UNIVERSITI TEKNOLOGI MARA

AERODYNAMIC PERFORMANCES OF TWIST MORPHING MAV WING

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ABSTRACT

Performing the biomimetic morphing method on a Micro Air Vehicle (MAV) wing is very challenging tasks due to the MAV wing size limitation, limited energy budgets, complicated morphing mechanism and complex aeroelastic interactions. These issues had restricted the application of morphing wing on MAV wing platform. As a result, the impact of twist morphing on MAV wing aerodynamics and structural performances was not fully understood. Thus, this thesis presents the investigation of wing structural, aerodynamics performance and flow structure formations on a basic twist morphing MAV wing named as Twist Morphing wing. A series of morphing force intensity was imposed on Twist Morphing wing design to elucidate the impact of twist morphing mobility. Fully coupled Fluid-Structure Interaction (FSI) simulation is the main methodology used in this works. The wing structural and airflow field problems over Twist Morphing wing were solved based on a three-dimensional (3D) linear quasi-static structural coupled with steady state, incompressible Reynolds Averaged Navier Stokes - Shear Stress Turbulence (RANS–SST) flow. The validation on aerodynamic performances showed good correlation between the FSI and wind tunnel test results. The wing structural results showed that Twist Morphing wings had produced high geometric twist magnitude (ϵ), which in turn, induced higher lift coefficient (C_L) and drag coefficient (C_D) performances on the wing. The flow structure investigations revealed that this benevolent and malevolent aerodynamics attitude contributed by low-pressure intensity and strong tip vortex (TV) strength induced on Twist Morphing wing. These phenomenon had turned out greater in Twist Morphing wing with higher morphing force (5N and 3N) configurations. However, Twist Morphing wing had also exhibited poor maximum aerodynamic efficiency ($C_L/C_{D\,max}$) performances. The massive drag coefficient distribution had overwhelmed the successive increase in lift coefficient generation, which consequently plunged the maximum aerodynamic efficiencydistribution magnitude on Twist Morphing wings. Hence, a multifidelity data Metamodel Based Design Optimization (MBDO) study was conducted to improve the maximum aerodynamic efficiency distribution on Twist Morphing wing. The optimal aerodynamic efficiency for Twist Morphing wing achieved at $C_L/C_{D\,max}$= 6.05 with angle of attack, morphing force and velocity magnitude set at 4.67°, 2.31 N and 9.42 m/s, respectively. Detail investigation on optimization outcome showed that the optimal Twist Morphing wing exhibited better maximum aerodynamic efficiency magnitude than the non-optimal flexible wings. This is due to weak tip vortex strength, which induced low drag coefficient magnitude on the optimal Twist Morphing wing.

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CHAPTER ONE
INTRODUCTION

1.1 RESEARCH BACKGROUND

A micro air vehicle (MAV) is a relatively new generation of aircraft. MAV design becomes a feasible aircraft design over the past 15 years due to continuous research in conventional aero-sciences [1]. Technically, MAV is defined as a micro scale class of Unmanned Aerial Vehicle (UAV), which has the wingspan equals to or less than 6 inch (approximately 15 cm). MAV velocity speed is less than 15 m/s, with the overall weight less than 1 kg. Meanwhile, the Reynolds number operation of MAV is below 100,000 [2], which is lower than conventional aircraft, as shown in Figure 1.1. According to Defense Advanced Research Projects Agency (DARPA), MAV was initially designed for military purpose [3]. Hence, MAV encompasses unique characteristics such as lightweight, affordable, stealthy, and expendables. In fact, MAV is characterized by its simple operation and equipped with a high-resolution image capturing system [4]. MAVs have shown some advantages in rapid deployment mission capabilities, as well as having stealthy characteristics and economic operations. This rapid deployment mission includes the information gathering in the surveillance mission, discovery, and communication of any vital and confined space [5]. The utilization of MAV can be feasible in such critical areas of battlefield region, confined rescue space or maybe biohazardous chemical and nuclear resources areas [6]. The development of MAV has rapidly progressed due to miniaturization of microelectromechanical systems (MEMS), smart materials, and availability of lightweight structures [7]–[10].

In general, MAV is categorized into three main design groups, as shown in Figure 1.2. Among the designs, the fixed-wing MAV is regarded as the best MAV design [11]. This is because the fixed-wing design offers better payload and endurance capabilities compared to rotary- or flapping-wing MAV of equal size [12]. The fixed-wing design such as Trocoid, Micro STAR, Flyswatter, MITE, Batplane, and Wasp are few examples of successful fixed-wing MAV design [4]. However, the