THERMOMECHANICAL COMPREHENSION OF THE BEHAVIOR OF SELF-REINFORCED COMPOSITES AND ITS UHMWPE REINFORCEMENTS

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CONTEXT

Major challenge: reducing energy consumption

In the automotive industry, it must be done during:
- manufacturing phase,
- use phase,
- end of life of a vehicle

Lightening of structures

Use recycled and recyclable materials

SOLUTIONS

Use of **composite materials**

On the market, **95%** [1] are **glass fiber** reinforced polymer composites

When fibers nature ≠ from matrix nature

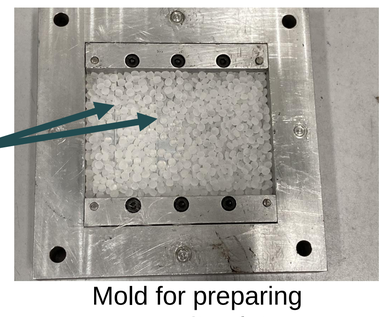
Potential of self-reinforced composites [2]

COMPOSITES OF INTEREST: SELF-REINFORCED POLYETHYLENE (SRPE)

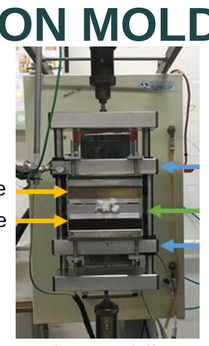
Matrix: mPE in pellets form

Reinforcements: Doyentrontex® commercial UHMWPE yarns

PROCESS: COMPRESSION MOLDING



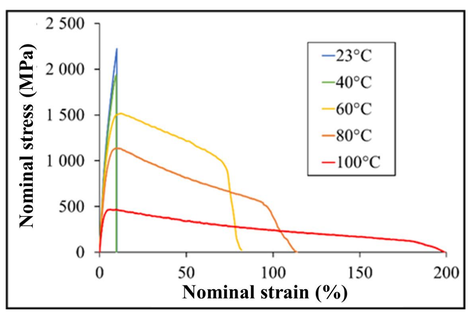
Mold for preparing composite plates

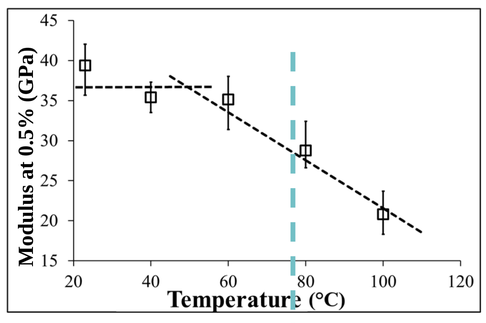


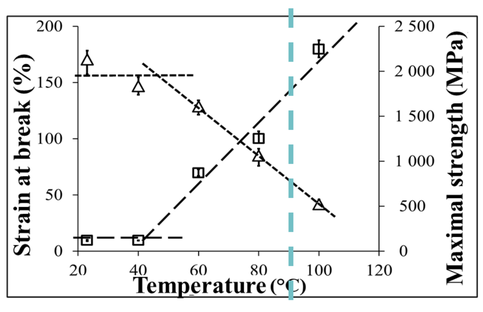
Compression molding process on a tensile machine

THERMOMECHANICAL BEHAVIOR OF UHMWPE YARNS

Monotonous tensile tests at different temperatures on yarns [3]



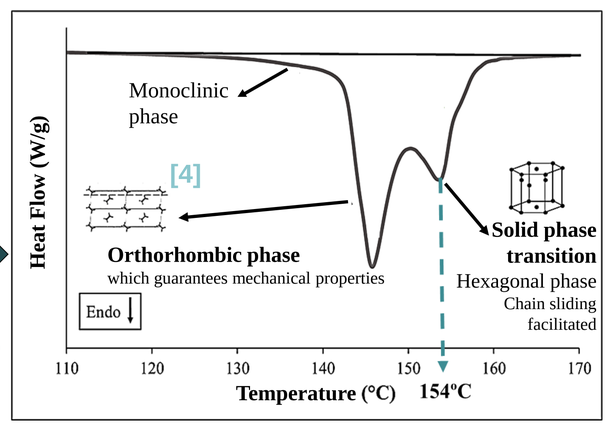




Behavior transition (≈ [47;50]°C)

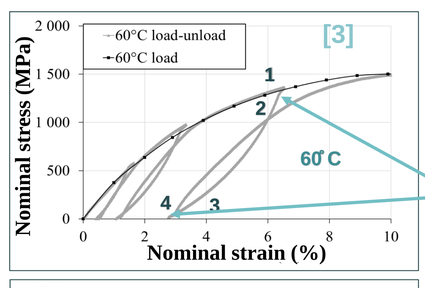
Cause

DSC of UHMWPE yarns



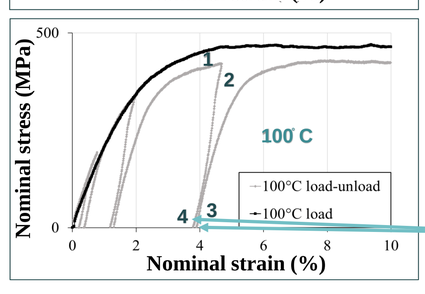
Phase transition is influenced by:
- A solicitation
- The stress (holding of yarns)
- Annealing

Load-unload tensile tests at different temperatures on yarns



Counter-curvatures present, synonymous of a **hyperelastic type of behavior** (idem at 23°C)

Similar tangent modulus (at location 2 and 4, idem at 23°C)



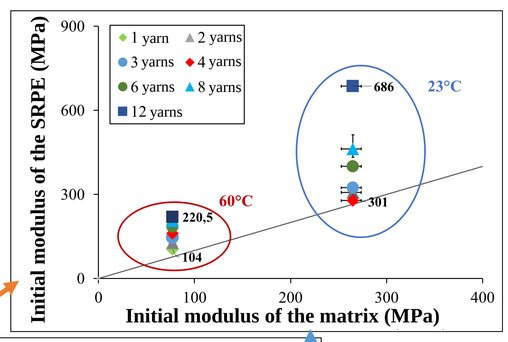
No loops, behavior **similar to elasto-viscoplasticity**

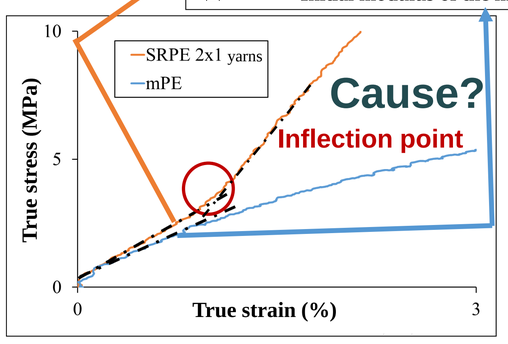
Similar tangent modulus (at location 3 and 4)

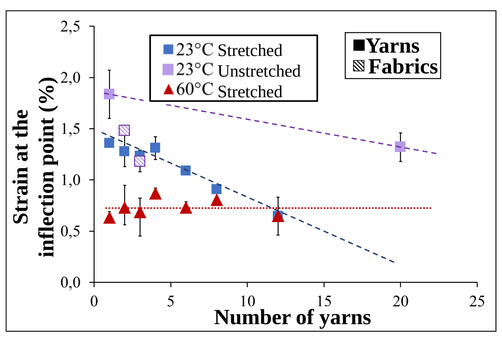
Complex behavior for the UHMWPE yarns

SPECIFIC BEHAVIOR OF SRPE COMPOSITES

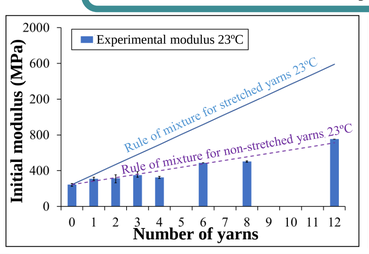
Tensile tests with strain control thanks to marker tracking

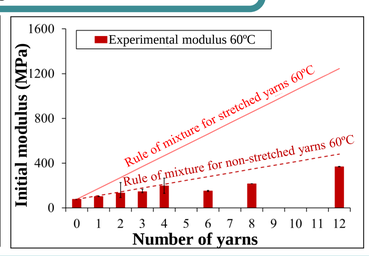






Inflection point present for all conditions analyzed



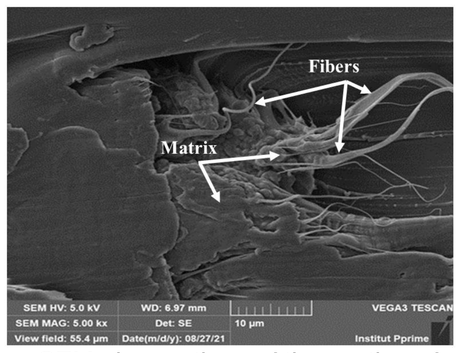


Yarns are expressed from the beginning

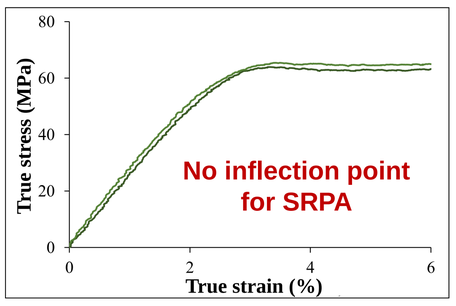
As a consequence of fibers misalignment

Inflection point caused by the misalignment of the fibers due to their **compression**, generated during the **cooling** of the plates due to the large **difference in the thermal expansion coefficients** of the components

- ☒ Related to a too fast cooling speed
- ☒ Related to the nature of the matrix
- ☒ Related to a degraded interface
- ☒ Related to the nature of the SRP
- ☑ Related to the intrinsic nature of UHMWPE reinforcements



SEM observations of the section of a monofilament SRPE



Tensile tests performed on SRPA (Self-Reinforced PolyAmide)

CONCLUSION

- **Complex behavior** of Doyentrontex® commercial yarns: observation of a behavior transition due to morphology transition under stress and/or temperature
- **Specific** behavior of SRPE for low deformations: appearance of an **inflection point** due to the **large difference between the thermal expansion coefficients** of the yarns and the matrix
- **For these promising composites, and even more than for more conventional composites, it is very important to know the behavior of the reinforcements which is complex to improve the understanding and prediction of the thermomechanical behavior**

[1] E. Witten, V. Mathes, M. Sauer, and M. Kühnel. 2018. « Composites Market Report 2018, Market developments, trends, outlooks and challenges »
[2] N. J. Capiati and R. S. Porter, 1975. « The Concept of One Polymer Composites Modelled with High Density Polyethylene ». Journal of Materials Science 10 (10): 1671-77. https://doi.org/10.1007/BF00554928.
[3] C. Roiron, E. Lainé, J.-C. Grandidier, D. Olivier, N. Garois, and C. Vix. 2020. « Study of the Thermomechanical Behavior of UHMWPE Yarns under Different Loading Paths ». Polymer Testing 89. https://doi.org/10.1016/j.polymertesting.2020.106717.
[4] L. Govaert, B. Brown, P. Smith. 1992. « Temperature Dependence of the Young's Modulus of Oriented Polyethylene ». Macromolecules 25 (13): 3480-83. https://doi.org/10.1021/ma00039a027.

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