Enseignement – Recherche
Sciences & technologies du bois

Discovering design principles of a wood-based insulating material through multi-objective optimization

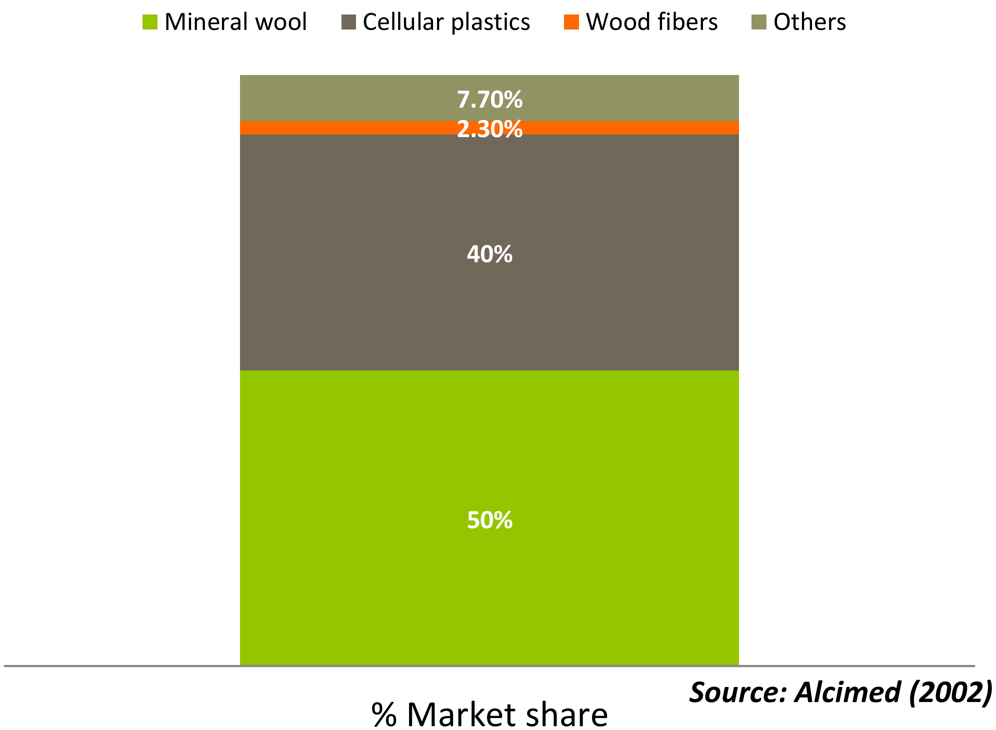
Mohamad Hobballah, Amadou Ndiaye, Franck Michaud, Mark Irle

Summary

- Context of the study
- Materials
- Methods
- Results
- Conclusions and perspectives
- Acknowledgement

Insulation products : some statistics

- Wood based insulating materials are still under used.
- Projected annual growth of 10% until 2020.



Source: Alcimed (2002)

To keep up with the 2020 expected regulations. Product development is a must

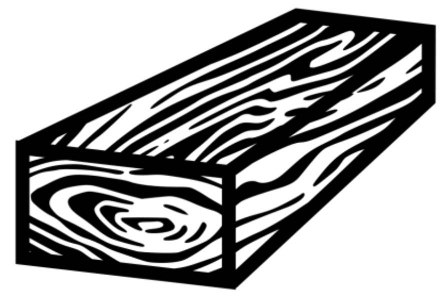
Optimization objectives

Actual product

High thermal conductivity
Low compression recovery

Research work

Desired product

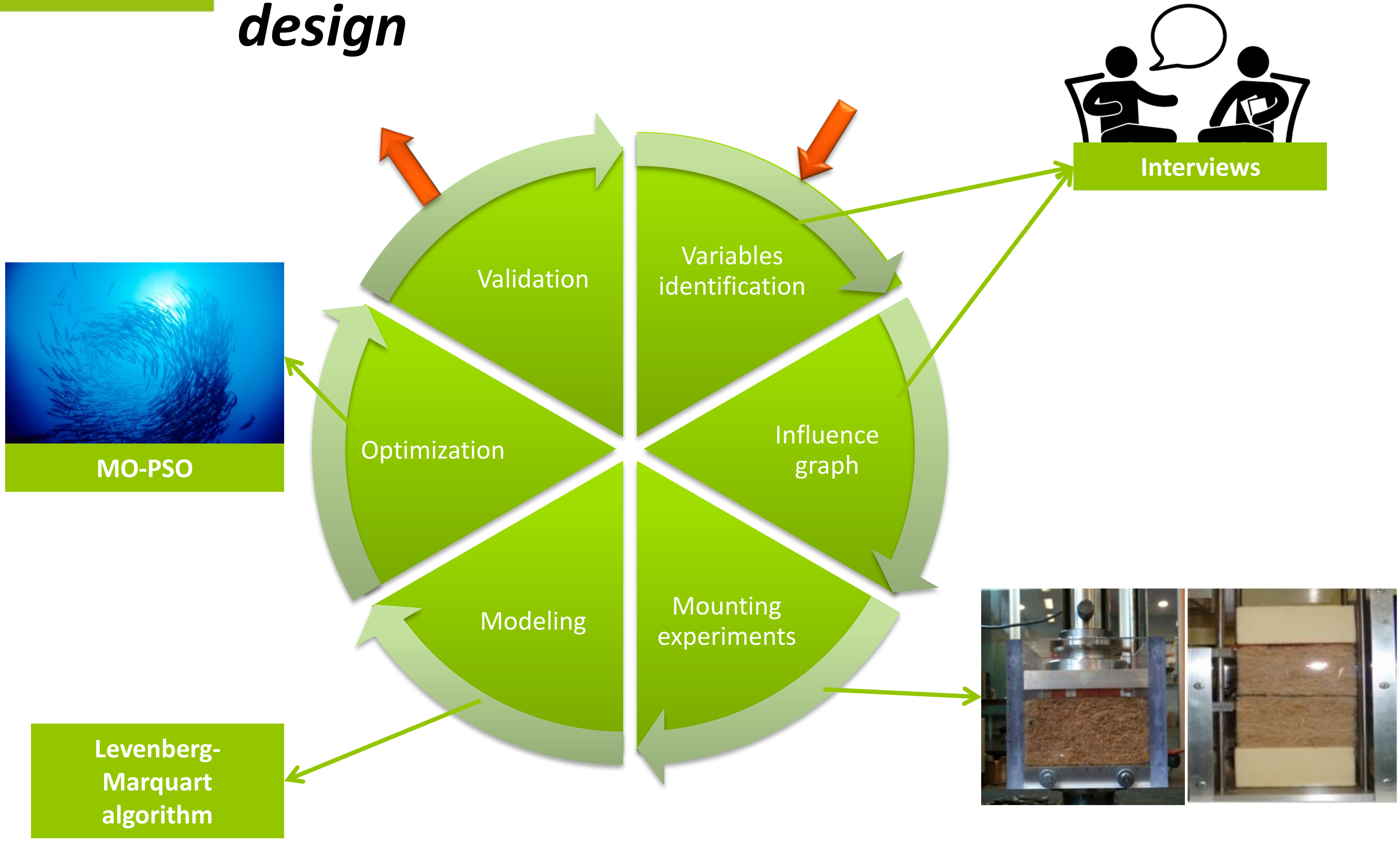


Low thermal conductivity
High compression recovery

Fibres resources and production process

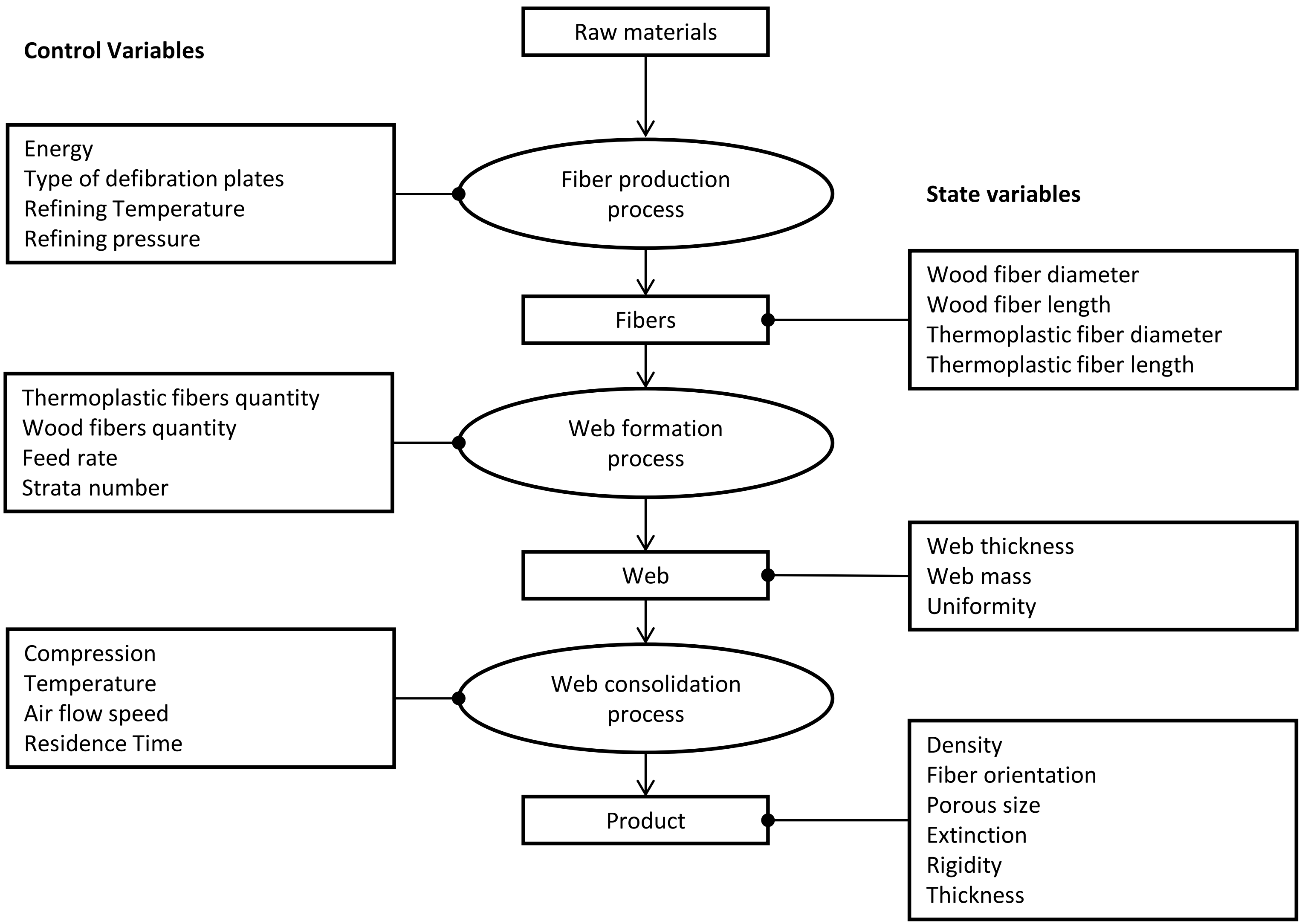
- Fibres
  - Wood fibres
    - Maritime pine
    - Loblolly pine
    - Poplar
    - Eucalyptus
    - Hemp
  - Thermoplastic fibres
    - PET long
    - PET short

Process of development of optimal design

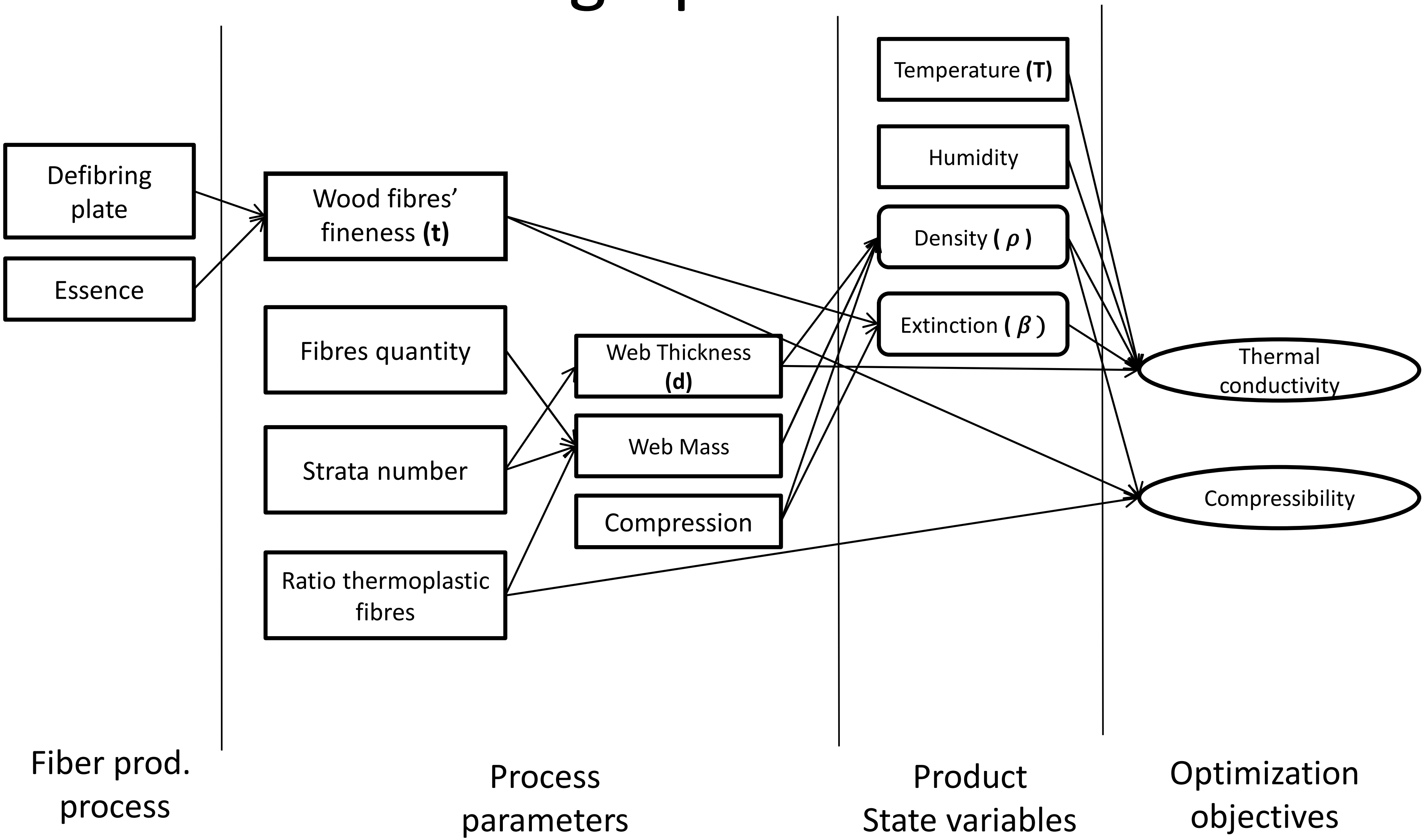


Results

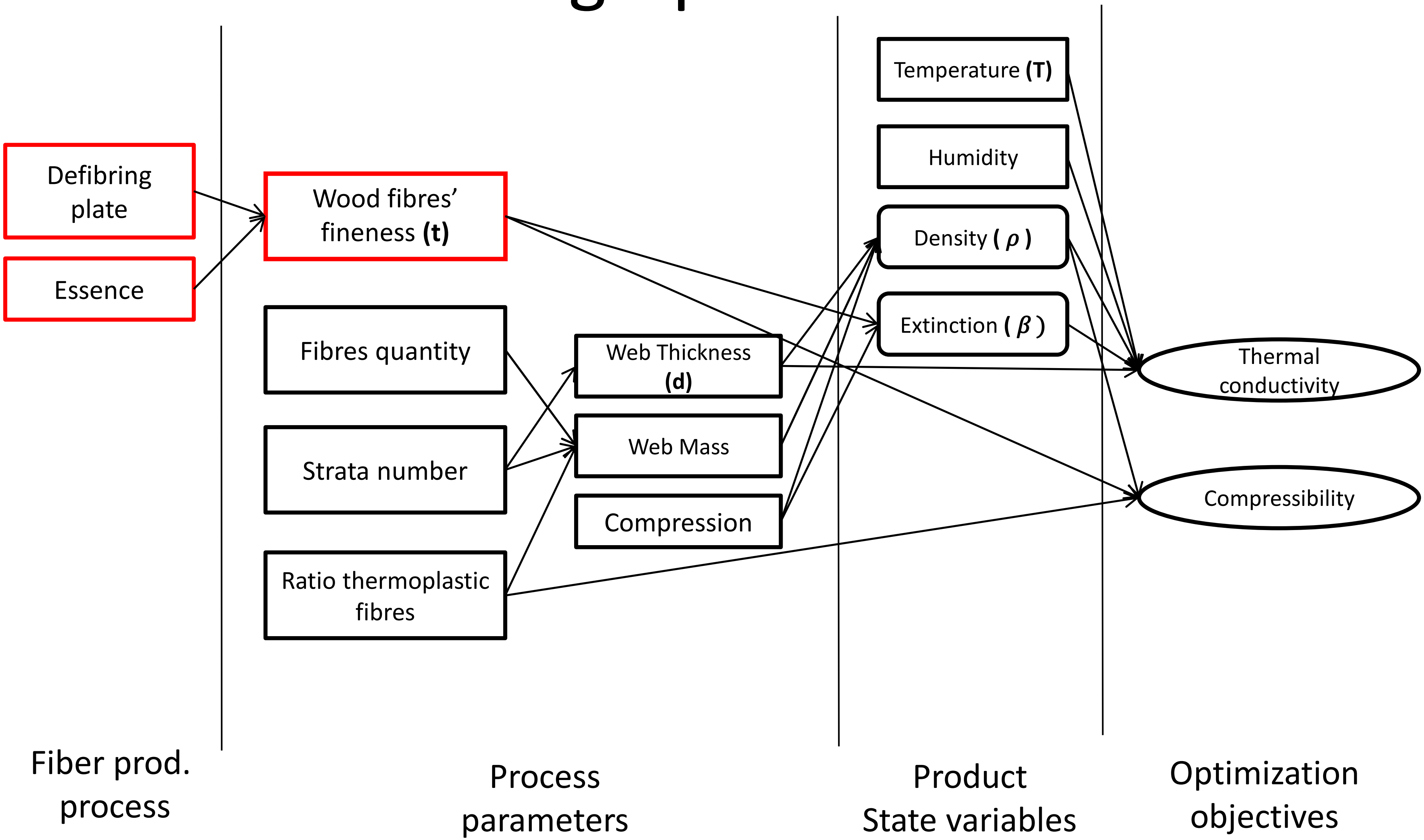
Variables identification



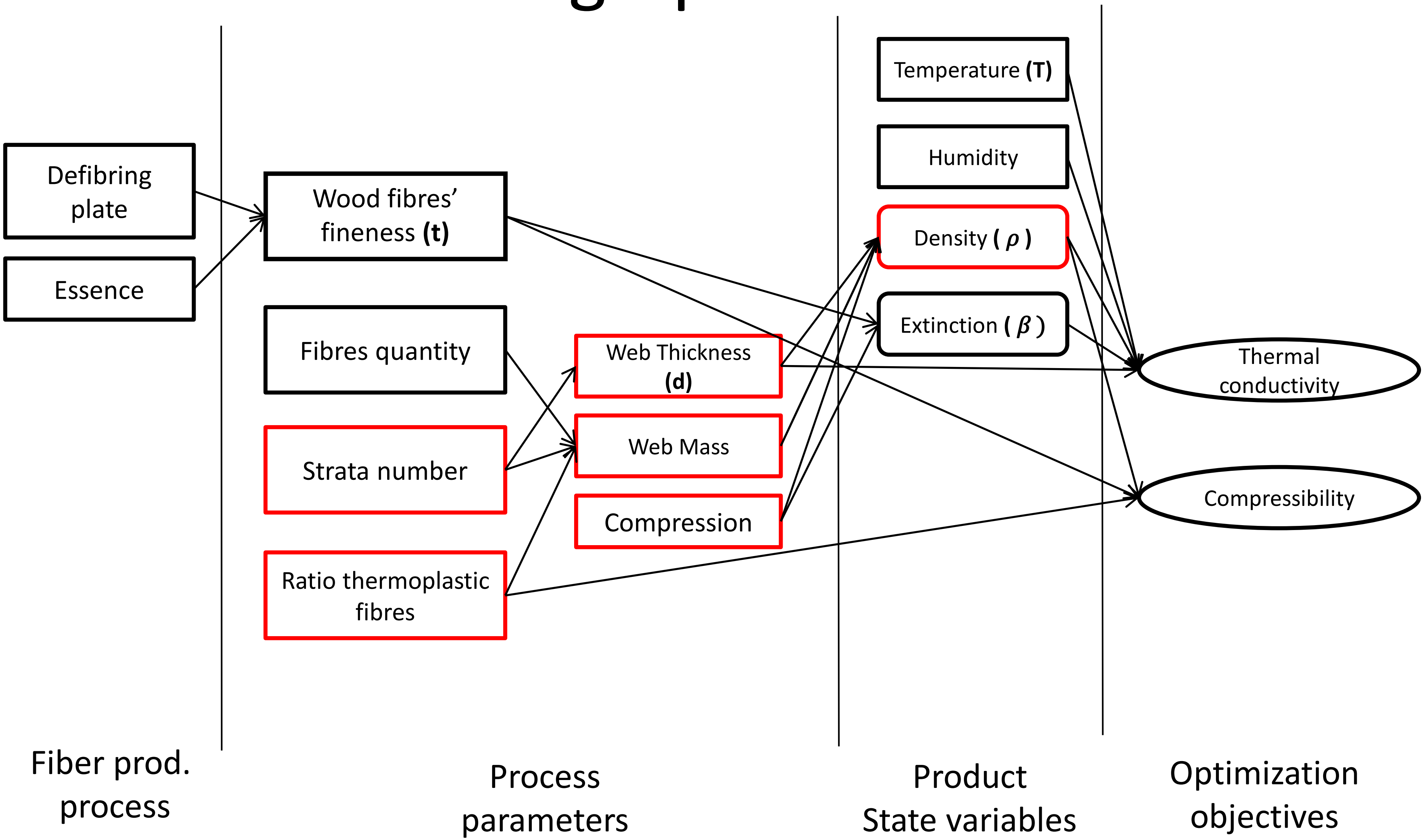
Influence graph



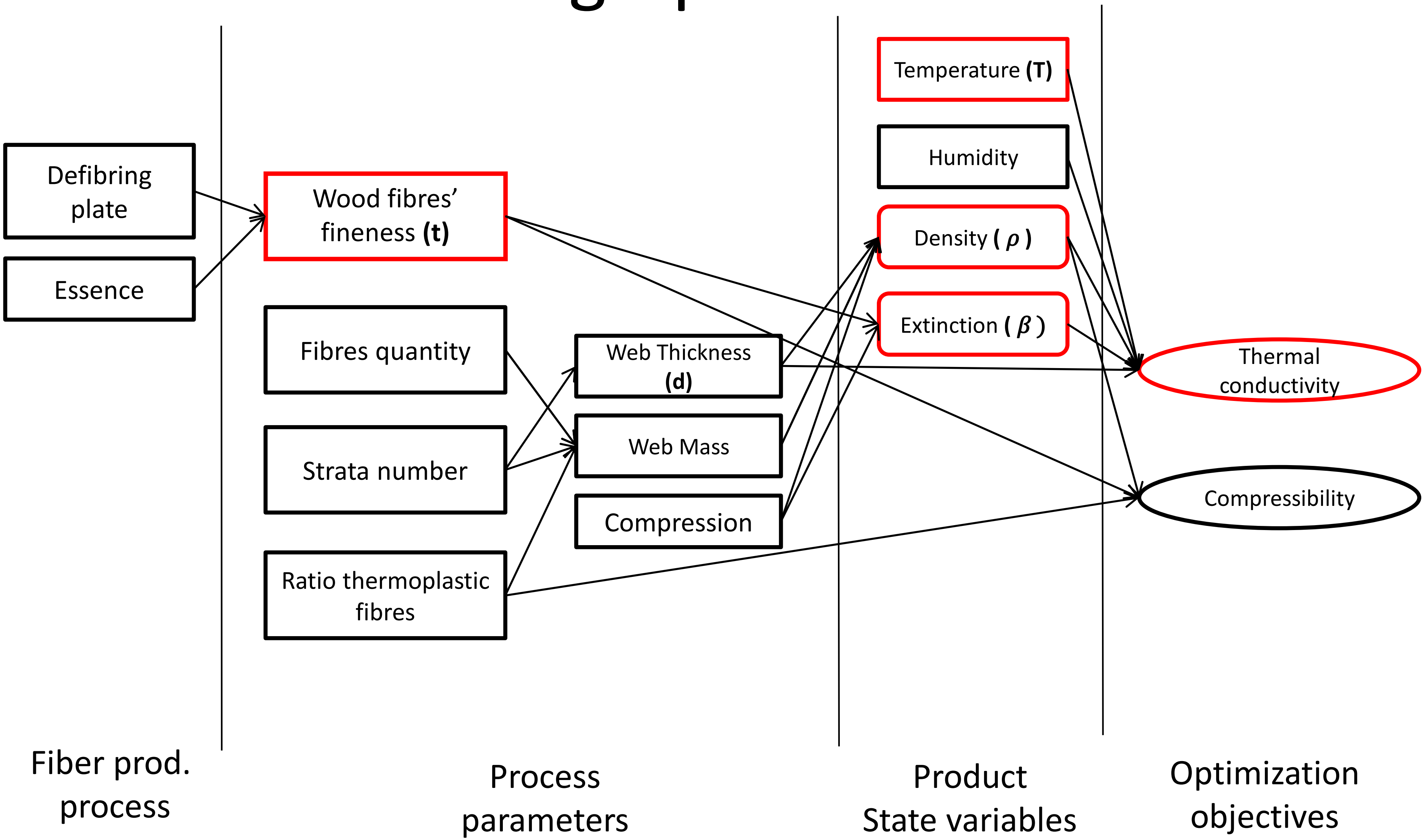
Influence graph



Influence graph



Influence graph



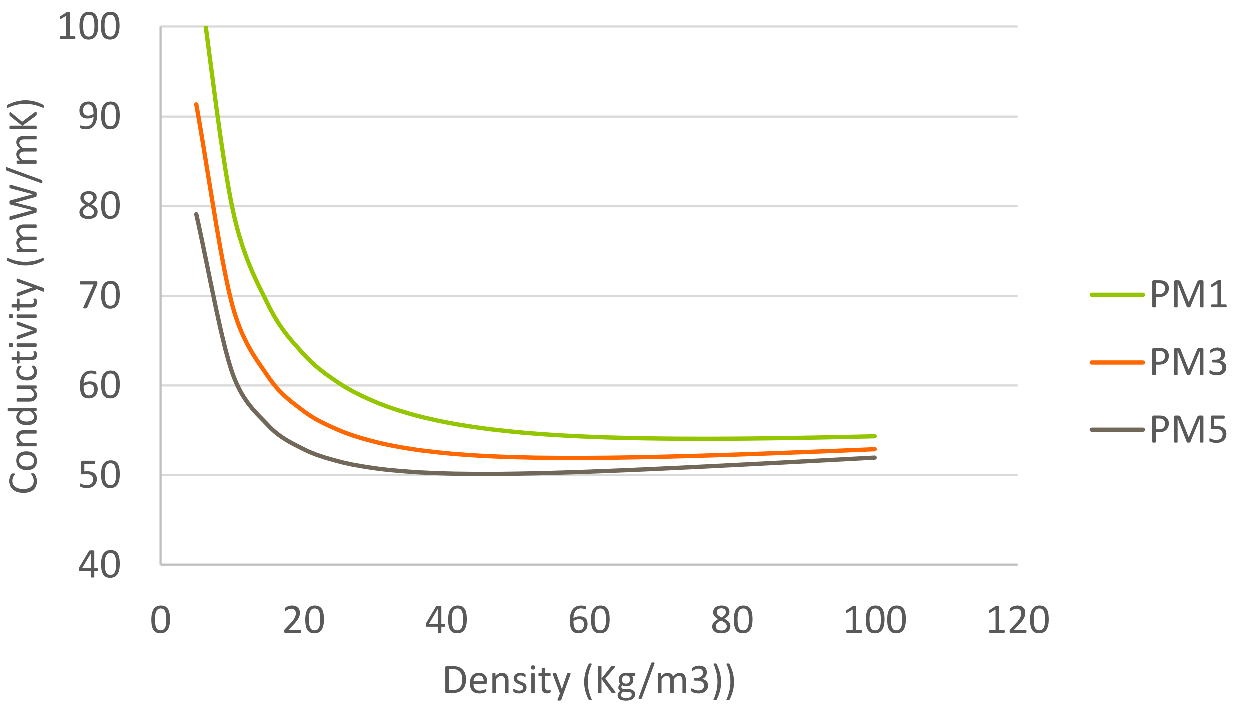
Modelling: Thermal conductivity

$$\lambda(\rho,\beta) = 0{,}2572 \cdot T^{0{,}77} + 0{,}17\rho^{0{,}24} \cdot (1 + 0{,}1883 \cdot T) + \frac{4\sigma T^3 d}{\left(\frac{2}{\varepsilon} - 1\right) + \beta\rho d}$$

Air | Solid | Radiation

$$\beta = 1827 \cdot t^{-1.549} + 3.086$$

T: Temperature
σ: Boltzmann constant (5.67*10^-5)
d: thickness (m)
ε: Wood emissivity (0,85)
ρ: Density(kg/m3)
β: extinction (m2/kg)
t: Fibre finesses (µm)



Modelling: Compressibility

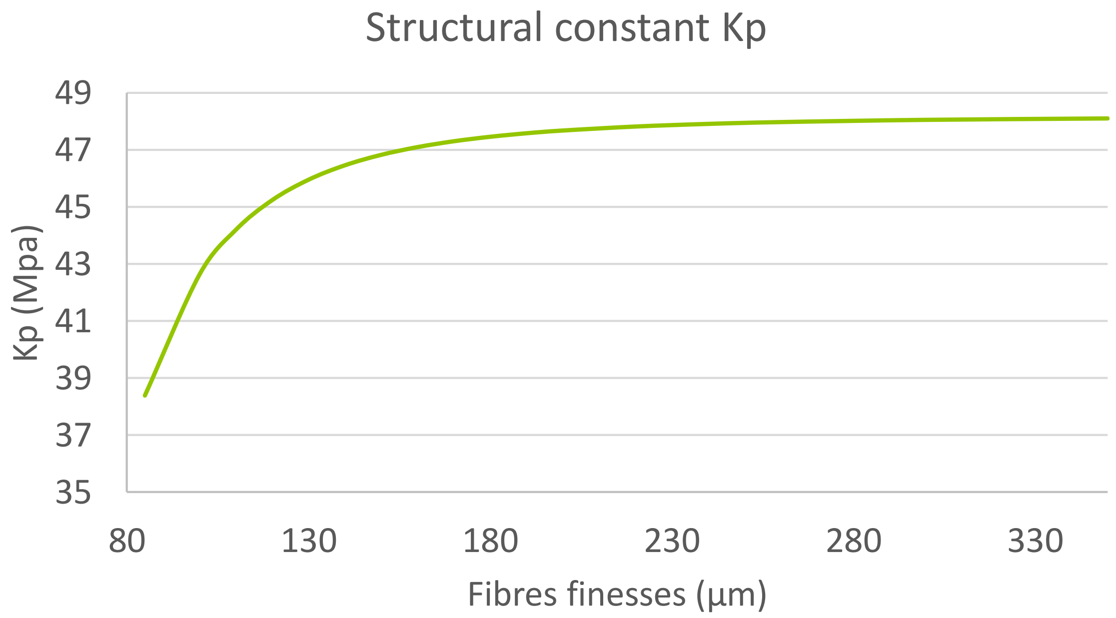
'Van wyk' model of compressibility in fibrous material

$$P = \underbrace{(-5.3 \cdot 10^{7} \cdot t^{-3.49} + 48.17)}_{\text{Structural constant 'Kp'}} \cdot (\mu^{3} - \mu_{0}^{3})$$

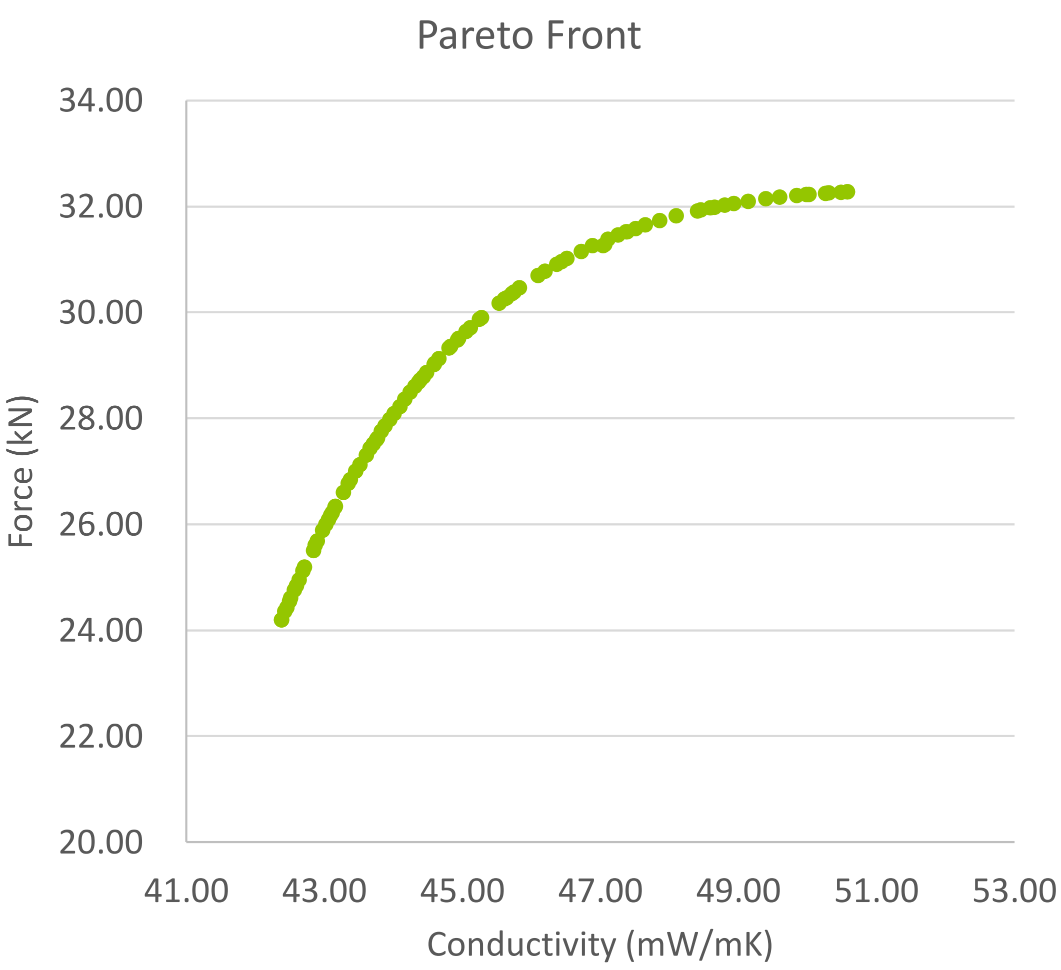
P: Force (kN)

t: Fibre finesses (μm)

μ: Fibre volume fraction



Pareto Front compressibility-conductivity



Solution example:

Density (ρ) = 70 kg.m^{-3}

Fineness (t) = 80 µm

Force (P) = 24.2 kN

Conductivity (λ) = 42.4 mW.mK^{-1}

Pareto front analysis

1- 83% of optimal solutions have a finesse value between 100 and 200 μm ➔ mixed raw materials??

2- 3 % of the front have a finesse value between 300 and 350 μm ➔ interval of finesse not optimal.

3- Optimal solution have a density between 60 and 75 kg.m^{-3}

Conclusion and future works

Conclusion:

1. Methodology for multidisciplinary complex problem.
2. Human factor have a huge impact on the success.
3. Ongoing research work.

Future works:

1. Introduction of production process parameters.
2. Introduction the economic and environmental objectives.
3. Multi-criteria analysis of optimal solutions.
4. Produce and test samples of the optimal solutions.

Acknowledgment

- The French Environment and Energy Management Agency (ADEME).
- PhD student Pierre Vignon, Post-Doctorate Huyen Tran and their supervisors: Christine Delisée, Pascal Doumalin, Jean-Pierre Da costa, Jérôme Moreau.