Optimization of Hybrid Composite Structures for Applications under Dynamic Loading Conditions

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Hybridization is mainly used to obtain the combined advantages of two or more types of fibers or matrices or both and at the same time mitigating their less desirable properties.

Hybrid composite materials have been developed and applied to larger applications over the last decade in structural and engineering industries. This is because researchers have determined that hybrid composites fulfil the need to reduce cost in terms of operation, maintenance, and construction, and enhance the performance requirements with respect to applicability range, strength, payload and stability. New technology industries have widely used composite materials owing to their excellent properties, such as high stiffness, high strength, excellent chemical resistance and good economic efficiency.

There has been an increase of recent study about the possible combinations of fiber in hybrid composites, natural/synthetic fibres, natural/natural fibres, or synthetic/ synthetic fibres, in thermoplastic or thermosetting matrix.

For industrial application that employ composite materials, like structural engineering, fibre reinforced composites made from long and continuous fibres show excellent possibility to reduce not only the weight but also lifetime maintenance costs owing to their corrosion and fatigue resistance. Fibre reinforced composites can be manufactured in large quantities, are more sustainable, as well as tougher and lighter than other common materials, such as steel. However, composites are costly and difficult to repair when exposed to impact damage.

There are two types of fibres: natural and synthetic fibres. Natural fibres show various advantages over their synthetic counterparts, such as low cost, acceptable specific strength properties, low density, and biodegradability. There has been increasing interest in the substitution of natural fibres for synthetic ones in engineering applications because of their eco-friendly and bio-renewable. About the impact properties only natural fibre reinforced composites cannot compete with synthetic fibre reinforced composites, so hybridisation could reduce the weakest aspects from both natural and synthetic fibres assuring sustainability and great impact energy absorption and better load carrying capacity.

It is important to understand how static loads affect the failure and damage of composite structures during an impact event. There are different types of impact loading such as low velocity, intermediate velocity, high/ballistic velocity and hyper velocity impact that produce extreme changes in energy transfer, energy dissipation and damage propagation mechanisms. Under low velocity impact, the composite material is damaged but is still able to operate however, for high velocity impact events, the composite is normally perforated or penetrated by the impactor. There are different factors influencing the impact behaviour of composite materials, for example type of matrix, laminate thickness, type of fibre, boundary conditions, fibre arrangement and stacking sequence. In the ballistic impact cannot be neglected also the kinetic energy, shape, and size of the impactor. Moreover the temperature variation dramatically affects the properties of polymer interlayer material and its suitability especially in terms of the impact performance of the whole laminated structure.

Hybridisation guarantees similar or better properties respect to the single elements, by taking advantages from the different properties of different used fibres, obtaining a composite with the more personalized performance .

Much research has been dedicated to improving the performance of synthetic-synthetic fibre hybrid composites under both high and low velocity impact tests; however, further research is necessary to evaluate the impact on the performance of natural-synthetic fibre composite materials in impact tests since it also has excellent structural properties.

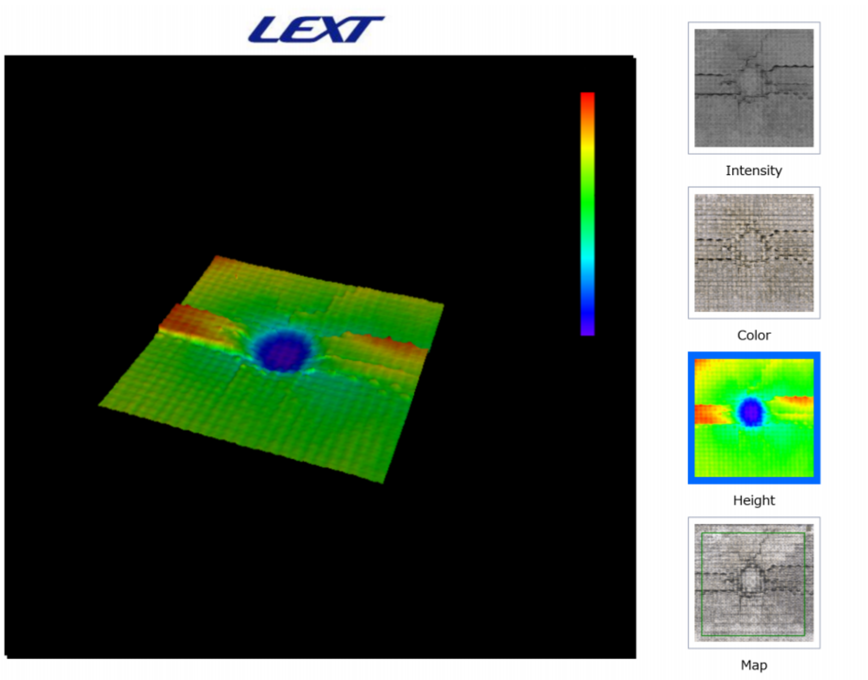
This PhD thesis wants to investigate the combination of both natural and synthetic composites with the purpose to optimize the behaviour under dynamic loading.

The thesis plan provides in the first year of the PhD for a literature review through most of the period to understand the state of the art of the research topic. The first step is the bibliographic study and the experimental analysis of the behaviour under dynamic loads of conventional composites (carbon, glass, basalt) in non-hybrid configuration. The aim is to have a clear frame of the behaviour of the single components of the hybrid laminates to be designed.

The second year was centred on the experimental campaign aimed to static and dynamic analysis of the identified hybrid laminates. The tests will be conducted initially according to the standard criteria and after varying different conditions such as temperature, loading conditions, staking sequence, boundary conditions, fibre arrangement, conditioning to simulate as much as possible different conditions of use. The aim is to identify the hybrid laminate that offers the best performance under dynamic loads and can be presented as an alternative material not only in terms of mechanical properties but also of sustainability.

Different non-destructive and destructive testing methods for the evaluation of composite damages are used. The confocal laser microscopy, is used for the identification of damages like the indentation, the plastic deformation impressed on the surface of the material during the loading phase at the contact point. Ultrasonic spectroscopy, an analysis based on absorption phenomenon clearly related to the material structure and periodicity and advantage, is utilized to characterize the material and identify the presence of defects of porosities. Other non-destructive testing for composite materials used is Holographic Interferometry, that can accurately track delamination growth and can also provide information on the through-the-thickness distribution of delamination.

In the final year of the PhD, once the optimal hybridization configuration has been identified, the best fabrication method is analyzed. The purpose is to identify the most advantageous manufacturing technology, economically and productively, considering new advanced methods like 3D printing in addition to the traditional techniques such as the infusion. The plan includes a period in an International research institute where to carry out complementary research activities.



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