Multi-length scale mechanical investigation of the flying insect thorax

Doctoral Defense

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Flying insects are small, efficient, and agile- all traits that engineers want to incorporate into designs for small flapping wing drones. Therefore, engineers are studying the adaptations that make insects so successful. One of those adaptations is indirect actuation. During indirect actuation, the flight muscles deform the thorax exoskeletal which is translated into wing rotation via the wing hinge, where the wings attach to the exoskeleton. Indirect actuation may reduce the energetic cost of flight by allowing energy to be stored in the thorax during one part of the wing cycle and then used later. Recent modeling efforts have simplified the indirect actuation flight system to a two degree of freedom mechanical model- a parallel elastic element represents the combined elasticity of the thorax exoskeleton and indirect flight muscles, and a series elastic element represents the elasticity of the wing hinge. However, the effective stiffnesses of the elastic elements have not been evaluated experimentally.

I hypothesize that thorax elasticity depends on the flight muscle activation type. Insects with synchronous flight muscles convert one action potential into one wing flap, while those with asynchronous flight muscles can convert a single action potential into many wing flaps. Comparing the thorax elastic properties of insects with synchronous and asynchronous muscle will address the knowledge gap of understanding how the thorax has evolved to support each of these muscle activation types. In this work, I compared the thoracic properties of insects with synchronous and asynchronous muscle on multiple scales using *in vivo* and *ex vivo* experimental studies and modeling These studies elucidate the connections between muscle activation, flight control, and flight energetics to inform engineers about which species they should mimic in their designs.

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