Polypropylene fibers nanocomposite: properties, structure and process parameters

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Polypropylene Fiber Nanocomposites: Properties, Structure and Process Parameters

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National Research Council Canada | Conseil national de recherches Canada

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Objectives

PP ≠ Engineering applications

Improve mechanical performance

- **Foreign fillers**
  - Talc, Glass fibers, etc.
  - Clay platelets (nanocomposite)
- **Oriented fibers**
  - Commercial products:
    - *Curv*
    - *Pure*
    - *etc*

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Oriented fibers
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Combine the two types of reinforcement

Oriented nanocomposite fibers to produce a composite
- Orientation of the polymer chain
- Clay reinforcement
- *Possible clay orientation*

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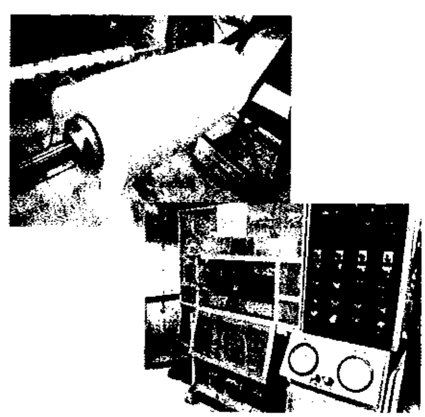
Overview

- **Experimental Procedure**
  - Material
    - Nanocomposite formulation
    - Fibers fabrication
  - Consolidation
- **Results**
  - Fibers characterization
    - Clay distribution
  - Consolidation
    - Voids distribution
    - Mechanical properties
- **Conclusions**



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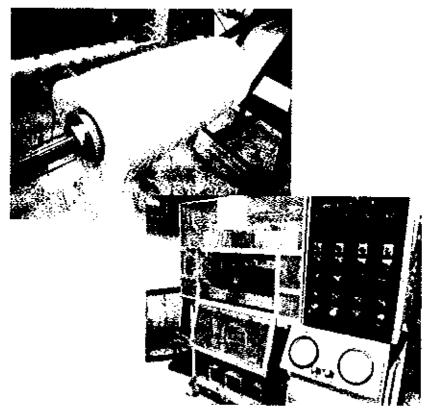

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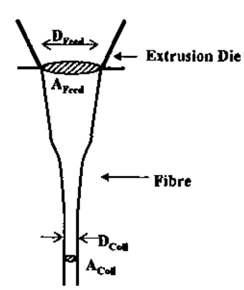
Nanocomposite formulation and fiber fabrication

Formulation:

Polypropylene
+
Clay platelets
+
Maleic anhydride grafted polypropylene
⬇
Nanocomposite

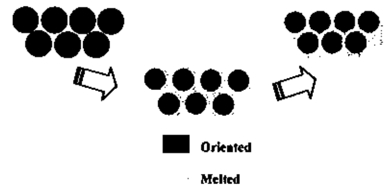
Fiber extrusion:

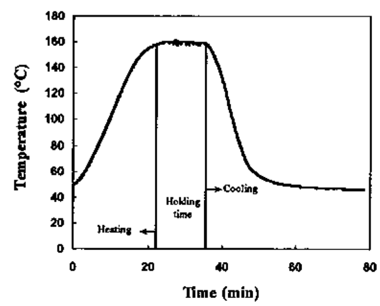


- **Fibers extruded at 220°C**
- **Draw ratio was defined as the ratio of collecting speed and feeding speed of the fibre**

Consolidation principle

- **Partially melt the oriented fibers to create a matrix phase...**
  - One fraction of the material remain oriented to provide good mechanical properties
  - The melted fraction of the fibers becomes the matrix phase



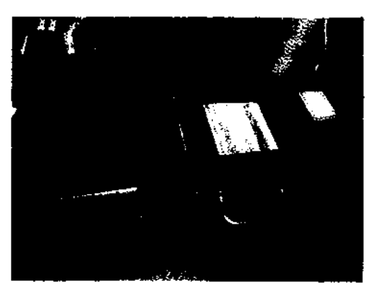


👍 Good fiber/matrix interface property because of chain continuity

👎 Narrow temperature window

Consolidation

- **Two different procedures:**
  - Unidirectional laminates
  - Reference plates
- ***Unidirectional laminates:***
  - Compression molding using aluminum tooling
  - Fibers aligned manually
  - 42 grams for 2-mm thick laminates
  - Parameters:
    - Pressure: 2.4 MPa (350 psi)
    - Temperatures: 160-167°C
    - Holding time: 5-15 minutes



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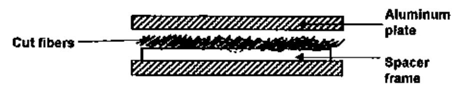
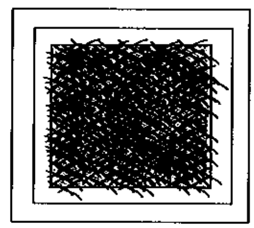
Consolidation

- **Two different procedures:**
  - **Unidirectional laminates**
  - **Reference plates**



- *Reference plates:*

  (Remove any possible orientation effect)
  - **Cut fibers (25.4 mm) randomly oriented**
  - **Compression molding using a spacer frame to prevent excessive flowing**
  - **Molding parameters:**
    - **Temperatures: 180°C**
    - **Holding time: 15 minutes**



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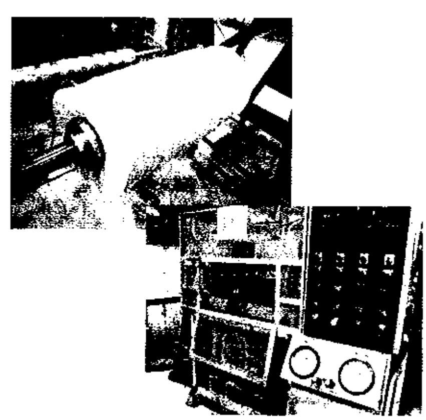

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Clay distribution

- Preferential alignment of the clay platelets is observed

- Clay platelets not completely exfoliated ⇨ aggregates can be observed

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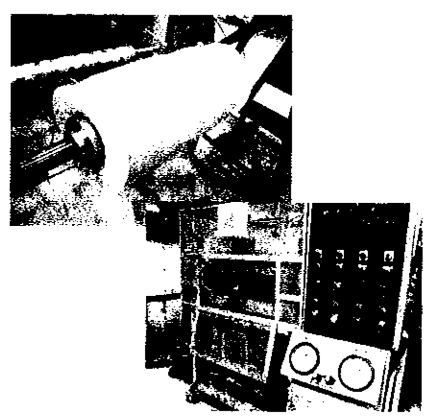

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Reference Plates

- **<u>Consolidation</u>**
  - Fiber pattern erase
  - Randomly distributed voids

- **<u>Mechanical properties</u>**

	Flexural Modulus (GPa)	Maximum Flexural Stress (MPa)
PP	1.64	60.1
PPNC	1.84	61.5

<u>Flexural modulus:</u> up 12% for PPNC
<u>Maximum Flexural stress:</u> no change

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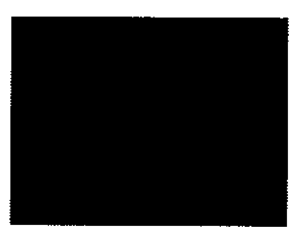
Void Distribution

- Consolidation temperature of 165°C
  - **Holding time: 5 minutes**
    - **Large porosities between the fibers**
      ⇨ Insufficient resin melting

  - **Holding time: 15 minutes**
    - **Small voids between the fibers**
      ⇨ significant improvement of the consolidation



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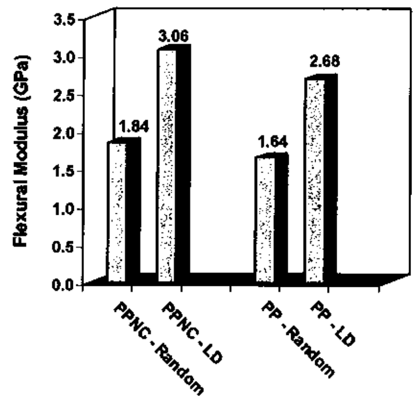
Mechanical Properties

- **Flexural Modulus**
  - **Nanocomposite:**
    - Longitudinal direction:
      - **Up 40% compared to randomly oriented**
      - **Up 12% compared to oriented PP**



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Mechanical Properties

- **Flexural Modulus**
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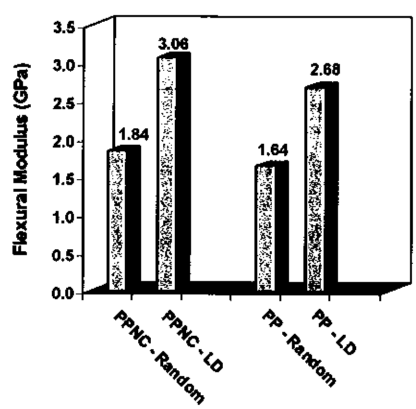
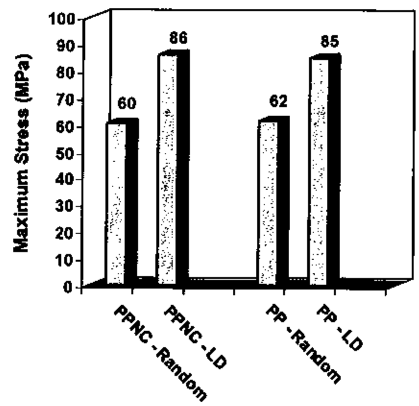
⇨ **Orientation and nanoparticles yield better results**



Mechanical Properties

- **Maximum Flexural Stress**
  - **Nanocomposite:**
    - Longitudinal direction:
      - Up 30% compared to randomly oriented
      - Similar to oriented PP



Mechanical Properties

- **Maximum Flexural Stress**
  - **Nanocomposite:**
    - Longitudinal direction:
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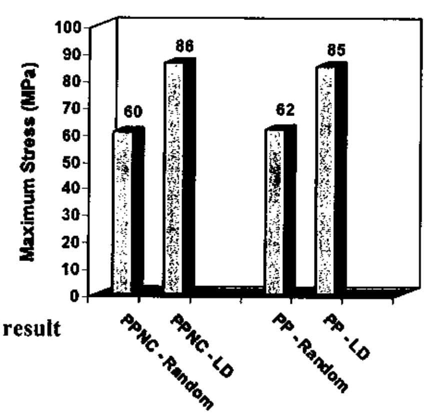
      - Similar to oriented PP

⇨ **Orientation gives better results**

⇨ **Addition of nanoparticles did not result in significant improvement**



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Conclusions and Future works

- **Polymer Fibers**
  - Significant improvement in mechanical properties
  - Better formulation will be used
  - Should high performance polymer be used?
- **Consolidation**
  - Very narrow processing window
  - Void content should be reduced
  - Promising mechanical properties
    - *40% improvement compared to randomly oriented fibers*