Water diffusion and mechanical behaviour of Nylon fibres

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Plan

I – Study context

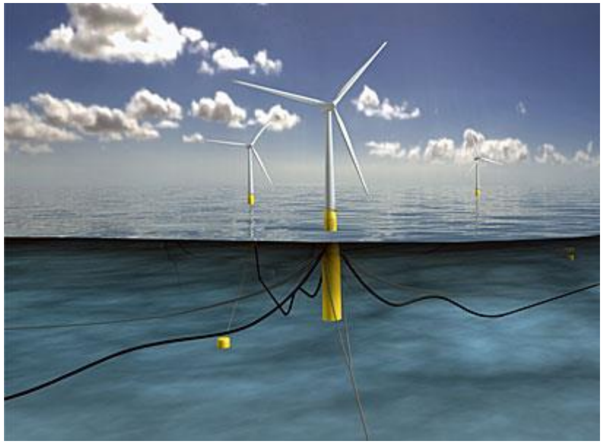
II – Water diffusion in Nylon fibres

III – Influence of water on Nylon fibres

IV – Conclusion

I
Study context

- Larger study : **Predict Nylon ropes behaviour in marine environment**

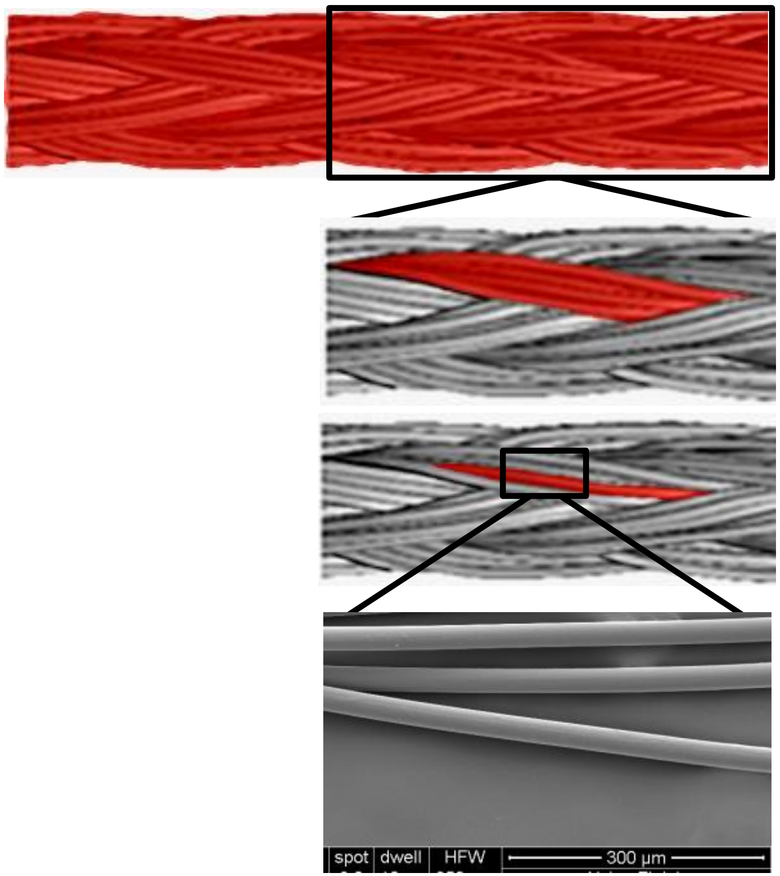


Study context

Predict **Nylon ropes** behaviour in marine environment

Ropes constructions

- Exemple of a braided rope



- Braided rope

Assembled Strands and Yarns

- Strands and Yarns

Assembly of filaments

Ø = from millimetres to few centimetres

- Mono-filaments of PA6

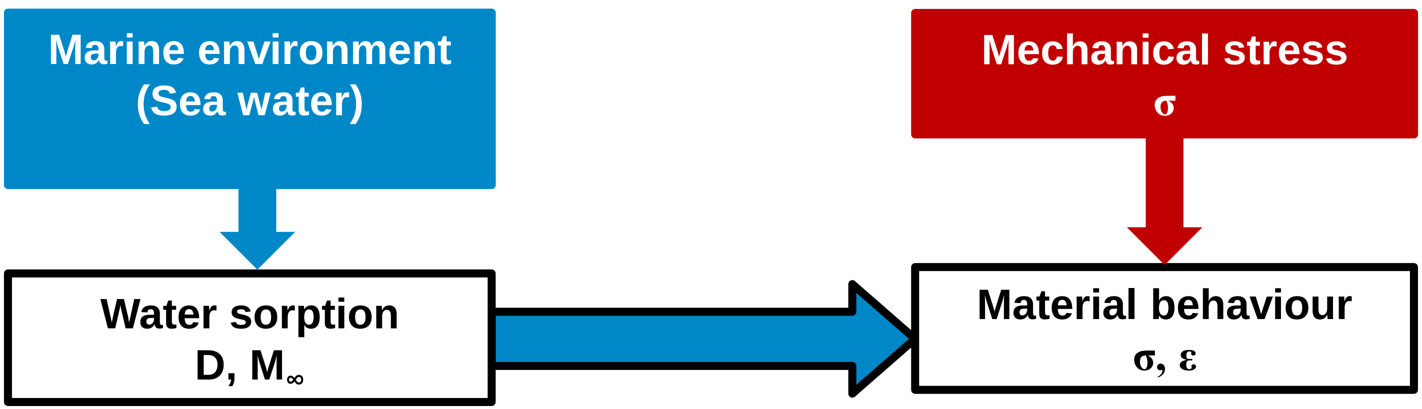
Ø = few microns

Study context

Predict Nylon ropes **behaviour in marine environment**

Nylon ropes behaviour in real life

- Ropes in the marine environment



- Previous studies :

- *Water diffusion : [Kawasaki et al. 1962]*
- *Mechanical behaviour : [Marcellan et al. 2006]*
- *Interaction of both : [Derombise et al. 2011] (not on Nylon)*

II
Water diffusion in Nylon fibres

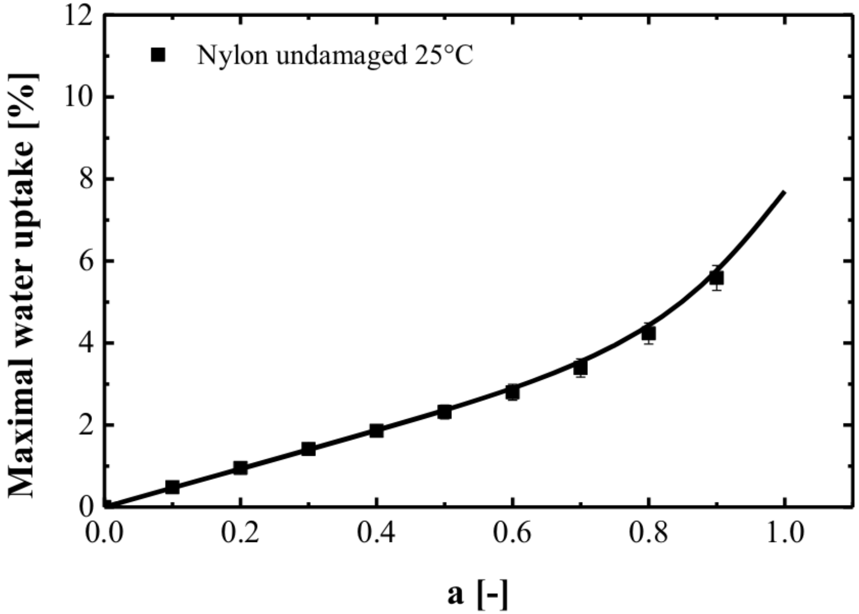
- Water diffusion in humid environment
- Water diffusion in sea water

Water diffusion in Nylon fibres

Water sorption in PA6 fibres

➢ In humid environment

- Based on DVS measurements
- Maximum water uptake is recorded at every 10%RH stage
- Measurements made from 10 to 90%RH



Results follow modified Henry's law with an Arrhenius function

$$C_\infty(a) = H \times a + b \times a^m = H_0 \times \exp\left(\frac{-E_a}{R \times T}\right) \times a + b \times a^m.$$

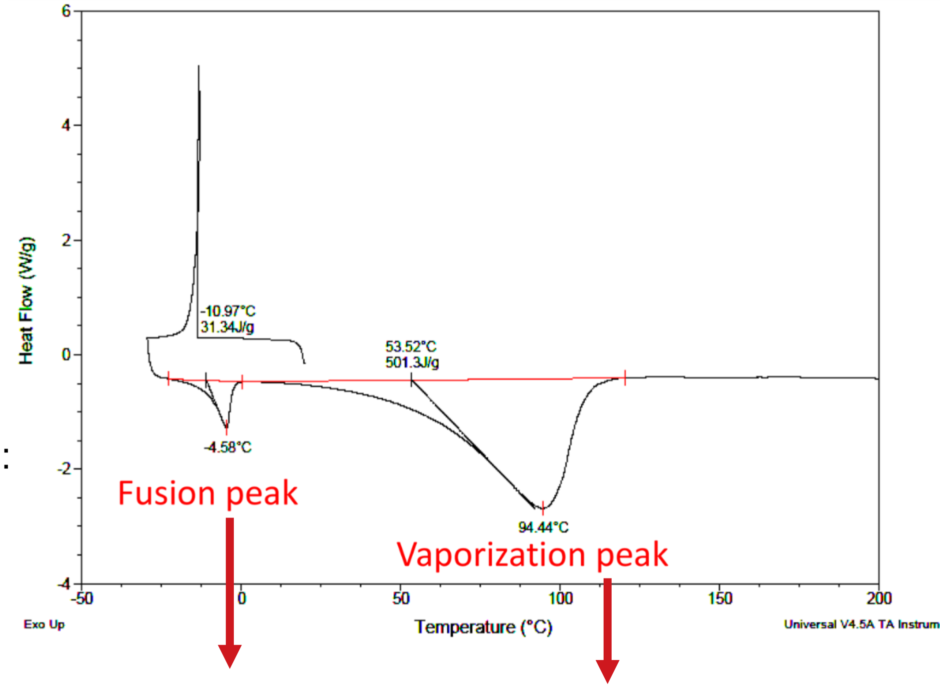
Arhant et al. 2016; Broudin et al. 2015

Water diffusion in Nylon fibres

Water sorption in PA6 fibres

➢ In sea water

- Based on DSC measurements
- Separation of water quantity inside and between fibres



Analysis of the Fusion and Vaporisation peak :

Fusion : Water located in between fibres

Vaporisation : Total water content

$$C_{i,\infty} = C_{t,\infty} - C_{e,\infty}.$$

$$C_{e,\infty} = \frac{\Delta H_f}{X_c \times \Delta H_f^0},$$

$$C_{t,\infty} = \frac{\Delta H_v}{X_c \times \Delta H_v^0},$$

Water diffusion in Nylon fibres

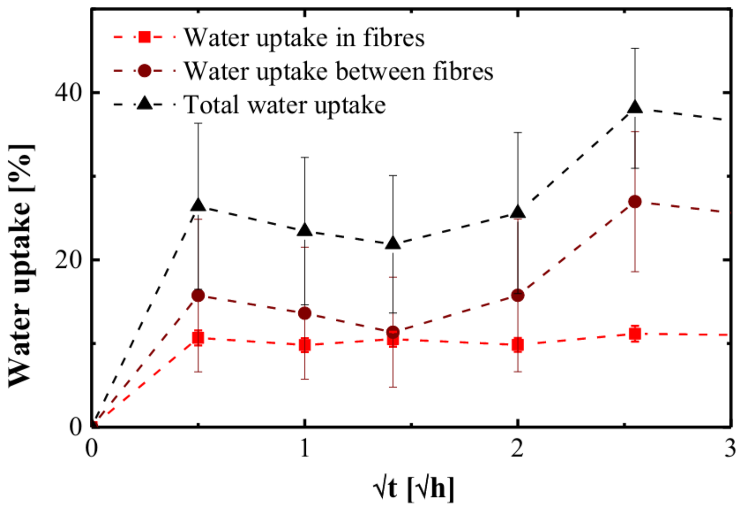
Water sorption in PA6 fibres

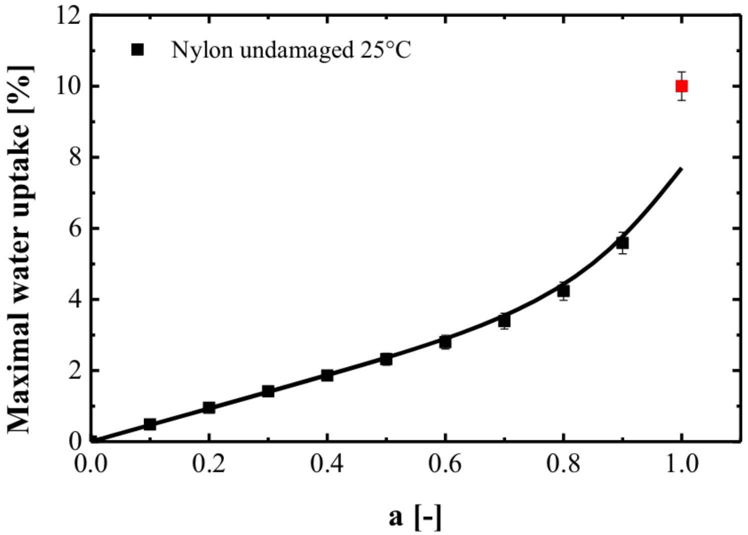
- In sea water

- Total water uptake and water uptake between fibres : no tendency

- Water uptake in fibres is constant (10%)

- Comparison with water uptake in humid conditions :
  - Does not match the prediction
  - Significantly higher





III
Water influence on Nylon Fibres

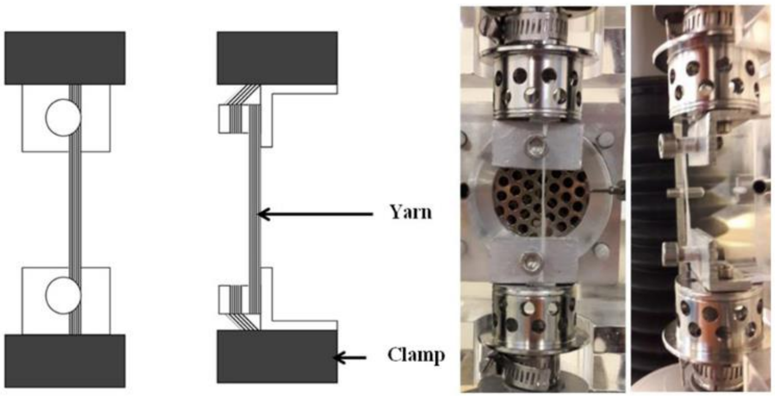
- Glass transition
- Mechanical behaviour

Water influence on Nylon ropes

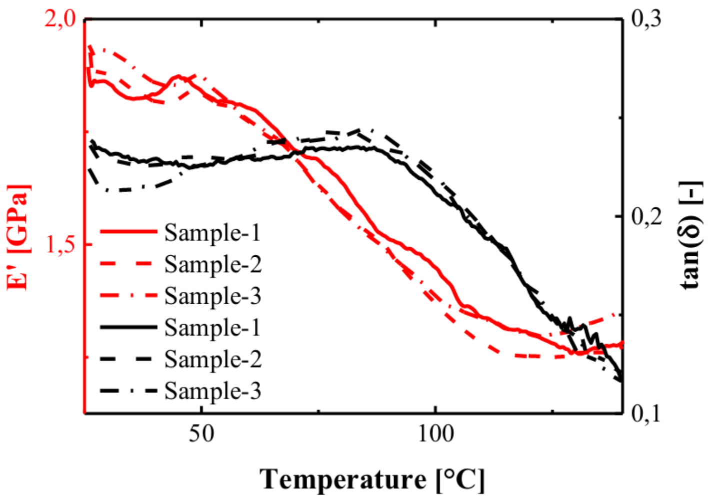
Glass transition of Nylon fibres

➢ In 0% RH atmosphere

- DMA measurements
- From 25 to 180°C
- Specific clamps



- Tg of nylon fibres around 55°C
- Higher than bulk PA6 (50°C)

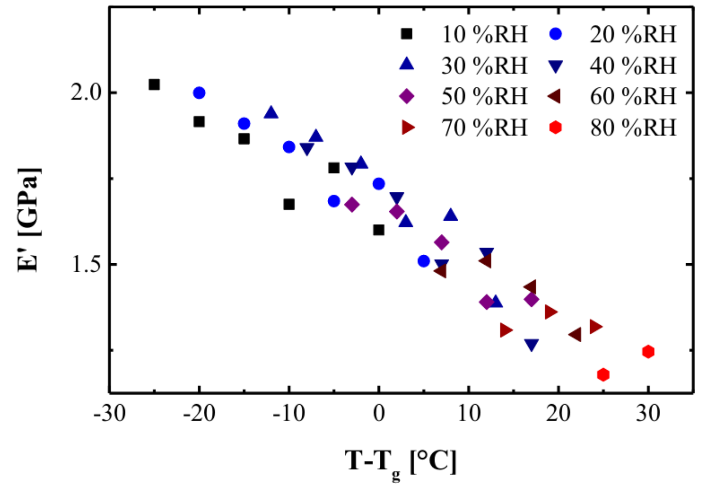


Water influence on Nylon ropes

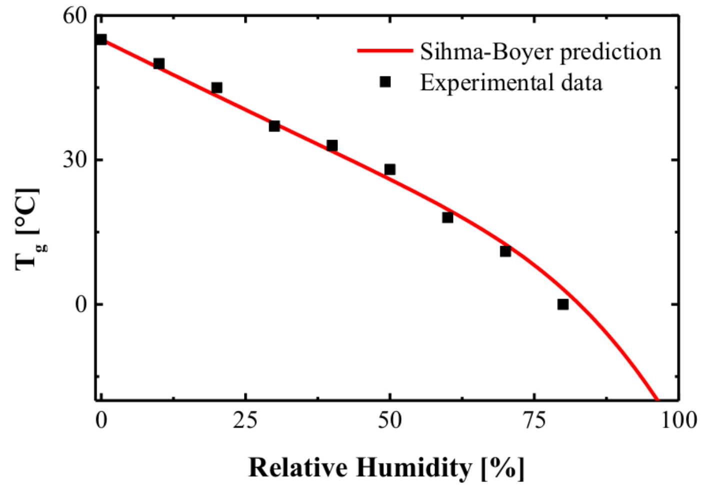
Glass transition of Nylon fibres

➢ In humid environment

- Temperature from 20 to 50°C
- Relative humidity from 10 to 80%RH
- T-Tg translation to fit the master curve at 0% RH



- Tg = f(RH%)
- Tg variations follow Sihma-Boyer prediction

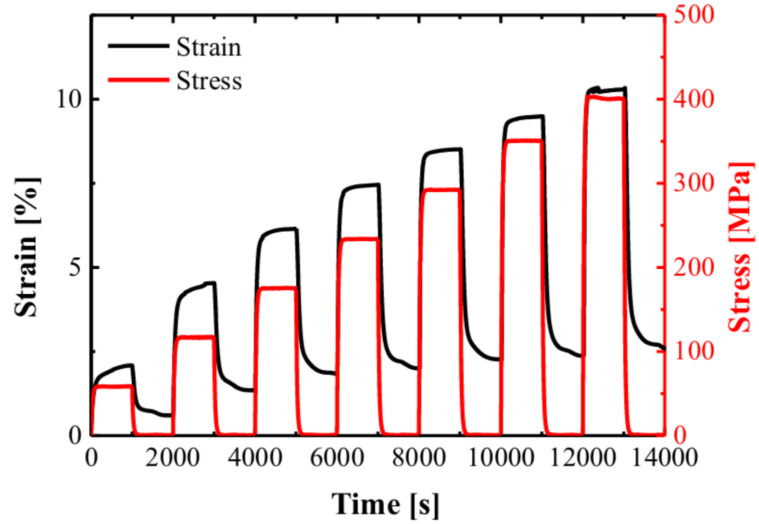


Water influence on Nylon ropes

Mechanical behaviour of PA6 fibres

➢ In 0% RH atmosphere

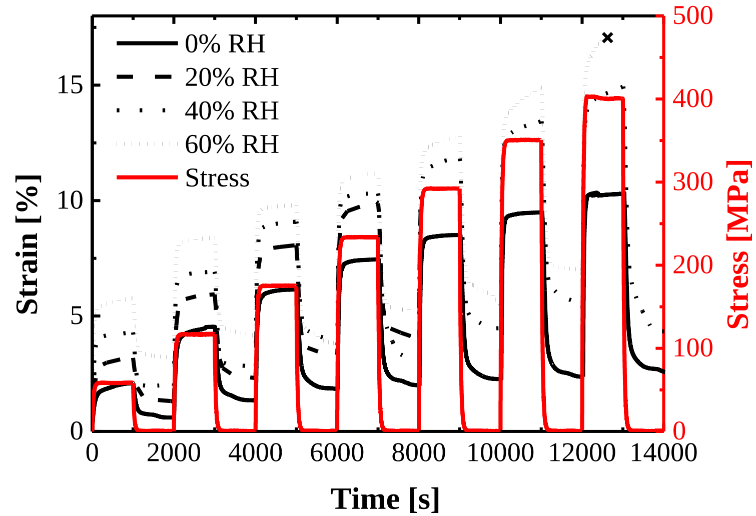
- Same device used for T_g
- 7 stress levels



➢ Under variable humid conditions

- Same 7 stress levels as for 0%RH
- Tests at 20, 40 and 60% RH condition

- Instantaneous an permanent strain increased
- Higher creep rate



IV
Conclusion

- Need to investigate the **behaviour immersed in sea water**
  - Difference between water sorption in RH and in sea water
  - Significant influence of water uptake on Nylon fibres behaviours (Tg, Creep)

- Need to investigate the **behaviour of Nylon ropes**
  - Water uptake in the fibres is different from the maximal sorption in yarns