Integration of the Spiral Pulley Negative Stiffness Mechanism into the FishBAC Morphing Wing

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ABSTRACT

The actuation system of morphing aircraft plays an important role in any promising morphing design. If the structure of the morphing wing needs to be deformed elastically, the actuation system will be required to provide an adequate actuation force while the weight and cost added to the morphing aircraft should be limited to the extent that the performance of the morphing aircraft will not be compromised.

The negative stiffness mechanism, which uses its stored energy to balance the energy requirement of the morphing aircraft, is a promising solution to design the actuation system. The negative stiffness is achieved by the spiral pulley with a spooling cable, which is connected to a pre-stretched spring. The rotation of the spiral pulley can release the energy stored in the spring, and generate the torque to deform the morphing structure. Due to the geometric configuration of the spiral pulley, decreasing torque will be output against the increasing rotation and show a negative stiffness of the mechanism, which will cancel out the positive stiffness of the morphing structure. Geometry optimisation of the spiral pulley is used to achieve the cancellation. By adopting the negative stiffness mechanism, it is expected that the energy requirement will be balanced, which can significantly reduce the input of external energy and therefore the weight and cost of the actuation system.

In the current study, the spiral pulley negative stiffness mechanism will be integrated into the Fish Bone Active Camber (FishBAC) morphing wing. The FishBAC wing is actuated by a torque to enable its elastic shape change. The torque requirement to deform the FishBAC wing will be tested to identify the positive stiffness. The corresponding negative stiffness can then be realised by the optimisation of the geometry configurations of the spiral pulleys. A functional model will be designed, built and tested to demonstrate the functionality of the negative stiffness mechanism. Bi-direction actuation of the negative stiffness mechanism will also be investigated.

Keywords: morphing aircraft, actuation system, morphing wing, negative stiffness, energy balancing