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# Natural fibre preforms for high performance biocomposites

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# Why natural fibre composites?

- Annually renewable material source
- Environmental benefits at use and disposal
- Some bast and leaf fibres (flax, hemp, kenaf, sisal, etc) have excellent mechanical properties
- Possible savings due to lower fibre cost
- Better working environment than glass fibres
- Performance benefits:
  - Lighter weight
  - Reduced fuel consumption for automobiles
  - Less sharp edges in a road accident
  - Noise absorption
  - Thermal insulation
- A major challenge is composite mechanical performance.

# Fibre orientations & composite mechanical properties

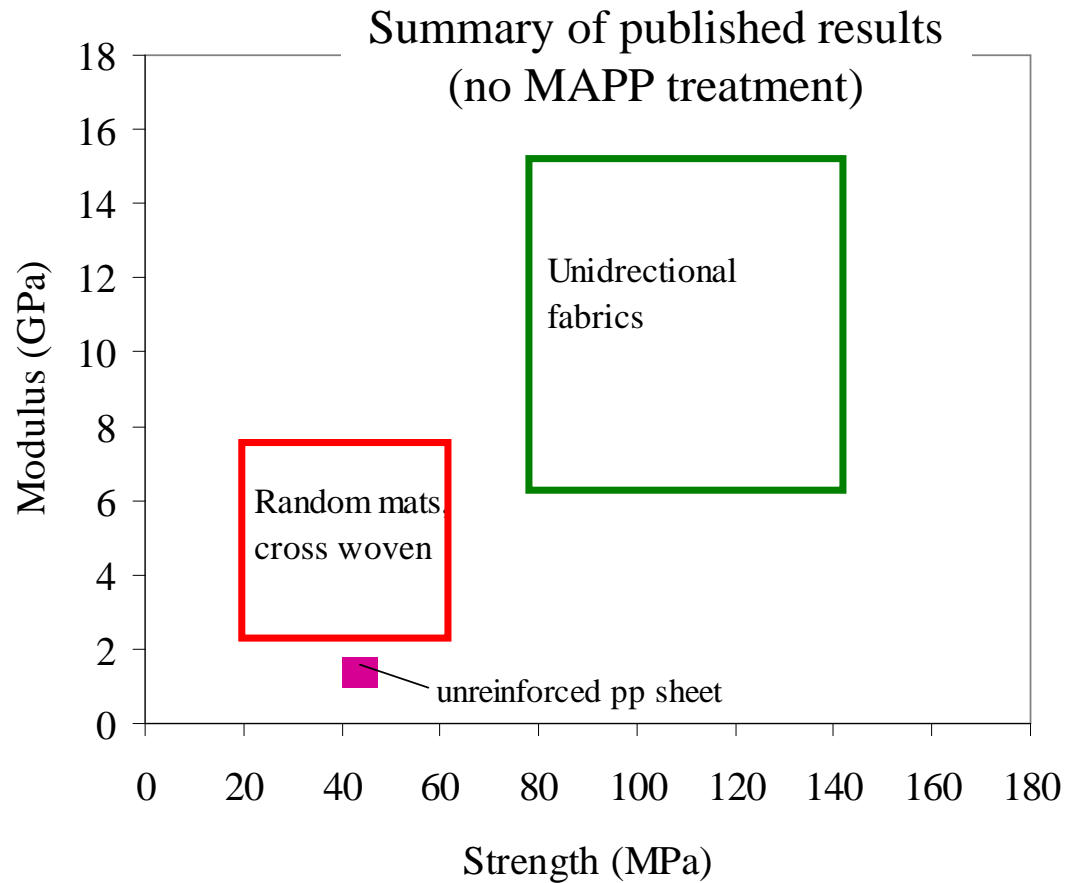
## Rule-of-mixtures

$$E_C = \eta_0 \eta_l V_f E_f + V_m E_m$$

## Fibre orientation factor

$$\eta_0 = \sum a_n \cos^4 \theta_n$$

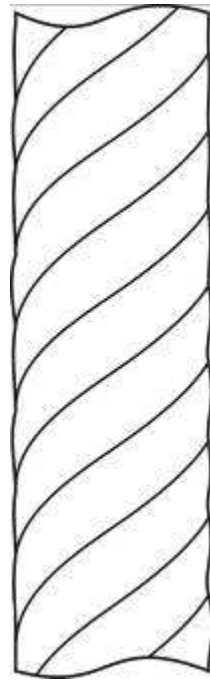
# Fibre architecture has a major influence on final composite performance



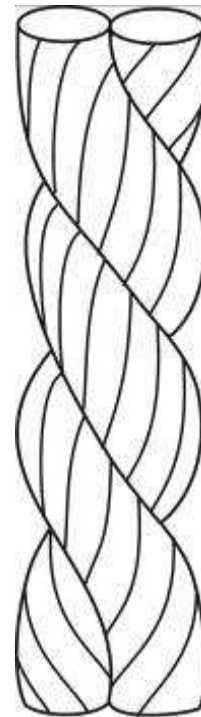
- **Cross-woven is not much better than random nonwoven.**
- **Unidirectional fabric is the best.**

# Fibres in unidirectional fabrics are not unidirectional.

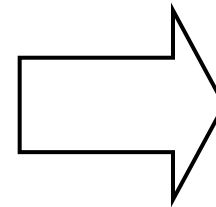
Fibres follow helical paths in conventional yarns



singles

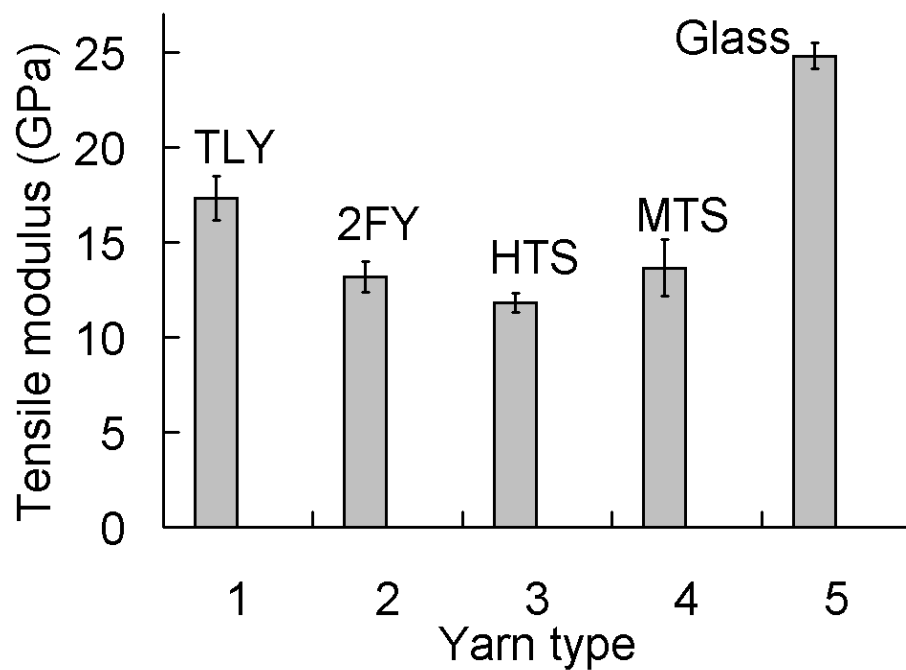


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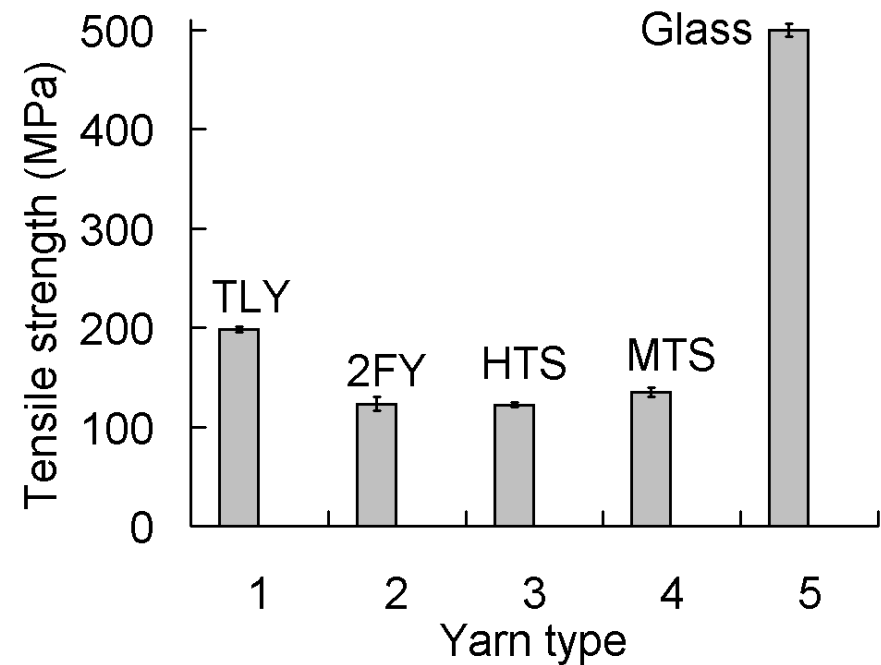


Twistless yarns

# Twistless yarn is the best structure



TLY: Twistless Yarn  
2FY: 2-Fold Yarn

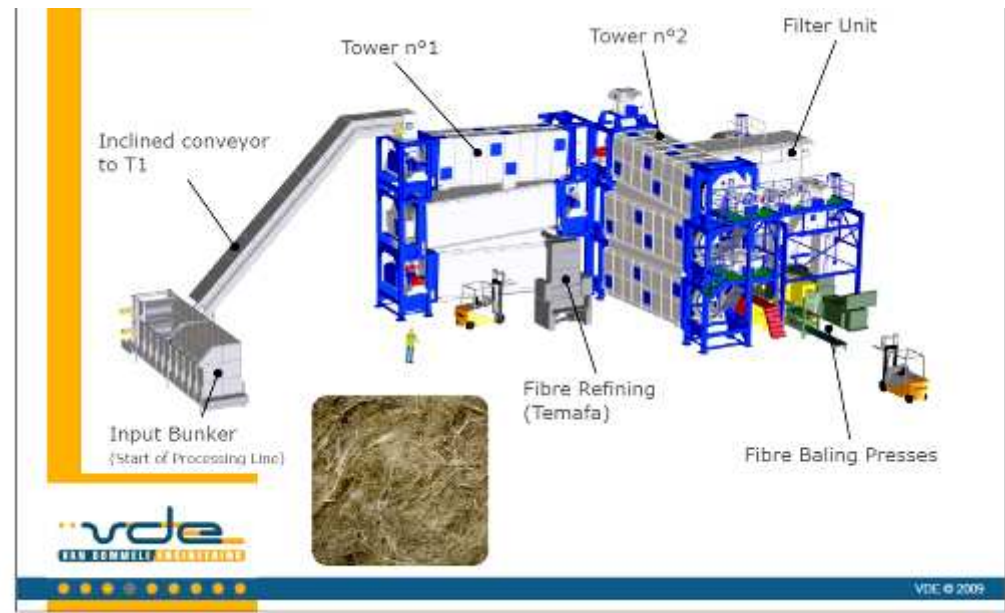


HTS High Twist Singles  
MTS: Medium twist Singles

## Flax/epoxy thermoset composites

# Cost of natural fibres

- Traditional spinnable flax (e.g., linen) is very expensive.
- Modern decorticated fibres cost about \$1/kg, significantly cheaper than glass fibres.
- These fibres are usually short and variable in length, suitable only for nonwoven processes, not for spinning and weaving.
- However, fibre strength is not very different from traditional fibre.

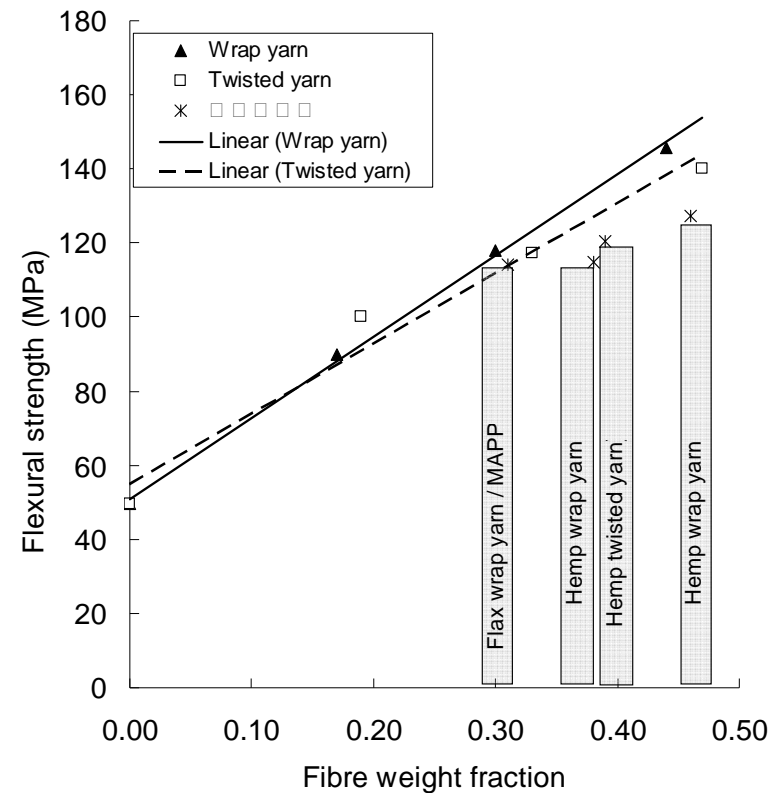


<http://www.vandommele.be>



# High performance composites from lower grade fibres

Polypropylene fibre is used as carrier for spinning low grade natural fibre. PP fibre becomes matrix in final composites.



Zhang and Miao, Composites Science and Technology 70 (2010) 130–135



# Minimising processing cost

- The most expensive operations in unidirectional fabric production are spinning and weaving.
- Nonwoven process is much cheaper, but random fibre orientation.
- The challenge is to a nonwoven preform that has :
  - excellent fibre alignment;
  - sufficient strength for downstream handling.

# Highly align natural fibre nonwoven mat

Blending flax/polypropylene fibres



Carding to obtain initial fibre batt



Drawing to improve fibre orientation

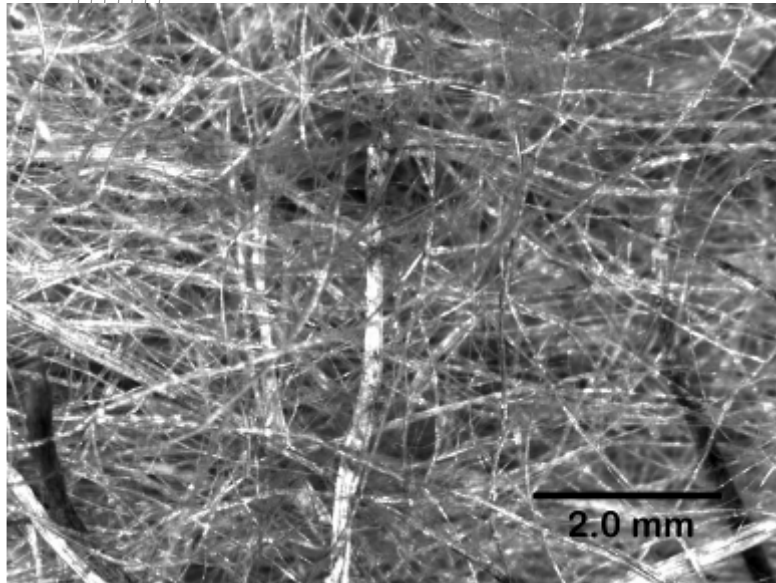


Bonding to produce a roll of unidirectional mat

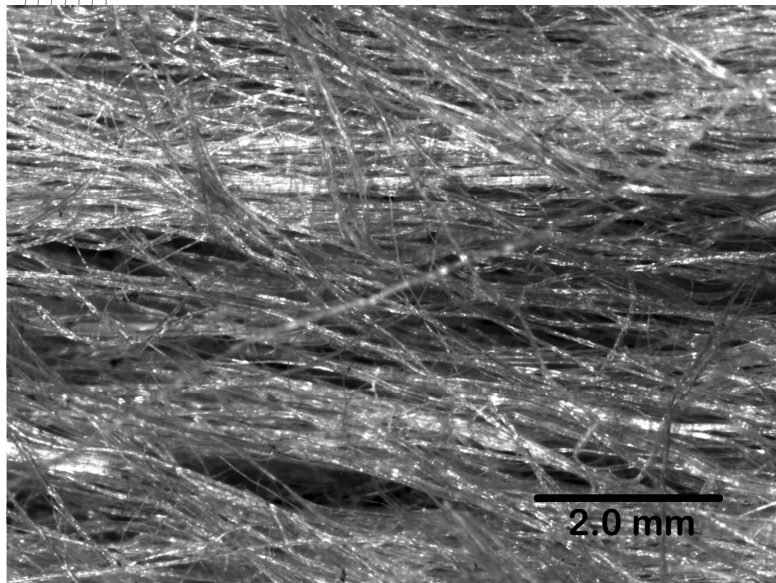


Compression moulding to produce  
high performance thermoplastic composites

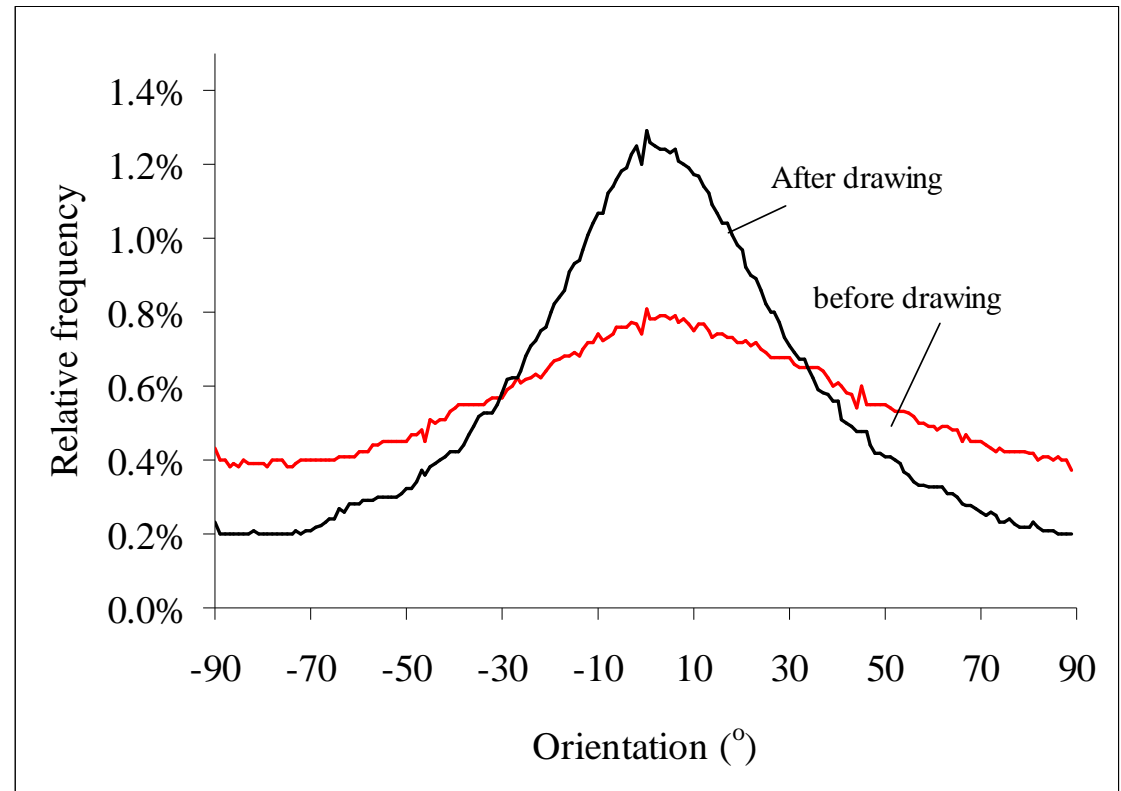
# Effect of drawing



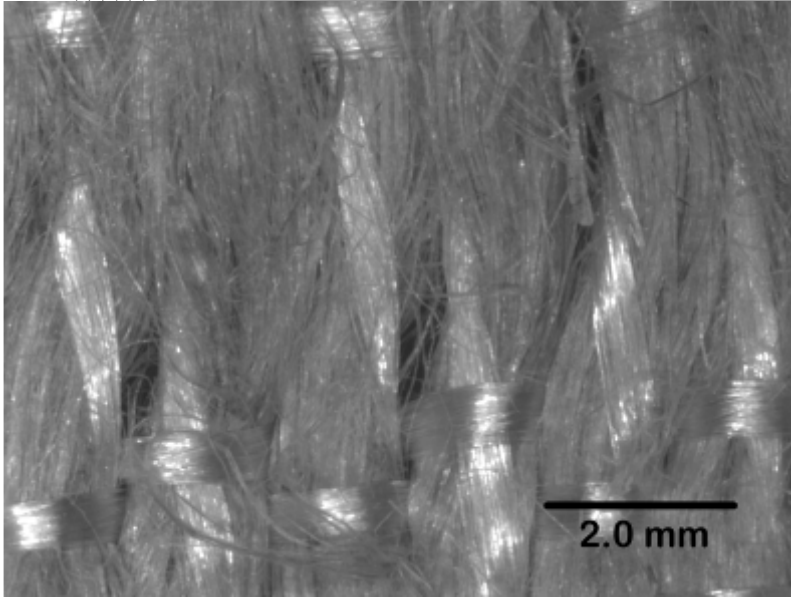
Before drawing



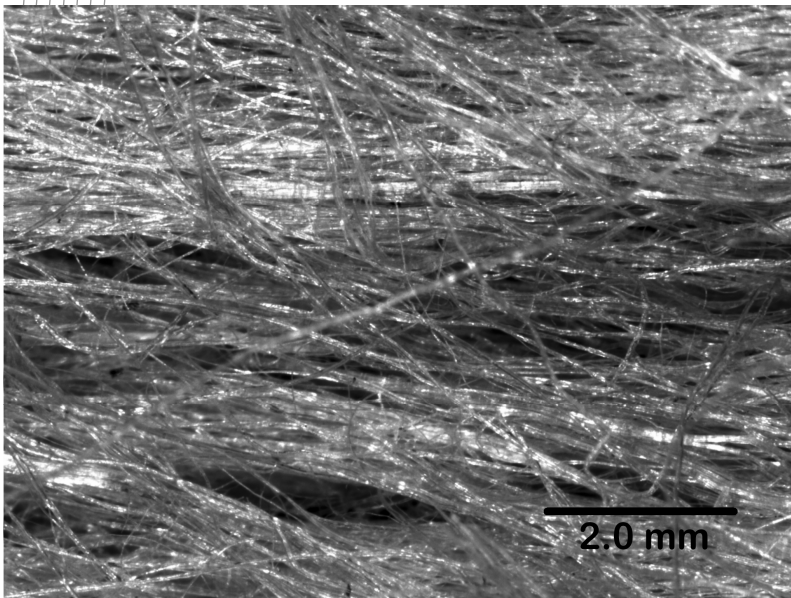
After drawing



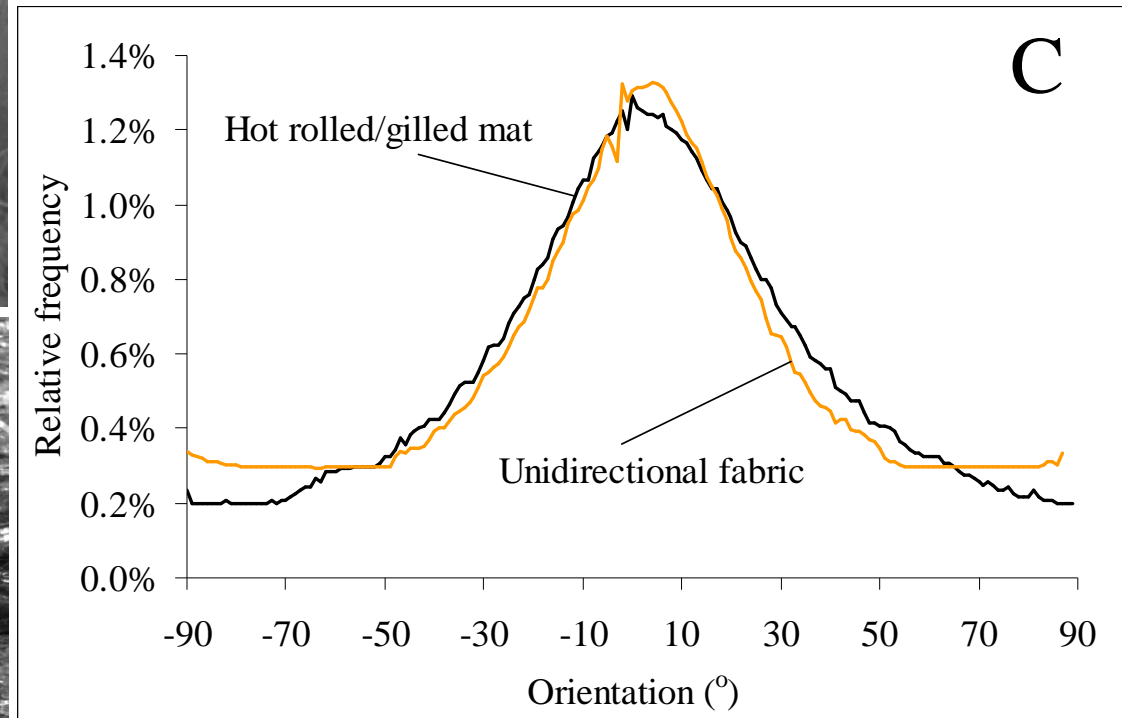
# Compare with unidirectional woven fabric



Unidirectional woven fabric  
of twistless wrap yarns

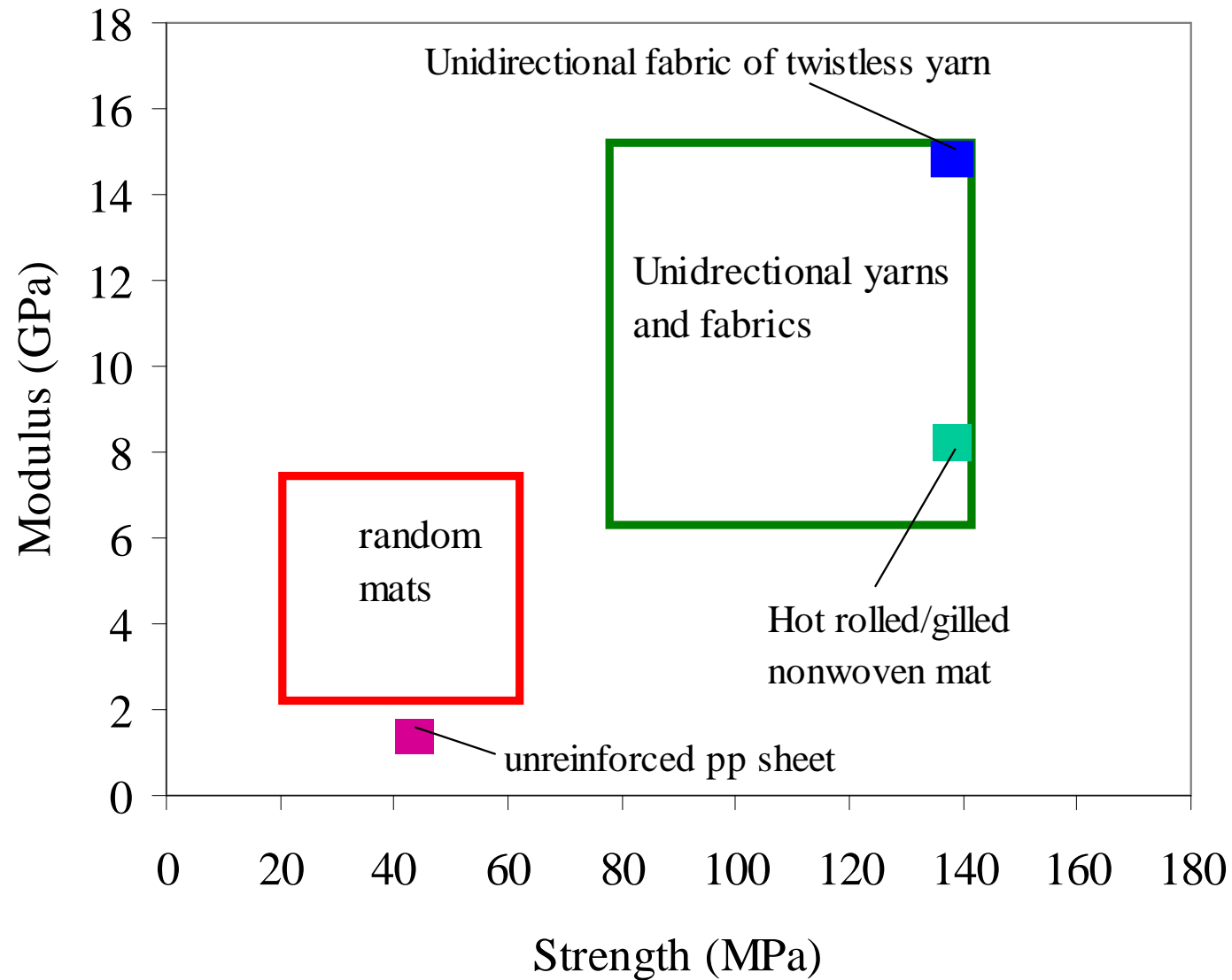


Unidirectional nonwoven mat



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# Composite performance



# Conclusions

- Carefully designed textile structures improve biocomposite performance.
- Low grade fibres is used to replace high grade fibres in high performance biocomposites.
- Preform manufacturing process is simplified to reduce production cost.
- Look forward to working with industry to develop specific products.

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**Thank you**

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