5. International Advisory Board

- **prof. Holm Altenbach** (The Martin Luther University, Halle, Germany)
- **prof. René de Borst** (The Eindhoven University of Technology, Eindhoven, The Netherlands)
- **prof. Matthew Cartmell** (The University of Glasgow, Glasgow, United Kingdom)
- **prof. Bhushan Karihaloo** (The Cardiff University, Cardiff, United Kingdom)
- **prof. Stefano Lenci** (The Polytechnic University of Marche, Ancona, Italy)
- **prof. Giulio Maier** (The Rector of the Centre for International Mechanical Sciences, Udine, Italy)
- **prof. George Papadopoulos** (The National University of Athens, Athens, Greece)
- **prof. George Papanicolaou** (The University of Patras, Patras, Greece)
- **prof. Ryszard Pyrz** (The Aalborg University, Aalborg, Denmark)
- **prof. Giuseppe Rega** (The "La Sapienza" University of Rome, Rome, Italy)
- **prof. Siegfried Schmauder** (The University of Stuttgart, Stuttgart, Germany)
- **prof. Marian Wiercigroch** (The University of Aberdeen, Aberdeen, United Kingdom)
- **Mr Pawel Chojnacki** (The Polish Aviation Works S.A., Swidnik, Poland) – representative of the regional industry
- **Mr. Richard Forster** (AIRBUS SAS, Blagnac Cedex, France) – representative of the EU industry
- **Mr. Dimitri K. Karagiannis** (The Integrated Aerospace Science Corporation – INASCO, Argyroupolis, Greece) – representative of the EU SME
- **dr. Adam Wasilewski** – (Mayor of Lublin, Poland) – representative of the local authority

6. Experts

- **Prof. René de Borst** – Eindhoven University of Technology, The Netherlands
- **Prof. Eduard Craciun** – Ovidius University of Constanta, Romania
- **Prof. Bhushan Karihaloo** – Cardiff University, United Kingdom
- **Prof. Giulio Maier** – Politecnico di Milano, Italy
- **Prof. Günter Radons** – Technical University Chemnitz, Germany

CONTACT

Address:
Prof. Tomasz Sadowski
Lublin University of Technology
Faculty of Civil Engineering and Architecture
Department of Solid Mechanics
Nadbystrzycka 40 Str.
20-618 Lublin
Poland

Project Coordinator:
Professor Tomasz Sadowski, PhD, DSc
e-mail: t.sadowski@pollub.pl, sadowski.t@gmail.com
phone: +48 81 5384386

Project Administrator:
Jolanta Sadowska, MSc
e-mail: j.sadowska@pollub.pl
phone: +48 81 5384386
fax: +48 81 5384174

www.cemcast.pollub.pl

Centre of Excellence

SEVENTH FRAMEWORK PROGRAMME

Modern Composites Applied in Aerospace and Surface Transport Infrastructure

CEMCAST

Co-ordinator:
Tomasz Sadowski

Grant agreement no.: FP7 – 245479

1 April 2010 – 31 March 2013
Lublin University of Technology, Poland

1. Concept

The project aims at continuation and advancement of activities initiated in FP6 Transfer of Knowledge project MTKD-CT-2004-014058 at the Centre for Modern Composite Materials (CMCM) created at the Lublin University of Technology (LUT). It is planned:

a) to unlock and develop the full research potential and increase research capacities of the CMCM staff in the areas of competence comprising modelling of composite and smart materials and their applications to aerospace and transport infrastructure (pavements and airfields), also modelling and control of dynamics of structures made of composites,

b) to establish new area of competence: innovative technologies for manufacturing of composites,

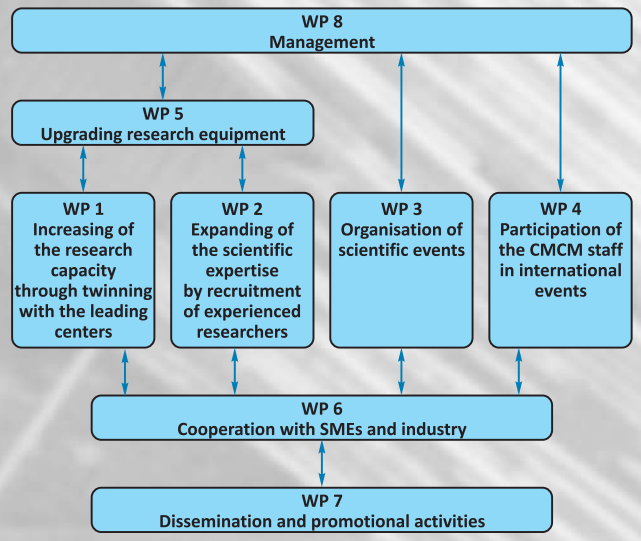
c) to upgrade research equipment for testing of composite materials. The project objectives will be accomplished by a coherent set of the following complementary actions: twinning collaboration, recruitment of experienced researchers, organisation of workshops and mini-symposia, participation in international conferences, purchase of equipment.

2. Project objectives

- to **unlock** and **develop** the full **research potential** of the CMCM staff in the areas of competence advanced in the previous project (modelling of composite materials and their applications to civil, mechanical and aircraft engineering),
- to establish **new area** of **competence**: innovative technologies for manufacturing of composites,
- to **broaden research** on applications of composites to means of transport, also pavements and airfields,
- to **upgrade** research **equipment** for testing of composite materials,
- to improve research potential for increased contribution to **regional economic** and **social development**,
- to strengthen the capability of the CMCM researchers for successful **participation** in research activities at EU level and in **FP7**,
- to provide better **integration** and visibility of the CMCM in the **ERA**.

3. Scientific goals

1. **Multidisciplinary** (cross-disciplinary) approach to **modelling of modern composite materials** with application of **multi-scale method**, starting from atomistic microscope observations. It is new, fast emerging scientific field. The initial composite internal structure strongly influences the composite behaviour and degradation under different types of loading: static, cyclic, dynamic or impact ones. Additional influence of the water, aggressive environment and high temperature usually accelerate degradation process, which can be described at different scale levels (nano-, micro-, meso-, macro-) and requires inclusion of the physical aspects in the theoretical description – research under the supervision of prof. **Tomasz Sadowski**
2. **Modelling and control of dynamics of structures** made of **composites** with embeded **active elements** taking into account **geometrical and material nonlinearities**, active and passive vibration suppression of chosen mechanical or/and civil engineering structures, study of possible transition from regular to irregular oscillations of design flexible composite structures, modelling of machining of composites – research under the supervision of prof. **Jerzy Warmiński**.



4. Twining Institutions

1. **Martin Luther University (MLU), Germany – prof. Holm Altenbach**
   Topic: Modelling of thermomechanical behaviour of composites
2. **Aalborg University (AU), Denmark – prof. Ryszard Pyrz**
   Topic: Structural characterisation of polymer matrix composites
3. **University of Glasgow (UG), United Kingdom – prof. Matthew Cartmell**
   Topic: Nonlinear dynamics and vibrations of composite structures with active elements
4. **University of Aberdeen (UA), United Kingdom – prof. Marian Wiercigroch**
   Topic: Experimental and numerical analysis of structures with geometrical and material nonlinearities.
5. **University of Roma "La Sapienza" (UR), Italy – prof. Giuseppe Rega**
   Topic: Modelling and nonlinear vibrations of flexible and composite structures
6. **Polytechnic University Marche (PUM), Italy – prof. Stefano Lenci**
   Topic: Modelling of intelligent composite materials and mechanical systems with application of nonlinear dynamics
7. **University of Stuttgart (US), Germany – prof. Siegfried Schmauder**
   Topic: Multiscale modelling and experimental analysis of ceramic matrix composites (CMC)
8. **National Technical University of Athens (NTUA), Greece – prof. George Papadopoulos**
   Topic: Testing of polymer matrix composites. Multiscale modelling of damage and fracture processes
9. **University of Porto (UPP), Portugal – prof. Pedro Ribeiro**
   Topic: Modelling and experimental testing of structures made of modern composite materials
10. **Politechnica University of Timisoara (PUT), Romania – prof. Liviu Marsavina**
    Topic: Numerical and mathematical modelling of cracks propagation in composite materials, including pavements (layered composites), experimental verification.
11. **University of Rousse (UR), Bulgaria – prof. Ivelin Ivanov**
    Topic: Impact loading response of modern composite materials applied in aerospace and surface transportation

Centre of Excellence

Modern Composites Applied in Aerospace and Surface Transport Infrastructure

CEMCAST

Co-ordinator:
Tomasz Sadowski

Funded by EC 7.FP under the Research Potential
(Coordination and support actions)

CONTENTS

GENERAL INFORMATION

1. Concept

The **CEMCAST FP7-245479** project aims at continuation and advancement of activities initiated in FP6 ToK project MTKD–CT–2004–014058 at the **Centre for Modern Composite Materials** (**CMCM**) created at the **Lublin University of Technology** (**LUT**). It is planned:

- to unlock and develop the full research potential and to increase research capacities of the CMCM staff in the areas of competence comprising modelling of composite and smart materials and their applications to aerospace and transport infrastructure (pavements and airfields); also in modelling and control of composite structures dynamics
- to establish new area of competence: innovative technologies for manufacturing of composites
- to upgrade research equipment for testing of composite materials

The project objectives are accomplished by a coherent set of the following complementary actions: twinning collaboration, recruitment of experienced researchers, organisation of workshops and mini-symposia, participation in international conferences, purchase of equipment. The project implementation will result in creating a **leading research centre in the Middle-East part of Europe in the multidisciplinary area** encompassing **modelling and experimental testing of composite and smart materials** and **their application to aircrafts, pavements and airfields**. The project will strengthen co-operation with the regional industry in terms of socio-economic aspects and will help to compensate disproportion (Lublin region is a less favoured one). It is also envisaged that the project will increase visibility and competitiveness at international level of the CMCM in the field of **composite materials and their applications to engineering structures**, resulting in deeper involvement of the CMCM in FP7 projects and better integration of the CMCM in the ERA.

2. Project objectives

- to **unlock** and **develop** the full **research potential** of the CMCM staff in the areas of competence advanced in the previous project (modelling of composite materials and their applications to civil, mechanical and aircraft engineering)
- to establish **new area** of **competence**: innovative technologies for manufacturing of composites
- to **broaden research** on applications of composites to means of transport, also pavements and airfields
- to **upgrade** research **equipment** for testing of composite materials
- to improve research potential for increased contribution to **regional economic** and **social development**
- to strengthen the capability of the CMCM researchers for successful **participation** in research activities at EU level and in **FP7**
- to provide **better integration** and visibility of the CMCM in the **ERA**.

The project objectives will be accomplished by a coherent set of the following complementary actions:

- twinning collaboration with partners form the previous project – **MTKD–CT–2004–014058** – (long-term cooperation) and newly selected excellent research entities in the EU in order to strengthen or to set-up **strategic partnership**
- **recruitment** of incoming **experienced researchers**
- **organisation** of **workshops** and **mini-symposia**, to facilitate transfer of knowledge at national and international level
- **participation** of the Centre's staff in **international events** (conferences, scientific meetings)
- substantial **improvement** of the existing research **equipment**
- increasing **cooperation** with regional **enterprises** (including SMEs)
- **dissemination** and **promotional** activities.

3. Scientific goal

The scientific goal is focused on **new ideas** and **innovations** in **modelling** of different types of **composite materials** and **application** of newly formulated concepts to **solution** of engineering **problems** in **aerospace** and **surface transport infrastructure**. The scientific activities within the project comprise:

- **multidisciplinary** (cross-disciplinary) approach to **modelling** of modern **composite materials** with application of **multi-scale method**, starting from atomistic microscope observations. It is new, fast emerging scientific field. The initial composite internal structure strongly influences the composite behaviour and degradation under different types of loading: static, cyclic, dynamic or impact ones. Additional influence of the water, aggressive environment and high temperature usually accelerates degradation process, which can be described at different scale levels (nano-, micro-, meso-, macro-) and requires inclusion of the physical aspects in the theoretical description – **research under the supervision of prof. Tomasz Sadowski**

- modelling and control of **dynamics** of **composite structures** with embeded **active elements** taking into account geometrical and material nonlinearities, **active** and **passive vibration** suppression with respect to selected mechanical or/and civil engineering structures, study of possible transition from regular to irregular oscillations of flexible composite structures, modelling of **composites machining** – **research under the supervision of prof. Jerzy Warmiński**
- experimental **testing** of newly created composite materials concerning estimation of the local **stress concentration** and resistance to **defects propagation**, composites properties during machining, testing of elements and structures under different type of excitations, **modal analysis**, experimental verification of vibrations control strategy
- **industrial applications** of composite models in designing of engineering structures, e.g. **smart composites** in **helicopters**, active and passive dampers, **thermal barrier coating** of engine elements, joining technologies, **pavements**, **bridges** and **airfields**.

The project aims at expanding of different aspects of composite technology and analyses carried out by the CMCM staff. In particular, **it is expected to introduce novel**, **innovative methodologies to modelling and testing of composites**. Moreover, by scientific exchange with leading European centres, the CMCM will strive to keep abreast of any research and technological developments in the areas already represented by the Centre. The ultimate goal is to become the **excellent centre, visible at EU level** in modern composite materials and their application to solution of engineering problems on a research scale and in parallel on a small pre-industrial scale, through reinforcing of the RTD capacity and capability.

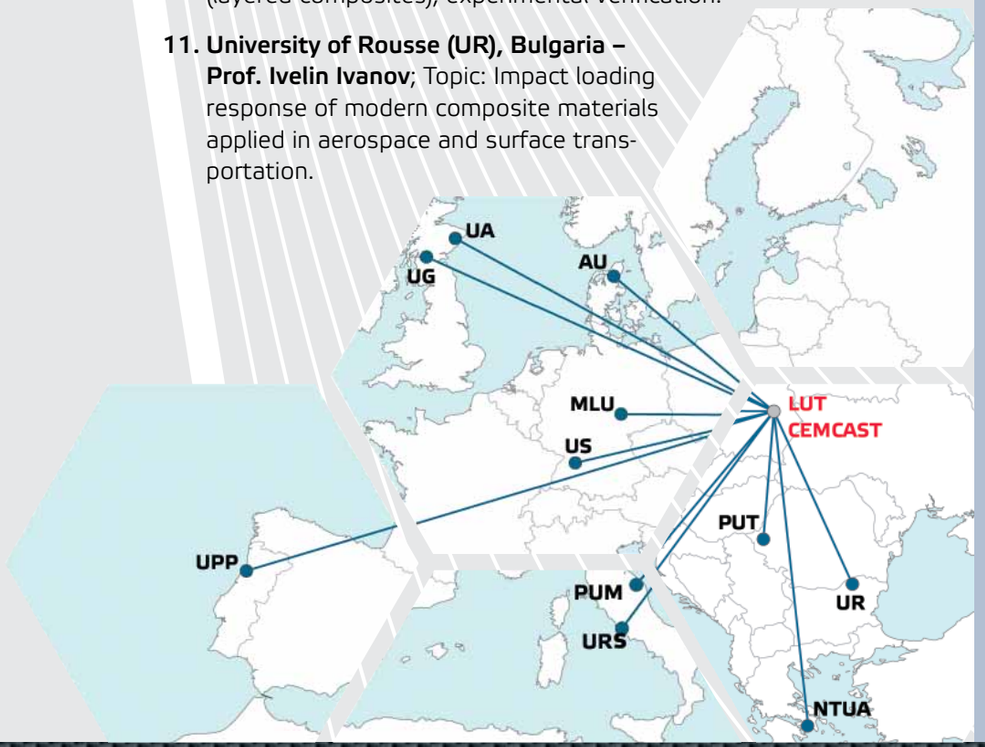
TWINNING INSTITUTIONS

Twinning with the leading EU centres significantly **increases research capacity** and **overall RTD capability** of the Centre. New knowledge absorbed by the CMCM's staff from incoming researchers as well as new testing methods and experimental techniques acquired by secondments of the Centre's staff at twinning institutions will **increase** the **scientific level** and **research quality** of each individual participant in the project and the Centre as the whole.

Twinning between the CMCM research groups and EU partner institutions is based on a close co-operation within defined scientific topics.

The twinning institutions in the project are as follows:

1. **Martin Luther University (MLU), Germany – Prof. Holm Altenbach**; Topic: Modelling of thermomechanical behaviour of composites.
2. **Aalborg University (AU), Denmark – Prof. Ryszard Pyrz**; Topic: Structural characterisation of polymer matrix composites.
3. **University of Glasgow (UG), United Kingdom – Prof. Matthew Cartmell**; Topic: Nonlinear dynamics and vibrations of composite structures with active elements.
4. **University of Aberdeen (UA), United Kingdom – Prof. Marian Wiercigroch**; Topic: Experimental and numerical analysis of structures with geometrical and material nonlinearities.
5. **University of Roma "La Sapienza" (URS), Italy – Prof. Giuseppe Rega**; Topic: Modelling and nonlinear vibrations of flexible and composite structures.
6. **Polytechnic University Marche (PUM), Italy – Prof. Stefano Lenci**; Topic: Modelling of intelligent composite materials and mechanical systems with application of nonlinear dynamics methods.
7. **University of Stuttgart (US), Germany – Prof. Siegfried Schmauder**; Topic: Multiscale modelling and experimental analysis of ceramic matrix composites (CMC).
8. **National Technical University of Athens (NTUA), Greece – Prof. George Papadopoulos**; Topic: Testing of polymer matrix composites. Multiscale modelling of damage and fracture processes.
9. **University of Porto (UPP), Portugal – Prof. Pedro Ribeiro**; Topic: Modelling and experimental testing of structures made of modern composite materials.
10. **Politechnica University of Timisoara (PUT), Romania – Prof. Liviu Marsavina**; Topic: Numerical and mathematical modelling of cracks propagation in composite materials, including pavements (layered composites); experimental verification.
11. **University of Rousse (UR), Bulgaria – Prof. Ivelin Ivanov**; Topic: Impact loading response of modern composite materials applied in aerospace and surface transportation.



PEOPLE

Experts

Experts in the project are **outstanding**, internationally recognised **scientists**, **editors** and members of the editorial boards in **international journals**. They act as a source of additional consultancy and expertise in solving research problems formulated within the project.

The experts in the project are as follows:

1. **Prof. René de Borst** – **Eindhoven University of Technology**, **The Netherlands** – an expert in the field of numerical modelling of engineering problems
2. **Prof. Eduard Craciun** – **Ovidius University of Constanta**, **Romania** – an expert in the field of mathematical modelling of cracks propagation
3. **Prof. Bhushan Karihaloo** – **Cardiff University**, **United Kingdom** – an expert in the field of modelling of different types of composite materials
4. **Prof. Giulio Maier** – **Politechnico di Milano**, **Italy** – an expert in the field of computational modelling of materials and structures
5. **Prof. George Papadopoulos** – **University of Patras**, **Greece** – an expert in the field of micromechanical modelling of composite materials
6. **Prof. Guenter Radons** – **Technical University Chemnitz**, **Germany** – an expert in the field of nonlinear dynamics of production systems

International Advisory Board

To assure successful implementation of overall tasks within the project and its effective management, the **International Advisory Board** (IAB), composed of **world recognised researchers** (experts in the research topics investigated by the CMCM staff), and **representatives of industry** was constituted.

The following eminent persons have accepted membership in the IAB:

- **Prof. Holm Altenbach** – The Martin Luther University, Halle, **Germany**
- **Prof. René de Borst** – The Eindhoven University of Technology, Eindhoven, **The Netherlands**
- **Prof. Matthew Cartmell** – The University of Glasgow, Glasgow, **United Kingdom**
- **Prof. Bhushan Karihaloo** – The Cardiff University, Cardiff, **United Kingdom**
- **Prof. Stefano Lenci** – The Polytechnic University of Marche, Ancona, **Italy**
- **Prof. Giulio Maier** – Politechnico di Milano, The Honorary Member of the Centre for International Mechanical Sciences, Udine, **Italy**
- **Prof. George Papadopoulos** – The National University of Athens, Athens; **Greece**

- **Prof. George Papanicolaou** – The University of Patras, Patras, **Greece**
- **Prof. Ryszrd Pyrz** – The Aalborg University, Aalborg, **Denmark**
- **Prof. Giuseppe Rega** – The University of Rome "La Sapienza", Rome, **Italy**
- **Prof. Siegfried Schmauder** – The University of Stuttgart, Stuttgart, **Germany**
- **Prof. Marian Wiercigroch** – The University of Aberdeen, Aberdeen, **United Kingdom**
- **Mr Paweł Chojnacki** – The Polish Aviation Works S.A., Świdnik, **Poland** – representative of the regional industry
- **Mr Richard Forster** – AIRBUS SAS, Blagnac Cedex, **France** – representative of the EU industry
- **Mr Dimitri K. Karagiannis** – The Integrated Aerospace Science Corporation – INASCO, Argyroupolis, **Greece** – representative of the EU SME

Recruited researchers

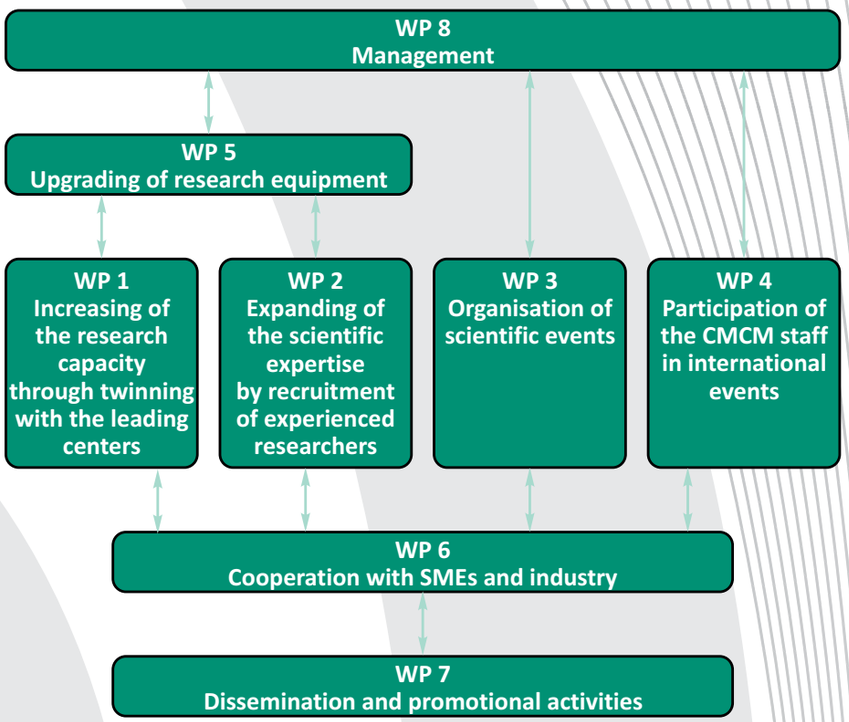
To increase research capacity at the CMCM, extend the area of competence and create an international working environment **5 experienced researchers** selected through an open international competition are employed for 2 years each.

1. **Assoc. Prof. Mircea Birsan** – University A.I. Cuza of Iasi, Iasi, **Romania**.
   Research topic: Layered composite plates and shells subjected to thermal and mechanical loading.
2. **Assoc. Prof. Vyacheslav Burlayenko** – National Technical University, Kharkov Polytechnical Institute, Kharkov, **Ukraine**.
   Research topic: Modelling and experimental investigations of damage and fracture process in the sandwich structures under mechanical loading.
3. **Dr. Fotios Georgiades** – National Technical University of Athens (PhD degree), Athens, **Greece**.
   Research topic: Nonlinear dynamic and control of flexible structures with active elements.
4. **Assoc. Prof. Emil Manoach** – Bulgarian Academy of Sciences, Sofia, **Bulgaria**.
   Research topic: Numerical modelling, optimisation and experimental investigations of flexible structures taking into account delamination and temperature influence.
5. **Prof. Vera Petrova** – Voronezh State University, Voronezh, **Russia**.
   Research topic: Thermal shock modelling in modern composite materials and also modelling of damage and fracture processes in functionally graded materials.

WORK PACKAGES

The project objectives are accomplished by a coherent set of the following complementary actions – **WORK PACKAGES** (**WP**):

Work Plan



WP 1 Increasing of the research capacity through twinning with the leading centres

Description of work

Twinning between the CMCM research groups and EU partner institutions is based on a close co-operation within defined scientific topics. Experts (consultants) act as a source of additional consultancy and expertise, whereas industrial partners formulate specific practical problems to solve.

Task 1.1 Twinning with the Martin Luther University (MLU), Germany – Prof. Holm Altenbach

Topic: Modelling of thermomechanical behaviour of composites:

- effective thermal properties for polymeric and metallic foams
- FGM materials – thermal barrier coating (TBC)
- sandwich honeycomb plates

Functionally graded materials become very popular for practical engineering applications. The basic problem in the constitutive modelling of this type of material is estimation of the **mechanical** and **thermal properties**. It is difficult task, particularly in the case of **foam materials**, e.g. polymer or metallic ones (1st scientific goal). There are two different types of composites with different internal structure, physical and micromechanical properties. However, it is necessary to formulate macroscopic constitutive relations with multi-scale approach in order to propose industrial partners convenient tool for applications in structural design. The 2nd scientific goal of this task concerns **layered composite materials** (TBC) – very popular as thin layers protecting aircraft engine components against the **thermal shock** (e.g. turbine blades).

Creation of the new materials for coatings requires formulation of the new constitutive model, including different physical and structural aspects into the analysis. For **aerospace** industrial **applications** the basic problem is to get relatively simple TBC model, which is based on the data obtained from laboratory observations. This will be possible thanks to new equipment purchased within this project. The expertise of **Prof. H. Altenbach** is required to strengthen the Centre's area of competence.

Expert (consultant): Prof. Bhushan Karihaloo, Cardiff University, UK – is an internationally recognised expert in the field of modelling of different types of composite materials.

Task 1.2 Twinning with the Aalborg University (AU), Denmark – Prof. Ryszard Pyrz

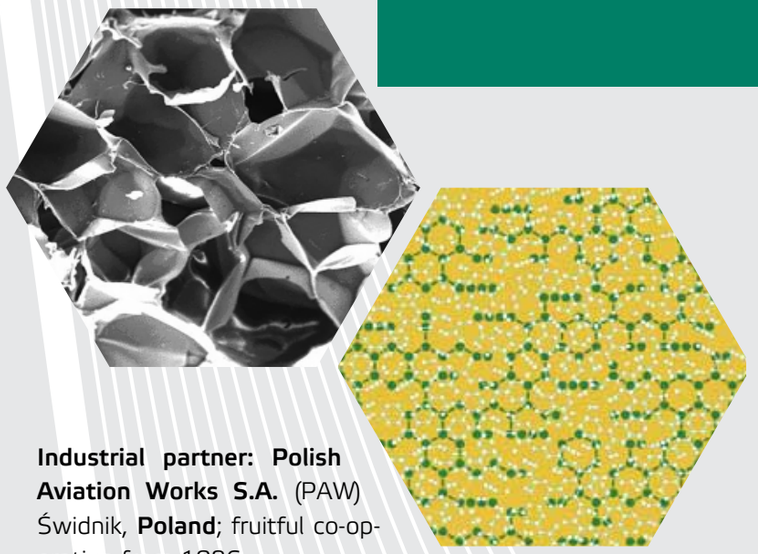
Topic: Structural characterisation of polymer matrix composites

Structural characterisation of the composites plays the basic role for material properties understanding and for modelling of its behaviour with application of multi-scale methods. The CMCM staff has expertise in **new technologies** of **composites manufacturing** (using modern autoclave for technological processes) and **non-destructive testing** of **multilayer composites**:

- polymer-ceramic fibres composites and FML laminates with and without active elements (piezofibres) before and after fatigue test – in particular: connection between metal sheet and composite in laminate, the internal structure of composite (pores, delamination, microcracks etc)
- ceramic-metal type composites – description of interlayer bonding, porosity estimation and discontinuities detection
- ceramic thin layers of titanium and titanium alloys

The aim of the current study within the CEMCAST project is elaboration of a **new technology** for production of the **novel composites applied** in **helicopters** or **light plane structures** for **Polish Aviation Works S.A. Świdnik.**

The micro-tomography method is essential for assessment of the quality of composite materials after technological process. **Prof. R. Pyrz** is a world expert in modelling and testing of new polymer matrix composite materials. His laboratory is equipped with new testing stands, where LUT staff will **get** the **expertise** in **non-destructive testing** and in **micro-tomography method** to **create novel** solutions in **technology** of **composite materials.**

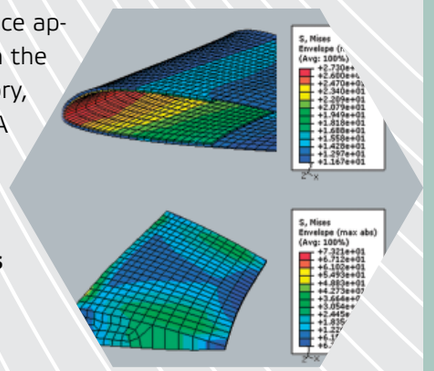


Industrial partner: Polish Aviation Works S.A. (PAW) Świdnik, **Poland**; fruitful co-operation from 1986.

Task 1.3 Twinning with the University of Glasgow (UG), UK – Prof. Matthew Cartmell

Topic: Nonlinear dynamics and vibrations of composite structures with active elements

The research concerns the **dynamics** of **composite structures** with embedded Shape Memory Alloys (SMA) or/and piezoelectric (PZT) elements. This kind of system together with a proper added control technique allows for the design of **intelligent composites,** capable of adaptation to various dynamical conditions. The proposed new solutions can be implemented for various mechanical or airspace applications. **Prof. M. Cartmell** is an expert in the field of nonlinear dynamics, vibrations theory, and in modelling and applications of SMA and PZT to mechanical systems. Cooperation with Prof. M. Cartmell increases the capacity of the Centre in undertaking **theoretical** and **experimental investigations** of **structures** with **active elements**.



Task 1.4 Twinning with University of Aberdeen (UA), UK – Prof. Marian Wiercigroch

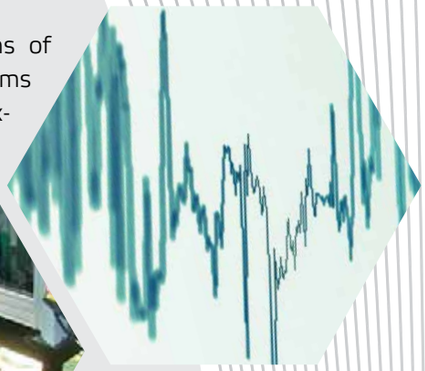
Topic: Experimental and numerical analysis of structures with geometrical and material nonlinearities

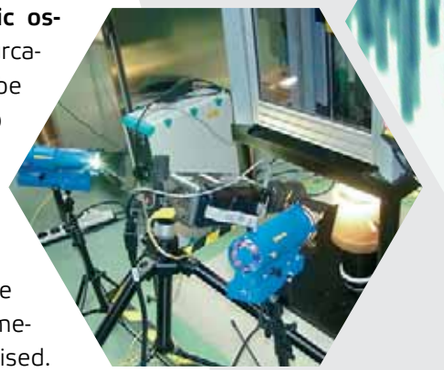
The research concerns investigations of **nonlinear phenomena** of systems under large deformations and systems with discontinuities. A special attention is paid to modelling of nonlinear normal modes of risers, activated during fluid flow, and to application of the pendulum based systems e.g. for energy extraction from the see waves, dynamics of impact oscillators used for increase of effectiveness of chosen machining processes. **Dynamics** of **cutting process** of **composite materials** or other modern, so called, almost unworkable materials are included in this research. **Nonlinear signal analysis** which allows for the model state space reconstruction and proper description of the process will be included as well. The dynamics group from Aberdeen University, leaded by **Prof. M.Wiercigroch** will strengthen knowledge and increase the Centre capacities in the theoretical and experimental analysis of the mentioned above research.

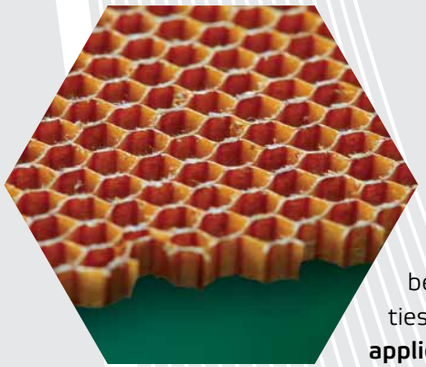
Task 1.5 Twinning with the University of Rome "La Sapienza" (URS), Italy – Prof. Giuseppe Rega

Topic: Modelling and nonlinear vibrations of flexible and composite structures

The research concerns modelling and vibrations of **nonlinear flexible structures** like cables, beams and plates under parametric, external or self- excitations. Transition from regular to **chaotic oscillations** and bifurcation points will be investigated. To avoid or minimise unwanted behaviour and to increase system integrity, the problem of parameters will be optimised.







The research concerns also **composite structures,** including micro-cracked materials via a multi-scale/multi-field approach, laminated plates, mechanical devices with pseudoelastic behaviour (SMA), systems with periodic properties. This research is important in many **practical applications** like electrical cables excited by wind, riser vibrations in offshore industry, composites in civil engineering or **aircraft dynamics**, e.g. **helicopter blades**. Cooperation with **Prof. G. Rega** will essentially strengthen the Centre's investigations in the field of modelling and dynamics of nonlinear flexible and composite structures.

Task 1.6 Twinning with the Polytechnic University Marche (PUM), Italy – Prof. Stefano Lenci

Topic: Modelling of intelligent composite materials and mechanical systems with application of nonlinear dynamics methods

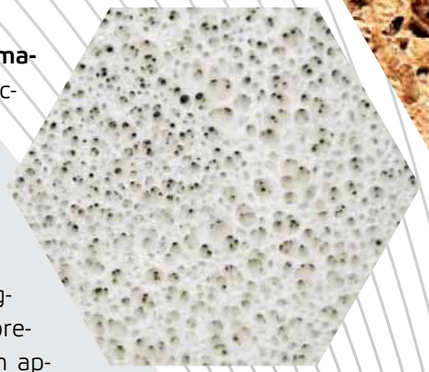
The **systems** with **memory** are now the rapidly developing field because of easy applications in the control procedure. Such systems are characterized by hysteretic loops which is of the great interest of the CMCM staff. The activity includes analytic consideration, simulations and modelling of systems with memory. The **research** will be **applied** to **composite materials** and those **active materials** which can be controlled by an external magnetic field and/or electric currents. The activity will include **modelling** and **simulations** of **systems** with **memory** and a stochastic component. It is planned to examine the bifurcations and apply new methods of dynamical systems identification as 0-1 test. The analytic treatment of higher dimension systems will include the Melnikov approach and the **multiscale** analysis.

The knowledge from **Prof. S.Lenci**, who is the international expert in the field of nonlinear dynamics: from basic nonlinear phenomena (local bifurcations, nonlinear external and/or internal resonances, etc.) to complex phenomena (global bifurcations, chaos, escape, dynamical integrity, etc.), is necessary to enlarge the CMCM area of competence in order to be able to model **intelligent composites** behaviour.

Expert (consultant): Prof. Guenter Radons Institute of Physics, Technical University of Chemnitz, (TUC), Chemnitz, **Germany**

Task 1.7 Twinning with the University of Stuttgart (US), Germany – Prof. Siegfried Schmauder

Topic: Multiscale modelling and experimental analysis of ceramic matrix composites (CMC)



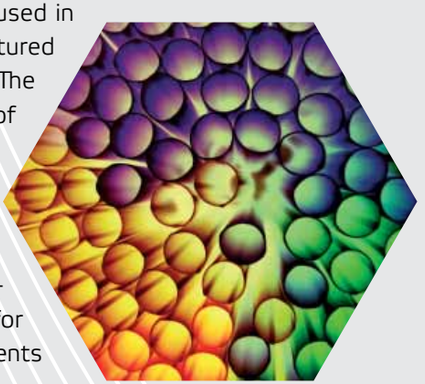
The **ceramic matrix composite materials** are widely used for structural elements in high temperature applications. The CMCM staff has long experience in modelling of the polycrystalline ceramics by application of multi-scale approach and homogenization method over the representative volume element. Such approach was used for modelling of porous ceramics under mechanical loading (reported at conferences as invited lectures, and in many papers published in international journals). The aim of this twinning is extension of the Centre's capacities to **modelling** of **CMC** by **homogenization technique** used by prof. S. Schmauder's group. Prof. Schmauder is a world leader in application of numerical approach in description of composite microstructures mechanics, starting from atomistic scale. His simulations of modern materials behaviour at nano-level were applied to different newly created materials subjected to mechanical and thermal loading. Laboratory at the University of Stuttgart is well equipped and allows for testing of highly brittle materials as CMC.

The scientific goal is **elaboration** of a **new experimental technique** for **estimation** of **mechanical properties** of the selected **ceramic matrix composites**. The CMCM staff will gain knowledge concerning newest approaches of homogenization technique for modelling of composite materials.

Expert (consultant): Prof. René de Borst, Eindhoven University of Technology (EUT)**, The Netherlands**; fruitful co-operation from 2003 comprising: organisation of a course on modelling of composite materials in CISM (Udine, Italy)-2004, organisation of the IUTAM Symposium on "Multiscale Modelling of Damage and Fracture Processes in Composite Materials" (Kazimierz Dolny, Poland)-2005, participation in the project MTKD-CT-2004-014058, common book published by Springer "Lecture Notes on Composite Materials. Current Topics and Achievements", (2008), ISBN 978-1-4020-8771-4.

Task 1.8 Twinning with the National Technical University of Athens (NTUA), Greece – Prof. George Papadopoulos

Topic: Testing of polymer matrix composites. Multiscale modelling of damage and fracture processes



Polymer matrix materials are widely used in different parts of helicopters manufactured in Polish Aviation Works S.A (PAW). The most important from practical point of view is description of **damage** and **fracture processes** under different states of **mechanical** (quasistatic, dynamic, cyclic) and **thermal loading**. The proper selection of evolution equations for damage growth is crucial for engineers designing structural elements made of composites.

At microscale level one can distinguish several different damage processes due to: matrix cracking, delamination, fibres breakage etc.

Experimental investigations of different damage mechanisms in polymer matrix composites are the main research activities of **Prof. G. Papadopoulos**, well known in the international fracture mechanics community. His achievements in application of caustic method in experimental dynamic process of cracks propagation were described in monograph "Fracture Mechanics" published by Springer. By twinning, the CMCM staff will gain the knowledge concerning **application** of the **caustic method**.

Expert (consultant): Prof. George Papanicolaou, University of Patras, (UP)**,** Patras, **Greece** – an expert in: micromechanical modelling of interfaces and interphases, prediction of viscoelastic behaviour of polymers and composites, prediction of damage in different aggressive environments. He is organiser of well known cyclic conference: "The International Conference on Structural Analysis of Advanced Materials".

Task 1.9 Twinning with the University of Porto (UPP), Portugal – Prof. Pedro Ribeiro

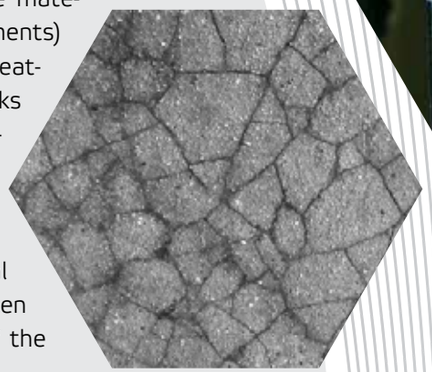
Topic: Modelling and experimental testing of structures made of modern composite materials

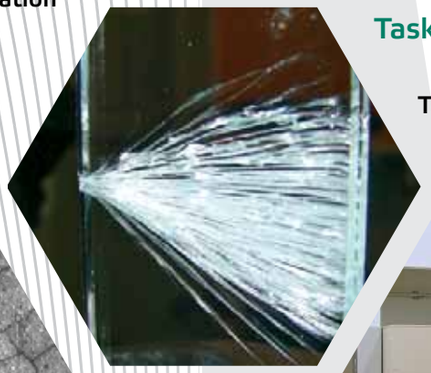
The research concerns **modelling** and experimental **testing** of modern **composite materials** under static and dynamic loads. Panels in advanced materials applicable to airspace engineering, as tow placed variable stiffness laminates and functionally graded material (metal/ceramic), are considered in particular. Dynamics of composite blades, with application to wind turbines, **crack propagation** and **delamination** in **dynamics** of **composites** with geometrical nonlinearities are also of interest. **Prof. Pedro Ribeiro** is an expert in modelling of dynamics of laminated panels and in nonlinear structural dynamics; additionally he has experience on thermoelastic and elasto-plastic vibrations. The team of UPP has strong expertise on delamination modelling and experimental analyses. Cooperation with Prof. P. Ribeiro essentially increases capacities of the Centre in the modelling of composite materials properties, damage and nonlinear vibrations.

Task 1.10 Twinning with the Politehnica University of Timisoara (PUT), Romania – Prof. Liviu Marsavina

Topic: Numerical and mathematical modelling of cracks propagation in composite materials, including pavements (layered composites); also experimental verification

The CMCM staff has experience in description of damage and fracture processes in brittle materials like polycrystalline ceramics or layered composites. Damage of polycrystalline materials and layered composites (pavements) is modelled at meso-scale level and treated as a process of setting micro-cracks growth due to different types of reasons (loading, aggressive corrosion, environmental effects etc.). Up till now the processes of **cracks propagation** were investigated for mechanical loading, quasi-static case. However, when the stress concentration at the tip of the crack overcomes critical value – a material resistance to crack propagation – the considered crack becomes instable. Cracks can accelerate and then dynamic growth takes place. The description of **dynamic cracks propagation** can be done by **numerical** or **mathematical modelling**. Considering the numerical approach **Prof. L. Marsavina** from Politehnica University of Timisoara, Romania has expertise in **determination of fracture parameters** at **different scales** (micro-, meso- and macro) also in simulation of crack propagation based on **Finite Element Method** (COSMOS/M, FRANC2D, FRANC3D) and Boundary Element Method (BEASY software). Prof. Marsavina has expertise also in **experimental determination** of **fracture toughness.** Purchasing of high speed ARAMIS system will allow for monitoring of the fast cracks propagation process. This is very important in aerospace applications, when cracks propagate in structural element under dynamic or cyclic loading. A precise estimation of **critical conditions** for unstable crack propagation is of crucial importance for **security** of **airplane passengers** and leads to prolongation of the aircraft period of use.





Expert (consultant): Prof. Eduard Craciun; Ovidius University of Constanta (OUC), Constanta, **Romania** – is an expert-consultant in application of mathematics for solution of engineering problems.

Task 1.11 Twinning with the University of Rousse (UR), Bulgaria – Prof. Ivelin Ivanov

Topic: Impact loading response of modern composite materials applied in aerospace and surface transportation

Impact loading is a very important case for estimation of composite materials response used for aerospace and pavements. Up to now the CMCM research group has not deep expertise in this field. Research towards modelling of the behaviour of the anisotropic elasto-plastic materials subjected to time dependent loading, including dynamic effects has been done. However, estimation of **damage state after**

low **impact** loading has not been investigated precisely so far. Purchase of the system for dynamic loading – within this project – will enlarge experimental capacity of the CMCM. Impact resistance is one of the most important properties for a designer to incorporate and one of the most difficult to quantify. Airplanes should be safe and therefore particularly wing panels should be tested as for incipient damage and internal yield points that occur during impact event.

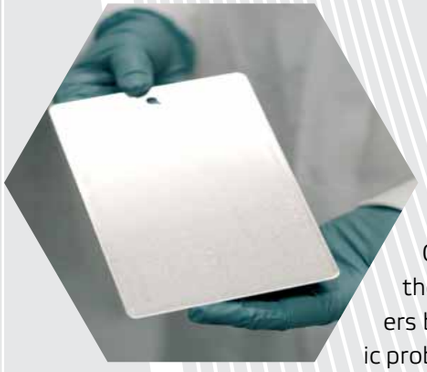
The theoretical description of the composites behaviour under impact involves implementation of computer programming and application of the Finite Element Method (FEM) software like Dyna3D and LS-Dyna for numerical simulations. Modelling of woven **composites** behaviour under **low velocity impact** requires additional knowledge concerning definition of progressive failure of the material with internal damage development and complicated viscoelastic or viscoplastic composite response. **Prof. I. Ivanov** has lengthy expertise in the modelling of **impact behaviour of composites** with application of FEM software (his Ph.D. thesis was done at the University of Cincinnati, USA). Twinning with his group will allow staff members of the CMCM to get extensive training in numerical modelling of impact response of modern composite materials.

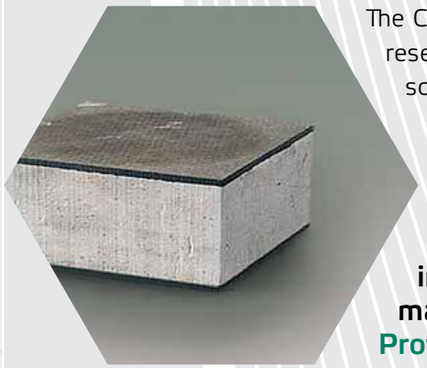
Expert (consultant): Prof. Giulio Maier (Honorary Member of International Centre for Mechanical Sciences – CISM, Udine), Politechnico di Milano, Milano, **Italy**.

WP 2 Expanding of the scientific expertise by recruitment of experienced researchers

Description of work

To increase research capacity at the CMCM, **5 experienced researchers** selected through an open international competition have been employed for **2 years each**.





Experienced researchers will **extend the area of competence** of the Centre and will help to create an **international working environment** for the Centre researchers. The CMCM staff will profit from the skills and knowledge of the experienced researchers by getting familiar with new approaches to scientific problems and techniques previously unknown to them. The CMCM will benefit from the visits by enhancing the research potential of its staff. Recruited postdoctoral scientists will perform the following tasks:

Task 2.1 Thermal shock modelling in modern composite materials. Damage and fracture process in functionally graded materials– recruited researcher: Prof. Vera Petrova (Russia)

Thermal Barriers Coatings are very popular as thin layers protecting aircraft engine components against the thermal shock (e.g. turbine blades). Creation of the new materials for coatings requires formulation of the new constitutive numerical model, including different aspects in the analysis: physical (including internal damage) and structural ones. For aerospace industrial application the basic problem is to get relatively simple TBC model, which is based on the data obtained from laboratory observations. The functionally graded materials (FGM) are important for modern application in the aerospace. Expertise of the recruited researcher concerns: numerical modelling by Finite Element Method (FEM) of damage and fracture processes in different types of FGM, skills with ABAQUS code and analytical modelling, writing own FEM programs in FORTRAN and C codes.

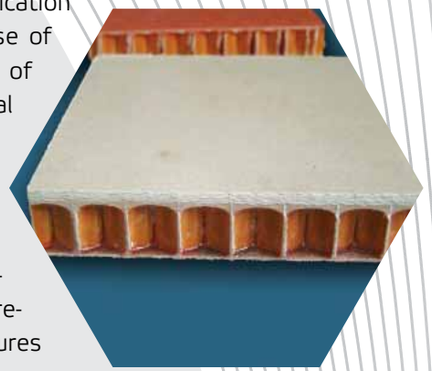
Task 2.2 Layered composite plates and shells subjected to thermal and mechanical loading – recruited researcher: Assoc. Prof. Mircea Birsan (Romania)

The knowledge of the required researcher concerns the theoretical modelling of the layered plates and shells made of new advanced materials, including

metallic foams or cellular materials. These kinds of problems have multiples applications in the aircraft industry and pavements design, where the influence of the temperature field is very important. The aim of the research is to formulate efficient and relatively simple theory for engineering applications. The important aspect is applicability of the formulated theory to description of damage initiation and propagation or fatigue processes in plates and shells.

Task 2.3 Modelling and experimental investigations of damage and fracture process in the sandwich structures under mechanical loading – cyclic and impact – recruited researcher: Assoc. Prof. Vyacheslav Burlayenko (Ukraine)

The response of sandwich structures under dynamic and impact loading is important for application in the aerospace. The necessary expertise of the recruited researcher covers: the use of advanced FEM technique in theoretical modelling with the help of the ABAQUS, LS-Dyna, Nastran-Patran codes, skills in preparation of own FEM programs in FORTRAN and C codes. The researcher has knowledge and experience concerning different experimental techniques for response estimation of the sandwich structures under consideration within CMCM.



Task 2.4 Nonlinear dynamic and control of flexible structures with active elements – recruited researcher: Dr. Fotios Georgiades (Greece)

The recruited researcher has special expertise on nonlinear dynamic and control of mechanical structures made of new composite materials which can be used in practical mechanical application e.g. helicopters or airplanes. He has also an experience in Nonlinear Normal Modes formulation for intelligent structures with embedded active elements e.g. piezoelectric components (PZT).

Task 2.5 Numerical modelling, optimisation and experimental investigations of flexible structures taking into account delamination and temperature influence – recruited researcher: Assoc. Prof. Emil Manoach (Bulgaria)

A specialised expertise on this topic from a recruited researcher increases capacity of the CMCM on theory of elasticity, nonlinear mechanics of continuous systems, advanced numerical modelling including FEM and experimental investigations of the composite materials taking into account delamination effects. The elaborated models will have possibility for predicting of such phenomena like delamination or destruction of the structure.

WP 3 Organisation of scientific events

Description of work

Organisation of the following scientific events such as: **workshops** and **minisymposia** related to the project topics will be performed. The events will aim at presentation of scientific achievements of the CMCM staff and all twinning partners and recruited researchers. It is planned to invite selected experts from different countries and representatives of the regional industry for exchange of knowledge. The following scientific events are planned:

Task 3.1 **CISM** (International Centre for Mechanical Sciences, Udine, Italy) **course** on "Multiscale and multiphysics modelling of complex materials" (2012), organisers: Prof. T. Sadowski and Prof. P. Trovalusci

Task 3.2 **IUTAM Symposium** on Nonlinear Dynamics for Advanced Technologies and Engineering Design (NDATED). Symposium was organised by the project partners, Chairman: Prof. M.Wiercigroch, Co-Chairman: Prof. G. Rega, Aberdeen, July 27-30, 2010, Prof. J. Warminski's group presented research results obtained within the project.

Task 3.3 **7th European Nonlinear Oscillations Conference** (ENOC 2011) will be organised by the project partner prof. G. Rega, Department of Structural and Geotechnical Engineering (DISG), University of Rome "La Sapienza", Italy, July 24-29, 2011. Prof. J. Warminski's group will present project results on nonlinear phenomena in mechanical and structural systems at mini-symposia organised by project partners.

Task 3.4 **Mini-symposium** on Nonlinear Oscillations and Control of Structures Made of Modern Materials (RANM'2012) at the conference Recent Advances in Nonlinear Mechanics (RANM 2012); mini-symposium organiser: Prof. J. Warminski (member of the Scientific Committee)

Task 3.5 **Workshop** on: Multiscale Modelling of Damage and Fracture Processes in Advanced Composite Materials, Kazimierz Dolny, Poland, 2012, organiser: prof. T.Sadowski

Task 3.6 **Workshop** on: Nonlinear Dynamical Phenomena in Mechanical, Aerospace and Civil Engineering, Kazimierz Dolny, Poland, 2011, organiser: Prof. J. Warminski

Task 3.7 **Workshop** on: Higher Dimensional Structures and Materials with Hysteresis, Kazimierz Dolny, Poland, 2012, organiser: Prof. G. Litak

WP 4 Participation of CMCM staff in international events (conferences)

Description of work

It is planned to support participation of the CMCM staff and recruited researchers in **25 conferences**. Participation in the most important scientific events in the world will promote achievements obtained within CEMCAST project and create possibilities to find new partners for future co-operation and preparation of the FP7 projects.

WP 5 Upgrading of research equipment

Description of work

The following items are planned to buy to **improve experimental capacities** at the CMCM, necessary for introducing new areas of competence, to create new opportunities for scientific activity resulted in joint research project in the framework of FP7 and to stimulate and strengthen the twinning collaboration in testing of composite materials.

For the **Laboratory of Non-destructive Testing**:

- **Extension** of the existing **3-D Image Correlation System ARAMIS** for high speed measurements of shape and displacements due to different types of loading. Up till now the CMCM has the standard ARAMIS system for monitoring changes of deformations and shapes under static or quasi-static observations of the composite material samples or structural elements (parts of aircrafts). However, aircraft elements operate in dynamic loadings (cyclic or impact) with very fast deformations due to variation of mechanical or thermal loading. Therefore upgrading the ARAMIS will create new opportunity for testing.
- **Thermovision infrared camera** – is a complete solution for inspection of components for cracks and other defects for a great variety of materials (metal, ceramics, composites) and structural elements like turbine blades (surface cracks and micro-cracks in the depth of the blade). It allows for non-destructive testing of aircrafts structures

for defects like delamination, loose rivets, cracks or water inclusions. The CMCM does not have the equipment like thermovision infrared camera, which could speed up inspection process of defects in various types of advanced composite materials and structural parts.

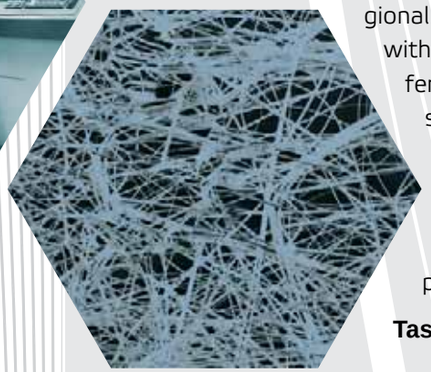
For the **Laboratory of Dynamic Testing**:

- **Testing system for multi-axial loading** of structural elements – dynamic loading with temperature chamber and furnace. Multi-axial testing of modern composite materials applied for aerospace and pavement industry are of crucial importance, particularly with the possibility of estimation at temperatures from – 70^0 to + 300 ^{0}C. The parts of the aircrafts engines, e.g. turbine blades are subjected to high temperature and their testing as for fracture toughness should be performed with furnace (up to 1400^{0}C). This new experimental stand will significantly increase testing facilities, with application to EU and regional industry needs.

For the **Laboratory of Environmental Effects**:

- **Stress screening system** for monitoring the behaviour of composite materials subjected to thermal loading with variation of the temperature up to 15 degrees/min. The system will be used for testing of structural elements applied in the aerospace and pavement industry. The setup will be used together with the newly developed ARAMIS system in order to monitor defects growth under quick temperature changes. Other option is possibility to perform thermal fatigue test. The system will significantly increase experimental capacities of the CMCM.

- **Corrosion chamber** will allow for: salt spray test, corrosion climate alternating test and walk-in salt spray test. The chamber will be used for testing of layered materials for pavements. However, aircraft parts are also influenced to different corrosive environments (e.g. condensed water test with SO_2), what could be investigated as for life time prediction of the structural parts or other advanced materials investigated within the project CEMCAST.



- **Temperature shock chamber** – the main purpose of the thermal shock is to determine the influence of the sudden temperature changes on the composite specimen or structural parts behaviour (e.g. degradation process). Other important issue in this test is to estimate the safe operation of the specimen or structural element after sudden temperature changes. The aircraft parts and pavements are subjected to fast temperature variations and therefore tests under temperature shock are necessary to check composite materials response. It is particularly important for composites used in the aerospace and road engineering, where security of passengers must be guaranteed.

WP 6 Cooperation with SMEs and industry

Description of work

In order to strengthen **co-operation** with the **regional industry** the representative of the CMCM co-operates with the representatives of the local government within Regional Operational Programme Lubelskie in the activities No 1: Entrepreneurship and Innovations and in No 4: Transport (Structural Funds). The co-operation with the regional industry will be activated by arrangement of meetings with international partners of the CEMCAST project to transfer knowledge and to look for involvement of the Lubelskie viovodeship industry and SMEs as partners in FP7 consortia.

The following tasks are planned:

Task 6.1 Lectures and seminars given by twinning partners for the local industry staff

Task 6.2 Meetings with the local industry representatives

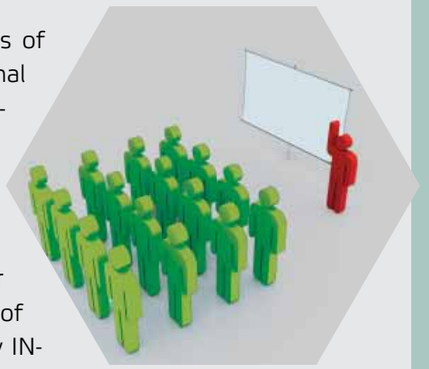
leading to preparation of joint projects at regional (structural funds) and European (FP7) levels

Task 6.3 Presentation given by the representative of INASCO on the involvement of SMEs in the preparation of joint projects at European level (FP-7). The focus will be on European Policies for the promotion of SMEs and the experience of other European regions. Aeronautics, Space and Materials sectors will be specially considered.

WP 7 Dissemination and promotional activities

The following activities are planned:

- preparation of the **web site** of the project with information concerning the Centre's activities
- preparation and publishing of a **brochure** in English about the CMCM activities
- preparation of the **poster** about CEMCAST
- the Centre's researchers will publish scientific **articles** and write reviews and **book chapters**. Copies of all publications each year will be collected in a bound form
- the CMCM will cooperate with **media** (TV, radio, press interviews) to become more visible to the public and to promote and popularise research in composite materials
- popularisation of the Centre's achievements during national science events like "**Science Festival**" and "**Open days**" to enable visits in laboratories to help to understand the importance of research carried out in the Centre and its role in quality of life improvement
- participation in **workshops** aimed at dissemination of projects results
- promotional activity at the **international level** will be arranged by INASCO and will comprise promotion and dissemination of the results of the project at the international level that could create the possibility to participate in research FP7 projects as a partner or at subcontractor level. Activities will include presentation of project results and partner skills at dissemination activities of projects that are coordinated by INASCO or in project where INASCO is participating.



WP 8 Management

The main tasks of management are:

- **to ensure** that all objectives are reached in time by regular review of project's deliverables and milestones in each WP by their Leaders
- **to monitor** progress of the project through periodic reporting – reports will be sent to WPs Leaders
- **to control** proper and effective use of financial resources
- **to create** an ad-hoc problems solving group to identify and overcome any problems that may arise during the project
- **to organise** project's meetings (monthly, twice a year, yearly) to facilitate effective communication among participating researchers
- **to provide** EC with the required information concerning project implementation and spending funds
- **to coordinate** smooth implementation process of all WPs (content-related and administrative)
- **to organise** meetings of the International Advisory Board
- **to contact** "Project Officer", twinning institutions and representatives of regional industry and authorities

SYNERGY WITH OTHER PROJECTS

Members of the CMCM co-operate with the Centre of Advanced Technologies "AERONET – Aviation Valley" (Rzeszów). That Centre aims at carrying out interdisciplinary, joint, long term research as well as implementing of different innovative technologies worked out at universities placed in the East-Middle and East-South regions of Poland to Polish aeronautical industry sector joint in the Technology Cluster "Aviation Valley" (http://aeronet.pl, http://www.dolinalotnicza.pl). Currently the CMCM participates in the project, which is accomplished within "AERONET – Aviation Valley". It is structural funds strategic research key project entitled: "Modern Material Technologies for Aerospace Industry" No POIG.01.01.02-00-015/08 (total funds: 26,9 mln EUR). The project is realized within the Operational Programme – Innovative Economy (IE OP) financed from the European Regional Development Fund – priority 1: Research and development of new technologies, measure 1.1 Support for scientific research for the development of a knowledge-based economy, submeasure 1.1.2 Strategic research and development programmes and it is co-ordinated by Rzeszow University of Technology, Poland (http://pkaero.prz.edu.pl).

CONTACT

Project Coordinator

Professor Tomasz Sadowski, PhD, DSc
e-mail: t.sadowski@pollub.pl, sadowski.t@gmail.com
phone: +48 81 5384386

Project Administrator

Jolanta Sadowska, MSc
e-mail: j.sadowska@pollub.pl
phone: +48 81 5384386
fax: +48 81 5384173

Address

Prof. Tomasz Sadowski
Lublin University of Technology
Faculty of Civil Engineering and Architecture
Department of Solid Mechanics
Nadbystrzycka 40 Str.
20-618 Lublin
Poland

CONTACT

Address:
Prof. Tomasz Sadowski
Lublin University of Technology
Faculty of Civil Engineering and Architecture
Department of Solid Mechanics
Nadbystrzycka 40 Str.
20-618 Lublin, Poland

Project Coordinator:
Professor Tomasz Sadowski, PhD, DSc
e-mail: t.sadowski@pollub.pl, sadowski.t@gmail.com
phone: +48 81 5384386

Project Administrator:
Jolanta Sadowska, MSc
e-mail: j.sadowska@pollub.pl
phone: +48 81 5384386
fax: +48 81 5384173

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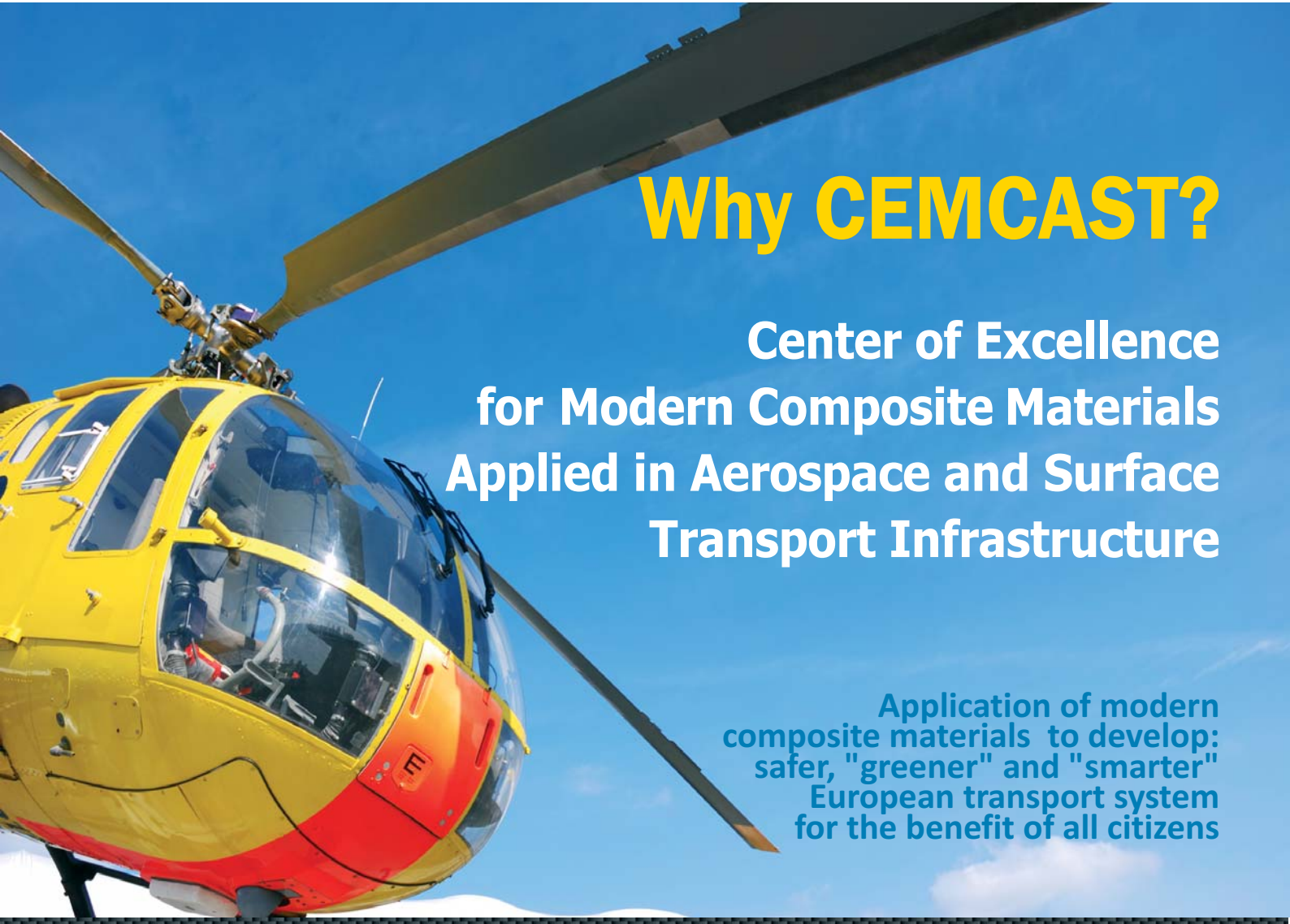
– Duration: 01.04.2010-31.03.2013 –
– EC Founding: 2 557 447 Euro –
– website: www.cemcast.pollub.pl; http://akropolis.pol.lublin.pl/users/sadowski –



Why CEMCAST?

Center of Excellence for Modern Composite Materials Applied in Aerospace and Surface Transport Infrastructure

Application of modern composite materials to develop: safer, "greener" and "smarter" European transport system for the benefit of all citizens

Funded by EC 7.FP
under the Research Potential
(Coordination and support actions)

Aims of the project:

- to increase and fully develop scientific capacities at the Lublin University of Technology (Poland) in the areas:
  - a) modeling and experimental testing of composite and smart materials applied in aircrafts and transport infrastructure (airfields, pavements)
  - b) modeling and control of dynamics of structures made of composites (helicopters)
- to become a leading research centre in the Middle-Eastern Europe in composites domain
- to strengthen international position of Lublin University of Technology by development of long term joint research and collaborative capacity with EU universities

The research is focused on:

- multidisciplinary approach to modelling of composites with application of multi-scale method under mechanical (e.g. fatigue, impact) and thermal loading
- control of dynamics of composite structures with embedded active elements, active and passive vibration suppression
- testing of composites: thermo-mechanical fatigue, low-velocity impact damage, crack propagation
- industrial application of composite models in designing of engineering structures: smart composites in helicopters, hybrid joining techniques of structural elements, thermal barrier coatings in engines

Facts and numbers:

- 11 excellent research entities (universities) from Bulgaria, Denmark, Germany, Greece, Italy, Portugal, Romania and UK are involved in twinning collaboration within the Project to create a world-class research in new, fast emerging fields
- 6 international experts from Germany, Greece, Italy, the Netherlands, Romania and UK act as a source of additional consultancy and expertise
- 5 experienced researchers from Bulgaria, Greece, Romania, Russia and Ukraine were employed for 2 years each to extend the area of competence and exchange knowledge
- 6 items of research equipment (3-D image correlation system ARAMIS, thermovision camera, testing system for multi-axial loading, stress screening system, temperature shock chamber and corrosion chamber) were purchased to carry out tests on composites

Contact
Tomasz Sadowski – Project Coordinator
Lublin University of Technology, Poland
e-mail: t.sadowski@pollub.pl
sadowski@gmail.com
phone: + 48 81 5384386

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