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A THREE DIMENSIONAL ITERATIVE PANEL METHOD FOR BIO-INSPIRED MULTI-BODY WINGS

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ABSTRACT

The continuing growth of Unmanned Aerial Vehicle (UAV) use in reconnaissance and surveillance has led to an increased demand for novel flight systems that improve vehicle flight capabilities in cluttered and turbulent environments. Bio-inspired wings with feather-like flaps have been proposed to enable bird-scale UAVs to fly robustly in such environments. This paper presents the development of a three-dimensional iterative constant strength doublet Adaptive Panel Method (APM) for calculating the flight characteristics of a multi-body wing operating in any of its possible configurations. A three-dimensional wake relaxation algorithm is incorporated into the model, which enables accurate wake shapes and down-stream roll-up for each flap configuration to be derived. Wake modeling is shown to improve the accuracy of the pressure distributions induced by the wake-body interactions. The flight coefficients calculated using this method are validated by experimental values obtained from a low speed suction wind tunnel operating at a Reynolds number of 300,000. Finally, it is shown that the APM aids in determining accurate surface loads for the preliminary design process of multi-body wings.

INTRODUCTION

In the last decade, focus has been given to developing wing designs that can increase the controllability and maneuverability of an aircraft while maintaining flight stability. The major issue concerning the development of any aerodynamic system is the vehicle's ability to withstand turbulence, avoid stalling and track the desired flight trajectory in cluttered environments[1][2]. Traditional control surfaces such as elevators, rudders and ailerons are employed in modern aircraft designs to provide flight stability and controllability. During World War II, several major advances were achieved in the development of high lift devices such as flaps, leading slats and slots that generate high lift-to-drag ratios during take-off and landing and later became an integral part of aircraft design.

Post World War II, focus increased on developing UAVs that can operate in hostile environments and gather intelligence remotely [1]. However, limitations on the size of the UAVs and delays inherent in remote operation have left them vulnerable to turbulence and wind gusts, creating stability and controllability problems. [2, 3, 4]. With the growing need for the development of a robust flight system that has the ability to overcome the flight restrictions induced by turbulent flows, focus has been given to develop systems which incorporate avian flow control characteristics [3, 4, 5]. This system consists of a series of feather-like flaps installed in both the chord- and span-wise directions, creating a wing structure which mimics the features of bird wings. Each flap has the ability to rotate both into the wing geometry and the inbound flow thereby creating different wing configurations to perform maneuvers that minimize the deviation from the UAV's desired flight path.

The multi-flap system (MFS) considered in this study consists of two wing stations of eight feather-like flaps with a bluff body as a leading edge, creating the profile of a NACA 4412 wing which is open at the wing tips, shown in Fig. 1. The flap deflections are denoted by δ_{ij}, as shown in Fig. 1(b), where index i denotes the span-wise station number (1 or 2), and index j denotes the flap number: 1-4 are the upper flaps and 5-8 are the lower flaps. A rigidly fixed leading edge element enables the airfoil to mimic the geometry of a NACA 4412 airfoil when in the rest configuration, thereby ensuring the wing remains efficient during cruise.