

Mechanical behaviour of « green » materials

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with the help of technical staff and administrative services.

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PhD students :

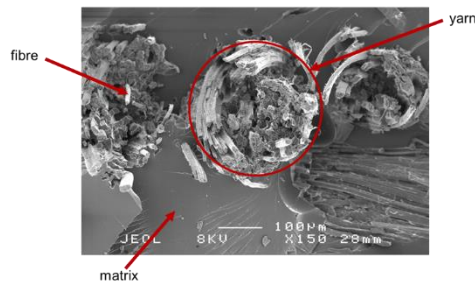
- 2013 - ... : Amélie Perrier, « Etude expérimentale et numérique du comportement mécanique de l'interface renfort/matrice dans des éco-composites. »
- 2013 - ... : Yann Lebaupin, « Comportement mécanique à l'impact et en post-impact d'un éco-composite à base de fibres de lin associées à une matrice thermoplastique biosourcée. » (coll. ESTACA-LAVAL)
- 2010-2013 : Davi Vasconcellos, « Comportement en fatigue avant et après impact de composites tissés chanvre/époxy. » (with European Label)
- 2007-2010 : Claire Bonnafous, « Analyse multi-échelle des mécanismes d'endommagement de composites chanvre/époxy à renforts tissés. Caractérisation de l'interface fibre/matrice. »
- 2004-2007 : Olivier De Almeida, « Etude de l'influence de la présence d'impuretés sur les mécanismes de déformations et d'endommagements du polypropylène recyclé. Analyse des champs tridimensionnels de déformations. » (ADEME)
- 2001-2004 : Thuy Quynh Lam, « Qualification mécanique de composites à base de polymères recyclés et de fibres végétales. Caractérisation des mécanismes de rupture par imagerie numérique. » (ADEME)

Programs and collaborations :

- 2014-2016 : program PICS CNRS n°6366 "ECAULT" : « Eco-Composites : damage Analysis Using Laser shock Technology » with IMP (Instytut Maszyn Przeplywowych - www.imp.gda.pl/en/) Gdansk, Poland, and PIMM-ParisTech.
- 2014-... : collaborative research on mechanical impact behaviour of eco-composites with IPCB (Institute for Polymers, Composites and Biomaterials - <http://www.ictmp.ct.cnr.it>), Napoli (Italy).
- 2012-... : collaborative research on mechanical behaviour of hybrid composites with Univ. La Sapienza (<http://www.uniroma1.it>), Roma, Italy.
- 2010-2011 : program ENSICHANVRE (MAPROSU CNRS) with Valagro, on the optimization of hemp fibre treatment.
- 2009-2012 : program BOREVE (ADEME) with Faurecia, MATEIS Lyon, LRMP St Etienne, IMFS-Strasbourg, FEMTO-Besançon, on material analysis for recycling the car bumpers.
- 2009-2010 : program Hemp Fibre (ACI PPRIME) with botanists of PhyMots-Univ. Poitiers, on influence of cultural conditions on mechanical properties of hemp fibres.
- 2007-2010 : program COMPOCHANVRE (Region) with CRITT Rochefort, Valagro, botanists of PhyMots-Univ. Poitiers, on mechanical behaviour of hemp/epoxy composite.
- 2005-... : invited researcher Dr. Min Shen in 2005 from Univ of Tianjin (<http://www.tju.edu.cn/english/>) China, pursuing collaborative research on mechanical behaviour of wood polymer composites.
- 2004-2007 : program RECYPRO (ACI Ministère) on mechanical behaviour of recycled polymers with MATEIS Lyon, LRMP St Etienne, IMFS-Strasbourg, FEMTO-Besançon.
- 2002-2004 : program AGRICE (ADEME-CNRS) with Hutchinson, on flexural behaviour of hemp/glass/PU sandwich materials.
- 2000-2002 : program AGRICE (ADEME-CNRS) with Valagro, on microstructural and mechanical study of wood/PA composites.

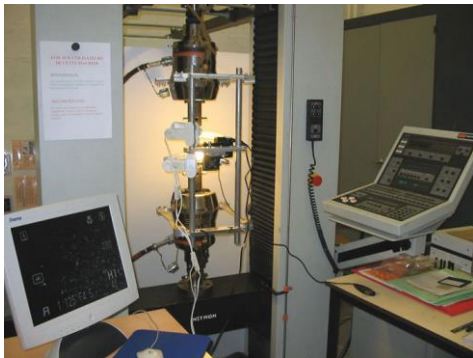
Context :

Global awareness of environmental issues has resulted in the emergence of “green” materials. These new materials offer eco-friendly and sustainable alternatives to classical ones, but their mechanical behaviour is not well known yet. The aim of this research topic is to analyse damage and strain mechanisms in recycled polymers and plant fibre composites, under different types of mechanical loading. For this purpose, multi-instrumented experimental tests are performed, at different scales of the studied materials. In particular, a specific attention is paid to the fibre/matrix interface characterization, which is a key-point for numerical modelling of composite behaviour.



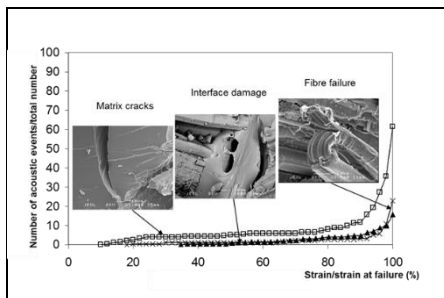
Studied materials

- ✓ Recycled or bio-sourced polymers.
- ✓ Plant fibre composites (hemp, flax, wood or straw reinforcement).
- ✓ Short fibres, medium fibres (non-woven mat), or long fibres (unidirectional ply or woven fabric) composites.
- ✓ Hybrid composites (basalt-carbon, flax-carbon).
- ✓ Thermoset or thermoplastic matrix.



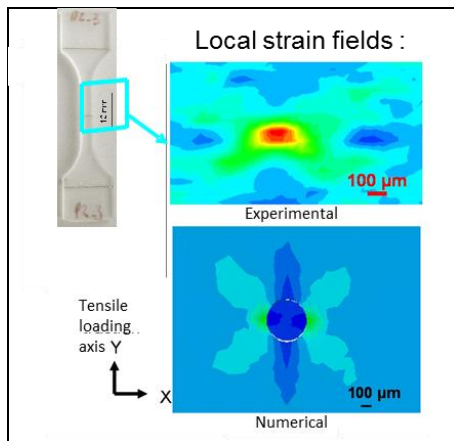
Analysis of damage, strain and failure mechanisms

- ✓ Fatigue and post-impact fatigue behaviour of hemp/epoxy composites.
- ✓ Determination of fatigue criterion for eco-composites.
- ✓ Tensile, fracture and impact behaviour of wood/PP, flax/PLA, hemp/epoxy composites.
- ✓ Full-field strain measurements by Digital Image Correlation (DIC) technique.
- ✓ Damage evolution analysis by coupling X-ray microtomography and acoustic emission methods.
- ✓ Material characterisation by using DSC, DMA, WAXS, optical and electron microscopy.
- ✓ Analytical and finite element modelling of eco-composite mechanical behaviour.
- ✓ Effect of stacking sequence, processing conditions, fibre quality, fibre length and ratio.
- ✓ Influence of ageing (thermal, moisture...).
- ✓ Properties of recycled polymers and recycled reinforced polymers.
- ✓ Comparison with classical composites (carbon and glass fibres).



Experimental and numerical characterisation of fibre/matrix interface behaviour

- ✓ Development of single-yarn samples, with different yarn orientations (0°, 45° and 90°).
- ✓ Conception of adapted micro-machine test.
- ✓ Determination of IFSS by fragmentation testing on hemp/epoxy interface.



- ✓ Experimental strain and stress field measurements by using Digital Image Correlation (DIC) and photoelasticity methods.
- ✓ Analysis of local constitutive law.
- ✓ Numerical simulations at different scales.
- ✓ Application of laser shock technique for interface testing.
- ✓ Influence of water sorption.
- ✓ Comparison of synthetic and bio-sourced polymer matrices.

Some publications :

F. LAGATTU, F. AMIN¹, S. PAUTROT, Y. A. BERTIN,

¹: *Valagro, Poitiers.*

"Etude de la rigidité et de la cristallinité de matériaux composites à matrice thermoplastique renforcée par des charges d'origine végétale."

Revue des Composites et des Matériaux Avancés, vol.10, 2, 2000, pp. 179-196.

S. PAUTROT, F. LAGATTU, P. GADAUD,

"Influence des renforts sur l'évolution en température du module d'Young de différents composites à matrice polymère."

Annales de Chimie, vol. 28, 4, 2003, pp. 43-52 (DOI : 10.1016/S0151-9107(03)00094-1).

J.C. DUPRE¹, F. LAGATTU,

¹: *Equipe photomécanique, LMS, Université de Poitiers.*

"Thermal and mechanical couplings in plain and wood fibre reinforced polypropylene during tensile and fracture tests."

Polymers and Polymer Composites, vol.15, n°6, pp. 453-462, 2007.

O. De ALMEIDA, F. LAGATTU, J. BRILAUD,

"Analysis by a 3D technique of volumetric deformation gradients : application to polypropylene/EPR/talc composites." Composites Part A, 39, 2008, pp. 1210-1217.

T.Q. TRUONG HOANG¹, F. LAGATTU, J. BRILAUD,

¹: *ESTACA, Laval.*

"Natural fiber reinforced recycled polypropylene : microstructural and mechanical properties."

Journal of Reinforced Plastics and Composites, Vol. 29, No. 2, 2010, pp.209-217.

M. SHEN¹, F. TOUCHARD, G. BEZINE, J. BRILAUD,

¹: *Université de Tianjin, Chine.*

"Development of a finite element model for Random Short Wood Fibres Reinforced Composites", European Physical Journal, On-line Journal, 8 pages, 2010.

C. BONNAFOUS, F. TOUCHARD, L. CHOCINSKI-ARNAULT,

"Multi scale analysis by acoustic emission of damage mechanisms in natural fibre woven fabrics/ epoxy composites." European Physical Journal, On-line Journal, 8 pages, 2010.

C. BONNAFOUS, F. TOUCHARD, L. CHOCINSKI-ARNAULT,

"Damage mechanisms in hemp-fibre woven fabric composites and comparison with glass-fibre composite." Polymers and Polymer Composites, Vol.19, No.7, 2011, pp.543-552.

L. CHOCINSKI-ARNAULT, F. TOUCHARD, M.P. BURON¹,

¹: *Faurecia, Audincourt.*

"Recyclage de pare-chocs automobiles : caractérisations microstructurale et mécanique avec suivi de l'endommagement", *Matériaux et Techniques*, Vol.100, No.5, 2012, pp.425-435 (DOI : 10.1051/mattech/2012006).

A. ABOT¹, C. BONNAFOUS, F. TOUCHARD, F. THIBAUT¹, L. CHOCINSKI-ARNAULT, R. LEMOINE¹, F. DEDALDECHAMP¹,

¹: *Equipe de biologie végétale, Univ. Poitiers.*

"Effects of cultural conditions on the hemp (*Cannabis sativa*) phloem fibres: biological development and mechanical properties." *Journal of Composite Materials*, 47, 8, 2013, pp. 1067-77.

C. BONNAFOUS, D. VASCONCELLOS, F. TOUCHARD, L. CHOCINSKI-ARNAULT,

"Experimental and numerical investigation of the interface between epoxy matrix and hemp yarn", *Composites Part A*, vol. 43, 2012, pp. 2046–2058.

T. Q. TRUONG HOANG¹, F. TOUCHARD,

¹: *ESTACA, Laval.*

"Non-woven flax fiber reinforced polypropylene : mechanical properties in static and low velocity impact behaviours", *Polymers and Polymer Composites*, 21, 5, 2013, pp. 259-270.

M. SHEN¹, F. TOUCHARD, G. BEZINE, J. BRILLAUD,

¹: *Université de Tianjin, Chine.*

"Direct numerical simulation of fracture behaviour for random short wood fibers reinforced composites, comparison with digital image correlation experiments", *International Journal of Thermoplastic Composite Materials*, 1-19, 2013. DOI : 10.1177/0892705713489324.

D. VASCONCELLOS, F. TOUCHARD, L. CHOCINSKI-ARNAULT,

"Tension-tension fatigue behaviour of woven hemp fibre reinforced epoxy composite: a multi-instrumented damage analysis." *International Journal of Fatigue*, 59, pp.159-169, 2014.

Y. LEBaupin¹, T.Q. TRUONG HOANG¹, M. CHAUVIN¹, F. TOUCHARD, A. BEIGBEDER²,

¹: *ESTACA, Laval, France.*

²: *CEMCA, Changé, France.*

« Propriétés microstructurales et mécaniques d'un composite unidirectionnel lin/polyamide 11. », *Revue Matériaux et Techniques*, 101, 7, pp. N24-1à4, 2013.

D. VASCONCELLOS, F. SARASINI¹, F. TOUCHARD, L. CHOCINSKI-ARNAULT, M. PUCCI, C. SANTULLI¹, J. TIRILLÒ¹, S. IANNACE², L. SORRENTINO²,

¹: *Sapienza Università di Roma, Italy.*

²: *CNR, Portici (NA), Italy.*

"Influence of low velocity impact on fatigue behaviour of woven hemp fibre reinforced epoxy composites." *Composites Part B*, 66, 2014, 46-57 (DOI information: 10.1016/j.compositesb.2014.04.025).