# Programme

## FiBreMoD School & Conference

Merging theory with experiments for improved mechanical performance of fibre-reinforced composites

FiBre_MoD
Marie Sklodowska-Curie European Training Network

9 - 12 DEC. 2019 | LEUVEN, BELGIUM

# Welcome

The FiBreMoD consortium welcomes you to the FiBreMoD school and conference on ***Merging theory with experiments for improved mechanical performance of fibre-reinforced composites.***

The scope of this FiBreMoD school and conference is not just the prediction and characterisation of the mechanical behaviour of composite materials, but also the ***measurement of the required constituent properties*** and input parameters as well as experimental validation techniques.

# Content

# Goals of the FiBreMoD project

Limiting the climate change-induced temperature increase to less than 2°C will require strong reductions in greenhouse gas emissions.

Lightweight materials and fibre-reinforced composites in particular, are a key enabling technology to achieve this goal. Current composite applications are however strongly overdesigned due to a lack of reliable design tools and predictive models for their mechanical properties. Developing, using and applying these models requires interdisciplinary researchers with a strong background in both modelling and experiments, but such researchers are scarce.

The 9 beneficiaries and 3 partner organisations in FiBreMoD aim to train 13 such researchers to become multi-talented and interdisciplinary researchers that will be highly coveted in the field of composites.

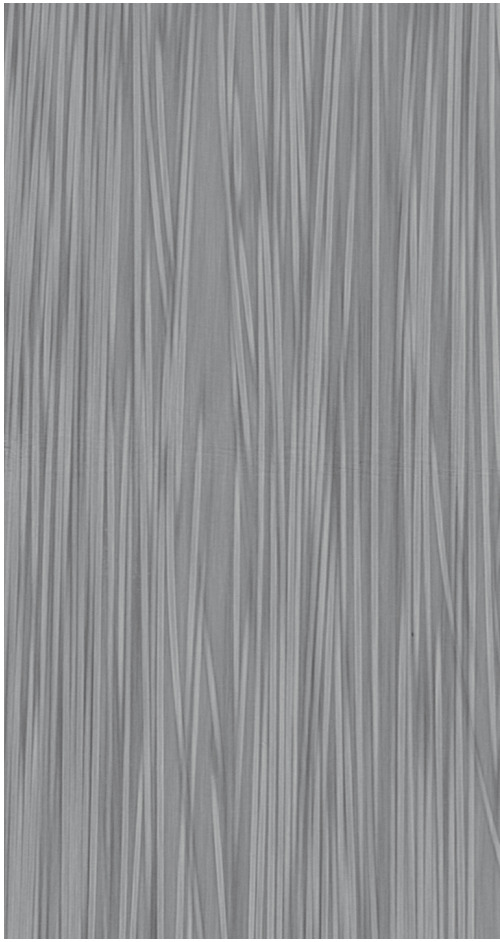
They will be intensively trained by leading experts with world-class facilities and will be supported by a strong industry participation and an extensive international network. The training programme places a strong emphasis on entrepreneurship and innovation skills not only by dedicated workshops but also by the involvement of the researchers in potential commercialisation. This approach will be key to improving the EU's innovation capacity. Simultaneously, the researchers will advance state-of-the-art composite

failure models to reach the required levels of accuracy and develop advanced and industry-friendly characterisation techniques for measuring the required input data.

The goal will be to enable blind predictions, which means that parameter fitting or tuning of the models is no longer required. These new and unprecedented levels of understanding coupled with improved prediction accuracy will be exploited to

1. design novel microstructures for hybrid, hierarchical and discontinuous fibre composites
2. increase the usefulness of models in practical composite applications.

The developed models will be validated and used to design composite cylinders and automotive parts.



# Organizing committee

## Chairs

Larissa Gorbatikh

Yentl Swolfs

Stepan Lomov

## Local organizing committee

Arsen Melnikov

Christian Breite

Francisco Mesquita

## International scientific committee

- Alain Thionnet
- Anna Matveeva
- Bin Wang
- Carlos Gonzalez
- Daniel Wagner
- Ian Sinclair
- Lucien Laiarinandrasana
- Mark Mavrogordato
- Mark Spearing
- Martin Kershbaum
- Michael Wisnom
- Paula Martinez
- Phillipe Sanial
- Sébastien Joannes
- Silvestre Pinho
- Soraia Pimenta
- Steve Bucknell
- Vicky Singery
- Xiaomeng Sui

# FiBreMoD researchers

## Carol Rodricks

WEIZMANN INSTITUTE OF SCIENCE

***Strength and Toughness tuning of Fibre-Reinforced Composites through Interfacial Topographical Obstacles***

Strength and toughness in engineering materials are typically mutually exclusive of each other, with one property being usually enhanced at the expense of the other.

Natural composites, on the other hand, display an optimised balance of strength, toughness and resources through hierarchical design strategies. One such strategy is the presence of internal interfaces that promote non-linear deformations and channel cracks through configurations that arrest crack.

My project studies the effects of structural obstacles at the interface of synthetic fibre-reinforced composites as a promising way forward to simultaneously stronger and tougher engineering materials with tuneable properties dependant on the topography of the interface.

My project focuses on intermittently spaced beads along the length of a continuous fibre – a novel type of topological obstacle at the interface of fibres in fibre-reinforced composites. Preliminary single fibre pullout tests of beaded fibres have shown promising results in increase in both strength and toughness in model composites as compared to beadless fibres.

Through the Plateau-Rayleigh instability the successful control of the bead parameters (size, angle, spacing) has been achieved. The system has the potential to be highly tuneable and an investigation into optimization and fine-tuning the system is currently being conducted.

# Faisal Islam

MINES PARISTECH

***From constituent properties to the mechanical behavior of composite structures***

The overall aim of my research is to develop a better understanding of the constituent properties of fibre reinforced composites, i.e. the properties of fibres, matrix and their interface.

To achieve this, a detailed experimental and statistical investigation has been conducted to understand the variations in the tensile strength of fibres and their morphology. These results have been statistically analysed to identify and evaluate the critical parameters which contribute to errors or uncertainty in fibre tensile strength measurement.

To further improve the fibre strength characterisation process, a data reduction technique based on Bayesian approach has been developed to model the tensile strength variation of brittle fibres. Additionally, novel methods to characterize the in-situ microscale properties of the matrix and interface have been developed.

This knowledge of uncertainties in constituent properties has also been used to simulate their effect on the mechanical behaviour of composite materials, as predicted by composite strength models. A better understanding of constituent properties would also empower these predictive models to make more reliable predictions for the behaviour and lifetime of composite structures.

# Jan Rojek

MINES PARISTECH

## *Modelling the long-term behaviour of carbon fibre composites*

The objective of this project has been to study phenomena influencing the strength of thick-walled pressure vessels. While the failure of these structures is mostly driven by fibre breakage, other factors are also present. High void content observed through X-ray microtomography and radial compressive stresses were identified as potential issues.

Since the large dimensions limit the possibilities of studying in situ the damage processes at the structural level, mechanical tests were carried out on representative specimens, recreating the critical loading conditions.

To study the effect of voids, laminates with different levels of void content were manufactured and tested.

The tests were performed on a custom-designed and manufactured biaxial mechanical setup. The results showed a significant strength reduction with respect to uniaxial tension.

A numerical approach has been developed to incorporate the observed phenomena into a framework of a multiscale fibre break model, allowing a virtual assessment of how different factors influence pressure vessel strength.

# Christian Breite

KU LEUVEN

## *Aligning longitudinal tensile failure models for composites with observable micro-scale in-situ material behaviour*

The key challenge of my PhD project is to improve, extend and experimentally validate existing models for the longitudinal tensile failure of unidirectional composites.

A new feature that was implemented in the KU Leuven strength model is the time-strain-dependent behaviour of the matrix (matrix visco-plasticity), which results in changing stress concentrations in intact fibres and stress recovery in broken fibres over applied strain and time.

With the updated model it is now possible to investigate the effect of strain / loading rate and long-time sustained strain / load on the tensile strength of a UD bundle.

To validate the fibre break model, high-resolution synchrotron computed tomography is used to create time resolved 3D scans of the progressing failure in UD composites.

The resulting datasets can have several hundreds of GB per specimen. Therefore, automated image analysis tools based on the InSegt algorithm from DTU were developed to gather quantitative data on the microstructure and fibre breaks.

# Erich Schöberl

UNIVERSITY OF SOUTHAMPTON


## *Advanced 3-D characterisation of failure mechanisms in fibre-reinforced composites*

To date, the effect of fibre breaks on the strain fields have not received attention in synchrotron experiments which has limited the understanding of the mechanics governing the failure mechanisms in coupons subjected to quasi-static tensile loading.

The work involves a novel application of Digital Volume Correlation (DVC) and in situ Synchrotron Radiation Computed Tomography (SRCT) to uniaxial loading in Carbon Fibre Reinforced Polymers (CFRPs) to generate mechanistically consistent measurements (e.g. the 'ineffective length') in relation to fibre failure events.

DVC is a relatively novel tool for quantifying full-field volumetric displacements and implicit strain fields.

To permit the application of DVC to displacements and/or strain measurements parallel to the fibre direction in well aligned unidirectional (UD) materials, a methodology was developed for the insertion of sparse populations of sub-micrometre particles within the matrix to act as displacement trackers (fiducial markers).

# Marco Alves

IMPERIAL COLLEGE LONDON

## *Modelling the variability and reliability of high-performance composite materials*

Throughout my PhD, I have developed a microstructure generator able to recreate the 3D features of the microstructure of tow based discontinuous composites (TBDCs), including tow waviness and volume fraction variations. I have developed a stochastic finite element framework to model the intrinsic variability of TBDCs and predict final failure.

The framework has the flexibility to be coupled with results obtained with process simulations, in order to model preferential fibre orientations. It also includes a physically based failure criteria which predicts damage initiation and is coupled with a ply-discount method to predict final failure.

The framework results have been validated against experimental results of different TBDC material systems. In addition, I have used the models developed for TBDCs to identify optimal microstructural features that maximise the material's strength. Ultra-thin and stiff tows were used to manufacture TBDCs with strength values of 600 MPa and stiffness of 90 Gpa, which is the strongest TBDC material system reported in the literature and present mechanical properties that compete with those of continuous quasi isotropic laminates.

My work has also focused on predicting the reliability of composites; I developed a computationally efficient model to predict the fatigue life of unidirectional composites under tension-tension loading. It generates stochastic S-N curves in less than 1 minute, using constituent properties as inputs.

The model results have been successfully validated against experimental results presented in the literature.

# Francisco Mesquita

## KU LEUVEN

***Unidirectional interlayer fibre-hybrid composites: longitudinal tensile failure and interactions between fibre types***

Fibre-hybrid composites are made of at least two fibre types embedded in a binding matrix. The mechanical properties of such composites can be advantageous relative to each of the reference composites.

The goal of the project was to predict the tensile failure of unidirectional interply fibre-hybrid composites. This involves the understanding of the ply failures and how the fibres interact between plies. Characterising the fibre strength distribution and the stress fields in the presence of (1) fibre breaks, (2) ply fractures and (3) delamination was fundamental to the execution of the project. A dual-scale model, that associated the fibre break accumulation with the formation of ply fractures and the growth of delamination, was the main achievement.

In-situ synchrotron CT tensile tests were also performed on interply fibre-hybrid composites. The experiments helped to identify the strengths and weaknesses in the model and provided new insights on the hybrid effect.

# Lorenzo Mencattelli

IMPERIAL COLLEGE LONDON

***Bio-inspired designs for enhanced damage tolerance of composite structures: Bouligand, Herringbone and multi-tailored bone-inspired strategies***

Lorenzo Mencattelli's research focuses on the development of three novel bio-inspired microstructural concepts, for point-by-point tailorable composite solutions, that exploit the ability to diffuse damage in a sub-critical state; these aim at enhancing the damage tolerance and the energy dissipation capability of conventional composite structures, creating design solutions with high industrial impact.

The Bouligand concept, inspired by the impact-resistant periodic region of the mantis shrimp's dactyl club, was developed to address the inherent low performances to through-the-thickness loading of carbon fibre composites (CFRPs). Tailored Bouligand microstructures achieved the largest improvement in damage tolerance ever reported with thin-ply CFRPs, resulting in a simultaneous increase in load-bearing capability, delay in catastrophic failure and increase in dissipated energy.

The Herringbone-Bouligand concept, inspired by the ultrastructural features of the mantis shrimp's dactyl club, was exploited to improve further the damage tolerance of Bouligand-inspired CFRPs. For the first time high-performance Herringbone-Bouligand microstructures were prototyped. Experimental tests showed that Herringbone-Bouligand microstructures delay onset of delaminations, greatly reduce the in-plane spreading of damage, increase the energy dissipation capability and contain damage within the tailored Herringbone-Bouligand region.

The multi-tailored bone-inspired concept, based on the introduction of patterns of discontinuities in the form of laser-cuts across the load-carrying fibres of FRPs, was adopted to devise a versatile design strategy that can be used to locally-tailor different damage tolerance requirements at different locations within the same structure.

Patterns of discontinuities can be successfully tailored to create high-energy dissipation paths through which damage is stabilised and diffused at sub-critical levels.

# Arsen Melnikov

KU LEUVEN

## *Unidirectional fibre bundles under non-uniform strain fields in composites*

Fibre-reinforced composites consist of unidirectional (UD) fibre bundles and non-uniformity of longitudinal tensile strain fields in them can be induced due to different reasons.

These reasons can be applied load (bending), damage development (cross-ply laminates) and material features (resin-rich zones in non-crimp fabric (NCF)).

To investigate the performance of these bundles and composites we employed the strength model for UD composites of Swolfs et al. which considers the fibre break development. This model was extended to apply non-uniform longitudinal tensile strain fields to UD fibre bundles making it first such model to our knowledge.

Based on this extended model we developed other models and methodologies to predict tensile strength of cross-ply laminates, UD NCF and flexure strength of UD composites failing in tension.

Subjecting carbon/epoxy UD composites to longitudinal bending we could predict the same flexure strength scaling with the specimen volume as in the experimental studies from the literature.

For carbon/epoxy cross-ply laminates and UD NCF composites, we observed the reduction of tensile strength in comparison to UD composites when we increased thickness of the transverse ply or size of the resin-rich zone accordingly.

# Fabio Malgioglio

SIEMENS DIGITAL INDUSTRIES SOFTWARE & KU LEUVEN

## *Material variability across the scales: towards virtual material characterisation of unidirectional composites under axial loading condition*

Composite materials, due to their superior properties and low density, are desirable in applications where weight reduction is crucial. Such materials present a complex mechanical behaviour.

The characterisation is nowadays one of the bottlenecks in the design phase, due to the costly experimental campaigns. Thus, high safety factors are used, limiting their lightweight potential.

The challenge of this research is to develop a fast and reliable Virtual Testing methodology based on finite elements to replicate the experimental tests needed for the material characterisation.

To predict the variability of the material properties, the material variability is included in the modelling in terms of

1. the variability of fibre strength (accounted for by means of fibre-break models)
2. variability of volume fraction
3. fibre misalignment (replicated with spatially-correlated random fields).

The modelling procedure was applied at coupon level to predict the longitudinal tensile properties and extended to cylindrical sections of type IV composite pressure vessels to assess the burst pressure.

Finally, a machine learning inspired strategy was successfully implemented to dramatically reduce the computational time required by the simulations.

# Ashok Rajpurohit

CHOMARAT TEXTILES INDUSTRIES &
MINES PARISTECH


## *Development of advanced carbon/glass fibre based hybrid composites*

In this work we develop novel hybrid textile reinforcements and fabricate series of fiber hybrid composites using T700S carbon and Advantex E-CR glass fibers for newer applications in the field of wind energy, sports and leisure.

Hybrid reinforcements and composites are fabricated at three different levels of hybrid configurations, namely, ply-level or interply, tow-level or intraply and fibre-level or intermingled hybrids.

The main objective of this work is to explore the balance of mechanical properties for fibre-hybrid composites under different loading conditions such as tensile, compression and flexion.

The objective is also to understand and discuss the hybrid or synergistic effect for the selected carbon and glass fibers hybridized at the three hybrid levels.

Toward achieving these objectives, the work explores and reports for the first time:

1. the effect of textile processes on the tensile strength and distribution for carbon and glass fibres
2. optimization of fibre spreading process for glass fibres
3. the use of commingled rovings made from two technical fibres such as carbon and glass
4. fabrication of new generation of thin-ply hybrids made by simultaneous spreading of carbon and glass fibres and studying the mechanical behavior of composites made from them.


## Martinus Putra Widjaja

BAM FEDERAL INSTITUTE FOR MATERIALS RESEARCH AND TESTING & MINES PARISTECH


### *Efficient approach for strength characterisation of real-scale composite pressure vessels using a multiscale model: Reduced volume method*

Predicting the burst pressure of a real scale composite pressure vessel (CPV) is a cumbersome process. The fibre break occurred in the microscale that controls the failure of composite structure must also be considered when evaluating the strength of a macroscale structure.

This pose a new challenge in terms of computational efficiency, as the macroscale structure is built upon millions of elements, which represent the fibre break evaluation in the microscale. Therefore, a Stationary Ergodic Random Function and Associated Integral Range (SERFAIR) concept is introduced and revealed that the fibre break model can be implemented only at certain part of the macroscale structure when the elements are assembled in certain direction. An attempt then has been made to apply this concept for predicting the failure of unidirectional composite specimen and it gave a good prediction.

The micro-CT scan of a type IV CPV had also been conducted to find the stacking sequence of its composite layer and also the fibre volume fraction of the hoop layer. This information then used for predicting the burst pressure of a type IV CPV. One out of four modelling configurations had been found to give a good correlation with the experimental data.

With this framework, one can perform the initial study for CPV design in a more efficient manner. In addition, as the model also considers the time-dependent effect, it would also assist the study of the long-term behavior of CPVs

# Luca M. Martulli

TOYOTA MOTOR EUROPE &
KU LEUVEN

***Static and fatigue performance and design of carbon fibre sheet moulding compound components***

Carbon Fibre Sheet Moulding Compound (CF-SMC) have a wide range of potential application in automotive.

The lack of available models for part design, however, is limiting the adoption of such materials.

In my research a numerical CAE tool for the prediction of stiffness and strength of CF-SMC part was developed. Moreover, to validate such a model, a thick-walled CF-SMC chassis component was designed, manufactured and tested. This was the thicker part ever reported in literature made of CF-SMC.

An investigation on the production of such an unusual part was conducted, highlighting the strength and weaknesses of such a compression moulding.

Moreover, an extensive fatigue experimental campaign was conducted on coupon level. This has highlighted the presence of a crack arrest mechanism, that confers exceptional fatigue resistance to CF-SMC.

Extending the very limited knowledge of the fatigue response of CF-SMC is also another step to a widespread adoption of these materials in industrial application.

# FiBreMoD publications

L. Mencattelli, S.T. Pinho, Ultra-thin-ply CFRP Bouligand bio-inspired structures with enhanced load-bearing capacity, delayed catastrophic failure and high energy dissipation capability, Composites Part A: Applied Science and Manufacturing (2019) 105655.

L. Mencattelli, S.T. Pinho, Realising bio-inspired impact damage tolerant thin-ply CFRP Bouligand structures via promoting diffused sub-critical helicoidal damage, Composites Science and Technology 182 (2019) 107684.

L. Mencattelli, J. Tang, Y. Swolfs, L. Gorbatikh, S.T. Pinho, Bio-inspired design for enhanced damage tolerance of self-reinforced polypropylene/carbon fibre polypropylene hybrid composites, Composites Part A: Applied Science and Manufacturing 121 (2019) p. 341-352.

J. Tang, Y. Swolfs, A. Aslani, L. Mencattelli, G. Bullegas, S.T. Pinho, S.V. Lomov, L. Gorbatikh, Engineering tensile behavior of hybrid carbon fibre/self-reinforced polypropylene composites by bio-inspired fibre discontinuities, Composites Part B: Engineering 178 (2019) 107502.

L.M. Martulli, L. Muyshondt, M. Kerschbaum, S. Pimenta, S.V. Lomov, Y. Swolfs, Carbon fibre sheet moulding compounds with high in-mould flow: Linking morphology to tensile and compressive properties, Composites Part A: Applied Science and Manufacturing 126 (2019) 105600.

L.M. Martulli, T. Creemers, E. Schöberl, N. Hale, M. Kerschbaum, S.V. Lomov, Y. Swolfs, A thick-walled sheet moulding compound automotive component: manufacturing and performance, Composites Part A: Applied Science and Manufacturing 128 (2019) 105688.

F. Mesquita, Y. Swolfs, S. V. Lomov, L. Gorbatikh, Ply fragmentation in unidirectional hybrid composites linked to stochastic fibre behaviour: A dual-scale model, Composites Science and Technology 181 (2019) 107702.

F. Islam, S. Joannès, S. Bucknell, Y. Leray, A. Bunsell, L. Laiarinandrasana, Investigation of tensile strength and dimensional variation of T700 carbon fibres using an improved experimental setup, Journal of Reinforced Plastics and Composites (2019) accepted.

F. Islam, S. Joannès, L. Laiarinandrasana, Evaluation of critical parameters in tensile strength measurement of single fibres, Journal of Composites Science 3 (2019) 69.

M. Alves, S. Pimenta, A computationally-efficient micromechanical model for the fatigue life of unidirectional composites under tension-tension loading, International Journal of Fatigue 116 (2018) p. 677- 690.

I. Greenfeld, C.W. Rodricks, X.M. Sui, H.D. Wagner, Beaded fiber composites—Stiffness and strength modelling, Journal of Mechanics and Physics of Solids 125 (2019) p. 384–400.

# School programme
## 9 & 10 December

### Monday 9 December

12h00 Registration and lunch
**Fibre, matrix & interfacial characterisation**
13h30 Introduction to the science of fibres: From statistical nature to mechanical properties | **Sebastien Joannès, Mines ParisTech**
14h20 Testing and characterisation of fibres to assess failure strength distribution | **Faisal Islam, Mines ParisTech**
14h45 Mechanical characterisation of thermoset resins for composite applications | **Christian Breite, KU Leuven**
15h10 Coffee break
15h45 A short tutorial about interface mechanics in fiber composites | **Daniel Wagner, Weizmann Institute of Science**
16h35 Characterisation of interfacial properties in model fibre composites | **Carol Rodricks, Weizmann Institute of Science**
17h00 Welcome reception with a wide selection of Belgian beers
20h00 ***End of the day***

# Tuesday 10 December

**Modelling composite behaviour**

08h45 Failure development in longitudinal tension of unidirectional composites | **Yentl Swolfs, KU Leuven**

09h35 On the fatigue of unidirectional composites: modelling approaches | **Marco Alves, Imperial College London**

10h00 Modelling the longitudinal failure of fibre-hybrid composites | **Francisco Mesquita, KU Leuven**

10h25 ***Break***

10h50 Development of failure criteria & multiscale failure simulation of CFRP structures | **Silvestre Pinho, Imperial College London**

11h40 Towards Integrated Computational Materials Engineering (ICME) | **Laszlo Farkas, Siemens Industry Software**

12h30 ***Lunch***

**Recycling**

13h30 Recycling carbon-fibre composites | **Soraia Pimenta, Imperial College London**

**Composite characterisation and experimental validation**

14h20 Developments, opportunities and challenges in the application of X-ray computed tomography to composite materials studies | **Ian Sinclair, University of Southampton**

15h10 Application of digital volume correlation to composite materials | **Erich Schöberl, University of Southampton**

15h45 ***Break***

16h10 Fiber-hybrid composites: processing and characterisation of textiles and composites | **Ashok Rajpurohit, Chomarat**

16h35 Damage tolerant composite structures: challenges, design strategies and applications | **Lorenzo Mencattelli, Imperial College London**

17h00 ***End of the day***

# Conference programme
## 11 & 12 December

### Wednesday 11 December

08h00 Registration

08h50 Opening words

09h00 Keynote: FiBreMoD project: designing novel composite microstructures and applications | **Larissa Gorbatikh, KU Leuven**

09h40 Interface - Chair: Yentl Swolfs
Strength and toughness tuning of fibre-reinforced composites through interfacial topographical obstacles | **Carol W. Rodricks, Israel Greenfeld, XiaoMeng Sui and H. Daniel Wagner (Weizmann Institute of Science)**

10h00 Interface - Chair: Yentl Swolfs
Fracture toughness determination of polymeric matrix materials with TDCB specimens and its validation by simulation and VCCT | **Wei Li, Xavier Valles Rebollo, Bin Wang and Gerhard Kalinka (BAM Federal Institute for Materials Research and Testing)**

10h20 Interface - Chair: Yentl Swolfs
Surface modification of UHMWPE fibres with Ar-$O_2$ plasma treatment | **Usman Sikander, Mark Hazzard, Bengisu Corakci-Donato, Michael Wisnom and Ian Hamerton (University of Bristol, DSM Materials Science Centre)**

10h40 ***Break***

11h05 Matrix and fibres - Chair: David Seveno
Numerical analysis of the effect of interfacial parameters on longitudinal fibre-matrix debonding | **Sina AhmadvashAghbash, Mahoor Mehdikhani, Yentl Swolfs**

11h25 Matrix and fibres - Chair: David Seveno
A shear transformation zone model to predict the deformation and failure of glassy polymers in fibre reinforced composites | **Frederik Van Loock, Jérémy Chevalier, Laurence Brassart, and Thomas Pardoen (Université catholique de Louvain, University of Oxford)**

11h45 Matrix and fibres - Chair: David Seveno
Comparative study of voiding and failure modes in thermoplastics and thermosetting matrices in fibre reinforced composites | **Lucien Laiarinandrasana (Mines ParisTech)**

12h05 Matrix and fibres - Chair: David Seveno
Natural fibres as raw materials for sustainable aligned discontinous fibre composites | **Ali Kandemir, Thomas R. Pozegic, Marco L. Longana and Ian Hamerton (University of Bristol)**

12h25 Matrix and fibres - Chair: David Seveno
Functional cellulose fibers for smart composites |
**Zainab Al. Maqdasi, Nazanin Emami, Roberts Joffe, Shailesh S. Chouhan, Ayoub Ouarga and Abdelghani Hajlane (Luleå University of Technology, Mohammed VI Polytechnic University, Ecole Nationale Supérieure d'Ingénieurs de Caen)**

12h45 ***Lunch***

13h45 Processing and characterisation - Chair: Stepan Lomov
relationships between processing parameters, mechanical and chemical properties of thick glass fibre reinforced thermoplastic methacrylic composites | **Sarah F. Gayot, Pierre Gérard, Thomas Pardoen and Christian Bailly (UCLouvain, Arkema France)**

14h05 Processing and characterisation - Chair: Stepan Lomov
Variability of strand-based sheet moulding compounds as failure determinant | **Luca M. Martulli, Martin Kerschbaum, Stepan V. Lomov and Yentl Swolfs (Toyota Motor Europe, KU Leuven)**

14h25 Processing and characterisation - Chair: Stepan Lomov
Recycled carbon fibre reinforced PET as feed for additive manufacturing for optimal composite performance | **Babs Van de Voorde, Amalia Katalagarianakis, Antoniya Toncheva, Jean-Marie Raquez, Peter Dubruel, Danny Van Hemelrijck, Lincy Pyl and Sandra Van Vlierberghe (Ghent University, SIM vzw, Vrije Universiteit Brussel, University of Mons)**

14h45 Processing and characterisation - Chair: Stepan Lomov
Two different interleaving approaches to mitigate impact damage propagation on carbon/epoxy laminates | **Luís Amorim, Ana Santos, João P. Nunes and Júlio C. Viana (University of Minho)**

15h05 Processing and characterisation - Chair: Stepan Lomov
Fully-uncoupled multi-directional delamination specimens: a preliminary validation | **Torquato Garulli, Daniele Fanteria, Anita Catapano and Eric Martin (Université de Bordeaux, University of Pisa)**

15h25 ***Break***

15h50 Bio-inspired and hybrid composites - Chair: Lucien Laiarinandrasana
Manufacturing and characterisation of bioinspired CFRP | **Verónica Rodríguez-García, Vanesa Martínez and Roberto Guzmán de Villoria (FIDAMC, Universidad Politécnica de Madrid, IMDEA Materials Institute)**

16h10 Bio-inspired and hybrid composites - Chair: Lucien Laiarinandrasana
Hybrid effect in critical energy release rates in all-carbon interlayer unidirectional fibre-hybrids | **Sergei B. Sapozhnikov, Yentl Swolfs and Stepan V. Lomov (South Ural State University, KU Leuven)**

16h30 Bio-inspired and hybrid composites - Chair: Lucien Laiarinandrasana
A micromechanical progressive failure model for predicting the tensile failure and damage development in hybrid unidirectional composite materials | **Jose M. Guerrero, Joan A. Mayugo, Josep Costa and Albert Turon (Universitat de Girona)**

16h50 Bio-inspired and hybrid composites - Chair: Lucien Laiarinandrasana
Fibre hybrid composites consisting of discontinuous waste carbon fibre and continuous glass filaments with improved impact strength | **Mir Mohammad Badrul Hasan, Anwar Abdkader and Chokri Cherif (TU Dresden)**

17h10 ***End of the day***

## Thursday 12 December

09h00 Keynote: Second benchmarking exercise for longitudinal tensile failure of UD composites: overview and first results | **Yentl Swolfs, KU Leuven**

09h40 Models of different scales - Chair: Larissa Gorbatikh
Material engineering for composites across scales and physics | **Anna Y. Matveeva, Oxana Shishkina, Fabio Malgioglio and Laszlo Farkas (Siemens Industry Software NV)**

10h00 Models of different scales - Chair: Larissa Gorbatikh
Distinct element method (DEM) for fibrous composites: toward computational guided manufacturing | **Traian Dumitrică, Grigorii Drozdov and Igor Ostanin (University of Minnesota)**

10h20 Models of different scales - Chair: Larissa Gorbatikh
What holds cellulose nano-fibrils together? | **Ali Khodayari, Aart W. van Vuure, Ulrich Hirn and David Seveno (KU Leuven, TU Graz)**

10h40 ***Break***

11h05 Mini orals (page 26-27)

11h45 Posters

12h20 ***Lunch***

13h20 Unidirectional composites - Chair: Sébastien Joannès
A machine learning inspired approach to predict the longitudinal tensile failure in unidirectional composites | **Fabio Malgioglio, Soraia Pimenta, Laszlo Farkas, Wim Desmet, Stepan V. Lomov and Yentl Swolfs (Siemens Digital Industries Software, Imperial College London, KU Leuven, Flanders Make)**

13h40 Unidirectional composites - Chair: Sébastien Joannès
Effects of dynamic failure and local peak stress in UD composites | **Mostafa Barzegar, Josep Costa and Claudio S. Lopes (IMDEA Materials, University of Girona)**

14h00 Unidirectional composites - Chair: Sébastien Joannès
Fibre-related damage in unidirectional composites under cyclic tension loadings | **Paolo A. Carraro, Lucio Maragoni and Marino Quaresimin (University of Padova)**

14h20 Unidirectional composites - Chair: Sébastien Joannès
Prediction of a fatigue limit of unidirectional fibre composites | **Bent F. Sørensen and Stergios Goutianos (Technical University of Denmark)**

14h40 Unidirectional composites - Chair: Sébastien Joannès
Compressive failure of fiber reinforced unidirectional composites: experimental approach and finite element analysis | **Abir Mejdoub, Christophe Bois, Jalal El Yagoubi, Thierry Lorriot and Hervé Wargnier (ENSAM ParisTech)**

15h00 ***Break***

15h20 Dedicated characterisation and modelling - Chair: Bent Sørensen
Synchrotron X-ray computed tomography study of braided composite tubes under torsion | **Yuan Chai, Ying Wang, Zeshan Yousaf, Nghia T. Vo, Prasad Potluri and Philip J. Withers (The University of Manchester, Diamond Light Source)**

15h40 Dedicated characterisation and modelling - Chair: Bent Sørensen
The effect of input properties to the predicted failure of a type IV composite pressure vessel using a multiscale model | **Martinus Putra Widjaja, Faisal Islam, Sebastien Joannès, Anthony Bunsell, Georg Mair and Alain Thionnet (BAM Federal Institute for Materials Research and Testing, Mines ParisTech, Université de Bourgogne)**

16h00 Dedicated characterisation and modelling - Chair: Bent Sørensen
Development of a modeling strategy to improve the embedded element method in composites modeling in case of matrix nonlinearity | **Alp Sik, Ercan Gurses and Baris Sabuncuoglu (Hacettepe University, Middle East Technical University)**

16h20 Dedicated characterisation and modelling - Chair: Bent Sørensen
Automated RVE generator of realistic voids for 3D textile composites manufactured by RTM | **Keerti K. Parvathaneni, Dmitry Vasiukov and Chung Hae Park (IMT Lille Douai, Université de Lille)**

16h40 Dedicated characterisation and modelling - Chair: Bent Sørensen
Influence of stitching on the tensile strength of unidirectional non-crimp fabric composites: investigation using multi-scale fibre bundle strength model | **Arsen Melnikov, Yentl Swolfs, Anna Matveeva, Larissa Gorbatikh and Stepan V. Lomov (KU Leuven, Siemens Industry Software NV)**

17h00 ***End of the day***

## Mini-oral & poster sessions: 12 Dec - 11h45

- Discrete element approach for modelling mechanical behaviour and damage of PA6/GF30
  **Ahmed Ammar, Willy Leclerc, Mohamed Guessasma and Nader Haddar (Université de Picardie Jules Verne, Université de Sfax)**
- Multiscale simulation framework for interlaced laminates
  **Rutger Kok, Francisca Martinez-Hergueta and Filipe Teixeira-Dias (University of Edinburgh)**
- Micro scale fiber-matrix model based on the discrete element method for a multi-scale modeling approach
  **Stefan Hesseler, Sebastian Felder, Scott E. Stapleton, Jaan-Willem Simon, Stefanie Reese and Thomas Gries (RWTH Aachen, University of Massachusets Lowell)**
- A unique approach to adhesive joint design: composite layup tailoring for bond-line stress optimisation
  **James R. Davidson, Edward D. McCarthy and Conchur M. Ó Brádaigh (The University of Edinburgh)**

- Quantitative comparison between fast fourier transform and finite element method for micromechanical modeling of composite
  **Xiao Ma, Keerti K. Parvathaneni, Stepan V. Lomov, Dmitry Vasiukov, Modesar Shakoor and Chung Hae Park (IMT Lille Douia, Université de Lille, KU Leuven)**
- Assessment of effective elastic properties of short-fiber reinforced polymer by micromechanical probabilistic model
  **Mohamed Hassani, Latifa Alimi, Tahar M. Guettaf , Skander Boukhezar, Nacira Sassane and Youcef Khadri (Research Center in Industrial Technologies CRTI, University of Badji Mokhtar)**
- Mode I translaminar fracture toughness of carbon-carbon hybrid thin-ply composites: modelling and characterisation
  **Guillaume Broggi, Joël Cugnoni and Véronique Michaud (EPFL, Haute Ecole d'Ingénieur et de Gestion-Vaud)**
- Properties of hybrid stainless steel woven wire mesh/glass fiber-reinforced epoxy composites under quasi-static tensile load
  **Tahreem Naveed, Hanno Pfitzer and Yentl Swolfs (BMW Group Germany, KU Leuven)**
- The influence of contamination on the recycled and reuse carbon fibre product
  **Jaganath Thirunavukkarasu, Mathilde Poulet, Thomas Turner and Stephen Pickering (ELG Carbon Fibre Ltd, The University of Nottingham)**
- Influence of build plate temperature on the tensile strength and stiffness of 3D printed rCF/rPET parts
  **Amalia Katalagarianakis, Babs Van de Voorde, Sandra Van Vlierberghe, Danny Van Hemelrijck and Lincy Pyl (VUB, UGent)**
- Three dimensional fibre and damage characterisation of injection moulded fibre reinforced thermoplastics by X-ray computed tomography
  **Julia Maurer, Dietmar Salaberger and Johann Kastner (University of Applied Sciences Upper Austria, Borealis Polyolefine GmbH)**
- Dynamic responses of sandwich composite beam with PVB viscoelastic core under moving load
  **Yacine Karmi, Youcef Khadri, Sabiha Tekili and Ali Daouadji (Université Badji Mokhtar, INSA Lyon)**
- Fire properties of CFRP and GFRP
  **Sankar Karuppannan Gopalraj and Timo Kärki (LUT University)**
- Improving the translaminar fracture toughness of carbon fibre composites by hybridisation with high-performance polymer fibres
  **Yoran Geboes, Amalia Katalagarianakis, Jan Ivens and Yentl Swolfs (KU Leuven)**

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