

Composites research @ Ghent University

Reinforcing your composites activities !

<http://www.composites.ugent.be/>

Ghent University (UGent) - Faculty of Engineering and Architecture
Department of Materials Science and Engineering
Research group "Mechanics of Materials and Structures"



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Who are we ?

The research group “*Mechanics of Materials and Structures*” at Ghent University is doing research for more than 25 years on the mechanics of composite materials. The composites group is lead by Prof. Joris DEGRIECK and Prof. Wim VAN PAEPEGEM, and counts almost 20 doctoral students.

Key research areas for composites:

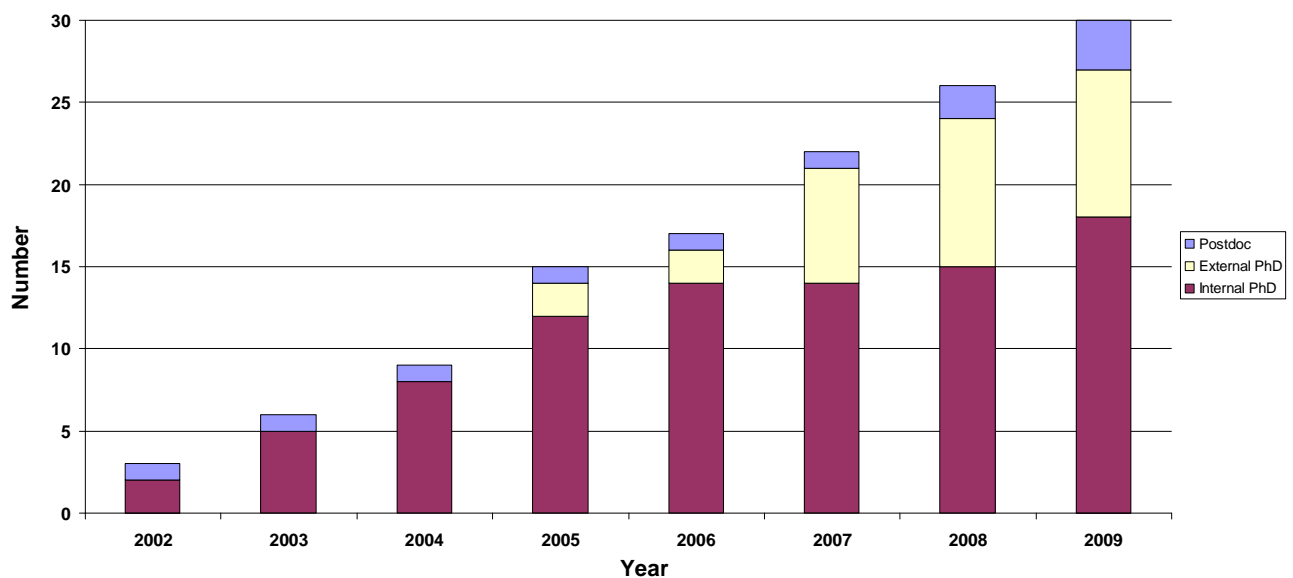
- **Impact** (bird strike, drop tests, crushing, blast loading, wave impact,...)
- **Fatigue** (tension, compression, bending, shear, biaxial,...)
- **NDT/NDE** (optical fibre sensors, ultrasound, moiré,...)
- **General mechanics** of fibre-reinforced composites

Mission statement:

“To study the mechanical behaviour of composite materials by a combined approach of instrumented experimental testing and adequate numerical modelling, in close collaboration with the composites industry and its suppliers”

Very strong growth of the research group over the last years

Evolution of internal PhD students, external PhD students and postdocs in research group UGent-MMC (2002-2009)



What are our competences ?

The next pages of this brochure are split into two sections:

- Our research areas
- Our industrial services

The section “Our research areas” gives a thematic overview of our current research activities in the field of composite materials:

- Aerospace composites
- Composites for wind energy
- Composites for wave energy
- Composites for bicycles
- Crash performant composites
- Blast proof composites
- Composite joints
- Next generation composites

The section “Our industrial services” lists the generic services that we offer to the industry, research institutes and other interested parties:

- Mechanical characterization
- Dynamic testing
- Inspection and monitoring
- Outdoor field testing
- Composite processing
- Numerical simulation and design
- Advanced finite element modelling



Our research areas

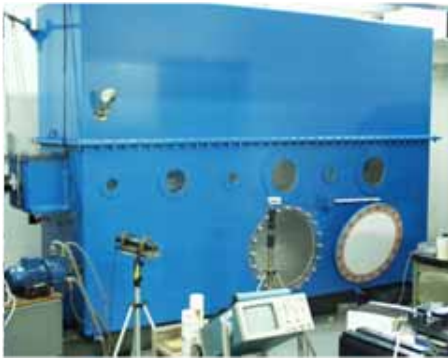
Our research activities are focused on the mechanics of composite materials for a wide range of loading conditions and industrial applications. Below are the thematic research areas that are currently covered by our research group.

- **Aerospace composites**
- **Composites for wind energy**
- **Composites for wave energy**
- **Composites for bicycles**
- **Crash performant composites**
- **Blast proof composites**
- **Composite joints**
- **Next generation composites**

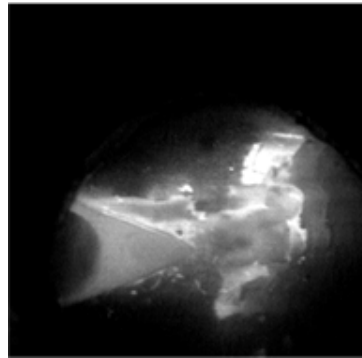


Our research areas > Aerospace composites

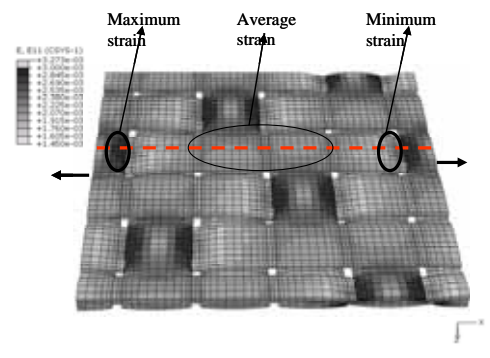
(in collaboration with TenCate, FOS&S and KULeuven)



UGent bird strike set-up



Bird impact of gelatine replica



Finite element model of satin weave composite

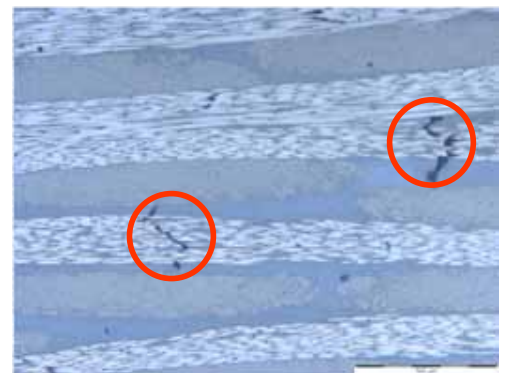
- Bird strike testing
- Drop weight impact testing
- Fatigue testing in tension, compression, bending and shear
- Microscopic inspection of (fatigue) damage mechanisms
- Embedded strain sensing
- Ultrasound inspection
- Simulation of static and dynamic behaviour



Embedded optical fibre sensors in thermoplastic composite



Fatigue testing of thermoplastic composite

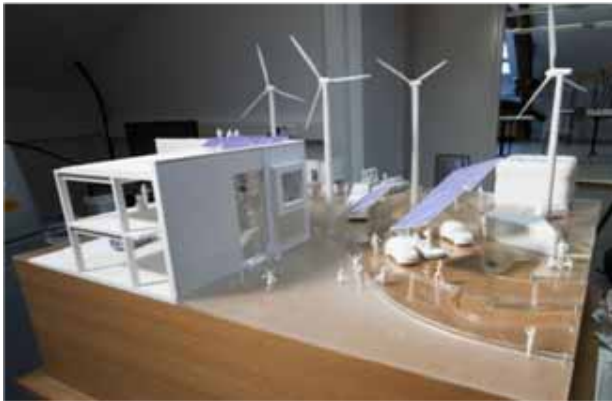


Microscopic inspection of fatigue damage in textile composite

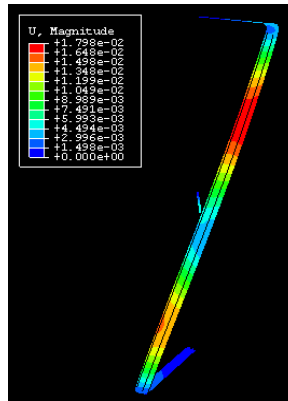


Our research areas > Composites for wind energy

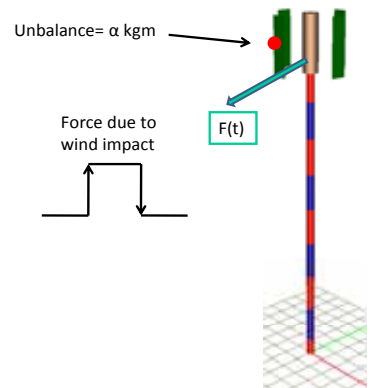
(in collaboration with Turby, SET (UGent) and Powerlink (UGent))



Scale model of "The Energy Box" at the World Expo 2010 in Shanghai (China) (Prof. Steven Van Dessel)

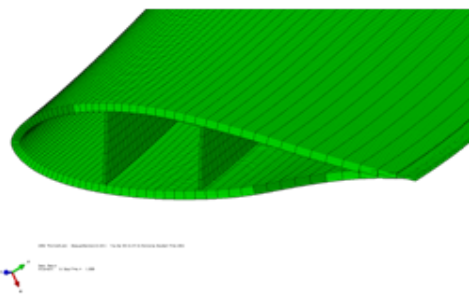


Blade design for vertical axis wind turbine

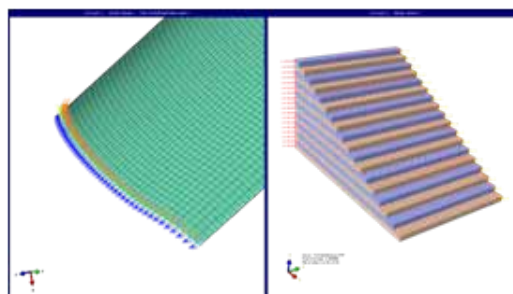


Simulation of effects of blade imbalance on the stability of the turbine tower

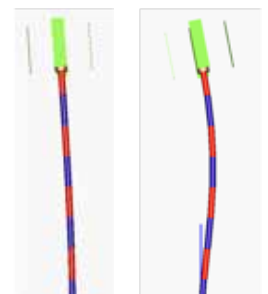
- Material selection and process requirements
- Field testing in the *Greenbridge* science park in Oostende
- High speed digital image recording of transient vibrations
- Design of composite blades
- Simulation of local stress and strain in the composite blades
- Simulation of effects of imbalance on the deformation of the mast



Finite element simulation of composite blade



Definition of composite lay-up and visualization of stacking sequence of turbine blade



First and second eigenmode of vertical axis wind turbine



Our research areas > Composites for wave energy

(in collaboration with SEEWEC and Flansea partners)

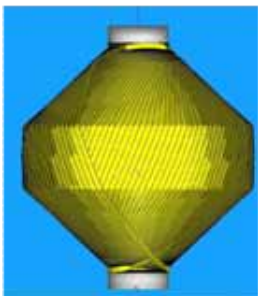


UGent lab-scale slamming set-up for wave impact

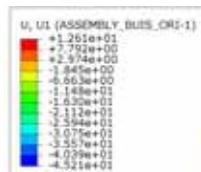


Large-scale slamming tests at the canal in Ghent

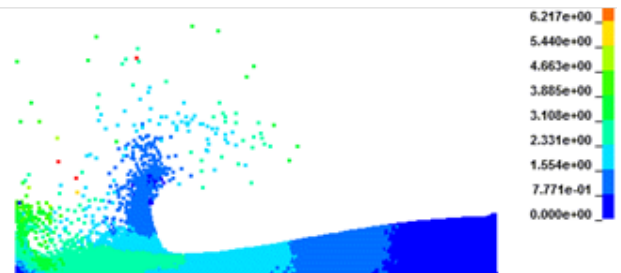
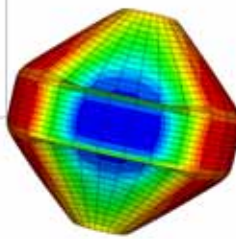
- Material selection for offshore use
- Small-scale testing of wave impact on rigid and deformable objects
- Large-scale testing of wave impact on composite structures
- Reliable pressure measurements during wave loading
- High speed digital image recording of wave impact events
- Simulation of movement of floatable composite buoys in a given sea state
- Simulation of wave loading on composite structures



Filament winding simulation of composite buoy



Survivability design of composite buoys for storm conditions



Simulation of breaking wave slamming

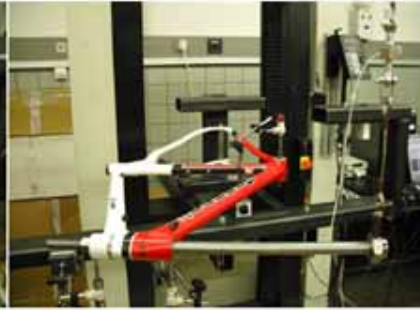


Our research areas > Composites for bicycles

(in collaboration with Museeuw Bikes and Merckx)



UGent test for bracket stiffness

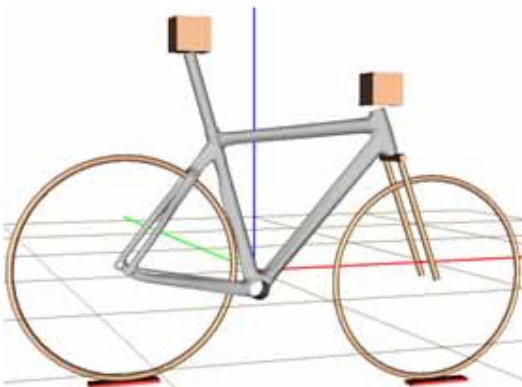


UGent test for torsion stiffness

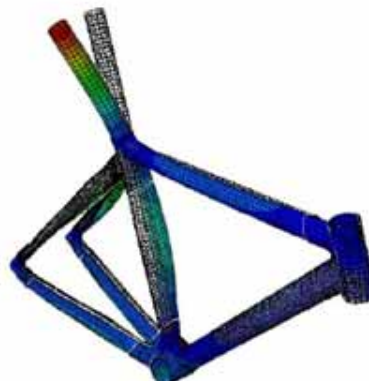


Instrumented racing bicycle for field testing of comfort and vibration levels

- Test set-up for bracket and torsion stiffness
- Test set-up for fatigue testing of bicycle frames
- Outdoor field testing with measurement of forces, accelerations, crank positions and strains
- Damping and vibration characterization of bicycle materials
- Damping and vibration testing of bicycle frames
- Simulation of the kinematics of bicycle racing frames
- Simulation of local stress and strain in bicycle frames



Kinematic model of racing bicycle with applied road accelerations



Finite element simulation of the free body vibration modes of a racing bicycle frame



UGent all-in-one test set-up for fatigue testing of racing bicycles

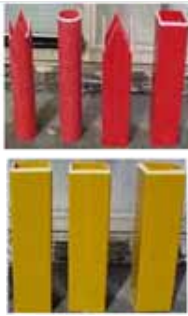


Our research areas > Crash performant composites

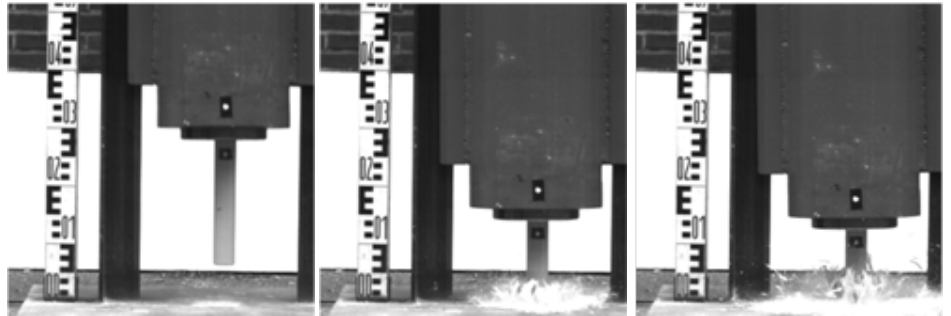
(in collaboration with Royal Military Academy (B) and Free University of Brussels (B))



Large-scale drop
tester



Energy absorbing
tubes



High-speed imaging of drop weight impact of circular pultruded composite tubes

- Selection of materials, geometry, triggering mechanism and fibre orientations
- Static crushing tests on composite tubes
- Dynamic crushing and energy absorption of composite tubes
- Measurement of dynamic contact force, decelerations and energy absorption
- High speed digital image recording of crushing events
- Simulation of crushing behaviour of composites



CP1 Tube

SP1 Tube

SP2 Tube

Final deformation pattern of different types of crushed composite tubes



CP1 Tube

SP1 Tube

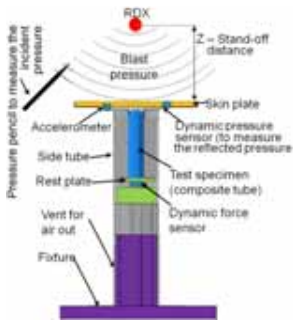
SP2 Tube

Corresponding simulation of the final deformation patterns

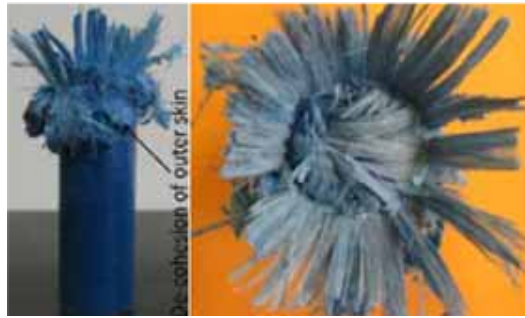


Our research areas > Blast proof composites

(in collaboration with Royal Military Academy (B) and Free University of Brussels (B))



Small-scale free air blast set-up at the Royal Military Academy

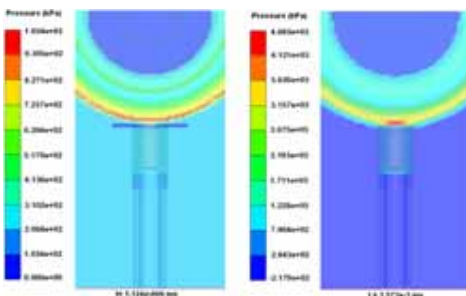


Crushing behaviour of pultruded composite tubes under free air blast loading



Large-scale blast tests with shock tube at the military domain in Brasschaat

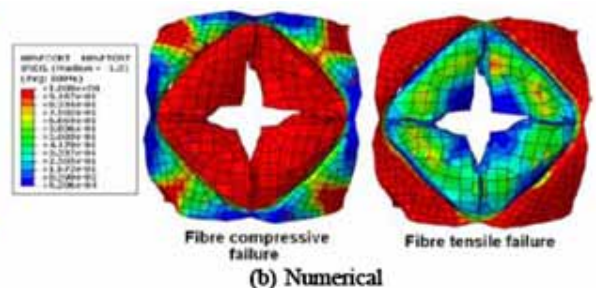
- Selection of materials, geometry, triggering mechanism and fibre orientations
- Small-scale air blast tests
- Large-scale air blast tests in shock tube
- High speed digital image recording of crushing events
- Measurement of dynamic contact force, decelerations and energy absorption
- Simulation of detonation and propagation of explosive
- Simulation of interaction of blast waves with composite



Simulation of detonation and propagation of shock wave in free air



(a) Experimental



(b) Numerical

Experimental and simulated deformation patterns of composite tubes under air blast loading

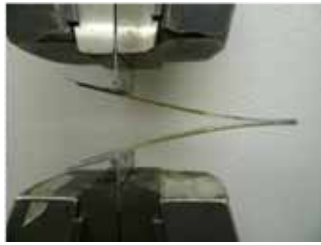


Our research areas > Composite joints

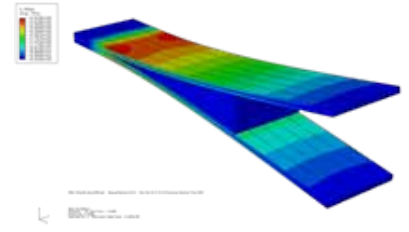
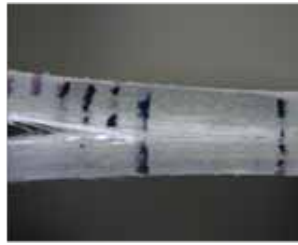
(in collaboration with Flanders Drive and Free University of Brussels)



Double Cantilever Beam (DCB) test for Mode I fracture toughness



Online microscopy of fracture toughness testing

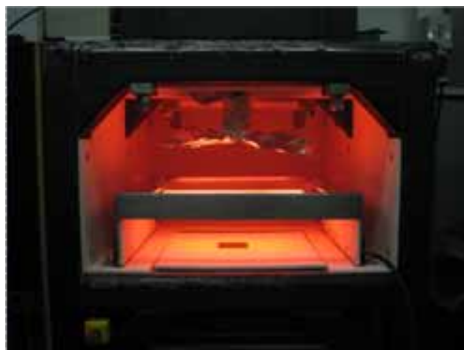


Simulation of mode I fracture test of adhesive joint

- Mechanical testing of adhesive joints (single lap shear, double lap shear, peel tests,...)
- Measurement of fracture toughness in mode I, mode II,...
- Online microscopy for in-situ evaluation of fracture behaviour
- Ultrasound inspection of adhesive joints
- Fusion bonding of thermoplastic composites
- Design of adhesive joints
- Analytical models for prediction of critical shear and peel stresses
- Simulation of fracture behaviour of adhesive joints



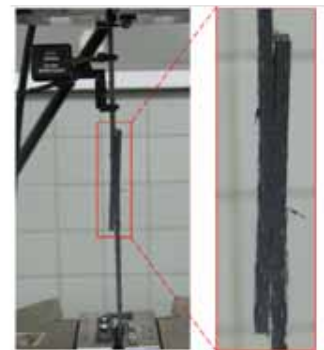
UGent infrared welding set-up



Fusion bonding of thermoplastic composites



Fusion bonded laminate

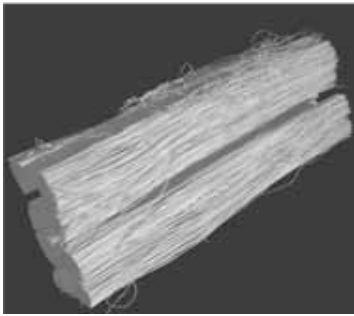


Single lap shear testing of fusion bonded joint



Our research areas > Next generation composites

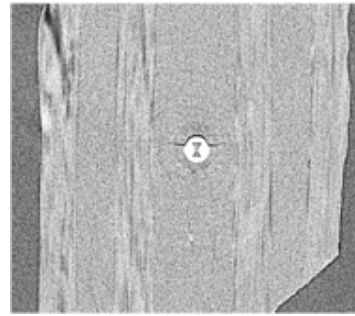
(In collaboration with research partners of SIM, FP7 SMARTFIBER and FP7 3DLightTrans)



Micro-tomography image of steel fibre filaments



Future turbine blade with embedded smart sensing



Micro-tomographic image of embedded optical fibre sensor in composite

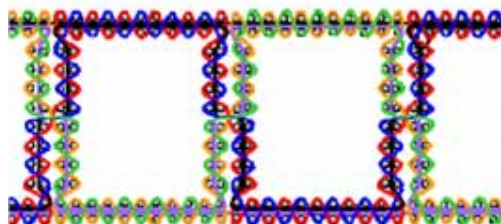


Structural flax fibre/epoxy composite

- Self-healing polymers and composites
- Self-sensing composites with embedded strain sensing and miniaturized wireless data-acquisition
- 3D woven thermoplastic composites for mass production of lightweight recyclable composites
- Nano-engineered steel fibre composites with increased toughness
- Structural natural fibre composites



Simulation of three-dimensional yarn in fibrous preform



Three-dimensional woven fabric (TU Dresden)



Three-dimensional woven glass fibre preform (TU Dresden)



Our industrial services

Over the years, our research group has developed a substantial expertise in characterization, testing, modelling and monitoring of composites and other materials. This expertise is available as a service to the industry, research institutes and other interested parties. The industrial services that we offer, are grouped in the following categories:

- **Mechanical characterization**
- **Dynamic testing**
- **Inspection and monitoring**
- **Outdoor field testing**
- **Composite processing**
- **Numerical simulation and design**
- **Advanced finite element modelling**



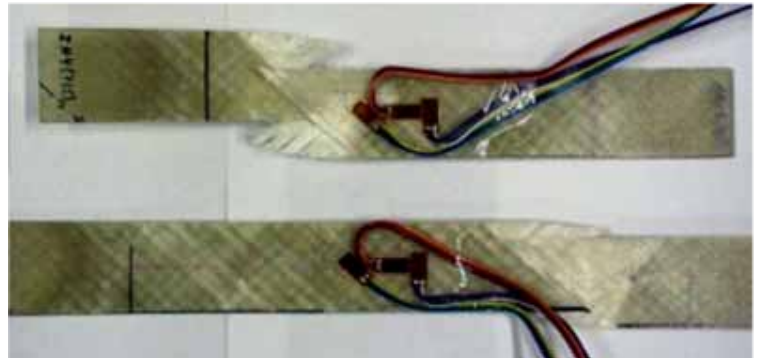
Our industrial services > Mechanical characterization



Electromechanical testing machine

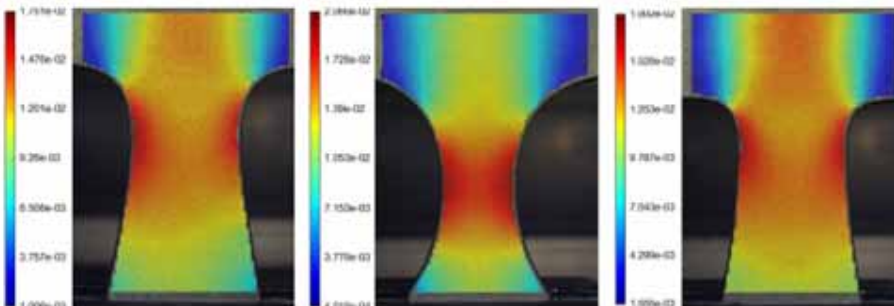


Servo-hydraulic testing machine



Bias tension testing of glass fibre/epoxy composites with bonded strain gauges

- Mechanical characterization of composites (elastic properties, tensile and compressive strength, bending strength, short beam shear strength, fracture toughness,...)
- Electromechanical Instron machine
- Two servo-hydraulic machines
- Temperature chamber
- Strain gauges (selection, bonding and read-out)
- Extensometer measurement
- Digital Image Correlation (DIC) for full-field strain measurement



Digital Image Correlation (DIC) for full-field strain measurement on cruciform specimens



Testing of pre-stressed section of sailing mast



Our industrial services > Dynamic testing



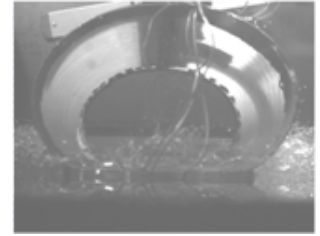
Drop weight testing of bumper component



Vibration testing of carbon/epoxy coupons



Dedicated accessories for fatigue testing



Slamming wave impact of a composite cylinder

- Two drop weight set-ups for dynamic impact testing
- Bird strike set-up
- Pendulum impact test rig
- Set-up for slamming wave impact
- Shaker for vibration testing
- Two servo-hydraulic machines for fatigue testing
- Digital high speed camera (up to 250 000 frames per second)
- Transient recorder oscilloscope (up to 100 MHz sampling frequency)
- Dynamic load cells, accelerometers, pressure sensors,...
- High speed data-acquisition of strain gauges
- Digital Image Correlation (DIC) for full-field strain measurement



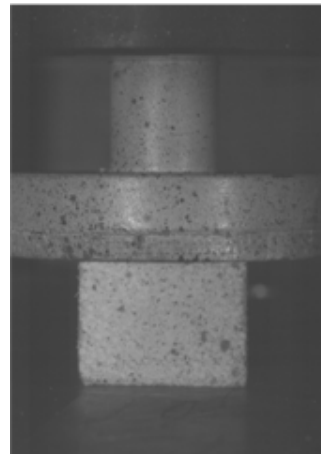
Drop weight test (height 3 m)



Drop weight test (height 12 m)



Pendulum impact test rig



Impact testing of foams for bicycle helmets

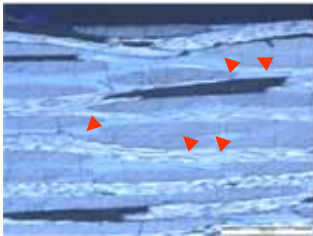


Rail shear fixture for fatigue testing in pure shear

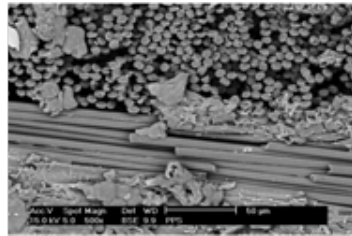


Our industrial services > Inspection and monitoring

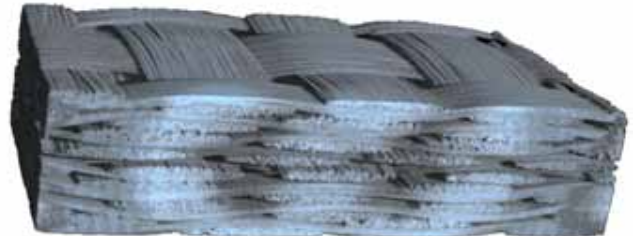
(in collaboration with Metallurgy research group (UGent) and X-ray lab (UGent))



Microscopic inspection of damage in composites



SEM image of textile composite



Micro-tomography measurement of plain weave glass/epoxy composite

- Embedded or surface mounted optical fibre sensors for in-situ strain measurement
- Ultrasound inspection for characterization of local damage
- Micro-tomography for nondestructive 3D visualization of microstructure of materials
- Scanning Electron Microscopy (SEM) – Transmission Electron Microscopy (TEM)
- Online microscopy during testing
- Post-mortem microscopic inspection (embedding, polishing and digital inspection)



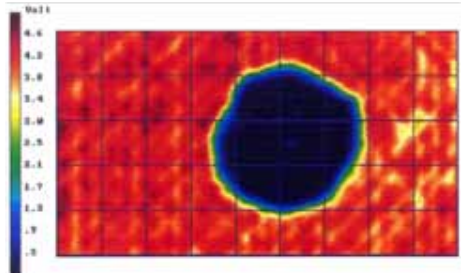
Pressure vessel with optical fibres



Testing of carbon/epoxy C-profile with embedded optical fibres



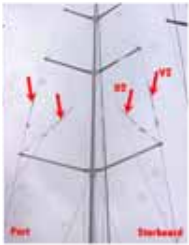
Ultrasound scanning set-up with five degrees of freedom



Ultrasound C-scan of delamination in impacted composite laminate



Our industrial services > Outdoor field testing



Strain measurement
on sailing yacht



Strain gauge measurement on sailing mast rigging



Proof-of-concept testing of a new type of wave energy
converter at sea

- Portable ultrasound phased array
- Digital high speed camera
- Stand-alone data-acquisition of strain gauges, accelerometers, force sensors, pressure sensors,...
- Portable oscilloscope for high speed data acquisition
- Experience with outdoor field testing at sea, river banks and other locations without electrical grid connection
- Expertise in battery-powered road measurements on bicycles and other vehicles,...



Portable transient recorder oscilloscope
(up to 100 MHz sample frequency)



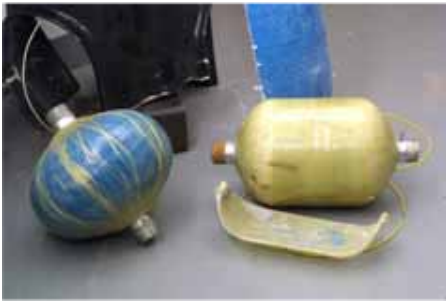
Digital high-speed camera (up to 250 000 frames
per second)



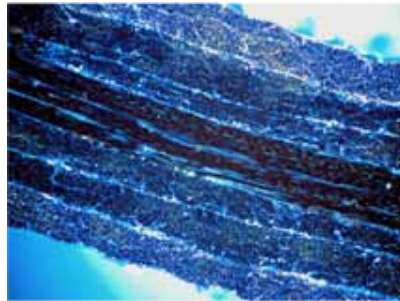
Portable ultrasound scanning equipment (with
64-probe phased array)



Our industrial services > Composite processing



Filament wound vessels



Autoclaved carbon/epoxy laminate (1 mm thick)



Fabric reinforcements for resin infusion and resin transfer moulding

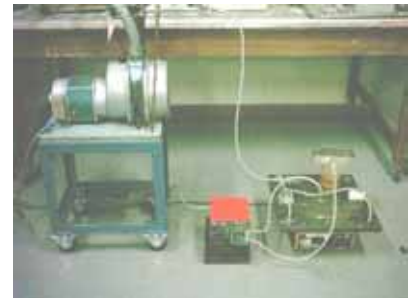
- Autoclave process with monitoring of curing cycle
- Resin transfer moulding
- Resin infusion
- Filament winding
- Adhesive joints
- Fusion bonding with infrared welding
- Determination of fibre volume fraction (matrix digestion, pyrolysis) and porosity content



Autoclave for thermoset prepregs



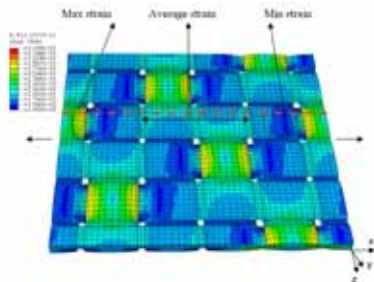
Filament winding of pressure vessels



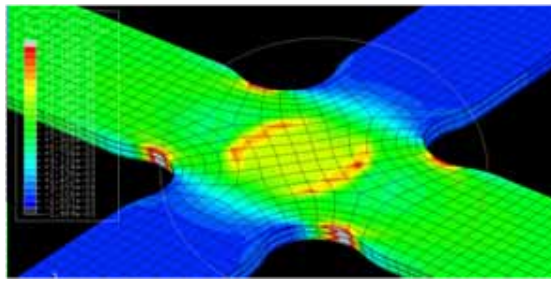
Vacuum-assisted resin transfer moulding for thermoset composites



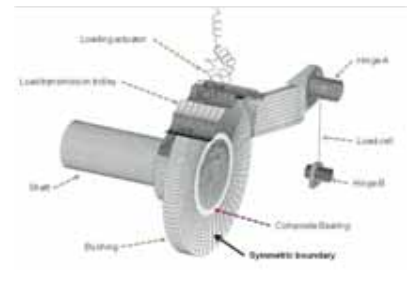
Our industrial services > Numerical simulation and design



Meso-scale unit cell model of a 5-harness satin weave carbon/PPS composite

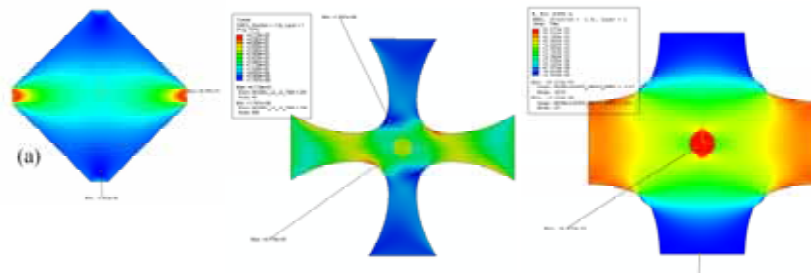


Simulation of strain concentrations in a biaxially loaded composite cruciform specimen

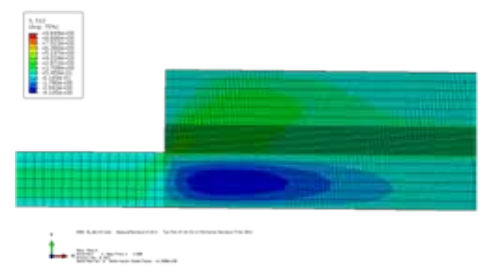


Three-dimensional model of friction and wear of large-scale composite bearings

- The complete modelling chain for simulation of the mechanics of composite structures is covered:
 - definition of CAD geometry (SolidWorks, Catia)
 - definition of ply stackings and draped layers (Catia/CPD, Simulayt)
 - static and dynamic finite element simulation (Abaqus, LS-Dyna)
 - optimization of topology and/or material parameters (iSight, evolutionary strategies)
 - kinematics and multibody dynamics of complex composite structures (UM, Mathcad)
- Simulation of mechanics of composites under wide variety of loadings (drop weight impact, crushing, blast loading, wave impact, fatigue, contact/wear, vibration and resonance, centrifugal and inertia forces,...)
- Access to High Performance Computing (HPC) cluster for calculation of very large finite element models (2000+ 64-bit cores, 3.2 Terabyte RAM)



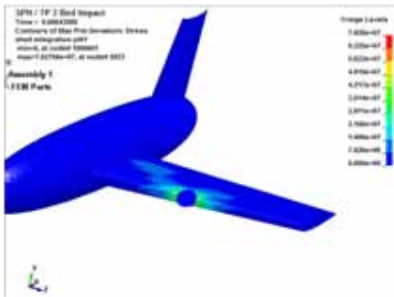
Topology optimization of cruciform geometry for biaxial testing of composite laminates



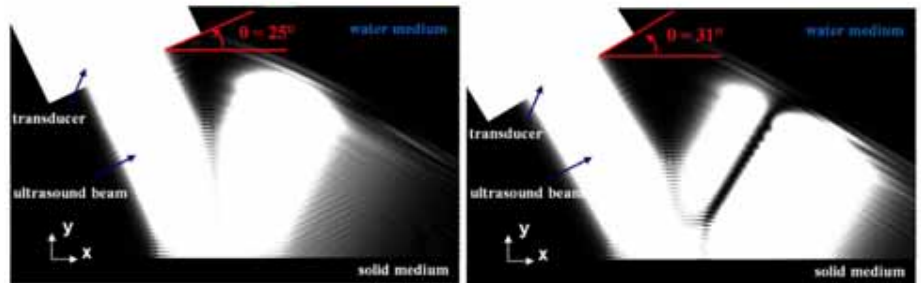
Simulation of stresses in the adhesive layer of a single lap shear joint



Our industrial services > Advanced finite element modelling

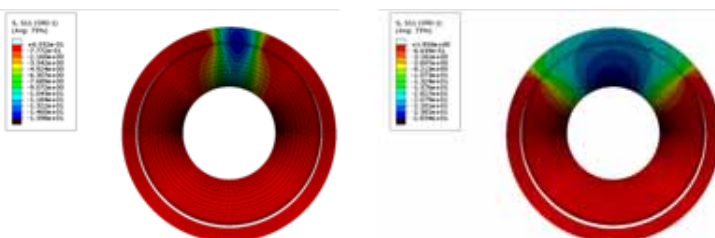


Simulated bird impact on aircraft wing

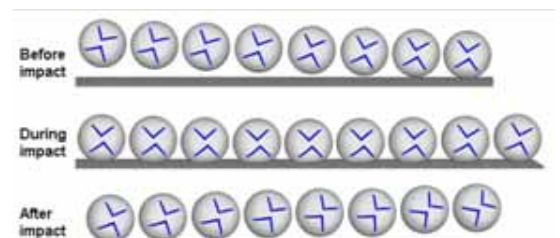


Calculated interaction of ultrasound beam with composite plate under different incident angles

- Simulation of bird impact on composite and metal structures (Smoothed Particle Hydrodynamics (SPH) method)
- Application of cohesive zone elements for simulation of delaminations, adhesive layers, fibre/matrix debonding,...
- Prediction of arbitrary crack growth in plastics and composites with the eXtended Finite Element Method (XFEM / Partition of Unity method)
- Modelling of friction and wear in composite bearings under dry sliding conditions (Mixed Lagrangian-Eulerian methods and material erosion modelling)
- Development of hybrid solid-shell elements for accurate simulation of interlaminar stresses in layered composites
- Simulation of dynamics/vibrations of pressurized layered shells (soccer ball, rubber tyre,...)
- Modelling interaction of (ultra)sound with composites and other layered materials
- Generation of finite element meshes for complicated composite geometries (wind turbine blades, three-dimensional woven structures,...) with orthotropic material orientations



Effect of progressive wear on the radial stress distribution in composite bearings



Simulation of oblique soccer ball bounce



Facts & Figures

Below are some facts and figures that illustrate the achievements of our research group over the last five years:

- 33 research projects with external funding over the last five years (2006-2010)
- Successful acquisition of advanced research equipment (digital high speed camera, high-speed transient recorder oscilloscope, electromagnetic shaker, portable ultrasound equipment, read-out unit for optical fibre sensors,...)
- 81 Science Citation Index publications over the last five years (2006-2010)
- 15 successfully defended PhD theses over the last five years (2006-2010)
- Over the last five years (2006-2010), 10 to 15 master thesis students every year
- JEC Paris Innovation award 2009 “Environment and energy”, awarded at the largest European exhibition on composites “JEC Composites” (<http://www.jeccomposites.com/>)
- ESCM Award 2008 for Wim Van Paepegem as “Best Young European researcher in composites”, awarded by the “European Society for Composite Materials (ESCM)” during the 13th European Conference on Composite Materials (ECCM-13, Stockholm, Sweden, 2-5 June 2008)
- 9 “Best paper/poster awards” over the last few years
- One of the best represented research groups at the largest European Conference on Composite Materials (ECCM)
- Collaborations with many Flemish and international companies



Partnerships

Our research group is embedded in a strong network of local, regional and international partnerships:

- Member of the “Materials Research Cluster Gent” which groups more than 200 scientists in a consortium of Ghent University and several research institutes and companies (Arcelor Mittal, BIL, Sirris, CRM, Clusta, SIM, Flamac, OCAS)
<http://www.mrcluster.be/>
- 
- Member of five valorisation consortia of Ghent University – Industrial Research Fund (IOF):
 - Plateau (Photonics Innovation Center)
 - DuraBUILDmaterials (Innovative technologies for durable building materials)
 - Victoris (Valorisation centre for technological optimization, research & innovation in sport)
 - ChemTech (Polymer and organic chemistry: from innovation to valorisation)
 - SET (Sustainable Energy Technologies)<http://www.techtransfer.ugent.be/> > IOF kenniscentra
 - Member of the Ghent Ostend Wind Research Institute (GOWind!)
http://www.set.ugent.be/Activities/en_GOWind.html
 - Member of the Steering Committee of SIM (Strategic Initiative Materials in Flanders)
<http://www.sim-flanders.be/>
 - Member of the council and executive committee of the European Society for Composite Materials (ESCM)
<http://www.escm.eu.org/>
 - Board member of the Society for the Advancement of Material and Process Engineering (SAMPE)
<http://www.sampe-benelux.org/>
 - Member of the FWO scientific research network “Optical Measurements Techniques for Structures and Systems (OPTIMESS)”
<http://optimesse.vub.ac.be/>
 - Member of the Permanent Committee of EURASEM – European Society for Experimental Mechanics
<http://www.eurasem.org/>
 - President of BNCM – The Belgian National Committee for Theoretical and Applied Mechanics
<http://www.rasab.be/> > National Scientific Committees



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