A Bat-wing Aircraft Using the Smart Joint Mechanism

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Abstract. A bat-like aircraft is proposed, using a smart joint mechanism to actuate the morphing of the wings. The smart joint stays in its deformed shape after cooling, which can be up to 5% of 25 mm length joint. The morphing of the wing shapes of three different bat species is evaluated using a planar lifting line analysis. The morphing improves the lift coefficient over 1000% and the lift to drag ratio over 300% at an angle of attack of 0.6°. The results compare well with what is expected from the type of flight and morphology that has been documented for the bats.

Introduction

Bats are renowned in both the biological and engineering community for their amazing skills and acrobatics in flight [1-4]. They are able to achieve these remarkable feats by morphing their wings through the actuation of their finger-like skeletal framework. It has already been theorized that morphing would allow one aircraft to achieve a multitude of functions and missions [5-7]. Morphing allows a wing to change shape to optimize the flight parameters for a given function. For example, at take-off an air vehicles needs to maximize the lift coefficient, during cruise the lift to drag ratio should be maximized, and the drag needs to be minimized to dash [7]. Bats also benefit by having a flexible membrane wing, allowing them to change their wing shape while maintaining a continuous surface, unlike the slats and flaps on air vehicles today. This membrane quality has also been used passively on micro air vehicles to alleviate gusts but affixing control devices to a flexible wing becomes challenging, if not impossible [8,9]. To achieve morphing control for a small air vehicle, a bat-like wing with a skeletal framework and membrane covering is proposed, using smart joint actuators at the joints of the skeletal "fingers" to morph the wing.

Background and Motivation

Smart Joint Mechanism. The Smart Joint is a low-profile morphing mechanism that functions as both a structural element and as the actuator itself, able to transition quickly between configurations such that the start and end conditions are stiff in bending and require no power consumption to maintain rigidity [10]. It can function as a bimorph actuator, such that bending can be achieved in either direction about the longitudinal axis as needed. The joint is a composite that makes use of three materials: shape memory alloy (SMA) as face sheets, shape memory polymer (SMP) for core material, and nichrome wire to provide additional heating. SMA is able to contract when heated above its transition temperature [11], and serves as a strain actuator for the structure when energized. The polymer serves as the variable rigidity element, as its elastic modulus decreases significantly when heated [12]. The joint is formed by placing cooled, elongated SMA at the exterior faces, with a core of SMP divided centrally by nichrome wire. As the heated SMA recovers strain by contracting along the length of the joint, it will provide sufficient stiffness to overcome the stress induced by bending the remaining structure. This will in turn yield a net curvature along the centroidal axis towards the actuator face.