

## TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	<b>April 26</b>	<b>April 27</b>	<b>April 28</b>	<b>April 29</b>	<b>April 30</b>
9.00 - 9.45	Registration	Kyosev	Boisse	Carlone	Kärger
9.45 - 10.30	Boisse	Kyosev	Boisse	Carlone	Kärger
11.00 - 11.45	Lomov	Kyosev	Binetruy	Carlone	Kärger
11.45 - 12.30	Lomov	Kyosev	Binetruy	Carlone	Boisse
14.00 - 14.45	Kärger	Lomov	Binetruy	Carlone	
14.45 - 15.30	Kärger	Lomov	Binetruy	Boisse	
16.00 - 16.45	Kyosev	Lomov	Binetruy	Boisse	
16.45 - 17.30	Kyosev	Lomov	Binetruy	Kärger	
18.00	Welcome Apertitif				

## ADMISSION AND ACCOMMODATION

The registration fee is 600.00 Euro + VAT\*, where applicable (bank charges are not included). The registration fee includes a complimentary bag, four fixed menu buffet lunches (on Friday upon request), hot beverages, downloadable lecture notes and wi-fi internet access.

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through the following web site: <http://www.cism.it>. A message of confirmation will be sent to accepted participants. Applicants requiring assistance with the registration should contact the secretariat at the following email address: [cism@cism.it](mailto:cism@cism.it).

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email to [cism@cism.it](mailto:cism@cism.it)) no later than two weeks prior to the start of the course.

Cancellation requests received during the two weeks prior to the start of the course will be charged a 50.00 Euro handling fee. Incorrect payments are also subject to a 50.00 Euro handling fee.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered lodging and/or board, if available, in a reasonably priced hotel or student guest house.

Requests should be sent to CISM Secretariat by **February 26, 2021** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

Information about travel and accommodation is available on the web site [www.cism.it](http://www.cism.it), or can be mailed upon request.

\* Italian VAT is 22%.

*For further information please contact:*

CISM  
 Palazzo del Torso  
 Piazza Garibaldi 18  
 33100 Udine (Italy)  
 tel. +39 0432 248511 (6 lines)  
 fax +39 0432 248550  
 e-mail: [cism@cism.it](mailto:cism@cism.it)  
[www.cism.it](http://www.cism.it)



# COMPOSITE MANUFACTURING PROCESSES: ANALYSES, MODELLING AND SIMULATIONS

Advanced School  
 coordinated by

**Philippe Boisse**  
 Université de Lyon  
 France

**Luise Kärger**  
 Karlsruhe Institute of Technology  
 Germany

**Udine April 26 - 30 2021**

# COMPOSITE MANUFACTURING PROCESSES: ANALYSES, MODELLING AND SIMULATIONS

Fiber reinforced composites are increasingly being used in the aerospace and automotive industry to cope with lightweighting challenges and meet high performance standards. The manufacturing processes are essential for the quality of the final composite. Simulation of composite manufacturing processes requires experimental analysis and modelling of the transformations involved. These simulations can prevent a time consuming and expensive "trial and error" process design. During the process, the phenomena concern fibrous materials in large deformation and the flow of resin into the fibrous reinforcement. They depend on heat transfer and sometimes phase change.

Experimental analysis, modelling and simulation of physical phenomena during composites forming are the objectives of the

course. It will concern in particular composite materials for structural parts. The analysis of forming of the reinforcement without resin (dry preform) and with non-hardened resin (prepreg) will be considered as well as thermomechanics and consolidation of the composite during prepreg forming and flow processes in composite materials. This course is aimed at Ph.D. students and Master students in the field of composite engineering. Researchers interested in composite forming are also welcome to attend this course. The main points to be covered in this course are as follows:

1. Draping of fibrous preforms and prepregs.

Forming of continuous fiber reinforcements leads to specific mechanical problems because of the relative slippage between the fibers and the quasi-inextensibility of the fibers. The following topics

are included in this theme:

- Mechanical tests for fibrous reinforcements (shear, biaxial tension, bending, transverse compaction).
  - Constitutive law for textile reinforcements (Hyper elasticity, hyper viscoelasticity...)
  - Simulations of preform deformation at macro, meso and microscale.
  - Specific finite elements, locking of textile materials
  - Full field strain measurements (DIC) and Micro CT analyses of internal geometry
  - Beyond the classical Cauchy approach. Generalized continuum mechanics.
2. Liquid composite moulding  
One of the most efficient composite manufacturing method is to impregnate the fiber reinforcement (the preform) by liquid flow of matrix material. Analysis and simulation of this flow within the fibrous preform

constitutes a broad scientific field necessary for modeling of composite manufacturing processes.

- Permeability (measure and virtual)
- Multi-scale flow models
- Saturation
- Investigation by X-ray CT
- Simulation techniques: FE-Control Volume, FE-Level Set, Pure FE

3. Thermo mechanics, Thermo kinetics and Couplings

Composite forming processes are carried out at high temperature and the coupling between mechanical and thermal behavior is important. Consolidation and crystallization of the resin are also coupled with the forming deformation

- Multi-scale and multi-physical models and algorithms
- Curing, crystallization, polymerization
- Residual stresses
- Coupling algorithmic

## PRELIMINARY SUGGESTED READINGS

Spencer, A. J. M. (1972). Deformations of fibre-reinforced materials. Oxford University Press.

Coussy, O. (2004). Poromechanics. John Wiley & Sons.

Lomov, S. V., I. Verpoest and F. Robitaille (2005). Manufacturing and internal geometry of textiles. Design and manufacture of textile composites. A. C. Long, Woodhead: 1-60.

Basar, Y., & Weichert, D. (2013). Nonlinear continuum mechanics of solids: fundamental

mathematical and physical concepts. Springer Science & Business Media.

Boisse, P. (Ed.). (2011). Composite reinforcements for optimum performance. Elsevier.

Henning, F., Kärger, L., Dörr, D., Schirmaier, F. J., Seuffert, J., and Bernath A.: Fast processing and continuous simulation of automotive structural composite components. Composites Science and Technology, (171):261–279, 2019. Bussetta P., and Correia N.:

Numerical forming of continuous fibre reinforced composite material: A review. Composites Part A: Applied Science and Manufacturing, 113:12–31, 2018. Kärger, L.; Bernath, A.; Fritz, F.; Galkin, S.; Magagnato, D.; Oeckerath, A.; Schön, A.; Henning, F.: Development and validation of a CAE chain for unidirectional fibre reinforced composite components. Composite Structures 132: 350–358, DOI: 10.1016/j.compstruct.2015.05.047, 2015. Y. Kyosev, Topology-Based

Modeling of Textile Structures and Their Joint Assemblies Principles, Algorithms and Limitations, Spinger, 2019, <https://www.springer.com/de/book/9783030025403>

Binetruy, C., Chinesta, F., & Keunings, R. (2015). Flows of Simple Fluids in Complex Microstructures: Composite Processing of Structural Polymer Composites. In Flows in Polymers, Reinforced Polymers and Composites (pp. 109-140). Springer, Cham.

## INVITED LECTURERS

**Boisse Philippe** - Université de Lyon, France

*6 lectures on:* Mechanics of textile reinforcement during forming. Hypoelastic and hyperelastic approaches. Specific mechanical characterization tests. Shell approaches for textile preforms. Limits of the mechanics of Cauchy. Second gradient approaches. Simulation of wrinkling during fibrous fabric forming. Thermomechanics and consolidation.

**Binetruy Christophe** - Centrale Nantes, France

*6 lectures on:* Liquid Composite Molding processes. Classification according to the main physical phenomena involved. Micro-scale and macro-scale modeling. Some constitutive laws and their characterization. Application to flow in stationary and deformable multi-scale fibrous media.

**Carlone Pierpaolo** - University of Salerno, Italy

*5 lectures on:* Pultrusion process. Characterization of resin systems for pultrusion processes. Modeling of reactive resin flow in non-homogeneous advancing porous medium. Modeling of the thermo-chemical behavior of the material. Stress-strain and pulling force prediction.

**Kärger Luise** - Karlsruhe Institute of Technology, Germany

*6 lectures on:* Continuous virtual process chain of CoFRP. Data interfaces, data convention, mapping, interpolation methods. Manufacturing effects and their thermo-chemo-mechanical influences on process and structural behavior. Draping effects, residual stresses, warpage.

**Kyosev Yordan** - TU Dresden, Germany

*6 lectures on:* Types of fiber based (textile) structures - woven, braided, warp and weft knitted, combined (multiaxial reinforced, stitched); fleeces (nonwoven). Typical tensile, shear, bending and compression behaviour of the different types. Influences between the structure topology, production parameters and forming influencing parameters.

**Lomov Stepan V.** - KU Leuven, Belgium

*6 lectures on:* Architecture of textile reinforcements (weaving, braiding, NCFs). Geometrical models of unit cells. Deformability of textiles: deformation modes (bending, compaction, shear, biaxial tension, friction), measurement and analytical models.

## LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants.