Folding of Origami-Based Multistable Laminates (FORMULA)

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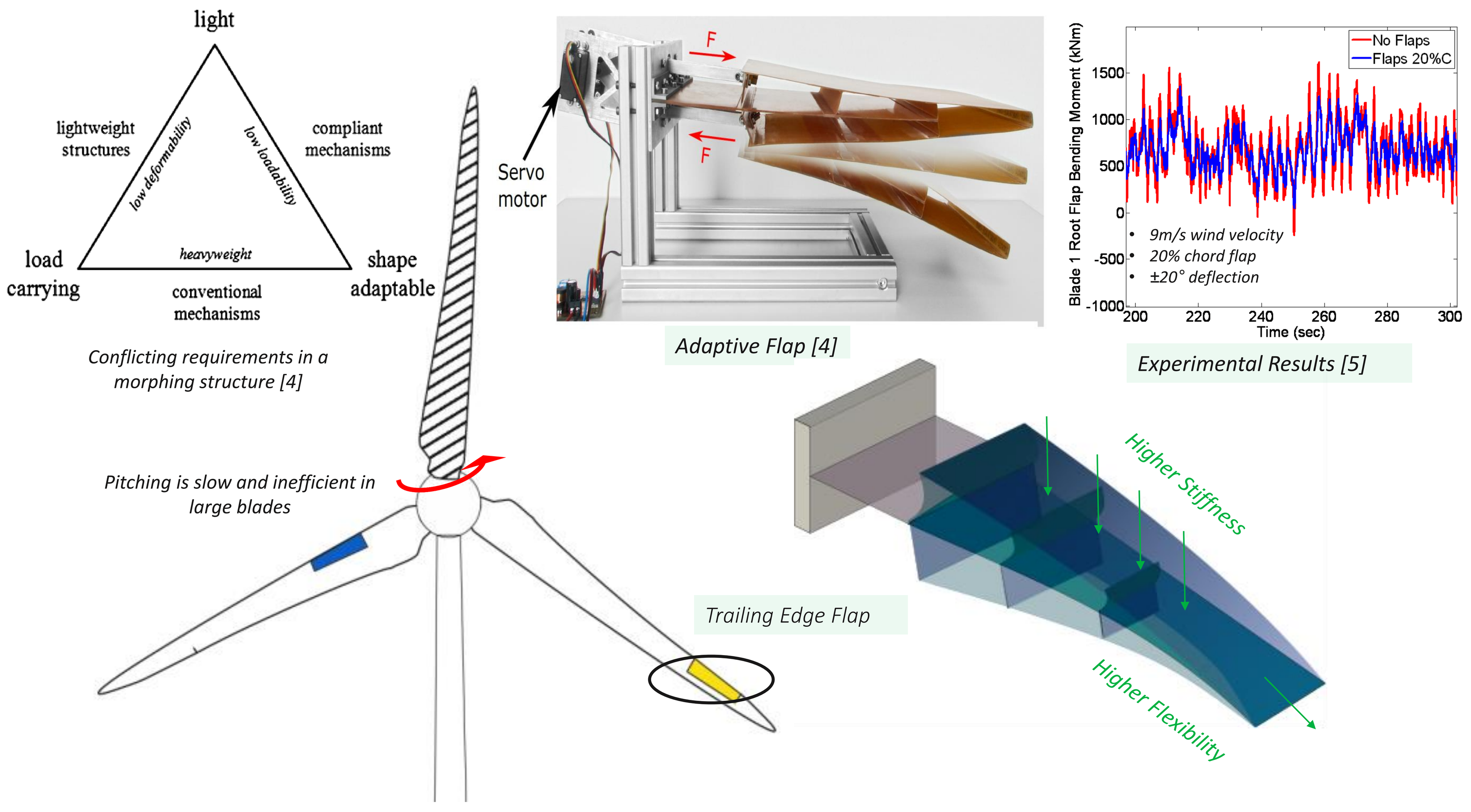
INTRODUCTION

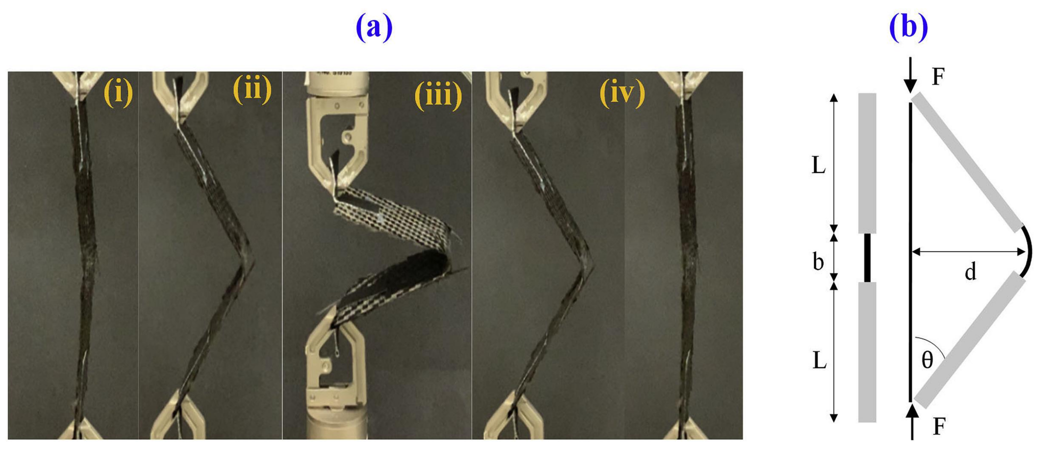
Wind energy is the fastest-growing renewable energy, with usage up fifty-fold in two decades. With the growth of the wind energy industry, there has been a steady increase in the size of rotor blades to lower the cost per kWh [1]. Upscaling the wind turbine increases the energy production, as the yielded energy is directly proportional to the square of the turbine radius *r*, as well as the wind flow is stronger at larger altitudes. However, bigger blades raise blade mass (by r^3) and critical stresses from bending at the blade root [2]. Additionally, they encounter variable aerodynamic loads from yawning, gusts, wind shear, and turbulence, increasing fatigue loads. Alleviating such critical loads can lead to significant reduction in cost, affecting required materials, maintenance costs and system reliability [3]. This study investigates adaptive flaps capable of rapidly altering blade profiles chord-wise or span-wise to mitigate critical stresses in the blade.



With the advancement of additive manufacturing in the last years, bespoke manufacturing by design allowing highly anisotropic architecture has opened new doors to realise efficient morphing mechanisms, particularly enabling us to address the conflicting requirements of load carrying capability, shape adaptability and lightweight requirements in a morphing structure.

OBJECTIVES

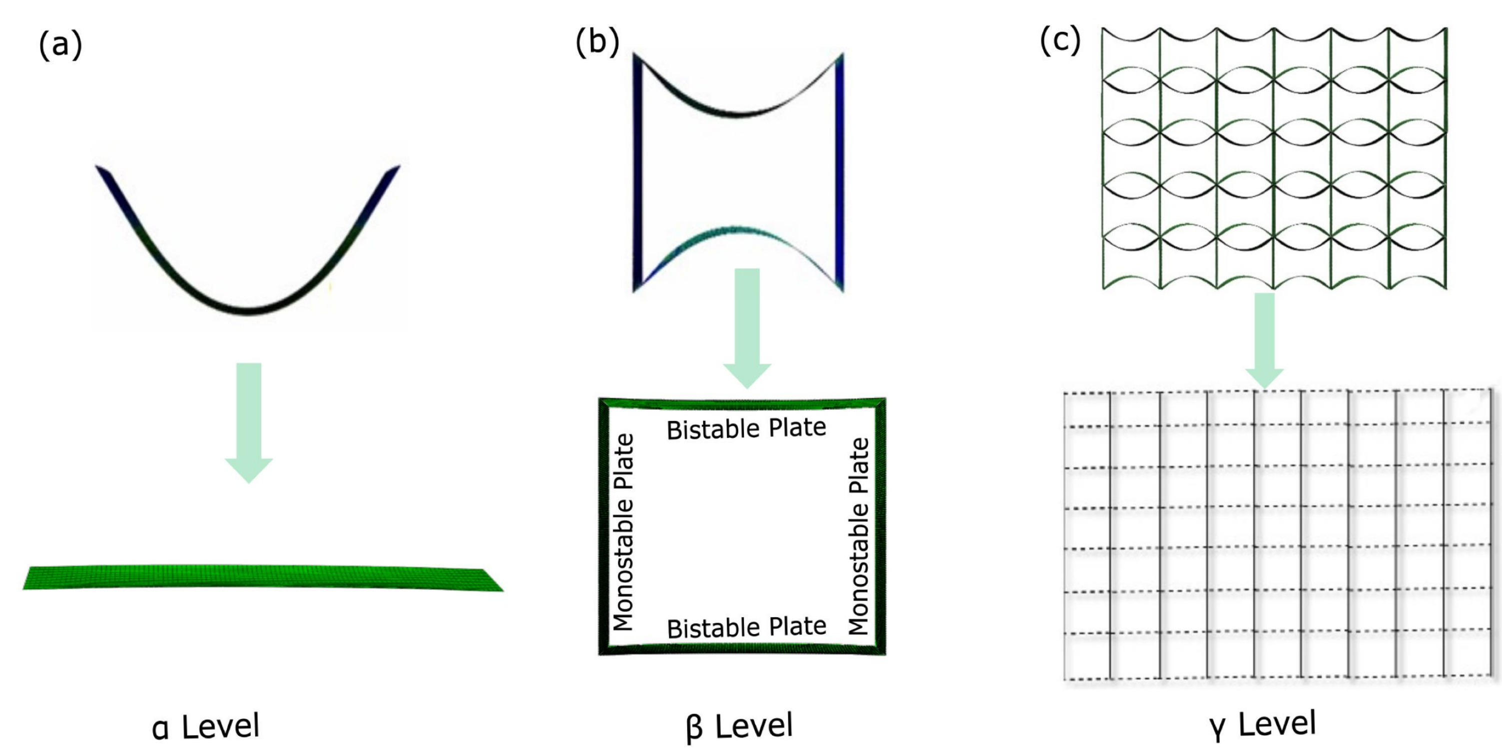
Instead of relying on conventional morphing concept involving many individual subunits, origami concepproject aims to designing a continuous structure with fiber composite laminates, which are not pre-creased but can be folded at desired locations by creating a hinge like bistable mechanisms to fold at desired locations



To build an **architectured material** for a **morphing flap** that is:

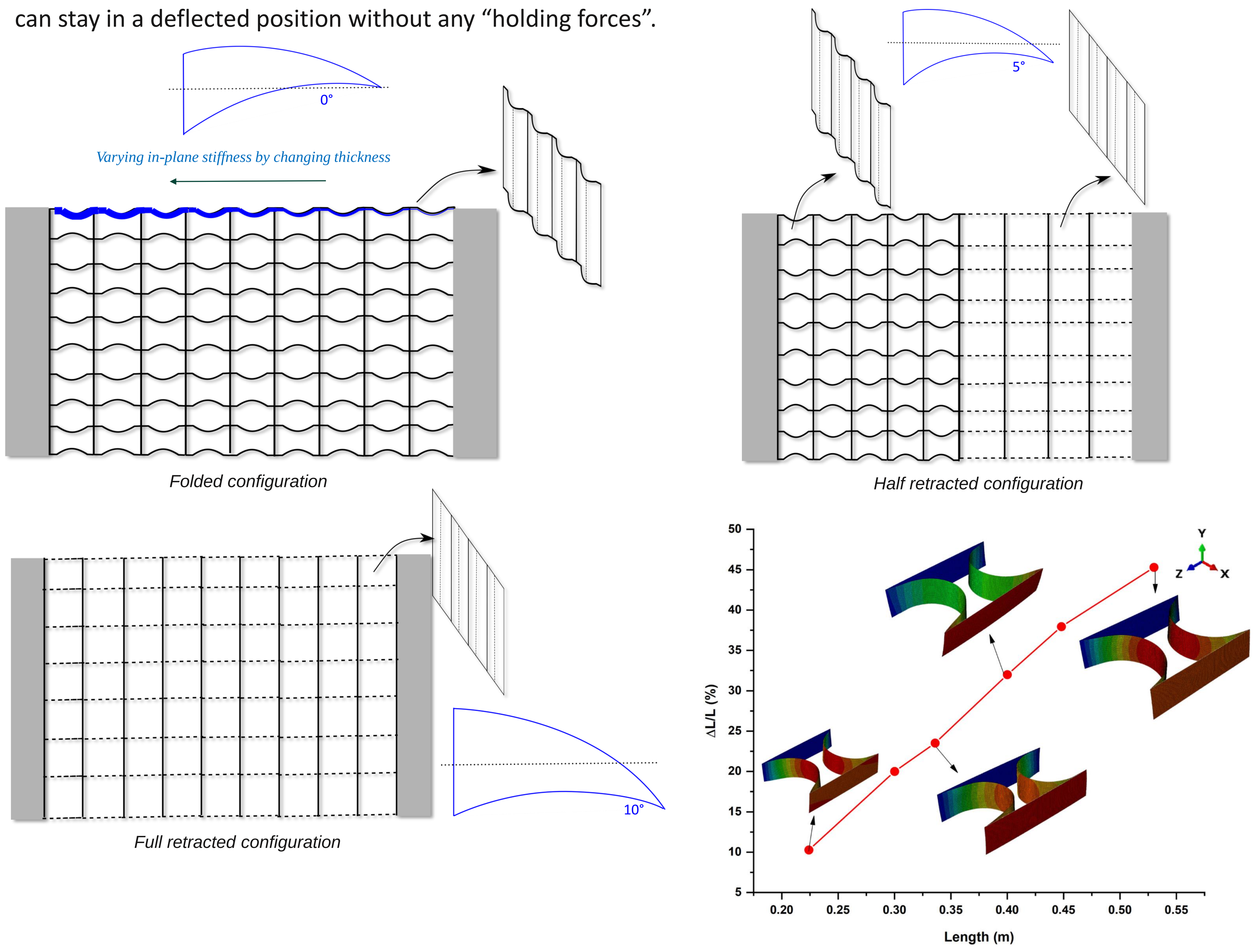
- Lightweight
- High out-of-plane stiffness (load-carrying)
- Flexible in in-plane direction (chord-wise)

Hierarchical modelling of Multistable Metastructures made of fiber reinforced composites [6]

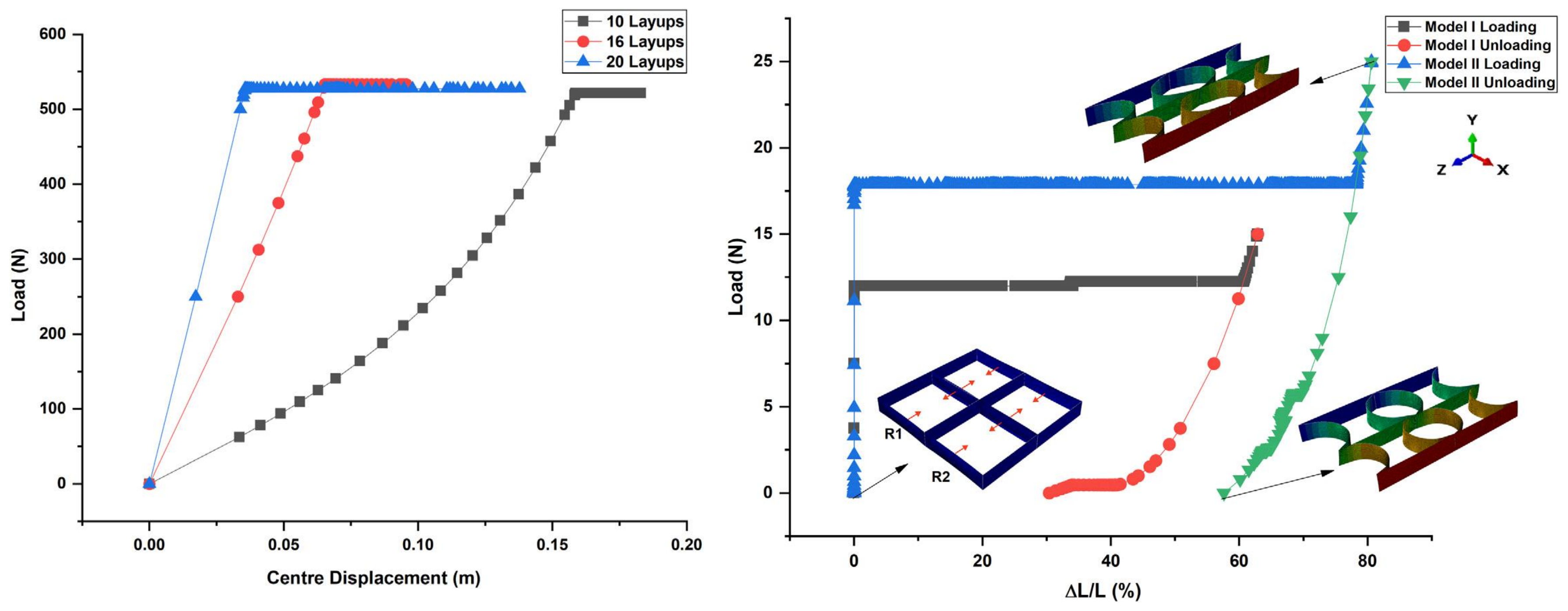


DESIGN

The flap consists of several unit cells, each exhibiting bistability. Upon snap-through from one stable shape to another, the flap can undergo a certain deflected angle with modest actuation requirements. Once deflected, tlap can stay in a deflected position without any "holding forces".



As individually tailoring each unit cells, it is possible to deform the trailing edge of a flap from folded configuration to full retracted configuration allowing a range of deflected angle.



The graph on the left shows the load carrying capability of the lattice, whereas the plot on the right side shows that the lattice can snap from one stable shape to another.

CONCLUSIONS

- A novel concept for designing adaptive structure is explored where snap-through instabilities of the constituent bistable elements are exploited to deflect the TE flap with a modest actuation requirement
- As individually tailoring each unit cells, it is possible to deform the trailing edge of a flap from folded configuration to full retracted configuration, resulting in a deflection.
- This concept of designing adaptive structure can used as design deployable structures like solar arrays in space, morphing applications in aerospace structures, bio-medical devices like stent grafts, bio-inspired robots, packing industry and also in the field of architecture (like shape adaptive facades).

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