NEWSLETTER # 3 / December 2017

Welcome to the third newsletter from the ECO-COMPASS project!

ECO-COMPASS gathers eight European partners from six countries and eleven Chinese partners for a period of three years, until March 2019. Our fundamental goal is to develop and assess ecological improved and multifunctional composites for application in the aviation sector.

Our public newsletters will regularly keep you up-to-date on the progress made within ECO-COMPASS. What's more, you will be given a possibility to discover how the consortium partners cooperate to achieve the project objectives. You will also find out how and when we disseminate the ECO-COMPASS results. This is in case you feel like meeting with us!

Word from the Coordinators

The ECO-COMPASS consortium has entered the second half of the project encouraged by the positive evaluation received from the Project Officer and External Reviewer.

In the third issue of the newsletter, you will find some feedback from the ECO-COMPASS special organised in the framework of the ICCS20 in September 2017. You will further get to know how the activities progressed within the project work packages. The "Get Together" section will inform you about the upcoming major events related to the ECO-COMPASS research fields. Last but not least, the interview will let you discover the day-to-day life of people involved in achieveing the project goals.

We also invite you to visit the ECO-COMPASS website (www.eco-compass.eu) which is regularly updated with pieces of news about the project. Feel free to inform us of any relevant publication, project or event which should be brought to the attention of the ECO-COMPASS community.

European Coordinator Jens Bachmann, German Aerospace Center (DLR)
Chinese Coordinator Xiaosu Yi, AVIC Beijing Institute of Aeronautical Materials

NEWS & EVENTS

The ECO-COMPASS partners are organising a special session in the framework of the 10th International Conference on Green Composites (ICGC-10). The conference will be held on 7-9 November in Quanzhou, P.R. China.

>> Read more

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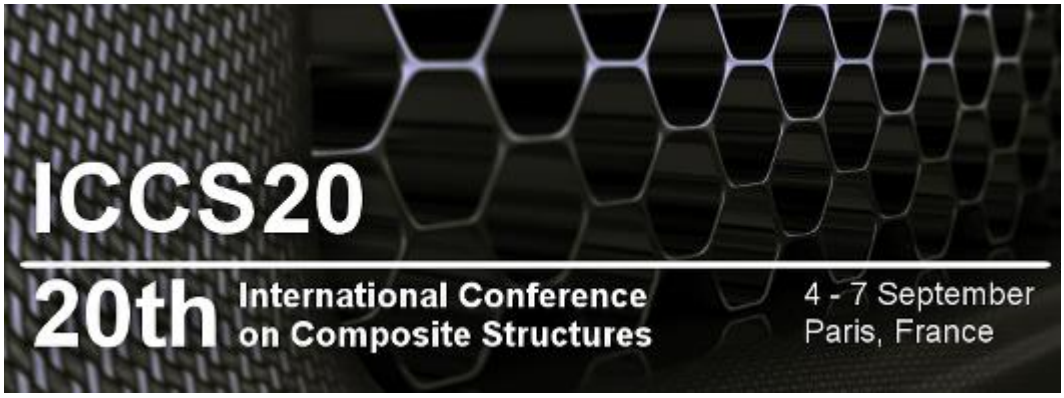
Feedback from ECO-COMPASS special session at ICCS20



The ECO-COMPASS partners organised a special session in collaboration with ICCS20 at the premises of the Conservatoire National des Arts et Métiers in Paris.The primary aim of this event was to offer the presenters a forum to engage with large audience, encourage open exchange of information and present the latest advancements of the project. About 100 delegates participated in the event.

The event proved to be a unique opportunity for the participants to obtain an overview of the recent achievements on the research scene, with 7 presentations from the participating European and Chinese organisations. The attendees had the opportunity to engage into fruitful discussions and networking with more than 30 representatives of academia, research community and industry involved in ECO-COMPASS. Finally, the 2 keynote presentations from distinguished individuals gave a clear insight on the future trends and priorities with respect to application of bio-based composite materials in aviation and aerospace, positioning the ECO-COMPASS project on the relative technology trajectory.

Some of the presentations can be downloaded from our website:

- Introduction: The ECO-COMPASS Project EU/China Cooperation: Introduction And Status After 18 Months by Jens BACHMANN, German Aerospace Center (DLR).
- Keynote speech No 1: Multifunctional And Green Composites And Structures For Sustainable Aviation by Xiao-Su YI, AVIC Composite Corporation Ltd.
- Keynote speech No 2: Biobased Composites Materials For Space Applications by Brigitte DEFOORT, Ariane Group.
- Contributive talk No 1: Lightning Damage Prediction of Carbon Fiber Composite Materials by Zhang SONG, Hefei Hangtai Electrophysics Co., Ltd.
- Contributive talk No 2: Electro-Thermo-Structural Coupling Analysis on Lightning Damage of CFRP Laminates by Qi DONG, Shandong University.
- Contributive talk No 3: Numerical and analytical evaluation of mechanical thermal and electrical properties of cnt/polymer multifunctional nanocomposites using representative units cells by Vasileios TZATZADAKIS, Laboratory of Technology and Strength of Materials Department of Mechanical Engineering and Aeronautics,University of Patras.
- Contributive talk No 4: Performance Enhancement of Natural Fiber Reinforced Polymer Composites through Nanoparticle Grafting by Guijun XIAN, Harbin Institute of Technology.
- Contributive talk No 5: Accounting for material non-linear behavior in multiscale analyses by Xavier Martinez, International Center for Numerical Methods in Engineering(CIMNE).
- Contributive talk No 6: Improving Interfacial Properties of Plant Fiber Reinforced Composites by a Multi-Scaled Design Methodology by Yan LI, Tongji University.
- Contributive talk No 7: BANANA COMPOSITE FABRIC: Numerical prediction and experimental correlation | BANTEX by Adrián Ortega, Leitat Technological Center.

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Figure 1: The ECO-COMPASS consortium together with Project Officer and External Reviewer during the mid-term review meeting on 6 September 2017.

ECO-REINFORCEMENTS FROM BIO-BASED AND RECYCLED FIBRES

In the research of Chinese partner Tongji University, electrophoretic deposition (EPD) was employed to modify sisal fibers with cellulose nanocrystals (CNCs). Sisal fibers were treated with alkali before CNCs were deposited on their surface. The synergic effects of alkali and CNCs on the mechanical properties of sisal fiber and its interfacial properties with epoxy resin over a range of temperatures were investigated. The results showed that a 62% increase in tensile modulus of sisal fibers was obtained. At room temperature, the CNCs coating did not show any obvious effect on the interfacial shear strength (IFSS) between sisal fiber and epoxy while changing the debonding mode with an increased debonding frictional force. In the case of being at elevated temperatures, the CNCs modification significantly reduced the inverse effect of temperature on IFSS owing to the formation of an interphase with improved thermo-mechanical stability. Moreover, the new flame retardant agent DOPO-MA was synthesized. DOPO-MA can provide better flame retardancy and lighten the influence on the mechanical properties of jute/polylactic acid (PLA) composites.

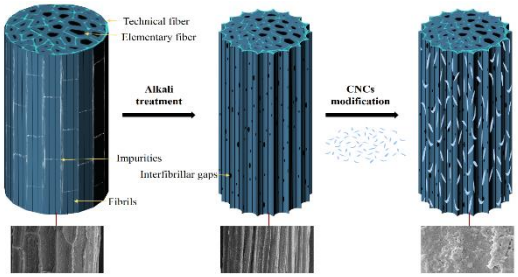

Figure 2: The schematic of synergistic effect of alkali treatment and CNCs modification on the structure of sisal fibers.

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BIO-RESINS

During the last months, Ningbo Institute Of Materials Technology has scaled-up the rosin based curing agent and the resin to ensure a fluid exchange of these materials with the European partners and for the prepregs preparation in other work packages. On the other hand, the partners have been working on other bio-based resins based on tannic acid and furan dicarboxylic acid (FDCA). These new materials show high mechanical properties which can be adjusted depending on the curing agent and its nature i.e. they are low-priced and stable at the conditions specified for aircraft secondary structures and interiors although they are bio-based. These properties make the materials suitable for the envisaged application.

In the meanwhile, LEITAT and INEGI have continued with the characterization of rosin based resins and optimization of the curing process obtaining excellent results. This system shows a Tg and degradation profile that makes it a perfect candidate for aircraft application.

In order to enhance the performance and the texture of these resins, some techniques have been studied such as sonication before curing, introduction of defoamers, mixing and curing systems under vacuum, etc. Finally, first trials of nanofillers introduction into the resin matrix have been performed starting with SiC nanoparticles dispersions.

Figure 3: 60 kg batch of scaled-up rosin based curing agent by NIMTE.

MANUFACTURING OF MULTIFUNCTIONAL GREEN COMPOSITES AND ELECTRICAL CONDUCTIVE COMPOSITES

During the last months of the project, bio based papers have been produced to manufacture green honeycomb. The green honeycomb has also been characterized with mechanical tests and flammability tests. The results have been compared to existing standard nomex honeycomb.

Composite sandwiches have been manufactured with the green honeycomb and with green prepreg made from bio based epoxy resin (rosin) and from natural ramie fibre fabric. Physicochemical tests have been performed on the green prepreg to define adapted curing cycles.

Surfacial conductive adhesive film has been developed for lightning strike protection. Lightening test have been performed on monolithic composite and obtained results compared to reference ECF solution.

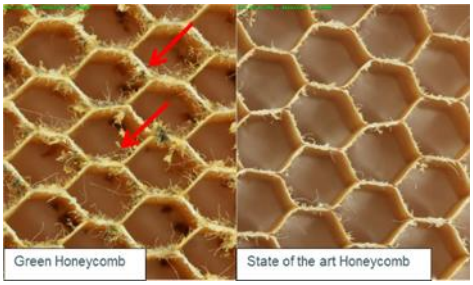

Figure 4: Green honeycomb compare dto state of the art honeycomb.

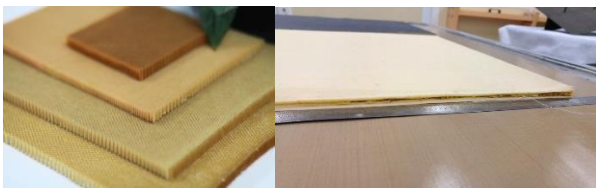

Figure 5: Sandwich panels made from green honeycomb and bio based prepreg.

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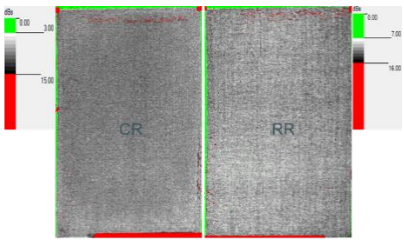
CHARACTERISATION

During the last months, two eco-composite panels have been manufactured at Airbus and sent to the EU partners for mechanical testing: carbon fibre fabric reinforcing rosin-based epoxy resin (CR); and ramie fabric rosin epoxy resin (RR). Both panels were manufactured with prepreg materials provided by our Chinese partners. Prior to cutting the specimens, C-Scans to assess the panels manufacturing quality were performed at National Composites Certification and Evaluation Facility (NCCEF) of the University of Manchester. The result (Figure 6) shows that both panels present very consistent manufacturing quality.

C-Scan equipment



C-Scan result

Figure 6: Carbon fibre (CR) and Ramie fibre (RR) composite panels C-scan.

Tensile testing

The tensile testing for the non-aged specimens were performed at NCCEF using the experimental set-up presented below (Figure 7), consisting of an Instron testing machine and a video-extensometer to measure the strains.

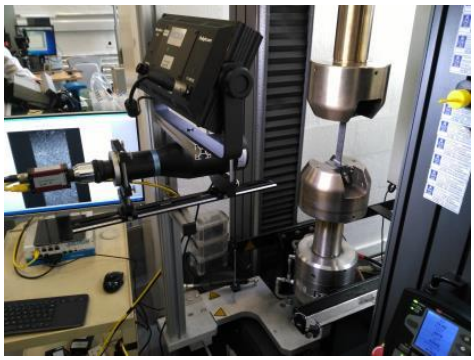


Figure 7: Tensile testing set-up.

As expected, the composite reinforced entirely with carbon fibres presents higher mechanical properties than the ramie ones. Meanwhile, a higher strain to failure and the non-linear behaviour of the ramie fibres are indications of higher energy dissipation capacity of ramie fibre composites. This constitutes a very important characteristic in terms of noise and vibration reduction applications.

Compression testing

Regarding the compression testing, the specimens of both composites have been instrumented with strain gauges on both sides; the tests are under progress at partner DLR (Figure 8).

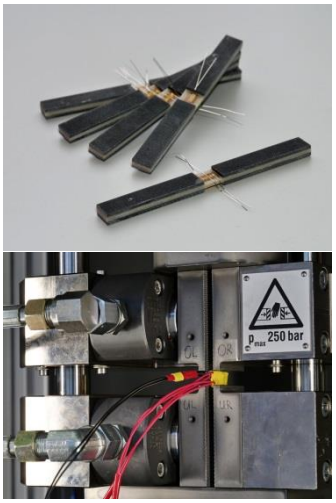


Figure 8: Compression testing.

Hygrothermal ageing of composites

Specimens for tensile and interlaminar shear strength (ILSS), and the required travellers, have started the ageing progress (at NCCEF, Airbus and Laboratory of Technology & Strength of Materials (LTSM) of the University of Patras). They have been placed in a conditioning chamber and exposed to a constant temperature of 70°C and 85% RH (Figure 9). Exposure up to 1000h is planned.

Preliminary measurements after one week showed weight increase of about 0.3% and 1% for the carbon and ramie composites, respectively. The higher weight increase for the ramie composite is in line with what was expected, due to its hydrophilic nature for being a natural vegetable-base fibre.

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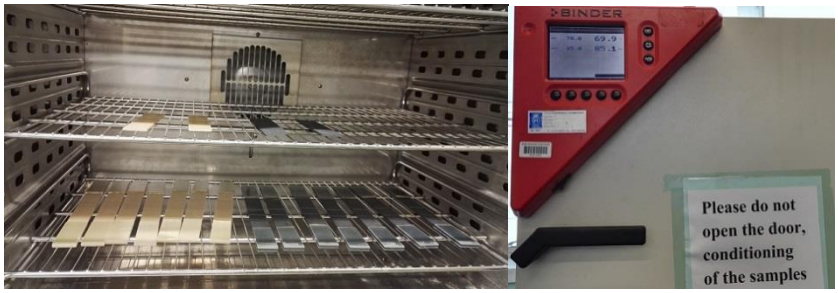

Figure 9: Hygrothermal ageing of composites in a conditioning chamber.

MODELING AND SIMULATION

At current stage, several of the numerical models that are being developed in ECO-COMPASS to characterize the performance of eco-composites are completed and are being used to calibrate the first experimental results obtained from other project workpackages.

CIMNE and LEITAT are working together in developing numerical models for the characterization of the mechanical performance of eco-composites. The results obtained with the in-house finite element method (FEM) codes developed by CIMNE will be compared with the results obtained by a commercial FEM package used by LEITAT. CIMNE is also coupling the multiscale analysis code developed with an optimization software. Once this is achieved, it will be possible to optimize the internal structure of the composite material to improve the mechanical response of the composite structure.

The University of Patras has developed a parametric numerical model for simulating the lighting strike of carbon fiber reinforced plastics (CFRPs), in order to evaluate the damage and its implications in the composite mechanical strength. Initial analyses conducted with this model show a good correlation with the experimental result, as it is shown in the following figure.

Shandong University has developed a numerical model to account for the coupled effect of thermal ablation and expansion on damage of the composite under a lighting strike load. This model, implemented in a commercial FEM software, improves the prediction of the damaged area in the composite, as it is capable of accounting for the different phenomena occurring in the composite during a lighting strike. This superposition of effects is shown in the following figure.

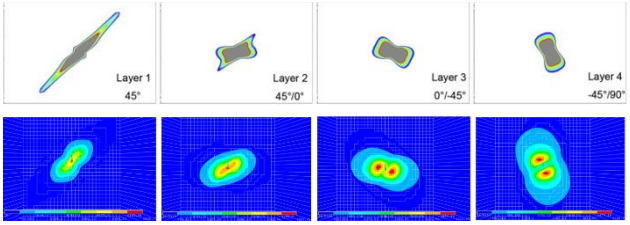

Figure 10: Temperature distribution in the different layers of the laminate, experimental results (top line) and numerical results (bottom line).

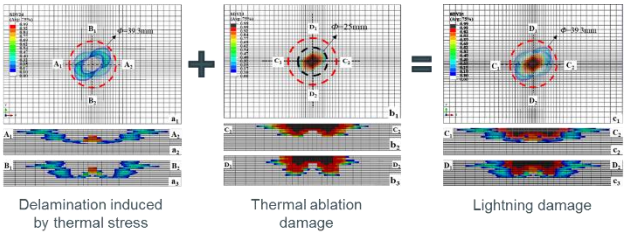

Figure 11: Superposition of effects in the final damage in the composite. The upper figures show a top view of the composite while the bottom figures show a transversal section of the composite in x and y direction.

REQUIREMENTS, APPLICATIONS AND DEMONSTRATORS

Several demonstrators for interior and secondary structure applications have been preliminarily defined:

- Trailing edge panel of horizontal tail with utilization of conductive prepreg against lightning strike. The part is about 1.6 m long.
- Elevator panel (integrated sandwich structure) with electrically conductive prepreg.
- Engine nacelle panel with electrically conductive composite.
- Interior panel with green honeycomb and bio based prepreg with flame retardant film on the surface.
- Sidewall sandwich for interior application.

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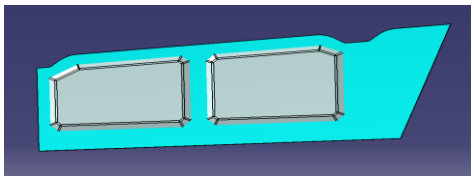

Figure 12: Exemple of demonstrator to be done with electrically conductive composite.

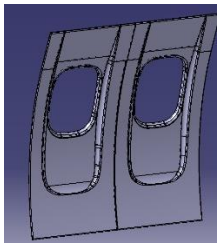

Figure 13: Exemple of demostrator to be done with with green honeycomb for aircraft cabin interior.

LIFE CYCLE ASSESSMENT

A peer reviewed paper has been published in open access in a special issue about green aviation research of Science China Technological Sciences (SCTS). The article, co-authored by Jens Bachmann (DLR), Carme Hidalgo (LEITAT) and Stéphanie Bricout (Airbus), is entitled "Environmental analysis of innovative sustainable composites with potential use in aviation sector – A Life Cycle Assessment Review". The motivation for this paper is to give an overview of potential environmental properties of eco-materials in aviation. The main focus is laid on the bio-fibres flax and ramie, recycled carbon fibres and bio-based thermoset resin systems. Furthermore, an overview of environmental aspects of existing composite materials used in aviation is given. A lack of Life Cycle Analysis (LCA) results for the substitution of synthetic materials by bio-based/recycled composite materials in aviation applications has been identified during the review. Therefore, available information from other transport areas, such as automotive, has been summarized. More detailed LCA data for eco-composite materials and technologies to improve their properties is important to understand potential environmental effects in aviation. The Chinese partner Harbin Institute Of Technology investigated in the data collection of ramie fibre cultivation, harvesting and degumming. Furthermore, data for rosin-based epoxy resin has been collected. Preliminary results obtained with a dedicated LCA software tool confirm the expected results of a reduced global warming potential (GWP) of ramie fibres compared to carbon fibres in the production phase. On the other hand, the environmental impact of fertilizers for the cultivation of natural fibres is higher compared to carbon fibres. This example shows clearly the importance of a complete LCA that includes different impact categories and life cycles of materials and components.

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GET TOGETHER

The list of scientific and technological events related to the ECO-COMPASS research fields can be found on our website. The file is regularly updated. Feel free to inform us of any other event likely to interest the ECO-COMPASS community. Hereunder you will find a short selection of major events to take place in the upcoming months.

JEC WORLD 2018 06-08 MARCH 2018, PARIS, FRANCE

JEC World 2018 International Composites Event is the biggest and most important world show dedicated to composites market. From raw material to processors and end-users, JEC World attracts each year in Paris over 40,000 professionals looking for innovation, new partners and insight on their industry's future. Featuring ground-breaking solutions, unique manufacturing and business opportunities, JEC World is a networking hub of creativity, vision and action. Source: http://www.jeccomposites.com/events/jec-world-2018/about-the-event/presentation

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TRANSPORT RESEARCH ARENA 16-19 APRIL 2018, VIENNA, AUSTRIA

Digitisation, automatisation and decarbonisation are major trends that will drastically change the way we live, work and use mobility and transport in the future. Under the heading of "A digital Era for Transport", the **Transport Research Arena** 2018 will explore, discuss and demonstrate these major paradigm shifts specifically directed at important areas of our life, such as transport, mobility, logistics and industrial production. Source: http://www.traconference.eu/about/chairman-address/

ICEAF V 20-22 JUNE 2018, CHIOS ISLANDS, GREECE

The series of the **International Conference of Engineering Against Failure** aims to provide on a bi-annual basis a forum to present relevant scientific and technological achievements and discuss with an audience of international experts. The scope of the conference is to attract interdisciplinary work dedicated to the design against and prevention of engineering failure. Works are expected to cover a number of different technological areas including aeronautics, construction, automotive, bioengineering, recycling, manufacturing, real-time systems, industrial systems, cyber physical systems. Source: http://ltsm.mead.upatras.gr/lab/lang_en/conference/view/7

ECCM 2018 24-28 JUNE 2018, ATHENS, GREECE

The **European Conference on Composite Materials** aims to be a forum for exchanging ideas, presenting the latest developments and trends, proposing innovative solutions and promoting international collaborations the field of composite materials and structures. Source: http://ceas2017.org/

8TH EASN-CEAS INTERNATIONAL WORKSHOP ON MANUFACTURING FOR GROWTH & INNOVATION 04-07 SEPTEMBER 2018, GLASGOW, UK

Responding to the increasing interest from the European Aeronautics Community for a scientific event which offers a forum for discussion and exchange of information about state-of-the-art research and development activities in aeronautics and air transport, EASN has announced its **8th EASN-CEAS International Workshop on Manufacturing for Growth & Innovation** will be co-organised with the CEAS and the University of Glasgow. Source: https://easnconference.eu/

ICGC-10 07-09 NOVEMBER 2018, QUANZHOU, P.R. CHINA

Sustainable development, industrial ecology, eco-efficiency and green chemistry are leading the next generation of materials, products and process development and progress. Green composite materials play an important role applying in the field of high strengh, light weight, recycling and regeneration. In this context, the **10th International Conference on Green Composites** aims to addrees the following topics: basic research and application of green composites, i.e. raw materials, function, design, analysis, mechanics, properties and characterization, testing and evaluation, process and fabrication, surface and interface, intelligence, recycling, biodegradable polymers and plastics, nano-celluloses and nano-biomaterials, cellulose based materials, wood polymer composites. Source: http://www.sampechina.org.cn/

INTERVIEW

ECO-COMPASS newsletters offer you the possibility of getting to know some of the project partners a little better… Thus, the interview section will let you discover the day-to-day life of the people involved in achieving the ECO-COMPASS goals.

In this edition of the ECO-COMPASS newsletter # 3, we propose you several tags which will lead the interview with researchers involved in the investigations: bio-resins – multifunctional – challenges – results - substitute.

ERIC RAMON, R&D JUNIOR RESEARCHER OF ADVANCED POLYMERS AREA, LEITAT TECHNOLOGICAL CENTER

JIN ZHU, FULL PROFESSOR OF NINGBO INSTITUE OF MATERIALS TECHNOLOGY, CHINESE ACADEMY OF SCIENCES

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Q1: You are the leaders of work package 3 (WP3) "**Bio-resins**" within ECO-COMPASS. Can you please remind us the objectives of this work package? What are the specific goals for the European and Chinese partners?

A1: Composite materials currently used in aircraft production are mainly fossil-sourced. The main objective of WP3 is to develop new bio-based resins to possibly substitute the currently used ones in aircraft secondary structures and interior composites. To achieve this final goal, various specific objectives were defined. We started from the selection of bio-based resins and curing agents with optimal properties to be used for this purpose, following with the synthesis of bio-based resins by the Chinese partners and improvement of the multifunctional properties of the resins by the European partners. Finally, a full characterization program was scheduled in order to compare the properties between bio-based filled and unfilled resins in terms of mechanical, thermal and rheological behavior, and also to compare filled bio-based resin and petroleum-based resin composites.

Q2: One of the tasks of WP3 concerns the "Resin sample manufacturing and improvement of **multifunctional** properties". How did you organize the collaboration between the Chinese partner Ningbo Institute Of Materials Technology and the EU partners LEITAT and INEGI? Have the partners exchanged any material?

A2: From the first moment, we have taken into account the capabilities and the expertise of each partner involved in WP3. For this reason, Ningbo Institute Of Materials Technology has been focusing its activities on the synthesis of the raw bio-based curing agents and resins. Once these materials are generated, Ningbo Institute Of Materials Technology send them to Europe where the materials are shared with LEITAT and INEGI. Then, these materials are characterized and studied for the optimization of the curing process as well as improved by means of nanofillers incorporation into the resin matrix before curing.

Regarding the exchange of materials, various shipments from China to Europe were scheduled in order to avoid being out of stock of materials in Europe.

Q3: You are also performing investigations on the characterization and comparison of filled and unfilled bio-based resins. What is innovative about these activities? What are the **challenges**?

A3: Nowadays, it is really difficult to find a bio-based resin with the desired properties able to be used as matrix for fiber reinforced composites for aircraft applications. In the ECO-COMPASS project, several novel bio-based resins and curing agents were synthesized and various selected nanofillers will be introduced into the resin matrix to avoid or minimize the lack of these properties and to make them able to be applied in aircraft secondary structures and interiors. Moreover, fire retardants which will be covalently linked to the resin matrix are being investigated to enhance the fire resistance of the composites.

Q4: How will the **results** of WP3 feed into the other activities of ECO-COMPASS? How will they be useful/beneficial to the consortium partners?

A4: It is really important to develop a good resin and to perform an excellent characterization of their properties and the curing process. This information will be shared with all the partners which will use it for their own activities in other work packages. At the end, the work packages of ECO-COMPASS project need to be linked one to each other and the results that we obtain for eco-reinforcements and bio-resins are the base for the activities of composite manufacturing, characterization, modeling and simulation, application and demonstrators and finally the results in the Life Cycle Assessment. This is the reason why the partners in WP3 do not work only focused on our activities but also keep in mind the activities of the following work packages and how they are related with our work.

Q5: Can bio-based resin systems **substitute** petrol-based resins in aviation in the near future in larger quantities?

A5: Bio-based materials are currently being used in various applications with lower demand of mechanical and thermal properties. It is for this reason that this project is a challenge itself. However, we are synthesizing several new bio-based resins which perform even better properties than the petroleum-based resins. This means that it can possible to substitute petroleum-based resins in aviation. The resins are now scaled up to pilot level and we could provide a large quantity in the near future if their overall performance is good enough. We are confident that there will be some bio-based systems potentially used in aeronautics and the ECO-COMPASS project is a big step in making this happen.

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