INCOM overview February 2015

The objective of the INCOM project is to develop techno-economically viable solutions and production methods for lightweight structures based on advanced sustainable materials for use in packaging, vehicles and aeronautical applications.

The main modules of the INCOM project are

- Nanofibrillated cellulose (NFC) production and modification process
- Composites processing and sandwich structure manufacturing
- Mechanical testing, verification and modelling
- Life cycle assessment

The core of the project is the manufacturing and modification of nanofibrillated cellulose. Two approaches are used. The first approach is the nanofibrillation of cellulose in a pre-polymer (monomer or oligomer) medium, allowing fibril consistencies higher than achieved when using an aqueous medium. This also avoids the problems related to incompatibility of aqueous medium and plastics as well as creating an optimal, high consistency, homogenous fibril dispersion in the resin to be used in composite structures. The second approach is the development of a quality tool for quantifying nanofibrillation in aqueous and other media as well as the optimization of the nanofibrillation of bioresidues. Resin with functionalised nano-reinforcement namely functionalised NFC, will be produced and used in both the core and the skin of structural sandwich composites.

For composite sandwich structures, three types of cores are being developed to meet different demands of these structures. These are an expanded NFC reinforced biobased PU foam core, a biobased thermoplastic foam core and a thermoplastic honeycomb core. The reinforced foamed cores are produced using chemical and physical blowing agents, resulting in low density (<50 kg/m^3) foams with high compression strength. The nano-reinforced polymer or hybrid coating is also used to strengthen the cell walls of a thermoplastic honeycomb core, targeting improvements in its mechanical performance. Particular focus is being given to rapid cure processes necessary to cure the coatings as well as inline production of the sandwich structure to increase the efficiency of the manufacture of these composite structures. The nano-reinforced coating will also be used for coating the expanded thermoplastic core.

During the development process an ecodesign approach will be used and evaluated by LCA from the early stages right through to the end of the project. This will ensure that a path of reduced environmental impact will be followed during the development of these new industrial processes for nanocellulose reinforced composites.

Progress during the first reporting period

The process of NFC production using bead milling has been developed to suit the milling of cellulose fibres in monomers (e.g. epoxy resin), sol-gel dispersion or solvents. Various milling trials with several cellulose-matrix combinations have been carried out and used to fabricate coatings, adhesives or moulded composite samples.

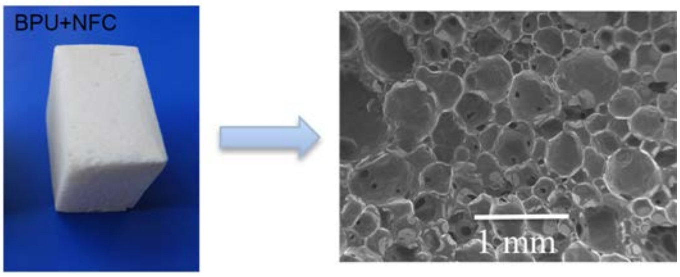
NFC has been produced from carrot- and barley residue with ultrafine grinding in aqueous solutions. The process and resulting NFC was compared to NFC isolated from birch kraft pulp. The use of a carrot residue resulted in a production of NFC with a low energy consumption meeting the project target of 2 MWh/t and of a higher quality that produced from birch NFC. The development of a tool for process monitoring based on viscosity has been tested and is currently being used to establish a more consistent quality of NFC. Additional process monitoring tools continue to be developed.

Illustration of the raw materials: birch kraft pulp, barley residue and carrot residue and the nanofibrillated cellulose obtained after bleaching and grinding

Several hybrid coating compositions have been studied targeting the incorporation of NFC into the coating as well as the adhesion of the coating on the polypropylene polymer films used in the honeycomb core. Using chemically modified NFC the incorporation capability into hybrid coatings was promising and enabled higher film thicknesses to be obtained. Dual cure mechanisms were found to be feasible with various coating compositions. The adhesion of hybrid coatings on these PP films seems to be challenging and physical treatment of the polymer is necessary.

Coating trials of honeycomb polymer films were made as part of the process development. Film coating processes were developed to fit the industrial in-line process of the honeycomb core. Different coatings were studied and an increase of compression strength was seen for some specific hybrid coated honeycomb cores. However further investigations are still required.

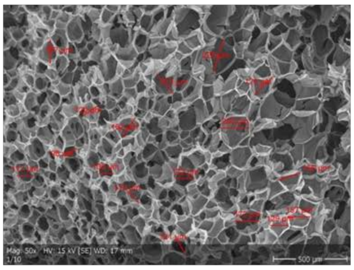
The foaming formulation of NFC reinforced biobased PU (BPU) foam has been developed. The compressive strength of the BPU foam was dramatically increased with the addition of NFC by 73% when compared to the neat BPU foam.



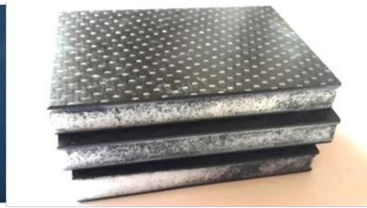
Biobased polyurethane with nanocellulose fibres

The initial thermoplastic core prototype structures, production parameters and properties for continuous extrusion foaming at laboratory and pilot scale have been demonstrated. Initial sandwich assembly tests were performed successfully using PLA foam as the core. It was shown that the cell size and uniform cell structure can be altered by different nucleating agents.

Material and production process development targeting light weight thermoplastic core structures produced in continuous extrusion foaming line



Foam structure, SEM image ×50



Initial sandwich assembly tests with foamed PLA core

Continuous pilot scale thermoplastic extrusion foam core for light weight sandwich structures

Initial sandwich structure samples have been manufactured successfully using cores and skins produced in the project. It was found that laboratory scale sandwich assembly can be done and the scale-up can be envisaged. The flexural properties showed that the performance of the studied sandwich structures is acceptable. However, it is clear that the skins and the assembly process in particular, require more development in the design and testing as well as material and process optimisation. Initial trials of manufacturing and testing laminate plates by RTM were done with and without the inclusion of first phase bead milled NFC. The initial production of vacuum infused plaques with NFC resin has also started. The specifications for the demonstrators have been defined by the partners.

A method has been established for the measurement and analysis of the density of nano-reinforced materials in order to evaluate the material quality in terms of porosity. The harmonisation process of tensile testing methods of polymer films has led to a validation of the measurements done by the three partners. The tensile testing of the coated films included the development of procedures for measuring coating thickness by optical microscopy, in addition to presenting a model for back-calculating the coating stiffness based on the measured stiffness of the coated polymer film.

Useful feedback on environmental, cost and safety issues has been provided to the project partners. The environmental impact of NFC production using bench scale ultrafine grinding, partially bio-based PU foams and honeycomb cores has been studied. The baseline LCC of ThermHex honeycomb core has been conducted. The screening and safety evaluation for composites containing cellulose nanomaterials has also been performed.

A scientific paper, Semi-rigid biopolyurethane foams based on palm-oil polyol and reinforced with cellulose nanocrystals by X. Zhou, M. Sain and K. Oksman from LTU has been submitted to Composites part A and a conference presentation “Volumetric composition of nanocomposites” by B. Madsen from DTU has been accepted for oral presentation at the International Conference on Composite Materials (ICCM20), Copenhagen, July 2015.

INCOM internal workshop at EconCore, Leuven, Belgium on February 2015