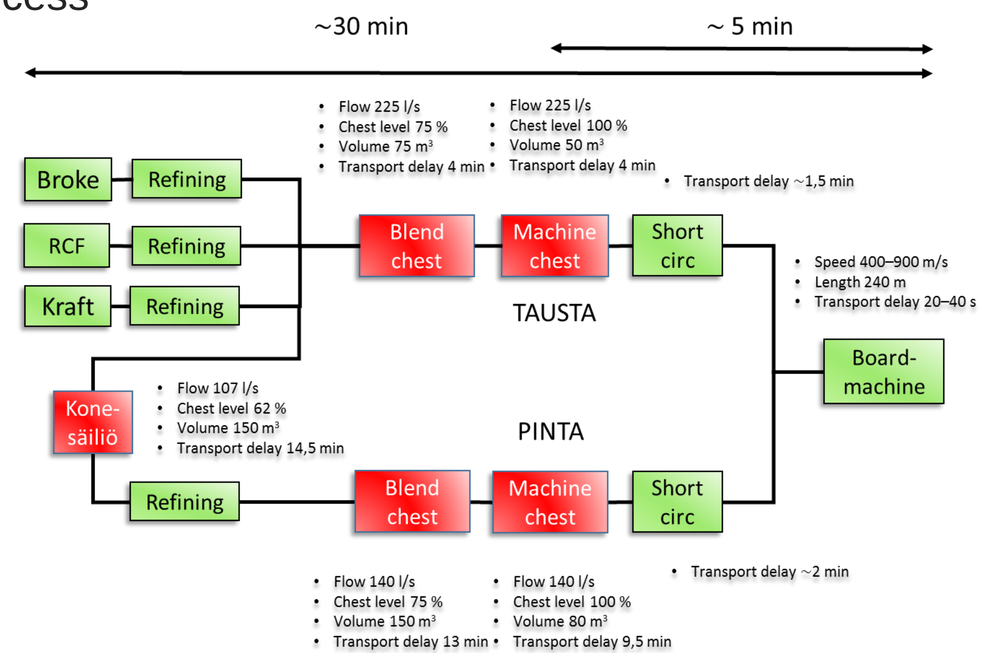
L. Paavilainen, Influence of fibre morphology and processing on the softwood sulphate pulp fibre and paper properties, Doctoral thesis, Helsinki, 1993, 155 p.

	Compression strength	Tensile strength
REFINING	+	+
FIBER ORIENTATION MD	+	++
FIBER ORIENTATION CD	–	– –
WET PRESSING	+	+
SIZE PRESSING	++	++
DRYING SHRINKAGE	– –	–
MOISTURE	– –	–

I. Kajanto, Structural mechanics of paper and board, in: K.J. Niskanen (ed.), Papermaking science and technology. Book 16, Paper physics, 2nd ed., totally updated version. ed., Finnish Paper Engineers' Association, Helsinki, 2008, pp. 229–264.

Data processing

- Requirements for the data:
  1. Paper Lab –sample moment is adjusted at the moment of a reel change
  2. Data is adjusted to the reel change time and affecting process delay is set properly
  3. Average window of data is set based on the changing dynamics of the process



Regression models for compressive strength

Compression index	Grade 1	Grade 2	Grade 3
Coefficient of determination, estimate	74 %	71 %	75 %
Coefficient of determination, prediction	68 %	63 %	71 %
Difference	6 %	8 %	4 %

Grade	Variables	
Grade 1	–	Moisture profile 2 sigma
	–	Draw of drying sections
	+	Dosing of total starch
	–	Total power of top ply refining
Grade 2	+	Orientation profile 2 sigma, top
	–	Draw of drying sections
	–	Wire speed
	+	Former water removal, top ply
	+	Dosing of total starch
Grade 3	–	Ash content measurement
	–	Moisture profile 2 sigma
	–	Draw of drying sections
	–	Former water removal, top ply
	+	Dosing of total starch

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Regression models for burst strength

Burst Index	Grade 1	Grade 2	Grade 3
Coefficient of determination, estimate	56 %	59 %	77 %
Coefficient of determination, prediction	50 %	63 %	78 %
Difference	6 %	-4 %	-1 %

Laji	Yhtälö	
Grade 1	–	Basis weigth 2 sigma
	+	Orientation 2 sigma, top
	–	Draw of drying sections vetoero
	–	Former water removal, top ply
	+	Dosing of total starch
	–	ASA adhesive dosing, base
Grade 2	–	Ash content measurement
	–	Basis weigth 2 sigma
	+	Orientation 2 sigma, pinta
	+	Total stock flow
	–	Jet-to-wire ratio, base
	+	Total SEC of refining base
Grade 3	–	Ash content measurement
	–	Basis weigth 2 sigma
	–	Jet-to-wire ratio, base
	+	Dosing of total starch
	+	Total SEC of refining base

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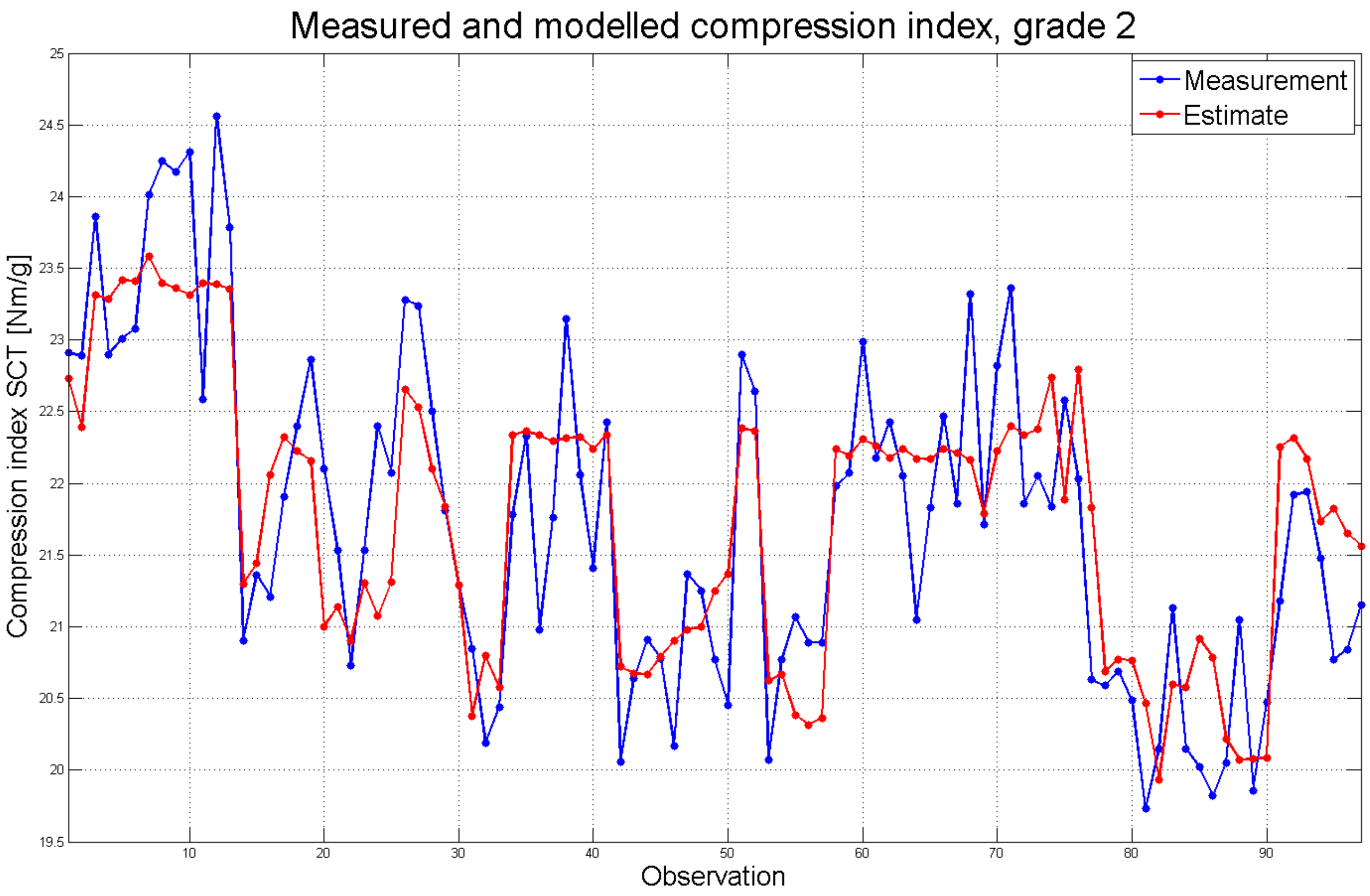
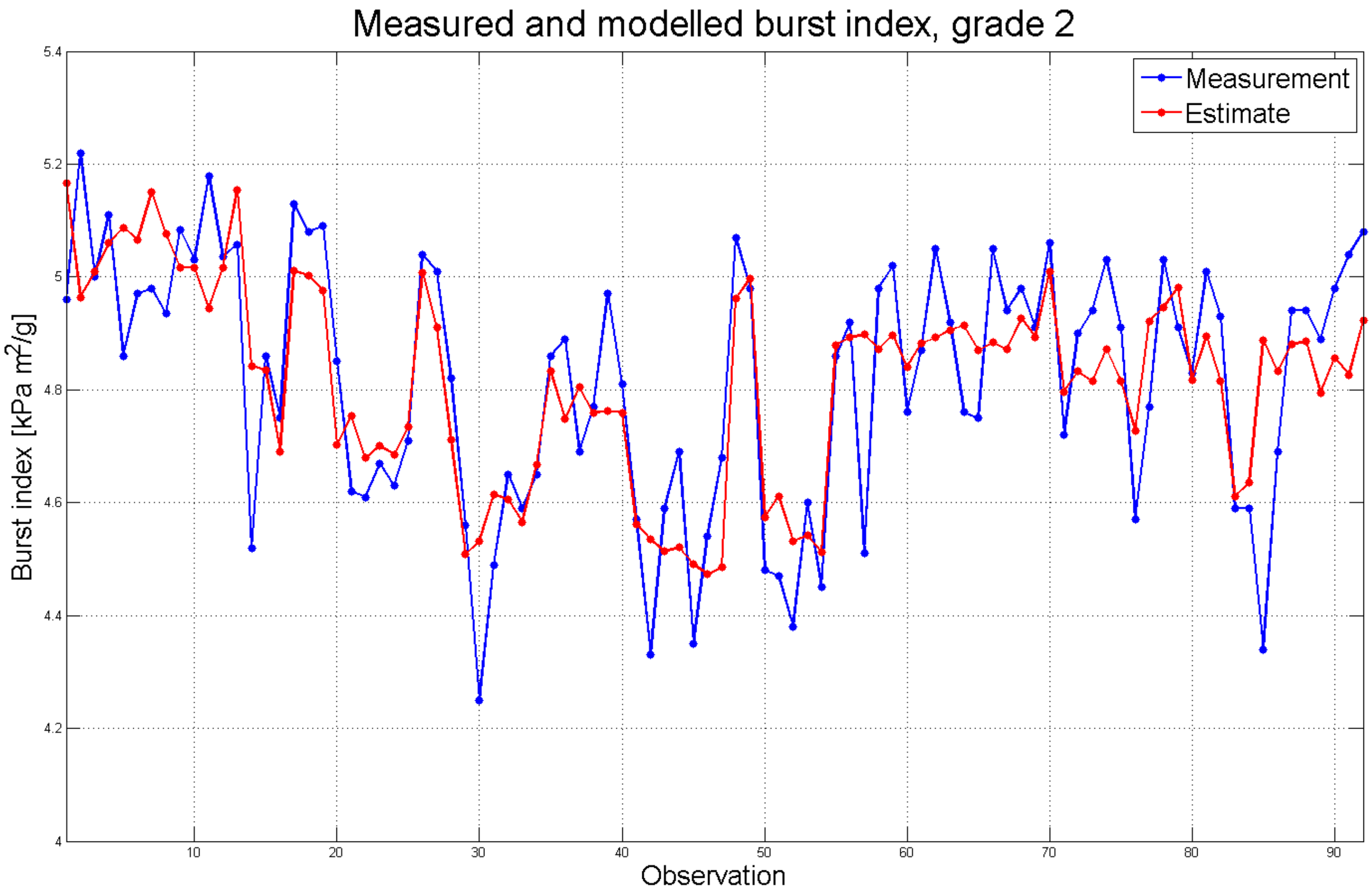
Modelling example

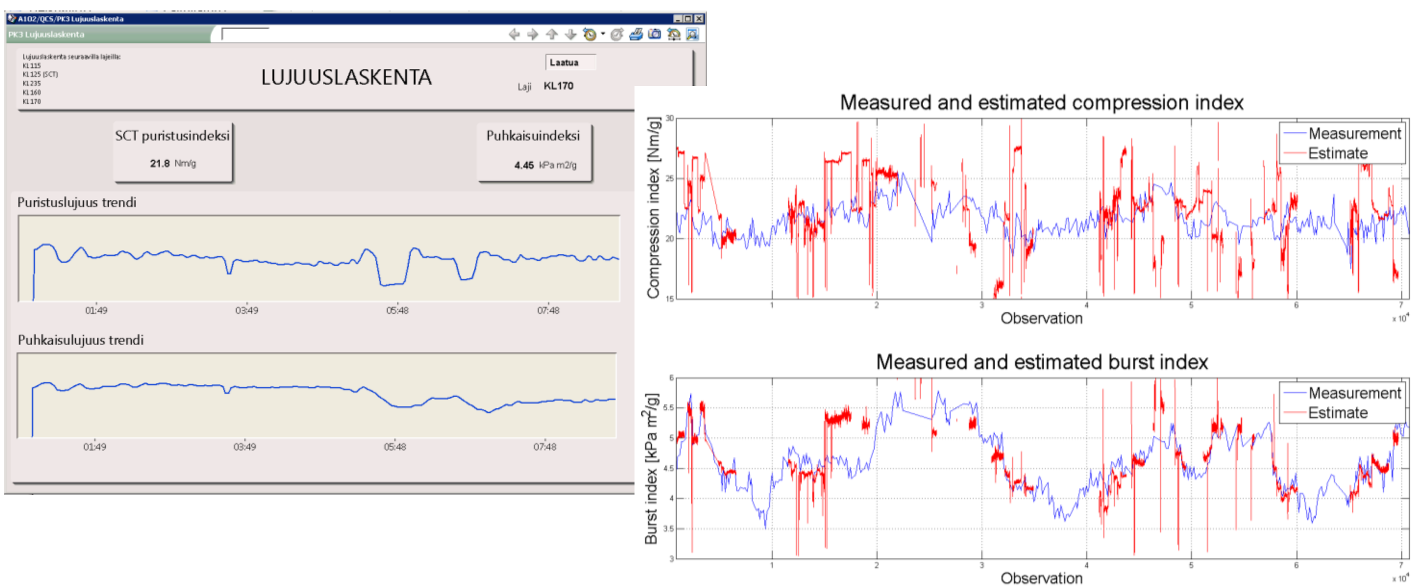


Modelling example



Examination of online application in the process

- Soft sensor is implemented to the system to eseimate compression and burst strength indexes
- The operation of soft sensor was not limited in this phase of the study
- Operating display and raw output of soft sensor in the system below



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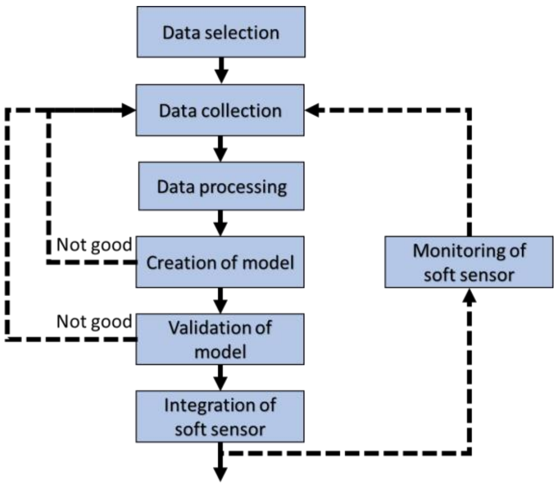
Soft sensor in action

- Soft sensor estimates the development of strength properties with good accuracy when following terms apply:
  - Explanatory process variables of the model are within the same operating range as they were during data collection
  - Inaccuracy of measurement method is noted
- The accuracy of models can be developed further
  - By collecting more data and tuning the models
  - By adding some critical measurements to process



Challenges in online estimation

- In boardmaking process the factors that are affecting board strength can be divided to two groups:
  - Variables with changing values (e. g. chemical dosing)
  - Variables with relatively constant values (e. g. press load)
- Challenges when there is variables that affect to strength but do not change much. The correlation is impossible to determine and therefore thes almost constant variable cannot be used in models
- Limitations of models. They cannot see or predict changes in process e. g. change of wire

Summary

- There is no “one size fits all” for board quality control
- Automated quality measurements are the basis for real time board quality prediction and control
- Process expertise is essential for data analysis and solution design
- Soft sensors are a to predict when and why pulp or board quality is going to change
- Model predictive control is the mechanism for adjusting the process to achieve quality objectives at minimum cost
- While each solution is customized, the process, tools, and expertise required to develop the solutions is similar

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