UltraFibre

- UltraFibre project -

Plasma treatment for improved adhesion in natural fibre polymer composites

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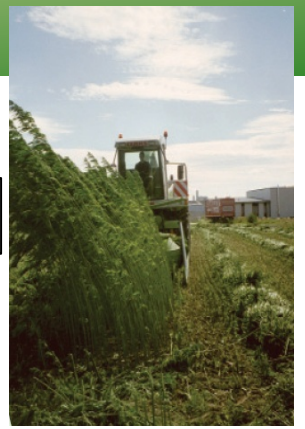
FP7-243456: UltraFibre

SEVENTH FRAMEWORK PROGRAMME

Project Overview

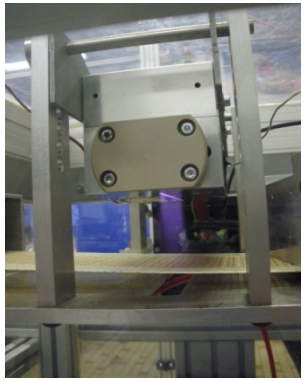
From Field to Product

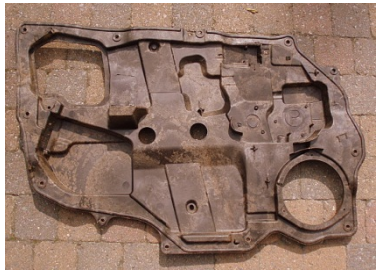


Fibre harvest & decortication

Ultrasonic treatment

Plasma treatment





Composite moulding

Hydro-acoustic treatment

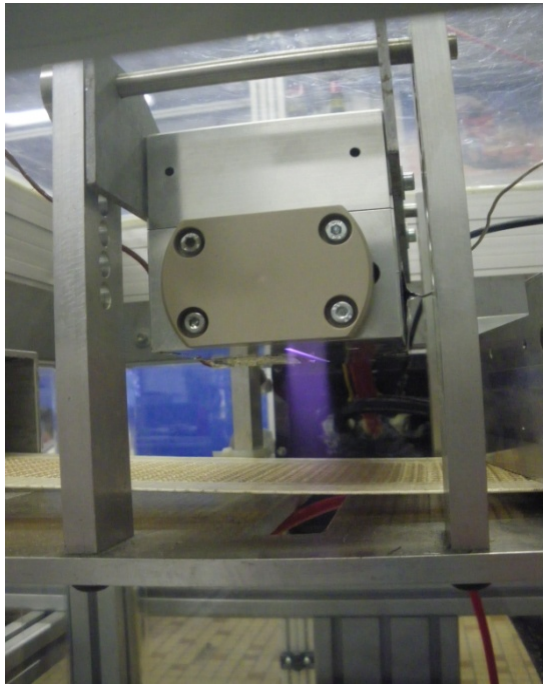
- Hydro-acoustic treatment creates intense cavitation and jet streaming: imploding vapour bubbles creating intense pressures and temperatures at molecular level in the fluid
- Industrial scale processing
  - Particle size reduction
  - De-agglomeration
  - Cell Disruption
  - Chemical Reaction “catalyst”
  - Micro mixing
  - Cleaning

Hydro-acoustics in UltraFibre

- Applied to the natural fibres (hemp & flax), aiming at separation of the elemental fibres and cleaning the fibre surface of pectins, lignin and other loosely bound materials prior to further processing.

Soft Plasma technology

- Plasma technology creates a partially ionized gas (plasma) which can be described as a chemically reactive gas.
- Main characteristic of the atmospheric pressure plasma process is that it performs treatment of a material surface only, without affecting the bulk properties of the material.



Plasma source,
ACXYS

Plasma applications

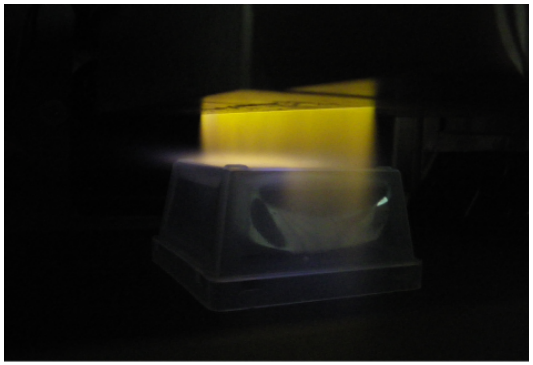
- Cleaning, etching (compatibility, adhesion)
- Decontamination, sterilization (preservation, anti inflammation)
- Activation (adhesion)
- Hydrophobization
- Coating (protection)
- Antistatic (handling)

Plasma in UltraFibre

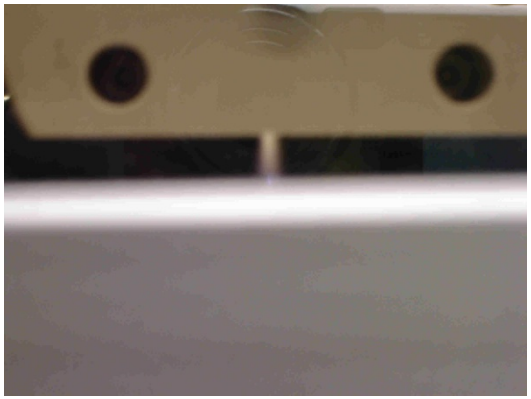
- Surface treatment of natural fibres (hemp & flax) will be undertaken using atmospheric plasma, also called soft plasma.
- Atmospheric Plasma aims at functionalisation of the natural fibre surface only, without affecting the bulk properties of the fibres.
- In this way, an improved fibre-matrix adhesion is aimed at, while retaining the fibre strength.

Plasma for industrial use

- The soft plasma technology can be easily scaled up.
- Unlike vacuum plasma, the atmospheric treatment conditions allow for easy integration into industrial production lines and enable high throughput processing.
- Soft plasma is a dry and clean process, using electricity and mainly nitrogen gas only.
- After plasma treatment, fibres are ready for packaging and shipment to composite manufacturers.

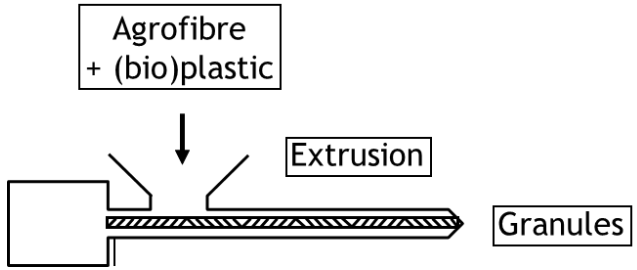


POST DISCHARGE PLASMA



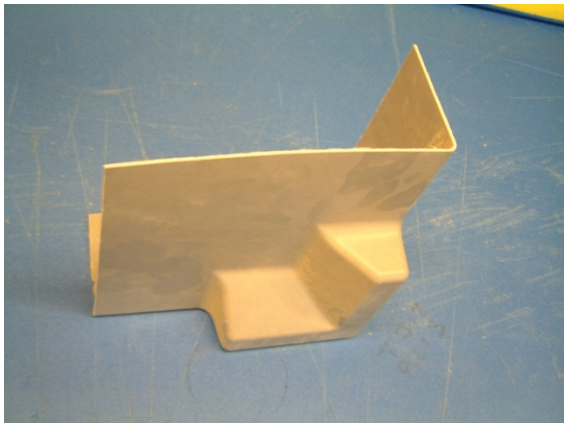
Composite manufacture

- Thermoplastics (PP & PLA)



Injection moulding

- Thermosets (UP)
  - SMC
  - RTM
  - Vacuum infusion



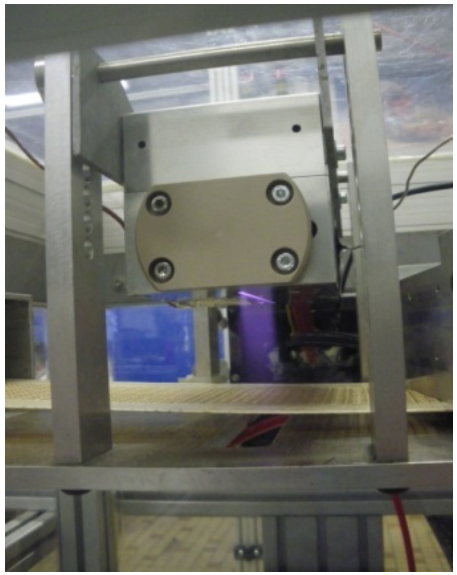
Literature

Literature review on natural fibre-polymer adhesion

- PP:
  - Commercial solution is MAPP.
  - Increase in flexural and tensile strength is 100% and 60%, respectively.
- PLA:
  - Development a research level.
  - 30% Increase in tensile strength may be expected.
  - Research results show increase in mechanical performance, strength performance of composites, however, is lower than for the pure PLA.
- Furan resin:
  - Research results show good adhesion to natural fibres without coupling agents.

Literature review on natural fibre-polymer adhesion

- UP:
  - Development at research level.
  - 60-70% Increase in composite strength may be expected.
- Plasma treatment has positive effect on composite mechanical properties:
  - In small reactor cells, under vacuum.
- UltraFibre develops atmospheric plasma technology for treatment of natural fibres for improved adhesion to polymers
  - Easy to scale up



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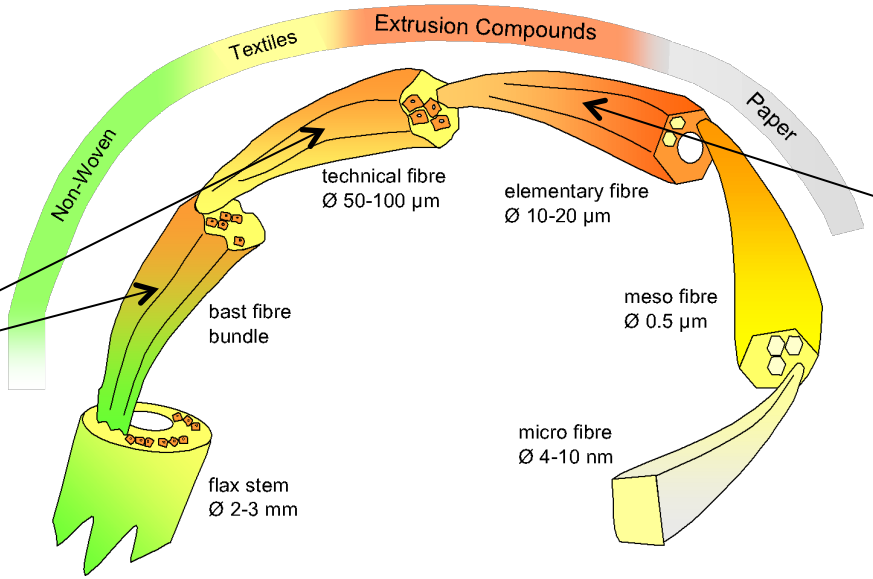
Plasma Treatment trials

Effective Plasma treatment

- Plasma treatment only modifies fibre surface
- Extrusion compounding and injection moulding exhibit fibre refining, thus creating fresh untreated surface
- Therefore, effective modification requires fibre refining prior to plasma treatment
- Fibre refining achieved using Shirley trash analyser

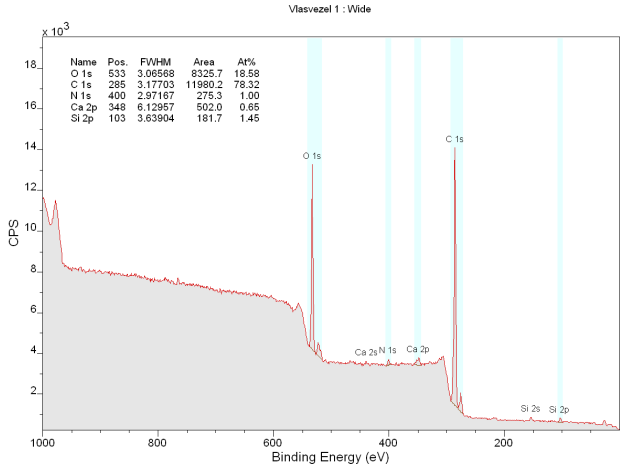


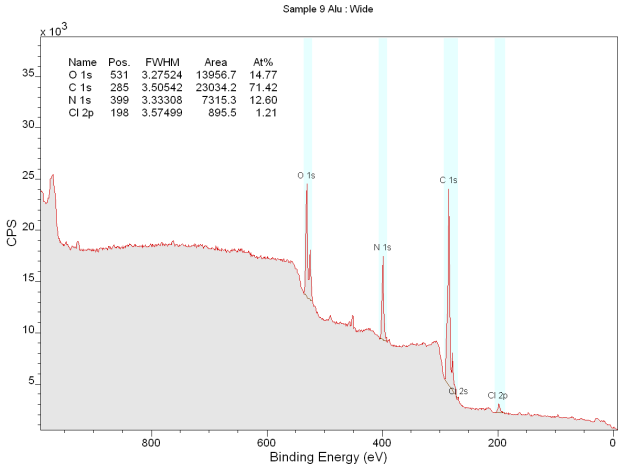
SEVENTH FRAMEWORK PROGRAMME

Effect of Plasma treatment on Fibre properties

- Hemp and Flax fibre surface modified (XPS)

	Oxygen	Carbon	Nitrogen
Hemp, untreated	21.4	76.0	1.5
Hemp, N_2 plasma	21.3	73.6	4.5
Hemp, N_2 + O_2 plasma	26.0	71.5	1.6
Hemp, N_2 + CO_2 plasma	29.2	67.3	2.6
Hemp, N_2 + H_2 plasma	20.5	77.3	1.5
Hemp, N_2 + N_2O plasma	30.7	66.4	1.6
Flax, untreated	15.6	82.8	0.9
Flax, N_2 plasma	11.2	84.9	3.2

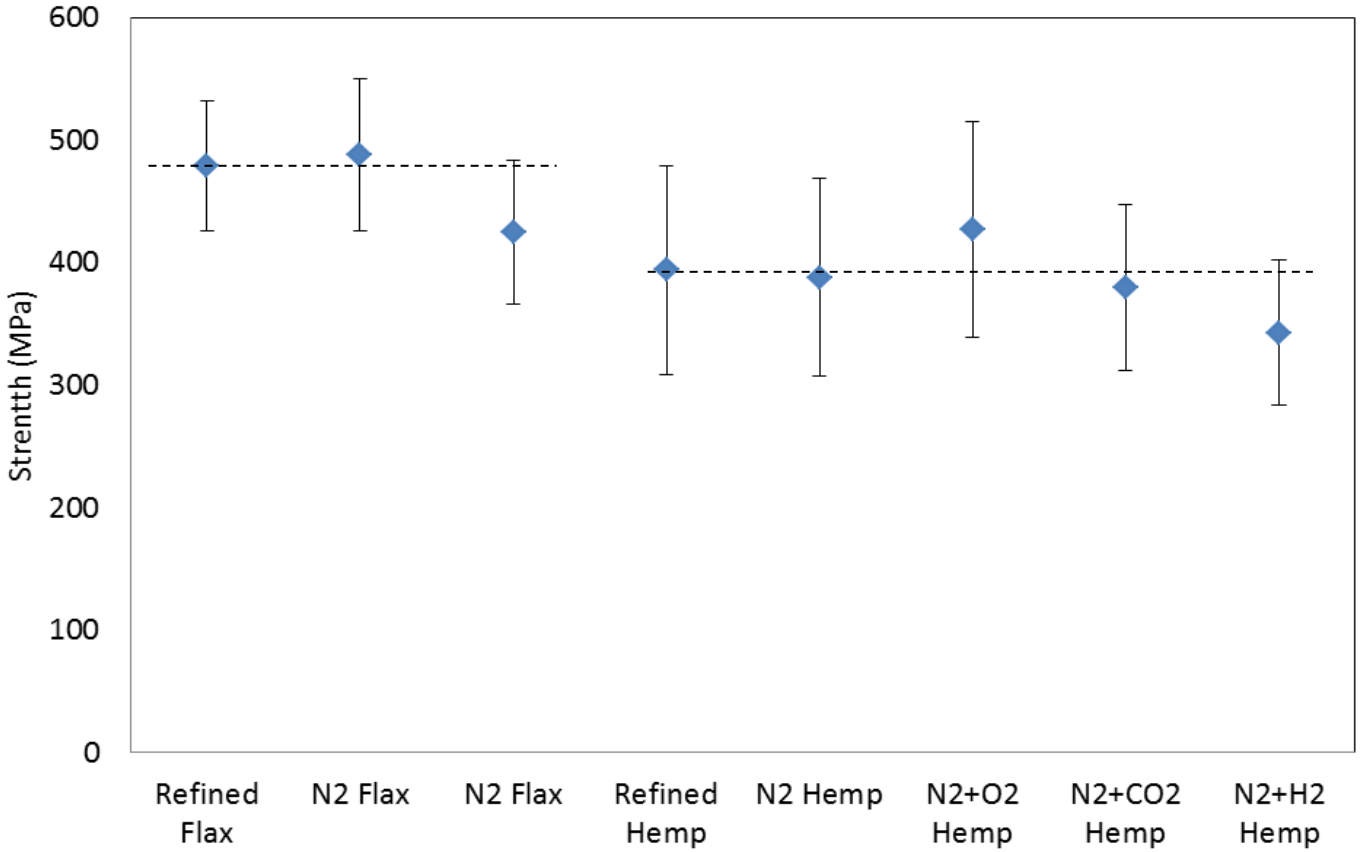




SEVENTH FRAMEWORK PROGRAMME

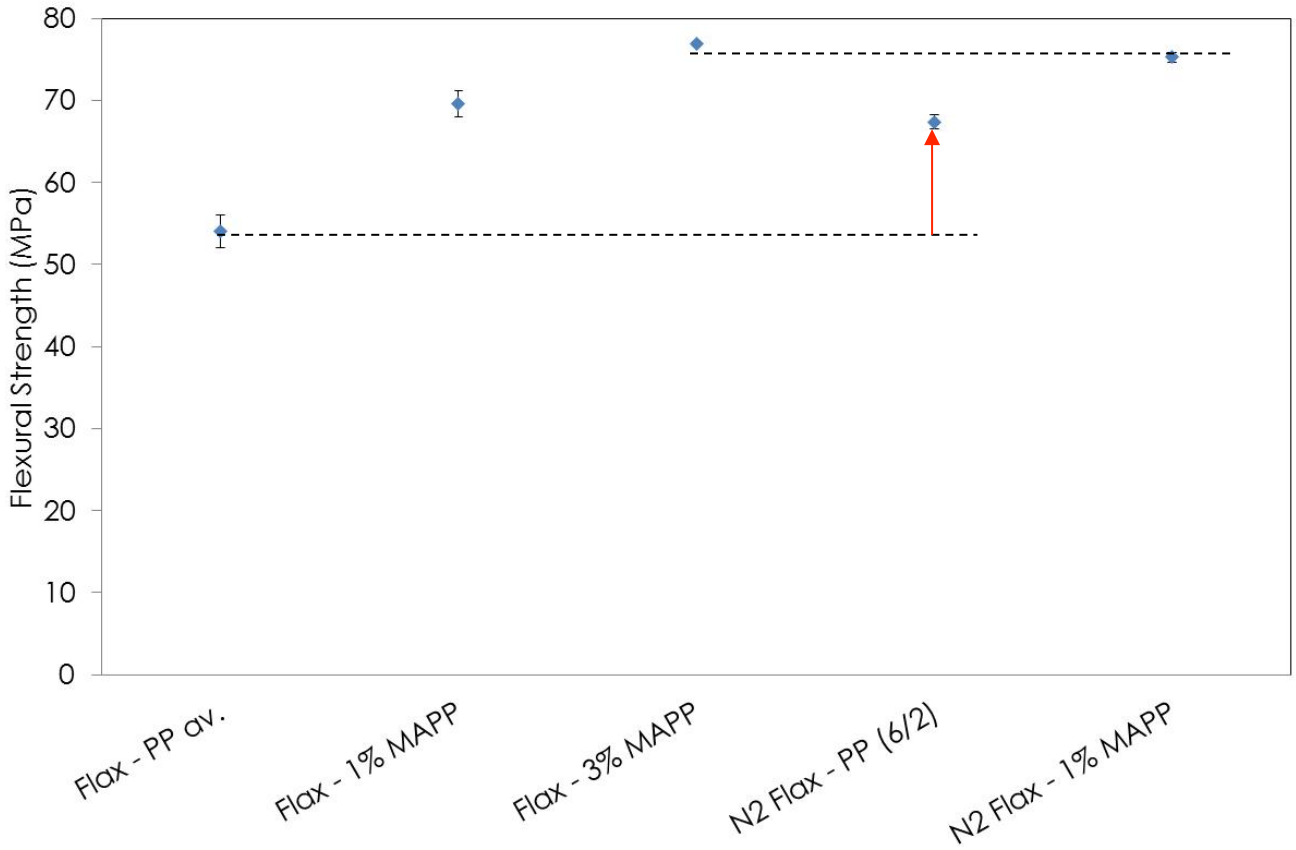
Effect of Plasma treatment on Fibre properties

- Hemp and Flax fibre strength retained



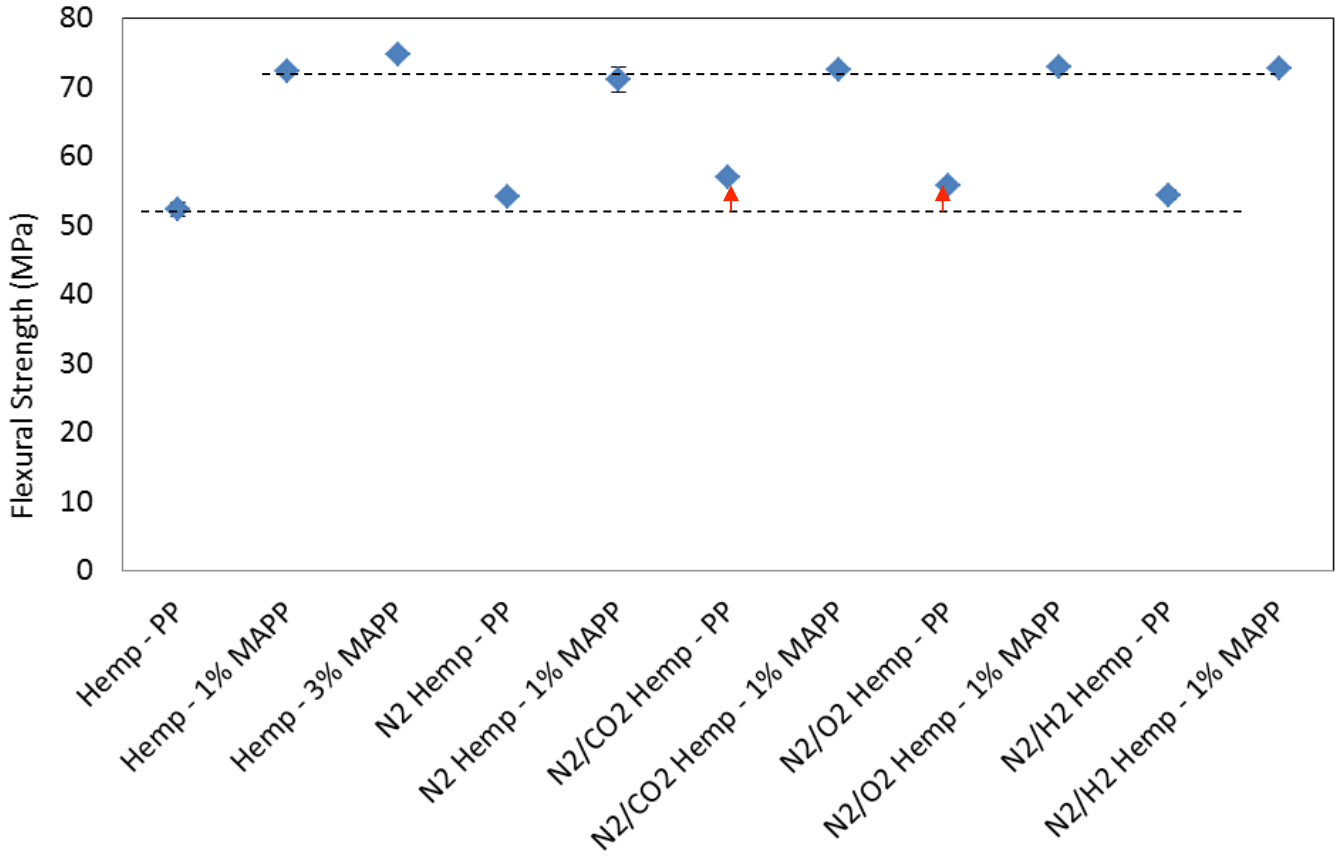
Effect of Plasma treatment on Composite performance

- Flax-PP flexural strength increases by 23%
- Flax-1% MAPP on level of untreated flax-3% MAPP



Effect of Plasma treatment on Composite performance

- Hemp-PP flexural strength not improved

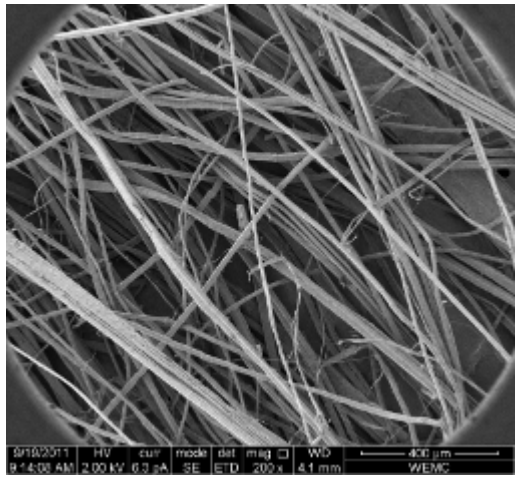


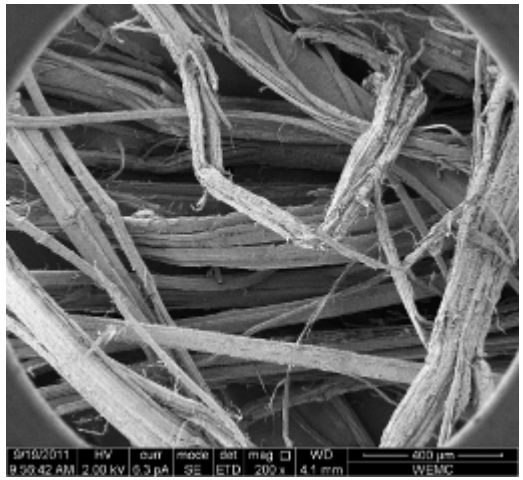
Effect of Plasma treatment on Composite performance

- Hemp fibre not fully refined prior to plasma treatment
- Further refining during extrusion compounding/injection moulding

Single fibres

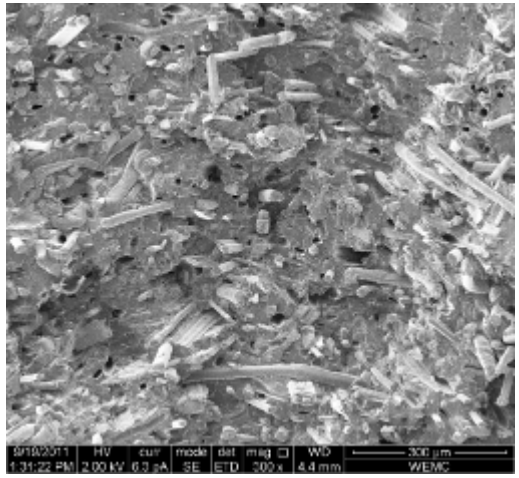
Fibre bundles

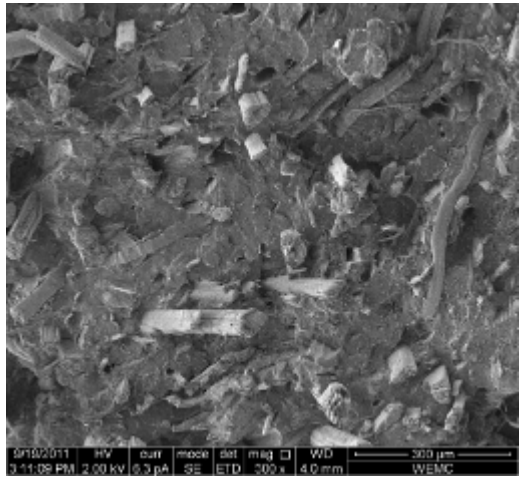




Flax

Hemp

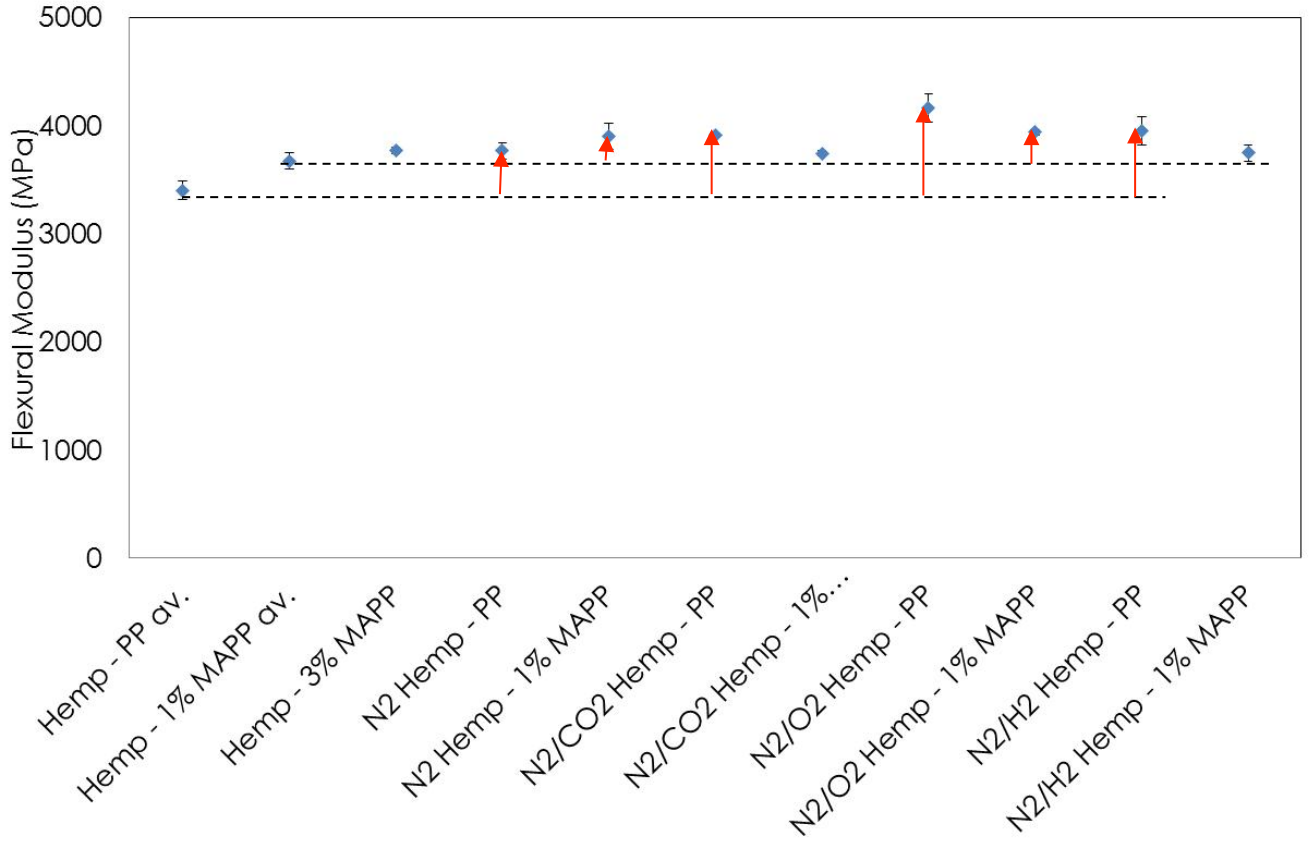




Single fibres mainly

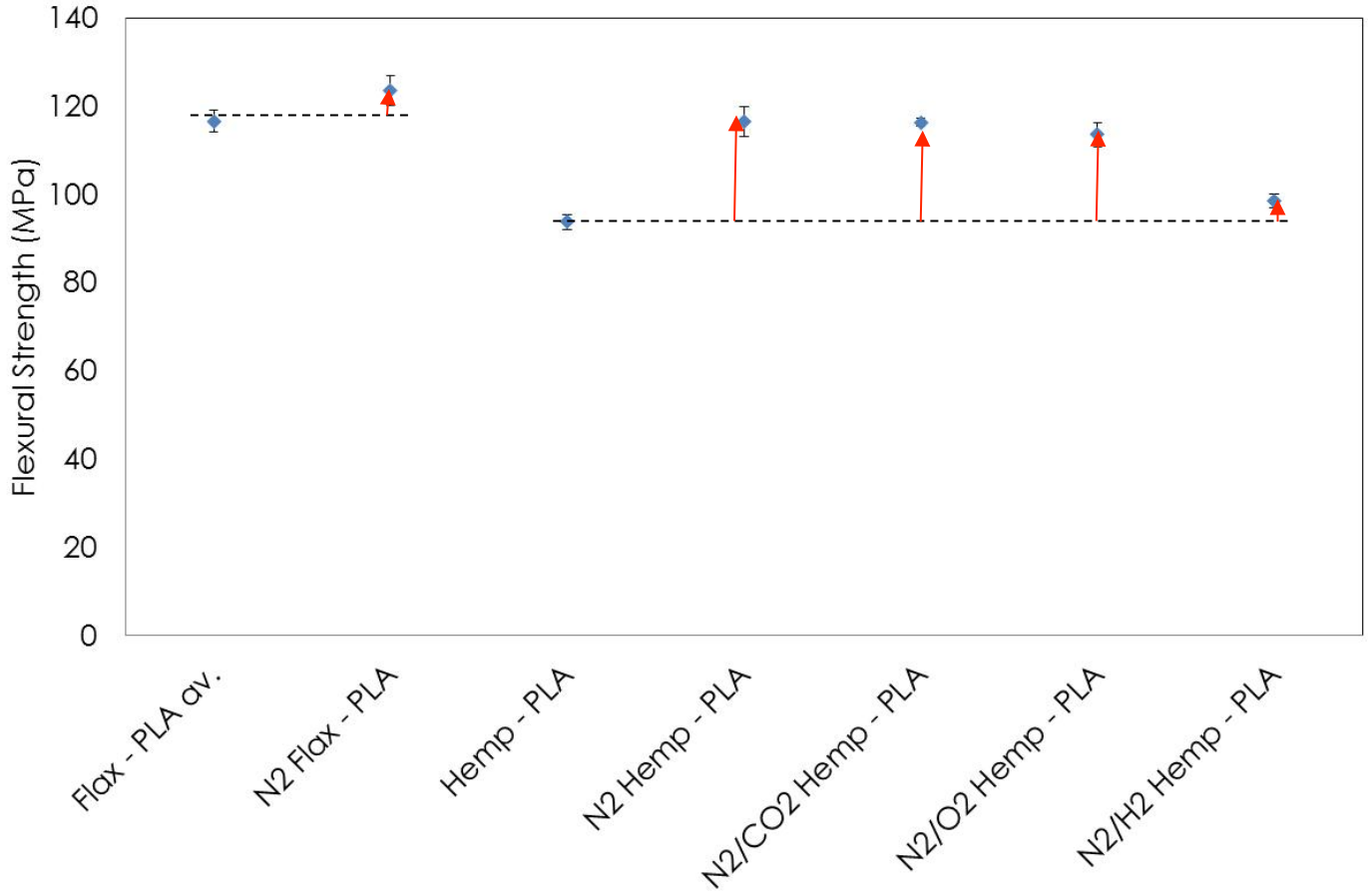
Effect of Plasma treatment on Composite performance

- Hemp-PP flexural modulus increases by 11-22%
- Usual solution to increase modulus is: use more fibres



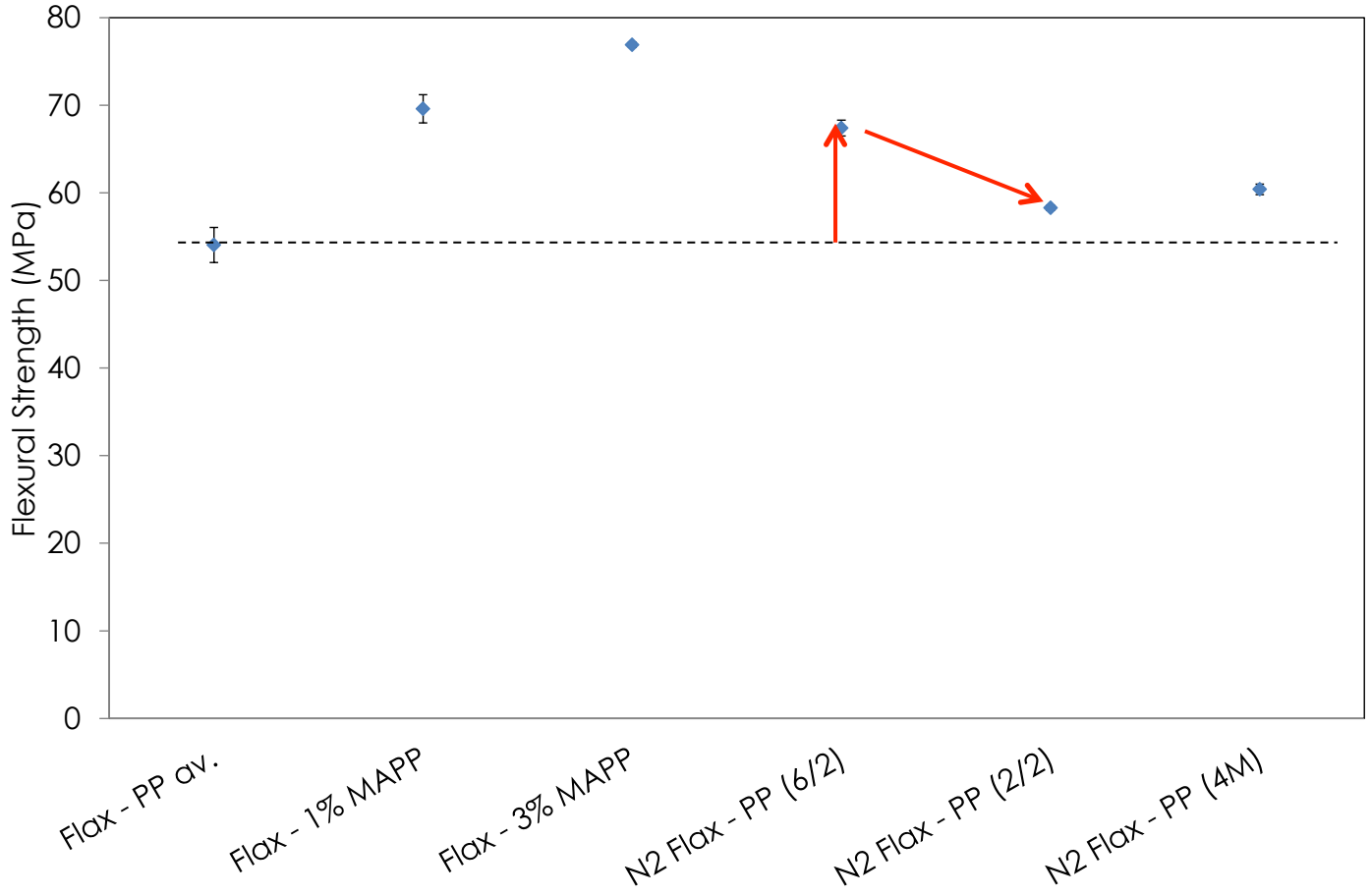
Effect of Plasma treatment on Composite performance

- Hemp-PLA flexural strength increases by 20-24%
- About 10% thinner product has same performance



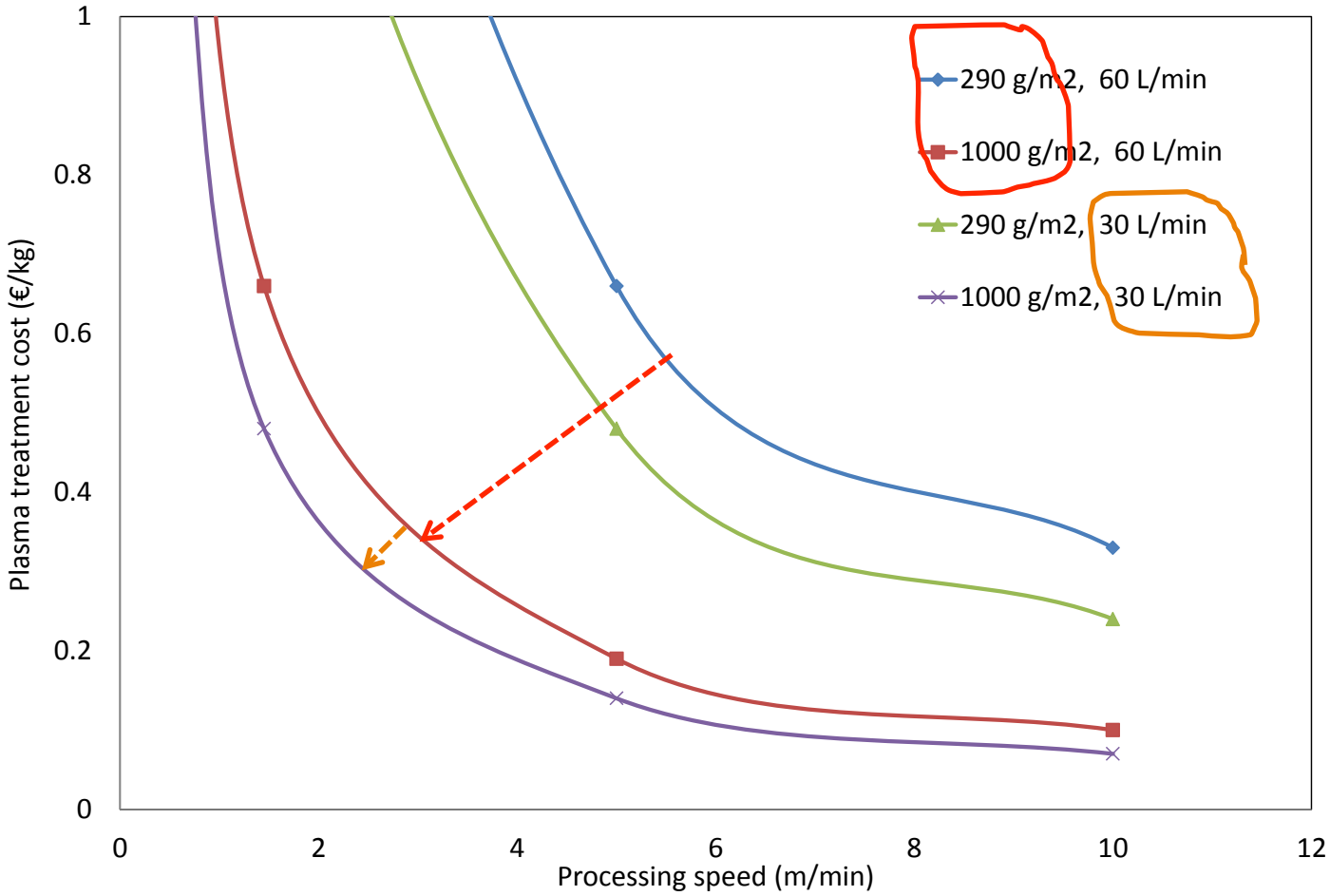
Effect of Plasma treatment on Composite performance

- Thorough plasma treatment required
- Plasma treatment quite durable



Economic review
PP Composites

- In particular mat weight influences cost → Coarse fibres required



Conclusions

- Plasma treatment seems best suitable for composites which do not exhibit fibre refining during processing: SMC, RTM, vacuum infusion
  - Higher processing rates (kg/h) expected for coarser fibres

- Further considerations:
  - Plasma treatment of Hemp-PP non-woven for NMT would activate both fibre and matrix
  - Finding reactants to apply directly after plasma treatment which may enhance adhesion to PP/MAPP or PLA or UP and which allow higher plasma processing rates
  - Plasma treatment may add other features to natural fibres

Partnership

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Further info & Acknowledgement

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