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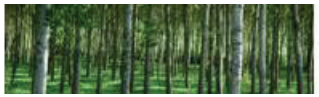
Influence of hemp fibers and shives preparation on their properties and correlations with properties of composite and concrete

Pierre RIVARD




P. Rivard[1], A. Le Duc[1], A. Duborper[1], N. Da Silva, P. Bono[1], A. Bergeret[2], A. Day[1]
[1]Fibres Recherche Développement (FRD), Troyes, France
[2]Centre des Matériaux des Mines d'Alès (C2MA), Ecole des mines d'Alès, Alès, France

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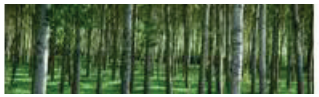
Private R&D company dedicated to the promotion of plant fibers




Fibres Recherche Développement®

FRD : create value

FRD mutualizes the research effort of 11 sharholders

- Natural fibers producers (75 % hemp, 25 % linseed, 15 % flax et wood)
- Agri-fibers transformers
- Agri-chemistry companies
- Investors

FRD make natural fibers usable in material industry

- A unique extraction, functionalization, caracterisation of technical natural fibers laboratory
- National research network : 30 technical centers and laboratories

MARKETS

Industrial / Purchaser

- Wish to integrate natural fibers
- Want a clearly identified partner as referent : range, quality, supply, materials formulation, technical and economical feasibility

FRD create value in a role of technical interface between two worlds and R&D support

RESSOURCES

Plant fiber producers

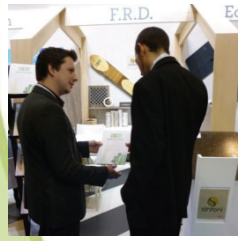
- Mastering resources
- Looking for fibers technical development
- Want to develop links with industry materials

Our Innovation Skills

- **Knowledge** of markets, products, actors, specifications, processes, resource and its mobilization
- **Fractionation** and **functionalization of fibers and preforms**
- **Materials formulation** incorporating natural fibers : **insulation, concrete, panels, plastics, composites**
- Characterization et **quality managment**
- **Installation and control of R&D projects**

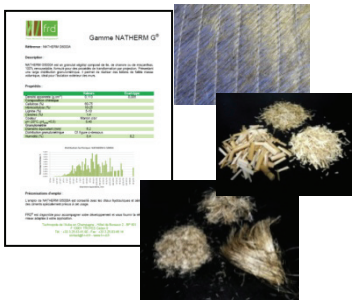
frd-Lab

Consulting



Services

- Custom supply
- Characterization
- Functionalization



Studies

- Natural fibers
- Variability control
- Retting
- Extracting processes
- Functionalization processes
- Concrete market
- Insulation market
- Composites market
- European fibers sourcing
- Exotic fibers sourcing
- Miscanthus potential valorisation
- …

Innovation Programme

- Provision of a range of natural fibers or fabrics to the markets of the insulation, concrete, plastics and composites **SINFONI**
- Development of biobased reinforcements composites **FINATHER, BIONICOMP,ACTINAT**
- Development of biodegradables thermoplastics material **MATAGRAF,**
- Development of hemp fabrics for clothing industry **CHAMAILLE**
- Development of natural fibers-based concrete and mortars **APBTP**
- Manufacturing of insulation materials **ISOL**
- Retting studies : **State of art** of retting process / **RIGHTLAB**

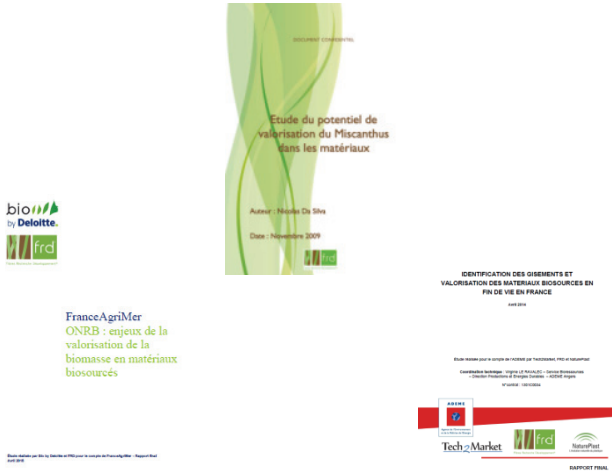
Based on material qualification

- Control the variability of performance **MAPROFI**
- Mastering fiber behaviour during extrusion **DEFIBREX**


FRD-Studies

- **Custom realization of : (France and International)**
  - Market study
  - Strategical study
  - Sourcing and supply study
  - Technological watchfulness
  - Writing technical part of patent application

- **Means :**
  - 1 dedicated team
  - 1 observatory « Technical Natural Fibers for Materials in France »
  - Knowledge of markets, products, processes, patents, publications, France and International studies



Example of done studies

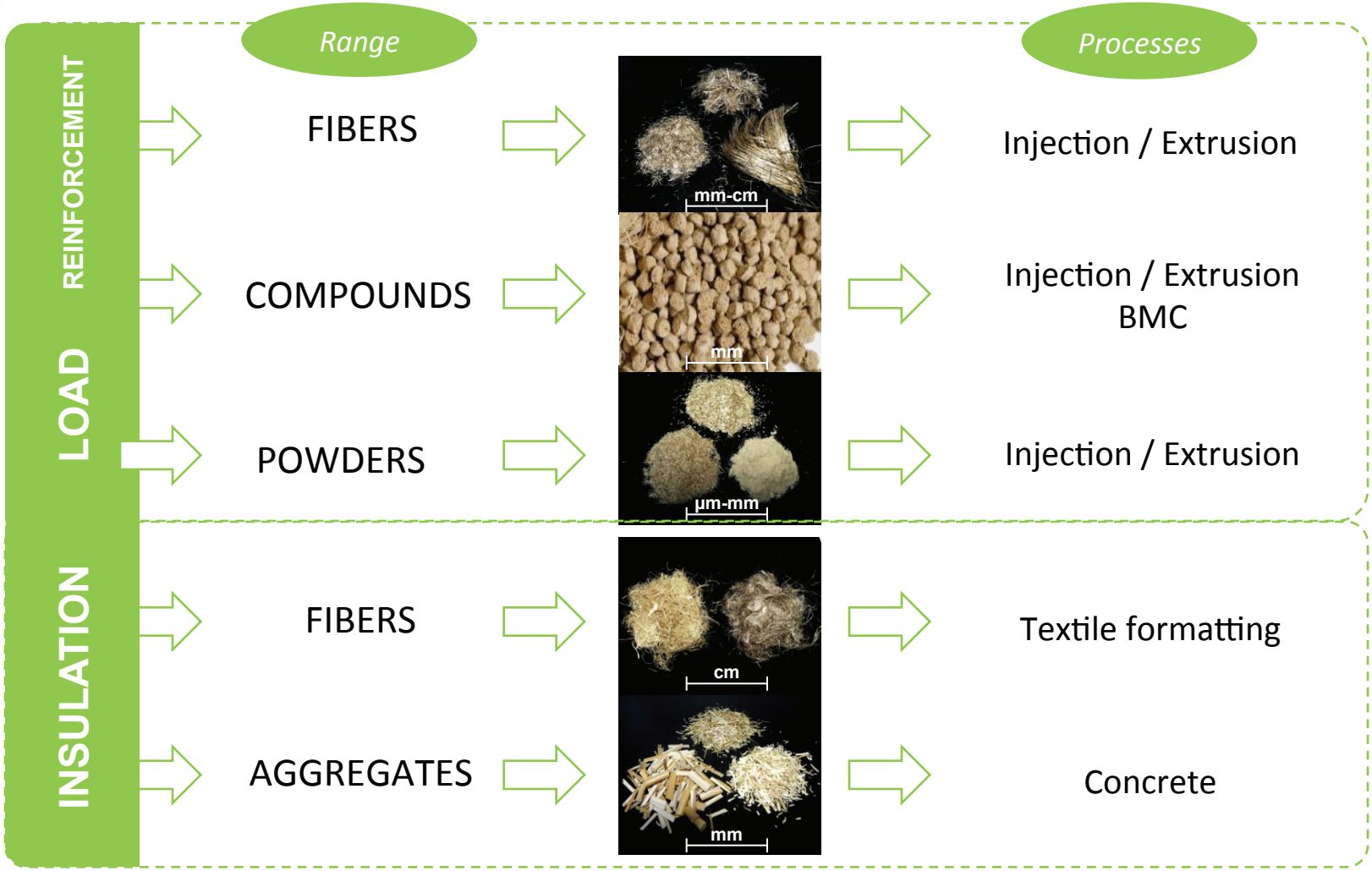
- Availability of Natural Fibers for material applications
- Structuring plant fibers sectors
- Underused products for chemistry and biobased materials
- Sourcing and valorization of biobased material in end of life
- Insulation and concrete biobased markets
- Biomass potential de valorization in material (miscanthus, oleaginous…) ; Concept of dedicated processing platform
- Retting industrial processes
- ….

FRD-Lab

- **Custom realization of research contracts**
  - Material innovation
  - Support the incorporation of plant fibers by substitution of mineral or organic fibers
  - Development and transfert of production processes
  - Continuous quality control, plants or materials (composites) assays and /or characterisation

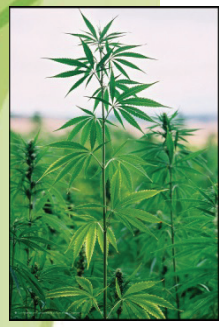
- **Means:**
  - 1 team dedicated to agromaterials R&D
  - 1 expertise in selection and realisation of a range of suitable material to all materials processes
  - Expertise in the realisation and conduction of research projects and mounting aid application package to the R&D
  - Custom material supply for laboratory and industrial tests, suppy the industrials in their activity during starting phase.

FRD-Solutions : Short fibers range



Our achievements / Current projects

faurecia
Interior Systems



Lightening

écocep

Polymer substitution

Agrafes CB
Au service durable de la vigne

Controlled degradability

Mechanical properties

BOMBARDIER
l'évolution de la mobilité

Stratiforme Industries

Troyes

Acoustic and/or Thermal insulation

LA CHANVRIÈRE

VIVESCIA
l'innovation par nature

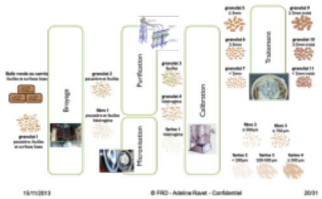
LAFARGE

Our achievements / Current work

LACOSTE

LA CHANVRIÈRE

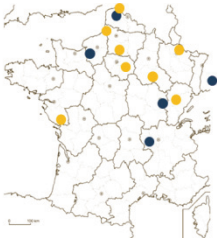
Support for the creation of supply chains



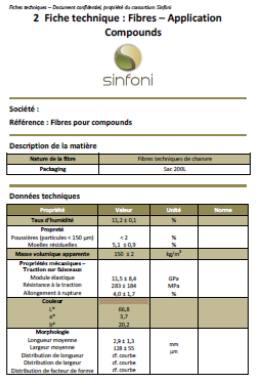
Coop énergie

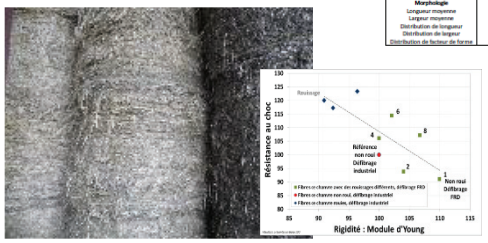
invivo AgroSolutions

- Fibres
- Renforts



Quality Control





Example with a producer for the same year of retted straw from 2 different plots having undergo the same technical route

LA CHANVRIÈRE

Studies

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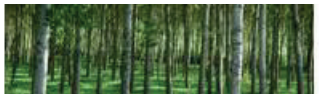


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Objectives

Substitution of mineral or organic fibers by natural fibers in material requires to answer the product specifications :

- In Plastics sector :
  - Improve the surface contidion
  - Propose industrializable solutions
- In Construction :
  - Mastery of shape factor
  - Decrease the heterogeneity of particle sizes

Develop technical solutions « Plant fractions »

- Mastered
- Characterized
- Transferable

Objectives

- Adapt plant material to the product specification using different types of process and settings.

Objectives

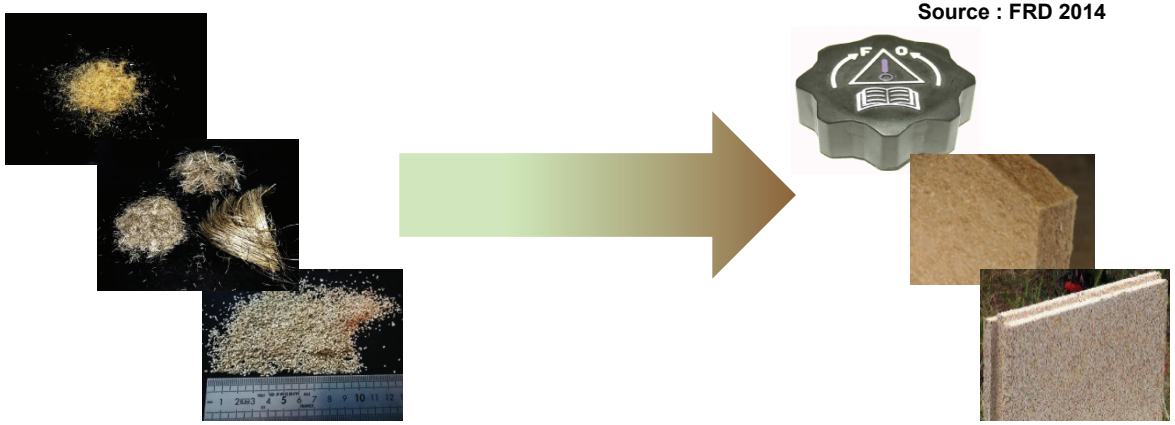
Objectives

– Adapt plant material to the product specification using different types of process and settings.

Product specification examples :

Markets	Morphological specification		
	Size	Shape (L/d)	Fibrillation
Plastics	µm-mm	15	High level
Insulation	cm	100	High level
Concrete	mm-cm	≈1	/

Source : FRD 2014



Objectives

Objectives

– Adapt plant material to the product specification using different types of process and settings.

Markets	Morphological specification		
	Size	Shape (L/d)	Fibrillation
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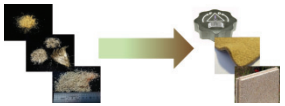

Available means :

Plant Material

- **1. Fractionation Process**
- **2. Moisture Content**
- **3. Retting Rate**

Objectives

Objectives

– Adapt plant material to the product specification using different types of process and settings.

Markets	Morphological specification		
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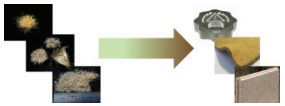


Available means :

Plant Material

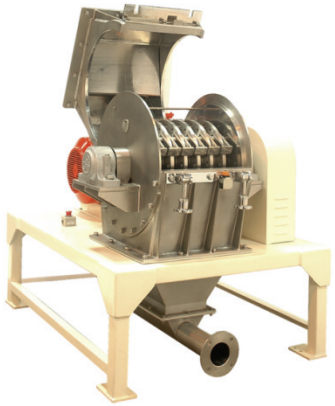
- **1. Fractionation Process**
- **2. Moisture Content**
- **3. Retting Rate**

1. Fractionation Process : Mill technologies

Semi-industrial and industrial scale :

- **Impact mill**

  The impact components of this mill are mobile and projects the material against its wall hitting them until they are small enough to pass through the grid.



- **Knife mill**

  The size reduction of the material is made by cutting between two blades (one on the rotor and one on the stator).

1. Fractionation Process : Mill technologies

Semi-industrial and industrial scale :

- **Attrition mill**

  The mill generate an important airflow which causes particle collisions. Collisions are such that the particles are milled by themselves.

- **Universal mill**

  The particles are projected between the rotor and the stator. The particles are hit until they are small enough.

1. Fractionation Process : Mill technologies

Laboratory scale :

- **High speed mill :**

  Close to the universal mill, this technology allows the rotation speed to go up to 18.000 rpm. This mill works horizontally.

- **Impact crusher :**

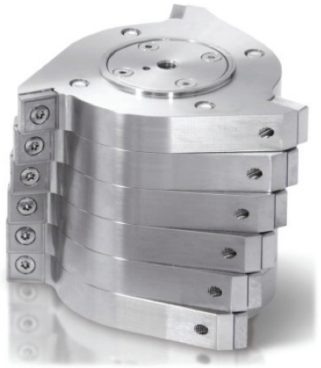
  This mill is a centrifugal mill in which the stator is a 360° grid. There is no vacuum system for particles draining

1. Fractionation Process : Mill technologies

Laboratory scale :

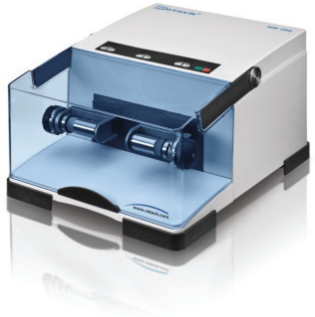
- **Shear mill :**

  Close to the knife mill technology, the rotor of this mill rubs particles against blades.



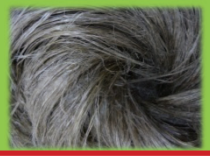
- **Ball vibration mill :**

  The particles are placed in bowls with balls. The mill generates high frequency vibrations (30/s) that allow balls to rub and crush the particles



1. Fractionation Process : Mill technologies

– All processes are not suitable in the state for fibers and shives :

Fractionation Processes	Fibers 	Shives 
Impact mill	😐	☺
Knife mill	☺	😐
Attrition mill	☹	😐
Universal mill	😐	☺
High Speed mill	☺	☺
Impact Crusher	😐	☺
Shear mill	☺	☺
Ball vibration mill	☹	☹

INDUSTRIAL SCALE

LABORATORY SCALE

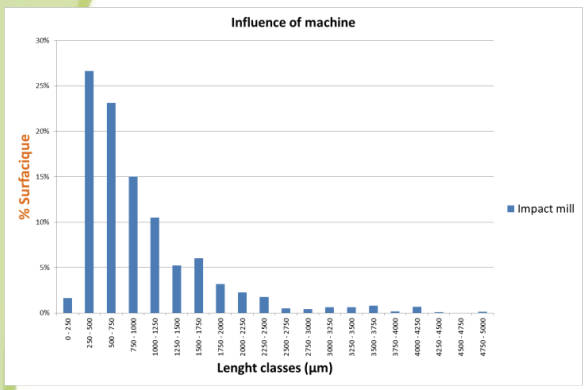
Conclusion : Large range of technology available for fractionation. Depending on the particle size required, you may need a previous reducing step.

1. Fractionation Process : Mill technologies

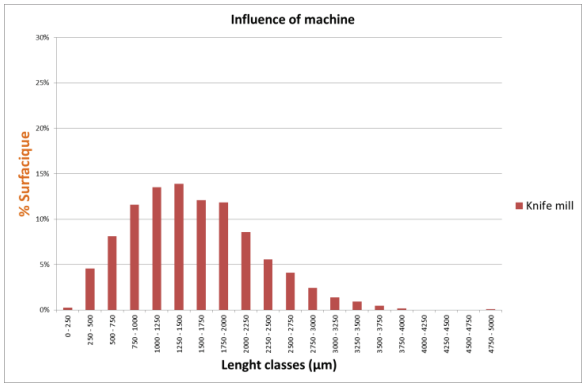
Experimental plan

- Plant material : 1 sample of **hemp fibers**
- 5 technologies
- Targeted particle size : 2 mm

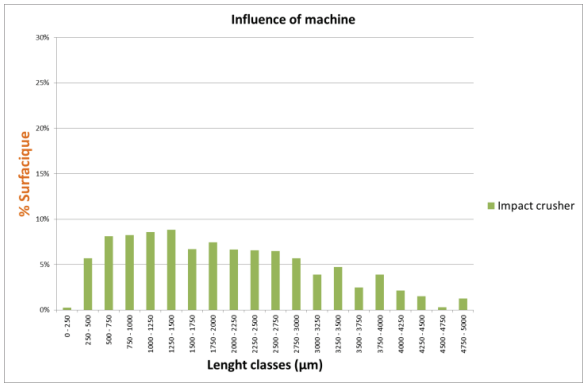
Morphological analysis



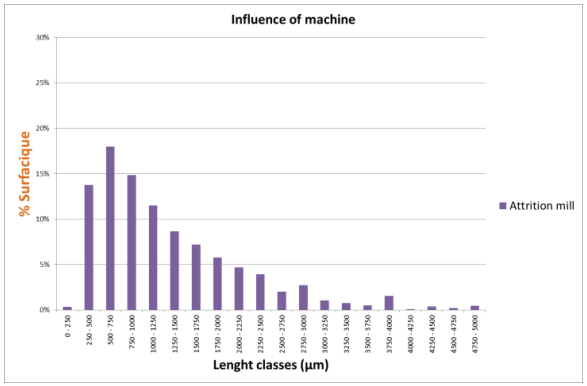
Impact mill



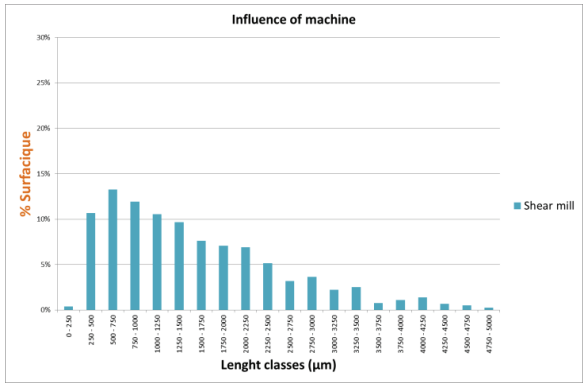
Knife mill



Impact crusher



Attrition mill

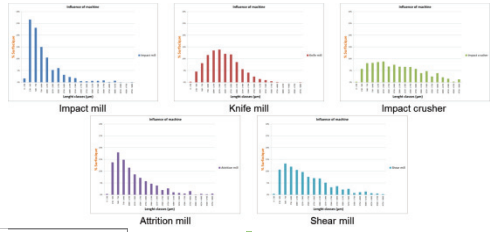


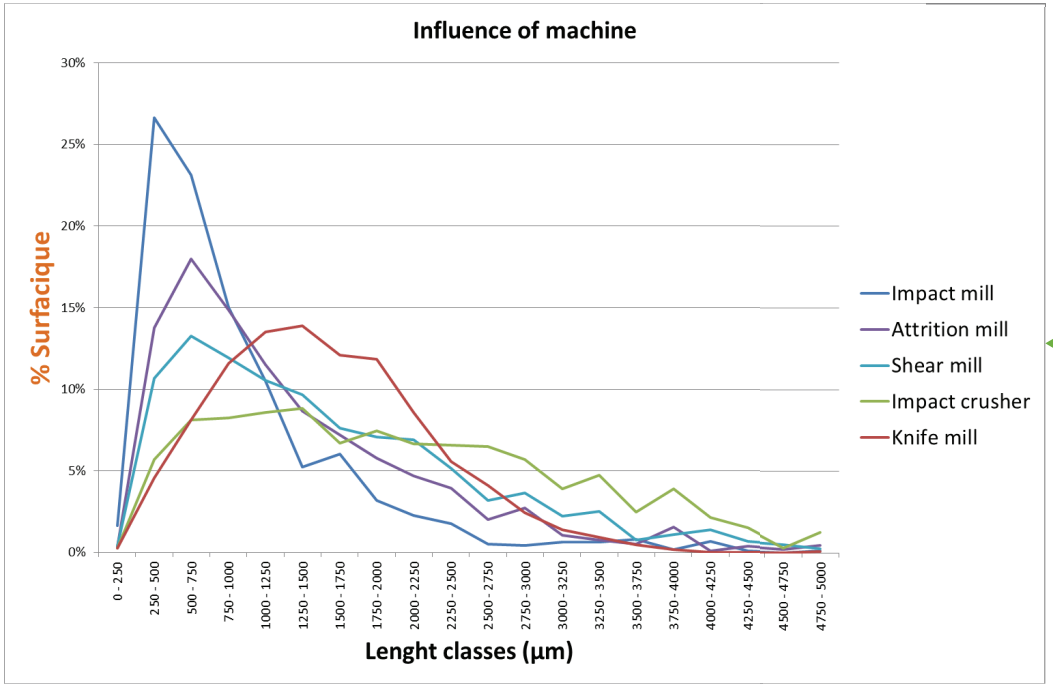
Shear mill

I. Fractionation Process : Mill technologies

Experimental plan

- Plant material : 1 sample of **hemp fibers**
- 5 technologies
- Targeted particle size : 2 mm





Data compilation

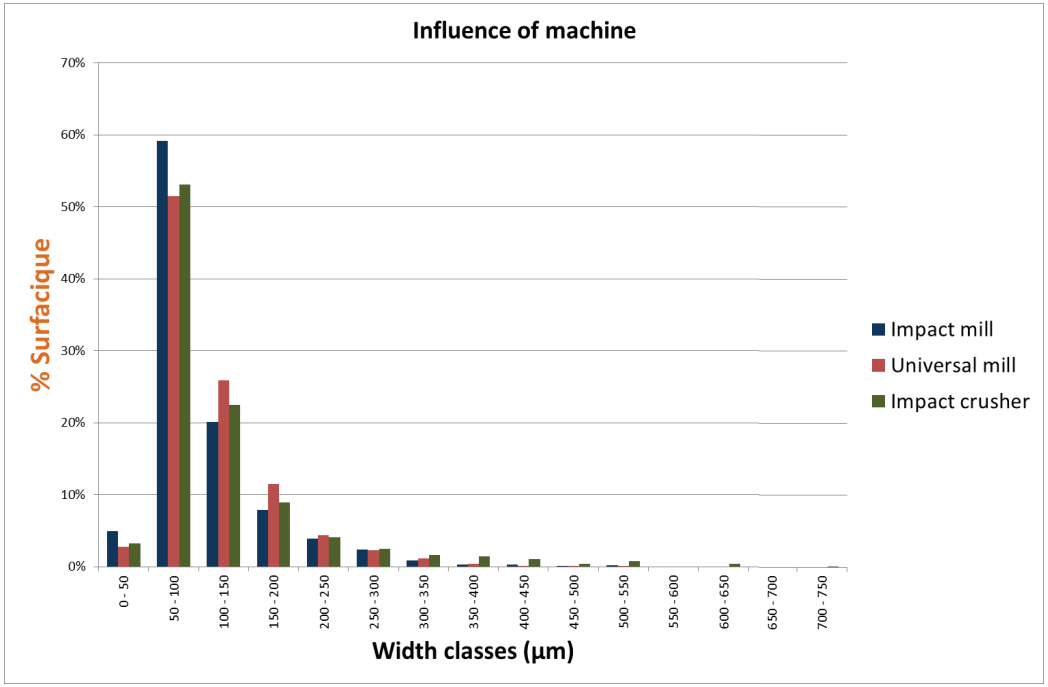
Conclusion : Morphological distributions show that fibers react differently depending on the mechanical stress undergone. Product specifications determines what technology use.

1. Fractionation Process : Mill technologies

Experimental plan

- Plant material : 1 sample of **hemp shives**
- 3 technologies
- Targeted particle size : 0,5 mm

Morphological analysis



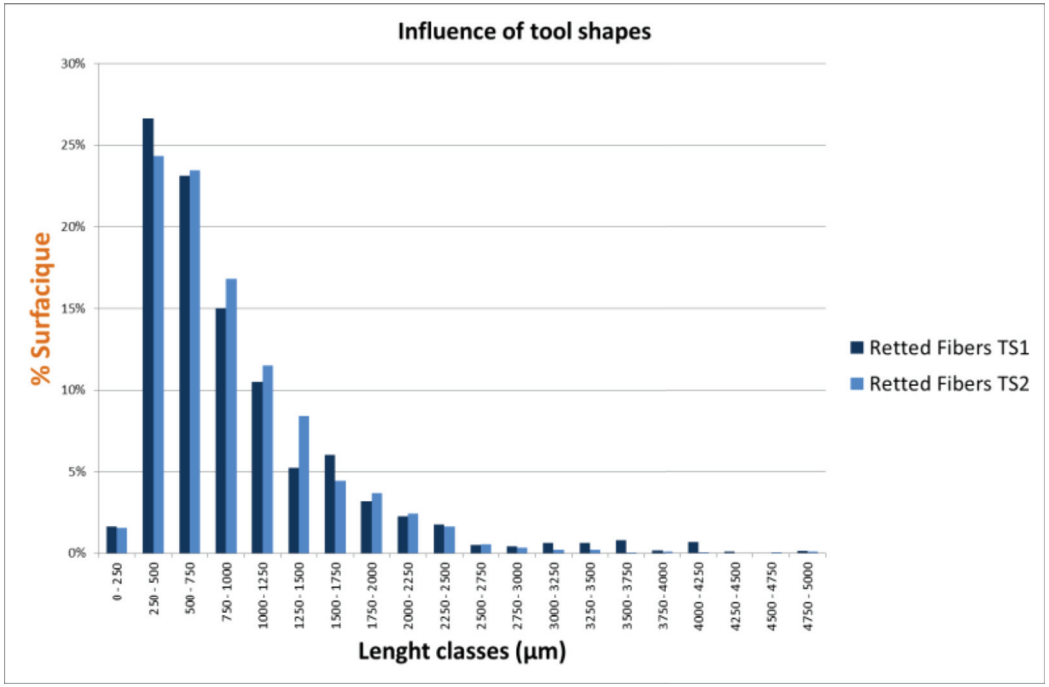
Conclusion : Contrary to fibers, fractionation process do not impact shives morphological properties.

I. Fractionation Process : Tool shapes

Experimental plan

- Plant material : 1 sample of **hemp fibers**
- 1 technology, **2 reducing tool shapes**
- Targeted particle size : 2 mm

Morphological analysis



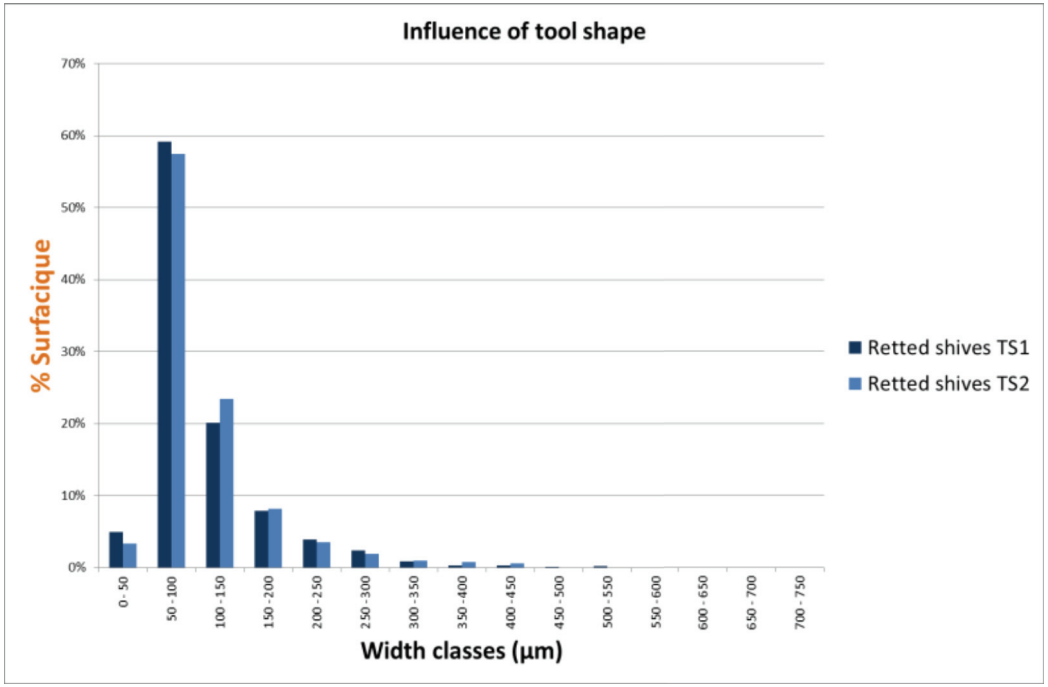
Conclusion : A lot of shapes are conceivable for milling tools.
The TS2 does not affect morphological properties.
In term of production, TS2 multiply efficiency by 2 for fibers.

1. Fractionation Process : Tool shapes

Experimental plan

- Plant material : 1 sample of **hemp shives**
- 1 technology, **2 reducing tool shapes**
- Targeted particle size : 0,5 mm

Morphological analysis



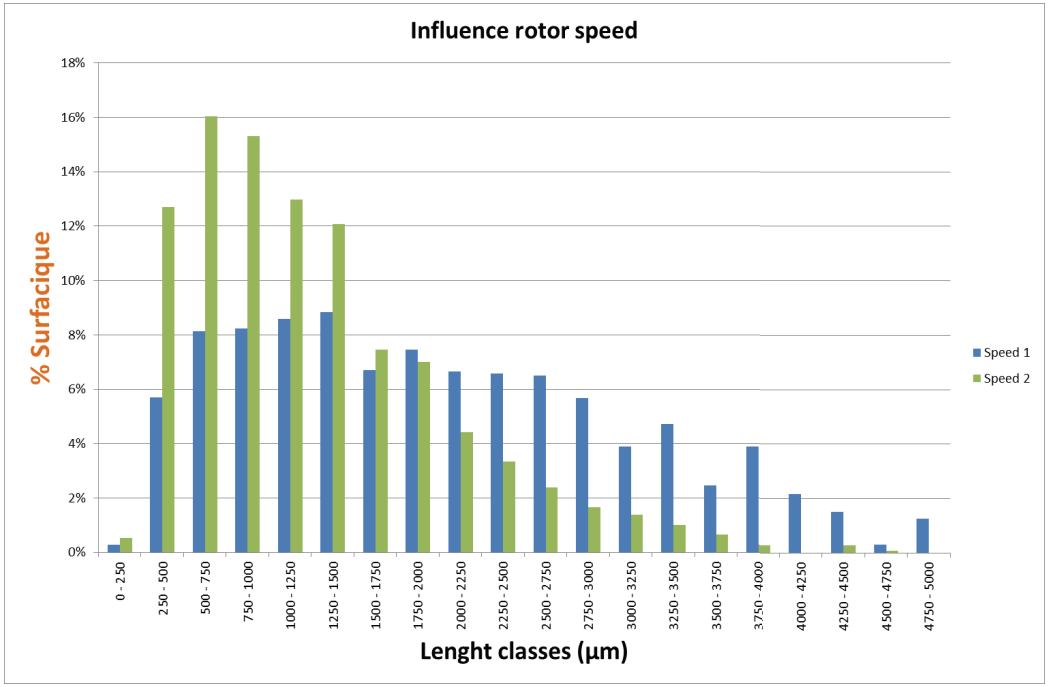
Conclusion : A lot of shapes are conceivable for milling tools.
The TS2 does not affect morphological properties.
In term of production, TS2 multiply efficiency by 3 for shives.

1. Fractionation Process : Rotation Speed

Experimental plan

- Plant material : 1 sample of **hemp fibers**
- 1 technology, 2 rotation speeds
- Targeted particle size : 2 mm

Morphological analysis



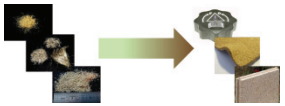
Conclusion : Higher speed allows to refocus the lengths distribution curve around smaller particle sizes

Objectives

Objectives

- Adapt plant material to the product specification using different types of process and settings.

Markets	Morphological specification		
	Size	Shape (L/d)	Fibrillation
Plastics	µm-mm	15	High level
Insulation	cm	100	High level
Concrete	mm-cm	≈1	/



Available means :

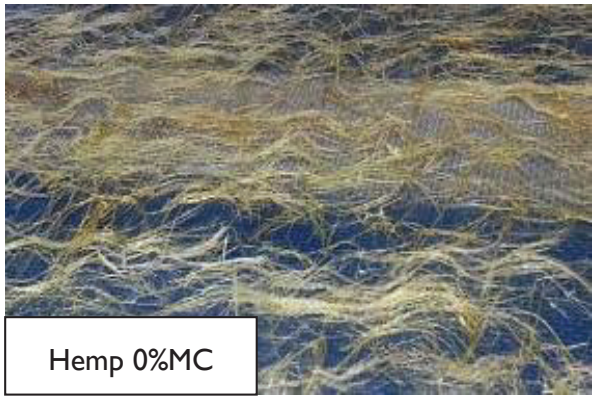
Plant Material

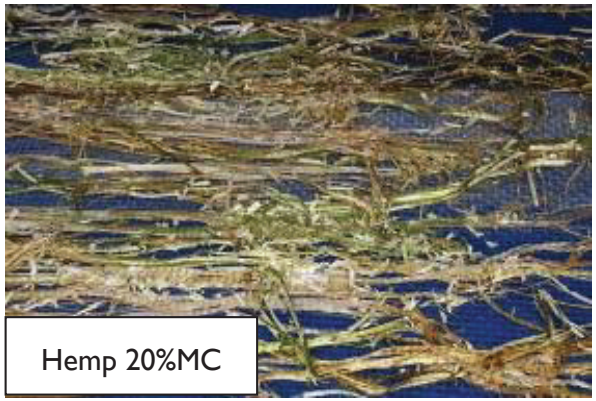
- **1. Fractionation Process**
- **2. Moisture Content**
- **3. Retting Rate**

2. Moisture content

Very important criterion for fiber extraction process :

- Impact on the rate of released dust during fiber extraction
- Impact on the efficiency of fibers and shives separation
- Impact on fiber thickness





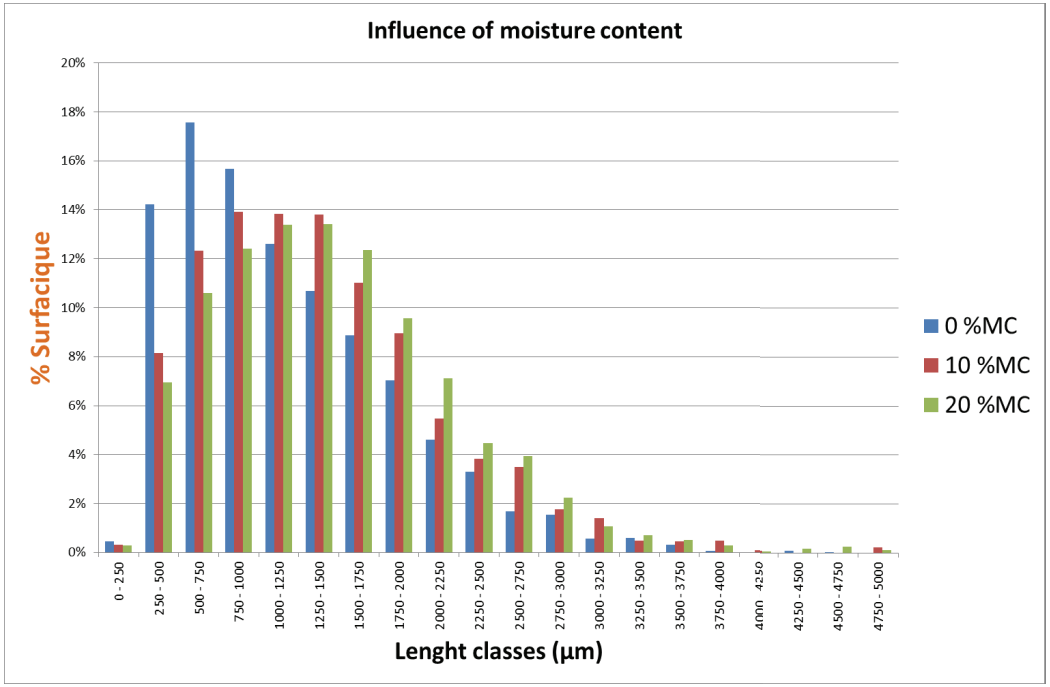
- Fiber moisture content intrinsic average :10 %MC (classical conditioning)
  - Possibility of drying to reduce moisture content near to 0 %MC
  - Possibility of increase the moisture content up to 15%MC by placing the samples in controlled environment

2. Moisture content

Experimental plan

- Plant material : 3 samples of **hemp fibers**
- 1 technology
- Targeted particle size : 2 mm

Morphological analysis



Conclusion : Dried fibers generate more dust and fine.
Need to control %MC before fractionation.

Objectives

Objectives

- Adapt plant material to the product specification using different types of process and settings.

Markets	Morphological specification		
	Size	Shape (L/d)	Fibrillation
Plastics	µm-mm	15	High level
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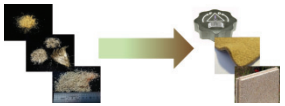


Available means :

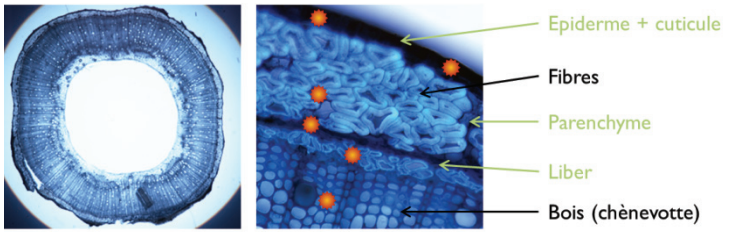
Plant Material

- **1. Fractionation Process**
- **2. Moisture Content**
- **3. Retting Rate**

3. Retting rate

"Summary definition"

- First step of straw fractionation
- Currently in field : dew retting
- Facilitates subsequent fiber extraction
- Complex (and dynamic) process



Qualitative source of variability

- Influence of retting on thickness / Chemical composition / Fibers surface properties / Mechanical properties / Smell / Homogeneity

FRD results (2011-2016) confirmed by scientific litterature

Retting impact on fiber qualities appears higher than other sources of variability

- soil and climate conditions
- agronomic conditions

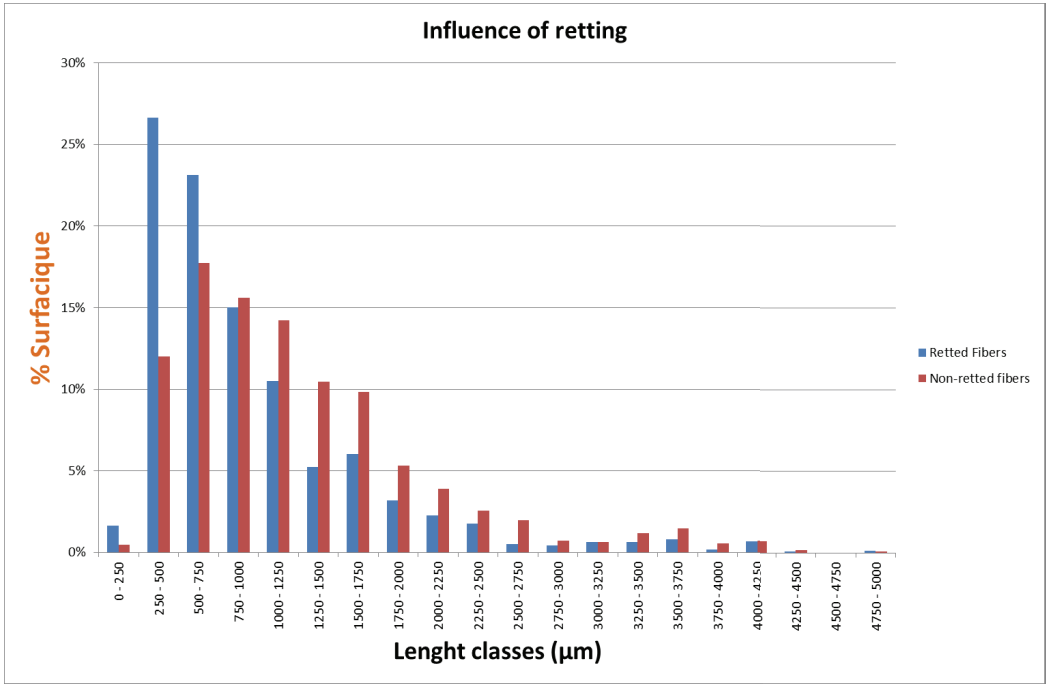
FRD results (2011-2016) issued from MAPROFI and SINFONI projects

3. Retting rate

Experimental plan

- 2 samples : Retted and non-retted **hemp fibers**
- 1 technology
- Targeted particle size : 2 mm

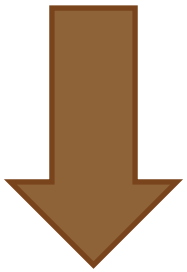
Morphological analysis



Conclusion : Retted fibers generate more dust and fine.
Need to control retted rate depending on product specifications.

Conclusions

- **Hemp fibers and shives fractionation result depends on :**
  - **Milling technology**
  - **Moisture content**
  - **Retting rate**
- **Each modular parameter must be taken into consideration to ensure the required result.**



WHY ?
Impact on final Product ?

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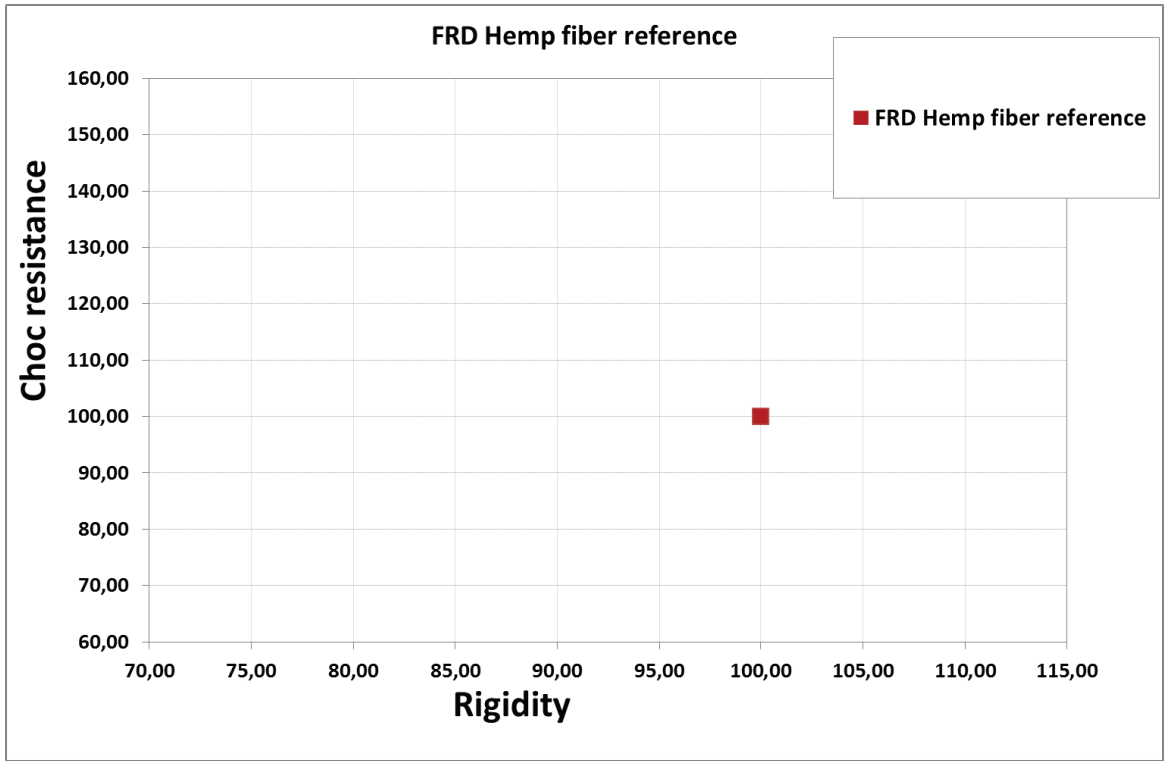
Mechanical assays on injected composites
(Hemp fiber – PP with similar fiber/PP ratio)



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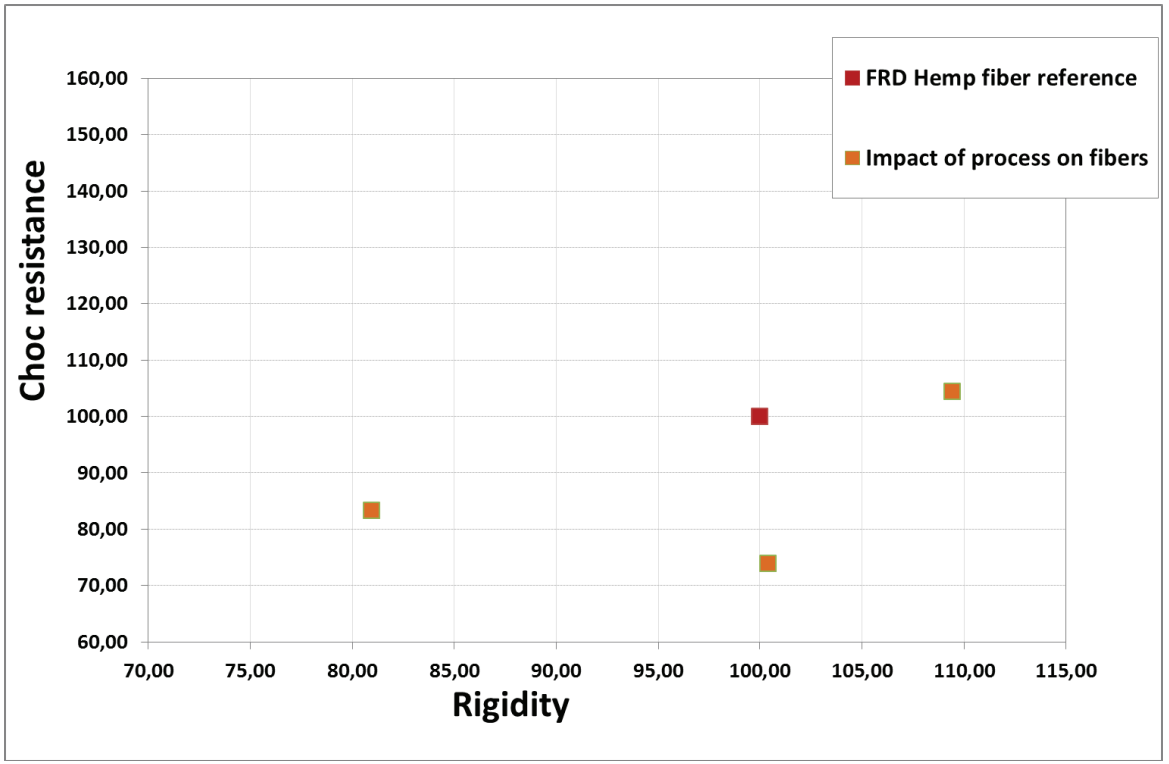

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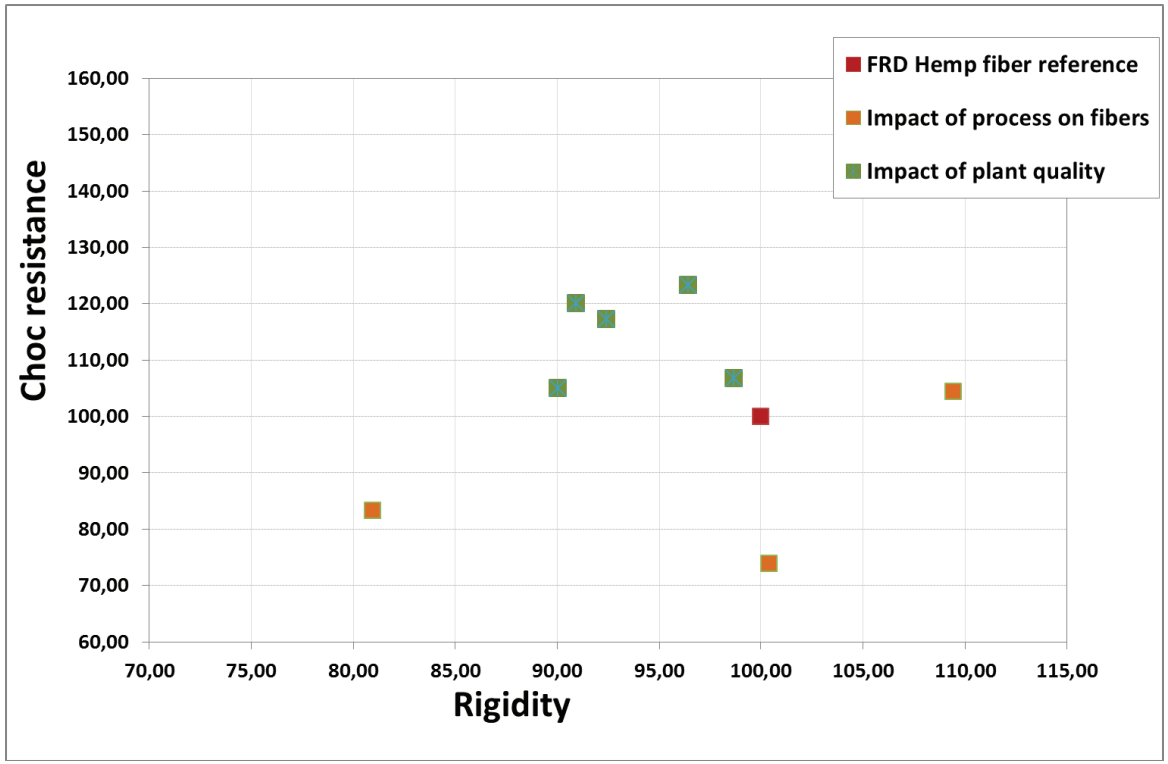

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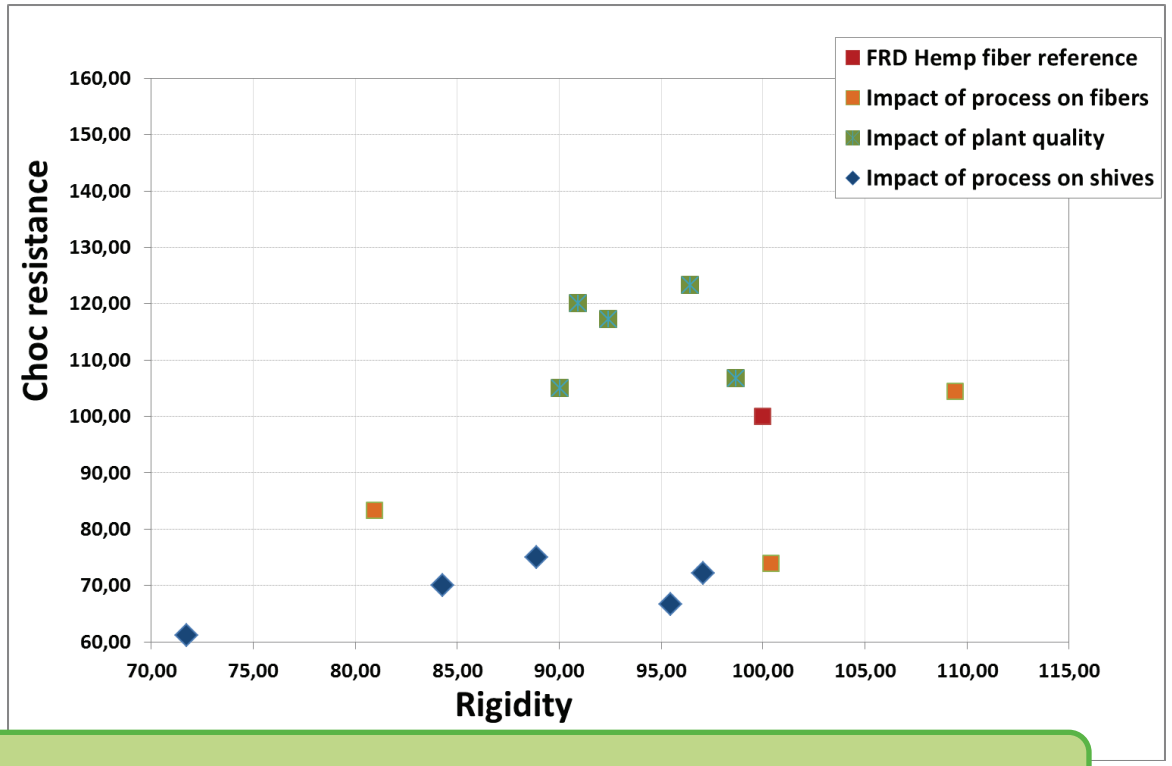

Fractionation parameters impacts also on final products

Conclusions

- Hemp fibers and shives fractionation result depends on :
  - Milling technology
  - Moisture content
  - Retting rate
- Each modular parameter must be taken into consideration to ensure the required result.

Fractionation parameters impacts also on final products

- Need to adapt material and process to the product specifications by :
  - Knowing the product implementation process :
    → **FRD : DEFIBREX**
  - Knowing the straw quality in the first place. It implies a continuous quality control :
    → **FRD : RightLab**

Conclusions

Optimizing fractionation step appears as a major key to adapt hemp fraction to final products : reduce damage on fiber, increase fiber separation, increase fiber fibrillation… To deals these question and others, we are opened to collaborate to European project.

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Thank you for your attention

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