Consiglio Nazionale delle Ricerche
ISTITUTO DI CHIMICA E TECNOLOGIA DEI POLIMERI

IRECE – "Industrial REcycling of Cfrp by Emulsification"

CfP : JTI-CS-2012-3-ECO-01-063

TITLE: Extrapolation to industrial condition of a cured composite and thermoplastic recycling process

GRANT AGREEMENT NUMBER: 335277

ICTP- CNR - Scientific Coordinator and Project Manager: Dr. Mario Malinconico

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Deliverable D6.1 – Dissemination and Final Report

Period: August 1st, 2013 – 31 March 2014

Target: The overall objective of this Workpackage is to disseminate the project results among three

different sectors:

-Plastic manufacturers

-Entities in charge of building activities

-Scientific community

Prepare the Final Report [month 12]

1 - INTRODUCTION

The dissemination activity of the IRECE Project was carried out through many tools, including participation to international conferences with poster and oral presentations, preparation of scientific papers, realization of a Webpage.

2 - Activity performed

2.1 - WEBSITE

The webpage of the project has been realized and is available at the address:

www.ireceproject.com

2.2 - Dissemination Activity during the whole project

2.2.1 – An interview was released by Dr. Malinconico, Project Coordinator, to the Research EU Magazine on 20 October 2013.

(http://cordis.europa.eu/news/rcn/36184_en.html).

The complete text of the interview was published on the magazine and available online for free.

36 research*eu results magazine — N° 26 — October 2013

INDUSTRIAL TECHNOLOGIES

Closing the loop for lightweight materials

From next-generation planes to electric vehicles and their already heavy batteries, every extra kilogramme matters when trying to achieve more sustainable transportation. Lightweight, high-performance materials have never been so successful, but their end-of-life remains a key concern.

Every time a scientist or engineer comes to grips with the brain-teasing issue of greenhouse gas emissions and reduced fossil-fuel consumption, the weight element is central. Much of materials science now revolves around discovering or enhancing lighter materials, with better — or at least equal — performance, which explains the tremendous success of composite materials such as carbon-fibre reinforced polymers.

However, there is another side to the coin. Composites still fall short of satisfactory second-life options, which is a real concern at a time when decision-makers increasingly think in terms of life-cycle assessments. Well aware of this issue and the urgency of solving it, the Institute of Chemistry and Technology of Polymers (ICTP) in Italy is investigating new waste-management processes with partners under the EU-funded SUSRAC[1] project.

Dr Mario Malinconico, who coordinates the project, told the *research*eu results* magazine about the consortium's achievements so far, their importance for the continued growth of the market and the remaining challenges before the end of the project.

What are the main objectives of the project?

Thermoplastic and thermoset composite materials are used in a wide range of applications, and about 1 million tonnes of composites are manufactured each year in Europe. This requires the setting up of specific strategies for composite-waste disposal, in particular for the recycling of this waste. Poor recyclability can be a barrier to the development — or even continued use — of composites in some markets.

The purpose of this research, which is part of the EU-funded Joint Technology Initiative 'Clean Sky', is to develop recyclable thermoplastic composite materials capable of handling high weight loads. Those would be made from ground thermoplastic, thermoset aircraft-waste composites, such as 'carbon-fibre-reinforced polymers' (CFRPs), and recycled expanded polystyrene from loose-fill packaging.

How important is it to solve this problem?

Addressing sustainability issues related to plastic materials is one of the core activities at the Institute of Chemistry and Technology of Polymers. This is of utmost importance if you consider that the worldwide demand for carbon fibres (CFs) reached approximately 35 000 tonnes in 2008 and that this number is expected to double by 2014, representing a growth rate of over 12 % per year.

CFRPs are now used in a widening range of applications, with the aircraft industry being one of the most impressive examples: CFRP accounts for 50 % of the weight of the new Boeing 787 and Airbus A350, and military aircraft are following a similar trend. The quick growth of the composite market raises the question of waste management, and it is only logical that recycling has become a high priority.

At same time, plastic packaging materials account for almost 40 % of all plastic consumption in the world, and loose-fill packaging materials are among the most difficult items to recycle due to their extreme lightness (on average one cubic metre of expanded polystyrene weighs only 30 kg).

The idea to combine both materials to make a thermoplastic composite for building or furniture applications requires an innovative process, which is where SUSRAC comes in.

What is new or innovative about the project and the way it is addressing these issues?

Two compounding methodologies were explored, namely traditional melt mixing and innovative cold mixing. In the latter, a low-boiling-point industrial solvent was employed to dilute and guarantee the homogeneity of the thermoplastic matrix at the micro- and macroscopic levels. It is a purely physical approach, in a closed-loop strategy, which we have been studying since 2005. It was first applied to glass-fibre-reinforced thermosetting matrices resulting from the dismantling of boats. The results so far prove that the cold-mixing approach results in a material with mechanical properties up to four times higher than those obtained with a classical melt-mixing approach.

What are some of the difficulties you have encountered and how did you solve them?

The main difficulty appeared at the very beginning of the process, as we needed to obtain a controlled size reduction of thermosetting materials made of stiff resin and very hard carbon fibres while ensuring low energy input and safe operation. This has been achieved in cooperation with an Italian producer of grinders, who designed an effective industrial grinder for us. Another problem was the handling of the industrial solvent necessary for the emulsification. This solvent needs to be recycled internally to get a closed loop, and we are on the way to solving this problem.

What are the concrete results from the research so far?

One of the most concrete results is the fact that we can claim to have obtained, at a pre-industrial scale, highly-filled thermoplastic composites made from end-of-use materials. Those come with properties that make them comparable to composites made of virgin materials. Moreover, the resulting composites are thermoplastic, with the advantage that they can be recycled all over again at the end of their second life.

When do you expect the project results to benefit the sector?

At the moment, SUSRAC is in the third semester of a two-year project, and we have already started an industrialisation phase with an Italian company specialised in the design of industrial production plants. At the end of this industrialisation phase, planned for the middle of 2014, we will have a clear view of the investment costs, and we will be able to propose the results to interested companies. We hope to be ready by the middle of 2015.

What are the next steps of the project, or next topics for your research?

The next step is the realisation of demonstrators of a big-enough size for testing in a full-scale environment, such as the production of a specific element or aircraft part. This could be important, because it will allow the reuse of materials from dismantled aircraft in new aircraft production. In a similar way, in the automotive industry nowadays, car parts are made using materials originating from the dismantling of old cars.

Dr Mario Malinconico

The SUSRAC project is coordinated by the Italian national research council (CNR). It also includes the Spanish research centre, Tecnalia, as a partner with a specific role in the validation of the fire resistance of the final material.

1 'Sustainable recycling of aircrafts composites'.

Funded under the FP7 specific programme 'Cooperation' via the 'Clean Sky Joint Undertaking' (CSJU), one of the EU's 'Joint Technology Initiatives' (JTI).
SUSRAC project website:
http://www.susracproject.com/
Clean Sky JTI website:
http://www.cleansky.eu/

Better aviation testing for structural safety

Advances in software and simulation technology are empowering aeronautics manufacturers to lower the costs of testing for structural safety.

An ongoing drive to increase safety in the aeronautics industry has the potential to save lives and maintain Europe's position as a pioneer in the industry. In principle, aeronautical components are designed based on the damage tolerance concept, which requires very accurate knowledge on fracture resistance and crack growth rate, among other crucial indications.

One new high-tech approach in this direction embraces the introduction of simulation-supported 'probability of detection' (POD) and 'non-destructive testing' (NDT) simulation. In this context, the EU-funded project PICASSO[1] built powerful new NDT software to detect structural flaws in components more efficiently.

In particular, the project team worked on advanced ways to determine the curve that calculates the probability of detecting defects (probability vs. defect size). This generally requires complicated and costly POD procedures, an issue that >

2.2.2 - Pierfrancesco Cerruti[a], Filippo Fedi[b], Roberto Avolio[a], Gennaro Gentile[a], Cosimo Carfagna[a], Paola Persico[a], Maria Emanuela Errico*[,a], Mario Malinconico[a], Maurizio Avella[a], "**Upcycling end-of-use materials: highly filled thermoplastic composites obtained loading waste carbon fiber composite into fluidified recycled polystyrene**"

Paper Submitted and accepted on Polymer Composites, available online from 20 December 2013: (http://onlinelibrary.wiley.com/doi/10.1002/pc.22815/abstract)

Polymer COMPOSITES

Article

Up-cycling end-of-use materials: Highly filled thermoplastic composites obtained by loading waste carbon fiber composite into fluidified recycled polystyrene

Pierfrancesco Cerruti[1], Filippo Fedi[2], Roberto Avolio[1], Gennaro Gentile[1], Cosimo Carfagna[1], Paola Persico[1], Maria Emanuela Errico[1], Mario Malinconico[1], Maurizio Avella[1,*]

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Carbon fibers reinforced epoxy resins are used in a wide range of applications, such as automotive and aerospace industry. Because of their thermosetting nature, recycling at the end of the life cycle is a difficult issue. However, lack of recyclability poses environmental concerns to the use of these composite materials. In this article, a sustainable, cost-effective technological approach aiming at recycling postconsumer carbon fibers reinforced thermosets (CFRT) is proposed. Composites containing 50 and 70 wt% of CFRT particles were prepared by incorporating the filler fraction into a fluidified postconsumer expanded polystyrene matrix. A cold mixing approach consisting in the use of a low boiling solvent as a binder to guarantee the dispersion homogeneity on micro- and macroscopic level was set up. For comparison, analog composites were also prepared through melt mixing process. Morphological, mechanical, and thermal analyses allowed to prove the effectiveness of the cold mixing approach and to evaluate the influence of particle size on the performance of new recycled composites. Thermogravimetric analysis and thermal conductivity tests of samples highlighted further peculiarities of the cold mixing process. The approach proposed is an effective recycling technology for CFRT and could be extended to other postconsumer materials. POLYM. COMPOS., 2013. © 2013 Society of Plastics Engineers

2.2.3 - Pierfrancesco Cerruti, Maurizio Avella, Maria Emanuela Errico, Mario Malinconico, and Raffaele Corvino, “New life for aircraft waste composites” SPE Society of Plastic Engineers, Plastic Researches Online,

http://www.4spepro.org/view.php?article=005367-2014-03-13&category=Composites

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10.2417/spepro.005367

New life for aircraft waste composites

Pierfrancesco Cerruti, Maurizio Avella, Maria Emanuela Errico, Mario Malinconico, and Raffaele Corvino

Recyclable thermoplastic composite materials, made of waste from dismantled aircraft and polystyrene loose-fill packaging, are capable of handling high weight loads.

Decision-makers in the aerospace industry are increasingly accustomed to considering life-cycle assessments of materials and parts. Thermoplastic and thermoset composite materials are used in a wide range of applications, and about one million tonnes of composites are manufactured each year in Europe. In particular, carbon-fiber-reinforced polymers (CFRPs) are now widely used in transportation, with the aircraft industry being one of the most impressive examples: CFRPs account for 50% of the weight of the new Boeing 787 and Airbus A350, and military aircraft are following a similar trend.[1]

The quick growth of the composite market raises the question of waste management, and it is only logical that recycling has become a high priority. Poor recyclability can be a barrier to the development—or even continued use—of composites in some markets.[2] Despite this, composites still fall short of satisfactory second-life options. At the same time, plastic packaging materials account for almost 40% of all plastic consumption in the world. Loose-fill packaging materials are among the most difficult items to recycle due to their extreme lightness (on average, one cubic meter of expanded polystyrene—EPS—weighs only 30kg). We investigated combining ground thermoplastic and thermoset aircraft-waste composites, such as CFRPs and recycled EPS from loose-fill packaging, to produce thermoplastic composites suitable for construction or furniture.[3,4]

We compared two compounding methods, namely, traditional melt mixing and innovative cold mixing. In the latter, we employed a recyclable low-molecular-weight (MW) emulsifier to make an EPS gel. We wanted to achieve a closed-loop process, which required internal recycling of the emulsifying solvent, and were able to achieve a recycling efficiency of as much as 95%. We next mixed the CFRP into the gel. To do this we needed to grind the CFRP particles, thermosetting materials made of stiff resin and very hard carbon fibers, to reduce them in size, while also ensuring low energy use and safe operation. To achieve this we worked with a producer of grinders, who designed an effective industrial grinder. We extruded the mixture by calendering (passing through heated rollers) to achieve a thermoplastic matrix that is homogeneous at the micro- and macroscopic levels. The cold mixing approach is purely physical and a closed loop (see Figure 1). The results so far prove that such a cold-mixing approach results in a material with mechanical properties up to four times higher than those obtained with a classical melt-mixing approach.

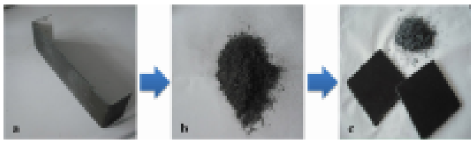


Figure 1. Schematic illustration of the process. (a) The original carbon-fiber-reinforced polymer (CFRP) element. (b) The ground material. (c) The final thermoplastic composite.

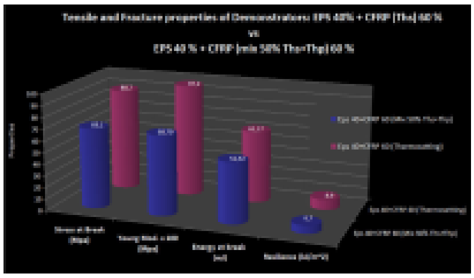
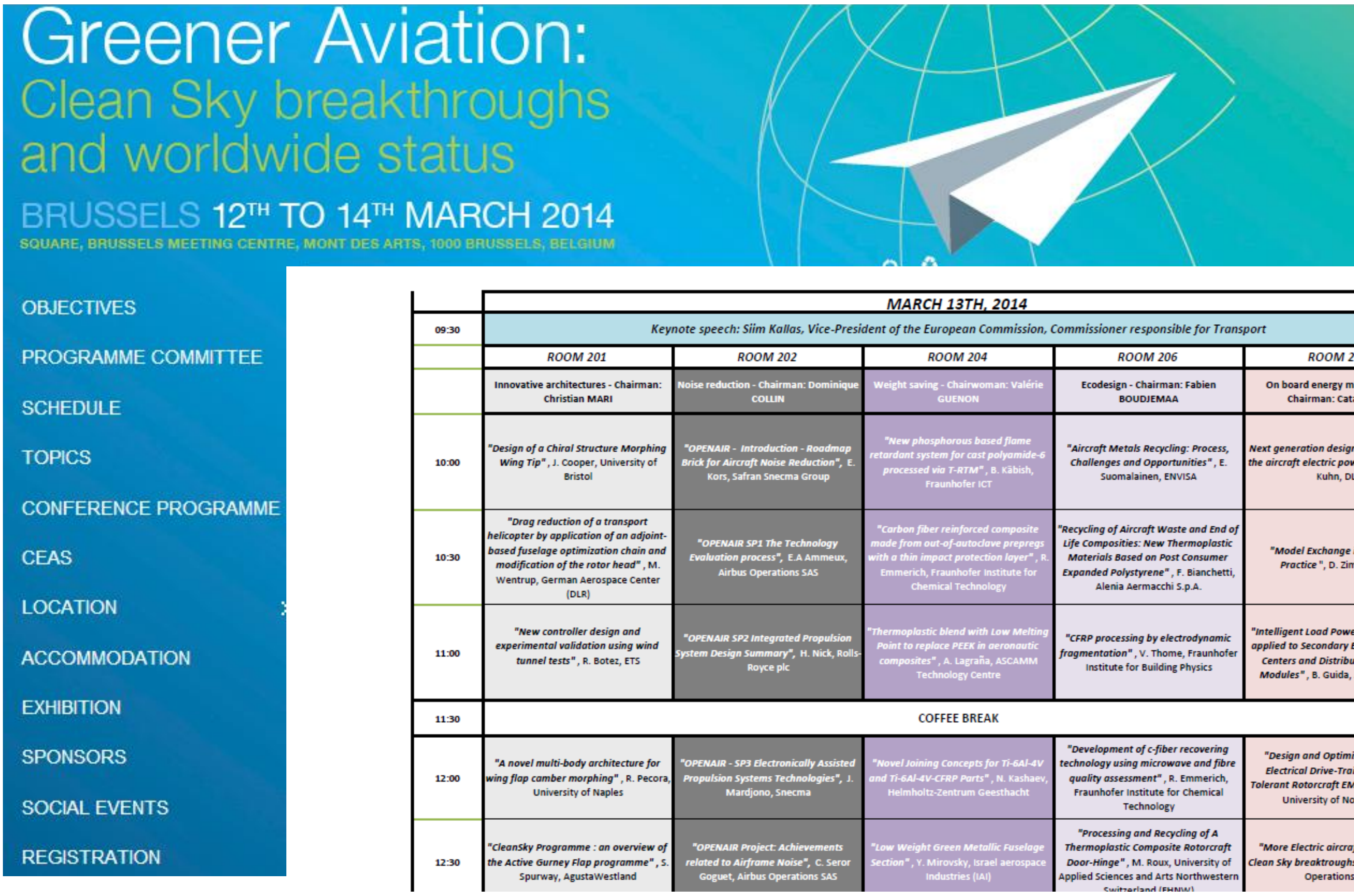


Figure 2. Results of ASTM D3039[5] mechanical tests of composites based on expanded polystyrene (EPS). Thp: Thermoplastic CFRPs. Ths: Thermosetting CFRPs.

We carried out mechanical tests according to ASTM standard methods for fiber-reinforced plastics (D3039 for tensile and fracture tests, D695 for compression tests, and D5961 for open hole bearing tests).[5–7]

Continued on next page

2.2.4 – Participation to the Conference “Greener Aviation”, Brussels, 12th to 14th March 2014, with an invited oral presentation delivered by Mr. Fernando Bianchetti, Alenia Aermacchi. Representatives of CNR (Mario Malinconico and Maurizio Avella) and of Rs Nova Die (Antonio De Falco, Francesca De Falco) have attended the conference.



	MARCH 13TH, 2014				
09:30	Keynote speech: Siim Kallas, Vice-President of the European Commission, Commissioner responsible for Transport				
	ROOM 201	ROOM 202	ROOM 204	ROOM 206	ROOM 2
	Innovative architectures - Chairman: Christian MARI	Noise reduction - Chairman: Dominique COLLIN	Weight saving - Chairwoman: Valérie GUENON	Ecodesign - Chairman: Fabien BOUDJEMAA	On board energy m Chairman: Cat
10:00	"Design of a Chiral Structure Morphing Wing Tip", J. Cooper, University of Bristol	"OPENAIR - Introduction - Roadmap Brick for Aircraft Noise Reduction", E. Kors, Safran Snecma Group	"New phosphorous based flame retardant system for cast polyamide-6 processed via T-RTM", B. Kābish, Fraunhofer ICT	"Aircraft Metals Recycling: Process, Challenges and Opportunities", E. Suomalainen, ENVISA	Next generation desig the aircraft electric pov Kuhn, DL
10:30	"Drag reduction of a transport helicopter by application of an adjoint-based fuselage optimization chain and modification of the rotor head", M. Wentrup, German Aerospace Center (DLR)	"OPENAIR SP1 The Technology Evaluation process", E.A Ammeux, Airbus Operations SAS	"Carbon fiber reinforced composite made from out-of-autoclave prepregs with a thin impact protection layer", R. Emmerich, Fraunhofer Institute for Chemical Technology	"Recycling of Aircraft Waste and End of Life Composites: New Thermoplastic Materials Based on Post Consumer Expanded Polystyrene", F. Bianchetti, Alenia Aermacchi S.p.A.	"Model Exchange Practice", D. Zim
11:00	"New controller design and experimental validation using wind tunnel tests", R. Botez, ETS	"OPENAIR SP2 Integrated Propulsion System Design Summary", H. Nick, Rolls-Royce plc	"Thermoplastic blend with Low Melting Point to replace PEEK in aeronautic composites", A. Lagraña, ASCAMM Technology Centre	"CFRP processing by electrodynamic fragmentation", V. Thome, Fraunhofer Institute for Building Physics	"Intelligent Load Powe applied to Secondary E Centers and Distribu Modules", B. Guida,
11:30	COFFEE BREAK				
12:00	"A novel multi-body architecture for wing flap camber morphing", R. Pecora, University of Naples	"OPENAIR - SP3 Electronically Assisted Propulsion Systems Technologies", J. Mardjono, Snecma	"Novel Joining Concepts for Ti-6Al-4V and Ti-6Al-4V-CFRP Parts", N. Kashaev, Helmholtz-Zentrum Geesthacht	"Development of c-fiber recovering technology using microwave and fibre quality assessment", R. Emmerich, Fraunhofer Institute for Chemical Technology	"Design and Optimi Electrical Drive-Trai Tolerant Rotorcraft EM University of No
12:30	"CleanSky Programme : an overview of the Active Gurney Flap programme", S. Spurway, AgustaWestland	"OPENAIR Project: Achievements related to Airframe Noise", C. Seror Goguet, Airbus Operations SAS	"Low Weight Green Metallic Fuselage Section", Y. Mirovsky, Israel aerospace Industries (IAI)	"Processing and Recycling of A Thermoplastic Composite Rotorcraft Door-Hinge", M. Roux, University of Applied Sciences and Arts Northwestern Switzerland (FHNW)	"More Electric aircra Clean Sky breakthrough Operations