feature

Pioneering Natural Composites for Net Zero Emissions

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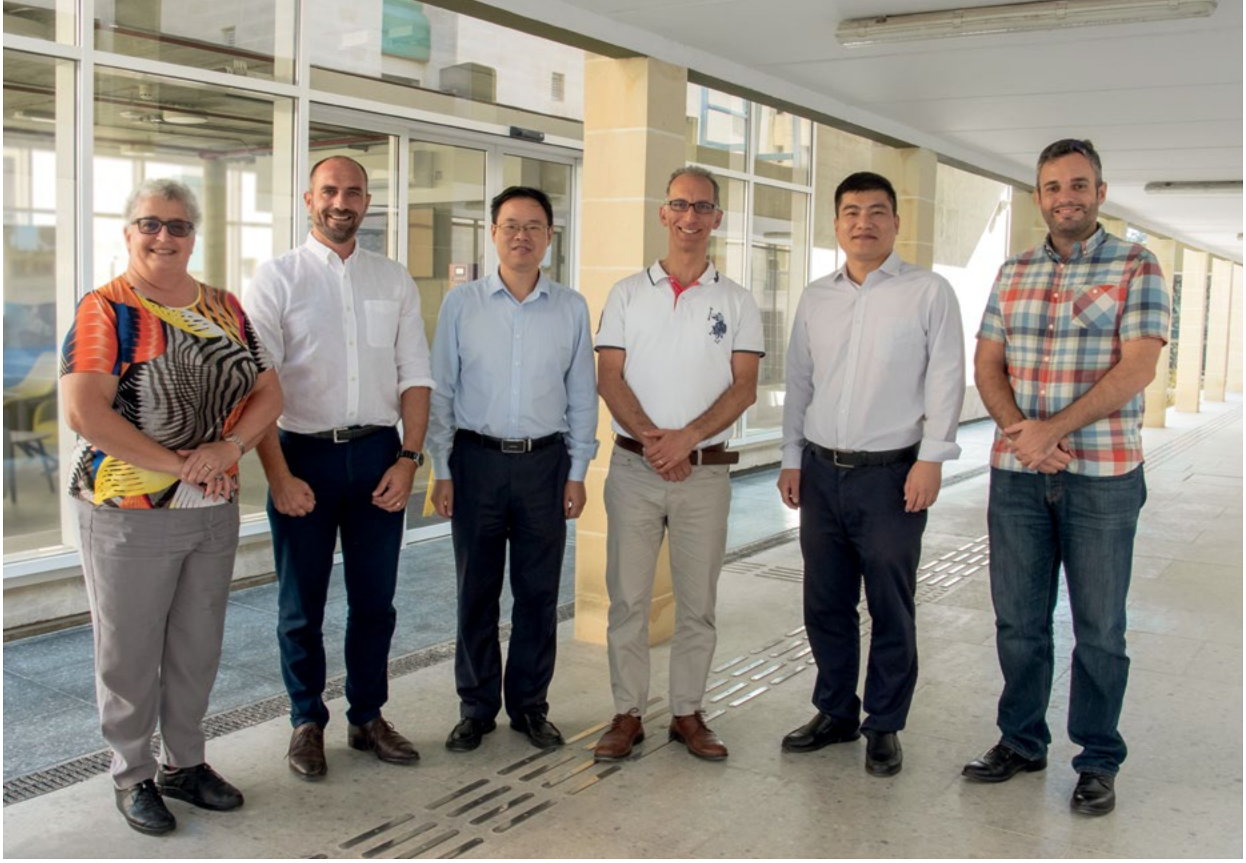
Fighting climate change requires systemic approaches that tackle the whole life cycle of a product. Composites are used across industries to produce robust, lightweight, and resistant materials, but their production uses fossil fuels, and the final product is non-recyclable and hazardous to the environment. In a joint effort, through the project Ecological Natural Fibre Reinforced Composites – ***ECO-Composite*** *– the UM and Zhejiang Sci-Tech University, China, are exploring the development of biodegradable alternatives to typical synthetic composites.*



ECO-Composite project investigators meeting at UM.
From left to right: Prof. Ing. Claire DeMarco, Prof. Ing. Duncan Camilleri, Prof. Zhenyu Wu, Prof. Ing. Martin Muscat, Prof. Hongjun Li, Dr Brian Ellul
Not present: Prof. Emmanuel Sinagra, Prof. Xiangdong Liu
Photo by James Moffett

The European Climate Law aims to mitigate global warming by ensuring that, by 2030, the European Union's member states reduce their carbon emissions by no less than 55% in comparison with 1990 levels and that by 2050, these emissions reach net zero. To achieve this goal and protect the planet from the consequences of the climate crisis, we need to rethink many of the systems and processes that keep our society running. One such effective strategy is to tackle the carbon footprint of a product's life cycle. Through individual and local governmental efforts, more reusable and recyclable products can be developed and used to reduce the production of waste.

When thinking about recycling, you may first turn to individual approaches: preferring reusable bags, recycling packages, buying second-hand clothes… However, it is also important to consider recycling on a larger industrial scale. For example, in 2020, carbon emissions in the transportation sector amounted to 24% of the world's energy-related emissions. While these emissions reflect the energy needed to power a car, not to produce it, many of these emissions would still be decreased by using lighter, recycled materials.

Transport industries, including automotive, aerospace, and even marine, rely on materials called composites that are a combination of fibres (such as carbon or glass fibres) and synthetic resins that are typically petroleum-based. Composites have revolutionised the world of industry and manufacturing due to their durability, lightness, and ability to withstand strong forces. Composites can also be produced to optimise and endure different functions and environments.

Prof. Ing. Duncan Camilleri, principal investigator of the project ECO-Composite from the Department of Mechanical Engineering at UM, explains to THINK that composites offer a high strength-to-weight ratio, meaning that with the right recipe of fibres and resin, the desired characteristics can be achieved more efficiently than with conventional materials. For example, placing fibres parallel to the direction of a force in a resin capable of encapsulating, protecting, and transferring loads between the fibre strands can allow the composite material to withstand larger forces than other materials. For each application, the composite components are chosen according to their 'strength, flexibility, rigidity, and potential' and are combined to make for a suitable advanced composite material with minimal weight.

Agave sisalana **in its natural habitat**
Image courtesy of ECO-Composite project

Sisal fibres extraction and processing
Photo by James Moffett

Still, despite such effectiveness, composites are not exactly helping us reach the carbon emission goals intended to stop the climate crisis. Most of the constituent materials (both the fibres and the resins) are derived from fossil fuels or require a high energy input to manufacture, resulting in high carbon emissions. Furthermore, synthetic composites are very hard to recycle and often end up incinerated or in landfills. When produced or incinerated, composites emit greenhouse gases, and in landfills, they occupy a lot of space (already scarce) and take years to decompose. In the process, they leach dangerous chemicals that contaminate soil and water, with synthetic resins being generally hazardous and even carcinogenic. Even if current composites are recycled, the process is not very efficient and, as Camilleri explains, requires a lot of energy.

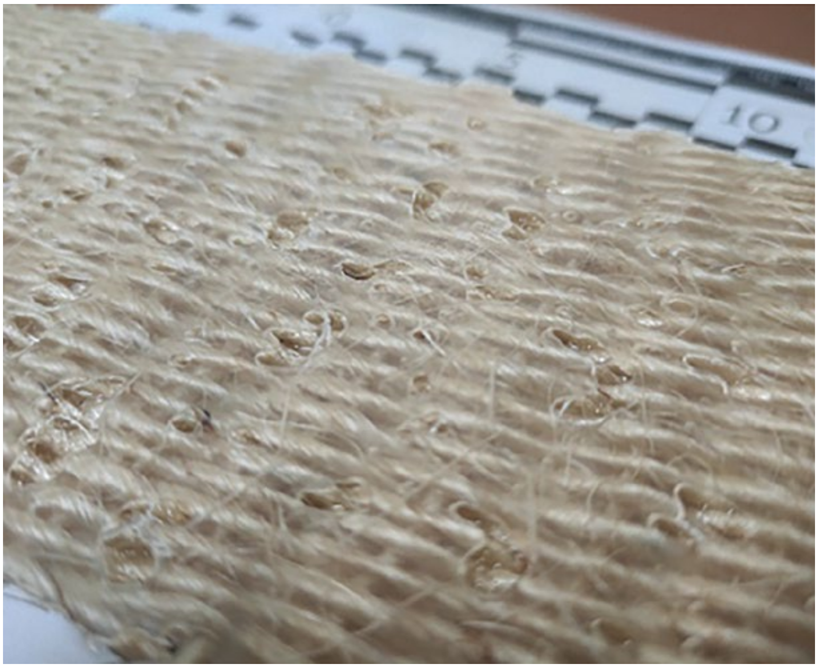
Luckily, a joint effort between the research teams at the Department of Mechanical Engineering (Faculty of Engineering) and the Department of Chemistry (Faculty of Science) at UM and the Faculty of Mechanical Engineering and Automation at Zhejiang Sci-Tech University, China is exploring the development of biodegradable composites. Specifically, the team is looking to develop composites reinforced with ecological natural fibre, or what they call eco-composites.

To do so, they have split efforts to create sustainable versions of the two components in composites. While UM focuses on developing plant-based fibres, the Zhejiang Sci-Tech University, China is looking at bio-resins.

According to Camilleri, plant-based fibres require less energy to produce than synthetic fibres. The plants they are extracted from (like flax, hemp, or sisal) naturally absorb CO_2 from the atmosphere, which also reduces the carbon footprint of the manufacturing process. With such materials, the final eco-composite will be biodegradable and decompose more quickly without contaminating soil and water.

Although the biocomposite industry is growing, developing these solutions comes with its challenges. Camilleri points out that for the eco-composite to maintain its shape and strength, the resin and fibres developed need to bind to each other to keep the material intact and promote the transfer of load from one fibre to another. Natural fibres also need to maintain their original strength, flexibility, and rigidity throughout the life cycle of the eco-composite.

The UM researchers are looking into different plant-based fibres and testing their properties to find effective replacements for the synthetic fibres currently available. Camilleri mentions that there is limited research on the use of biodegradable fibres in composite materials. The team hopes to fill this gap by testing the performance of composites produced from flax and/or sisal fibres combined with the appropriate bio-resins.



Bio-based woven mat
Image courtesy of ECO-Composite project

Flax is already used in the industry. It's known to have good damping properties, and the relative ease of spinning and weaving it into mats makes it a favourite for biocomposites. It is, however, more expensive to produce, and its properties are still being studied.

Sisal, on the other hand, is not often seen in biocomposites since it is more difficult to spin into a yarn and develop a closely packed fibre mat. Camilleri's team was already working with fibre extracted from the *Agave sisalana* plant when they realised its potential to strengthen a biocomposite, possibly by combining it with other natural fibres.

Simultaneously, the team in China is trying to produce bio-resins that are compatible with these two fibres. Camilleri, who knew the lead researcher from China from his Ph.D. studies, reached out to develop the Ecological Natural Fibre Reinforced Composites, ECO-Composite project, gaining funding from the Malta Council for Science and Technology (MCST) and the Ministry for Science and Technology of the People's Republic of China (MOST), through the SINO-MALTA Fund 2022 (Science and Technology Cooperation).

Currently, the project is still trying to determine what new materials will result from this endeavour and what industries they may be applied to. It will all depend on how the different components work together and the ultimate properties of the final eco-composites. It seems, however, that natural fibres are not as strong as the synthetic composites already in use.

Camilleri used the automotive industry to explain this further: 'Vehicle parts are generally made of steel, but these can easily be replaced by composite materials. Load-carrying structural components need to be strong, so carbon fibre composites are usually employed. On the other hand, bumpers must absorb energy and reduce the impact force exerted on passengers, implying that materials with good damping and energy-absorbing characteristics are more applicable. Furthermore, the interior components, such as the vehicle's dashboard and door, need to be aesthetically pleasing and capable of reducing noise and vibration. Composites made from natural fibres have excellent damping properties and can therefore be used for these applications.'

Hopefully, in the future, we will see more and more natural-material-based composites available across industries, from fuel-efficient cars to durable furniture. Incorporated into a circular economy, they could become both profitable and sustainable alternatives to the polluting petroleum-based composites currently on the market.