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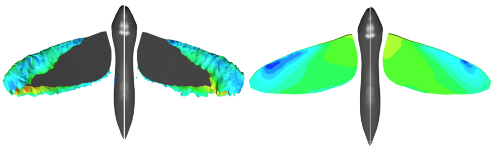
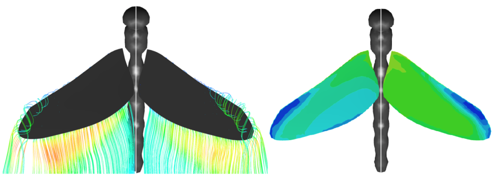
Subject Area	Innovation in Products, Processes and Materials

Fluid-Structure Interaction Analysis of a Dragonfly Wing

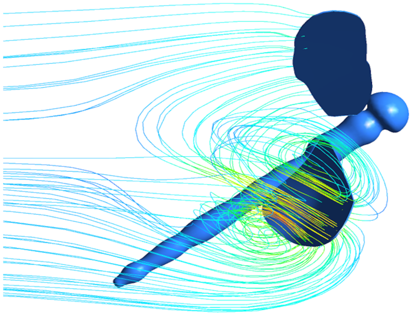
Master thesis



Hawkmoth: Left wing flexible and right wing rigid. Left: Vorticity. Right: Pressure contour. The negative pressure area generates lift.



Dragonfly: Left wing flexible and right wing rigid. Left: Velocity. Right: Pressure contour. The negative pressure area generates lift.



Flexible dragonfly with fore- and hindwing. Streamlines indicate Leading- and Trailing Edge Vortex.

Introduction: Micro-air-vehicles (MAVs) are becoming more and more important for spe-cial military and civil missions. The most common MAVs are the flapping orrotary MAVs. The flapping MAVs are using unsteady aerodynamics, like the flapping-wing flight of insects, to generate the lift and thrust even with small sizes. To build efficient and small MAVs the insect flight needs to be further investigated.

Objective: This thesis focuses on the comparison of a flexible and a rigid insect wing. In order to simulate the flexible wing a 3D Fluid-Structure Interaction (FSI) analysis is made using the commercial program "Analysis System" (ANSYS) Fluent and ANSYS Mechanical.

Result: The setup for the FSI simulation is evaluated with a simulation of a flexible hawkmoth wing in hovering mode by Nakata and Liu [1]. Therefore different ANSYS Fluent settings, mesh sizes and remeshing options are tested. To introduce the wing motion rigid revolute joints are used in ANSYS Mechanical. Due to the wing venation pattern orthotropic material properties are applied. The material properties are validated by measuring the stiffness. Furthermore, it leads to the result that a flexible wing structure improves the aerodynamic performance by about 13% of the hovering flight. The validated setup is applied to a dragonfly in forward flight mode. The flexible and the rigid wing are compared for different flapping motions as well as for different wing configurations (A: Single wing config., B: Tandem wing config., C: Tandem wing config. with a fixed feathering angle, D: Tandem wing config. in counter phase).

- A The weight of the dragonfly is not supported by the generated lift. The lift is increased by 15%, the drag decreased by 40% and the lift-to-drag ratio shows a 47% higher performance for the flexible wing.
- B The weight of the dragonfly is not supported by the generated lift. The lift is increased by 20%, the drag decreased by 26%. The two wings influence each other.
- C The weight of the dragonfly is supported by the generated lift. The lift is increased by 4%, the drag decreased by 25% and the lift-to-drag ratio shows a 32% higher performance for the flexible wing.
- D The weight of the dragonfly is supported by the generated lift. The lift is increased by 5%, the drag decreased by 4% and the lift-to-drag ratio shows a 9% higher performance for the flexible wing.

The aerodynamic performance is increased with a flexible wing independently from the motion. The simulation results are highly sensitive to the wing motion as well as to the boundary conditions.