

**INVESTIGATION OF AERODYNAMIC  
CHARACTERISTICS OF A WING MODEL WITH  
RGV WINGLET**

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**INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF  
A WING MODEL WITH RGV WINGLET**

**by**

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This thesis is dedicated to my late father who always supported and  
guided me in every level ...

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## LIST OF SYMBOLS

|                    |   |
|--------------------|---|
| $\lim$             | limit   |
| $\theta$           | angle in degree   |
| $\rho$             | Density in $kg/m^2$                                     |
| $\mu$              | Viscosity, $kg/m.s$                                     |
| $t$                | time, s   |
| $S_m$              | Source Term   |
| $\nabla$           | Divergence  |
| $\vec{v}$          | Flow velocity vector field                              |
| $p$                | Static Pressure, Pa                                     |
| $\bar{\bar{\tau}}$ | Stress Tensor   |
| $\rho \vec{g}$     | Gravitational body                                      |
| $\vec{F}$          | External body force                                     |
| $I$                | Unit Tensor   |
| $\phi$             | Scalar Quantity   |
| $\phi_f$           | Scalar Face Quantity                                    |
| $\nabla\phi$       | Gradient  |
| $\Delta\vec{s}$    | distance from upwind cell centroid to the face centroid |

|                 |  |
|-----------------|--|
| $\tilde{G}_k$   | generation of turbulence kinetic energy due to mean velocity gradients |
| $G_\omega$      | the generation of $\omega$   |
| $\Gamma_k$      | effective diffusivity of k   |
| $\Gamma_\omega$ | effective diffusivity of $\omega$                                      |
| $Y_k$           | Dissipation of k due to turbulence                                     |
| $Y_\omega$      | Dissipation of $\omega$ due to turbulence                              |
| $D_\omega$      | cross-diffusion term   |
| $S_k$           | Source Term for k  |
| $S_\omega$      | Source Term for $\omega$   |
| $T$             | Static temperature in Kelvin   |
| $T_0$           | Reference temperature in Kelvin  |
| $\mu_0$         | Reference Viscosity, $kg/m.s$  |
| $S$             | Effective temperature in Kelvin  |

## LIST OF ABBREVIATIONS

|            |                             |
|------------|-----------------------------|
| <b>USM</b> | Universiti Sains Malaysia   |
| <b>RGV</b> | Ruppells Griffon Vulture    |
| <b>CFD</b> | Computational Fluid Dynamic |
| <b>PIV</b> | Particle Image Velocimetry  |
| <b>BL</b>  | Boundary Layer              |
| <b>AR</b>  | Aspect Ratio                |
| <b>SST</b> | Shear-Stress Transport      |
| $F_L$      | Lift Force in N             |
| $F_D$      | Drag Force, N               |
| $C_D$      | Coefficient of Drag         |
| $C_L$      | Coefficient of Lift         |
| $C_M$      | Coefficient of Moment       |

# KAJIAN AERODINAMIK UNTUK SAYAP MODEL DENGAN HUJUNG SAYAP RGV

## ABSTRAK

Kerja ini menerangkan ciri-ciri aerodinamik model pesawat sayap dengan dan tanpa RGV hujung sayap. Kajian CFD dengan menggunakan ANSYS 15.0 telah dijalankan untuk mengkaji kesan penggunaan hujung sayap yang di atas sayap segi empat tepat. Sayap ini terdiri daripada 660 mm rentang dan 121 mm panjang kord dimana nisbah aspek adalah 5.45. Aerofoil yang digunakan untuk membina struktur keseluruhan adalah NACA 65(3) – 218. Sayap segi empat tepat dengan konfigurasi berbeza hujung sayap dan sudut hujung sayap telah direka menggunakan perisian CATIA P3 V5R13. Hasil eksperimen sayap tanpa hujung sayap dan satu konfigurasi hujung sayap mendatar telah digunakan untuk pengesahan. Semua reka bentuk telah dianalisis dengan  $Ma$  0.06 [Reynolds Nombor =  $1.7 \times 10^5$ ] pada sudut serangan pada 4 darjah dan 6 darjah di mana boleh mendapatkan keputusan aerofoil pengeluaran maksimum. Tidak Berstruktur grid mesh segi tiga dengan kadar inflasi 20 pilihan lapisan prisma yang semakin meningkat telah dilaksanakan dengan sel pertama di atas dinding yang ditetapkan pada  $y$  adalah 0.1 mm. Dalam Fluent 15.0, pergolakan model Transition SST [4 eqn] dengan 2nd order mengikut arah angin konfigurasi telah digunakan. Perbandingan telah dibuat kepada ciri-ciri aerodinamik seperti pekali angkat [ $C_L$ ], pekali seretan [ $C_D$ ], angkat / seretan nisbah  $\frac{C_L}{C_D}$  dan hujung pusaran untuk mendapatkan reka bentuk terbaik RGV hujung sayap. Hasil CFD menunjukkan 15% - 30% pengurangan dalam

pekali seretan dan peningkatan 5% to 25% dalam pekali angkat dengan menggunakan RGV hujung sayap.

# INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF A WING MODEL WITH RGV WINGLET

## ABSTRACT

This work describes the aerodynamic characteristics of an aircraft model wing with RGV winglet. A Computational Fluid Dynamics (CFD) study using ANSYS 15.0 is conducted to study the effect of the RGV winglet on a rectangular wing. The wing consists of 660 mm span and 121 mm chord length where the aspect ratio is 5.45. The NACA 65(3) – 218 aerofoil is used herein. The rectangular wing with different configuration and cant angle of winglets have been designed using CATIA P3 V5R13 software. The design has been analyzed with Mach 0.06 [Reynolds Number =  $1.7 \times 10^5$ ] at various AOA using unstructured triangular grids with the growing prism inflation 20 layer option has been implemented with first cell above the wall set at  $y$  is 0.1 mm. The turbulence model is based on Transition SST [4 eqn] with wall functions. A comparative study is done on aerodynamic features such as lift coefficient [ $C_L$ ], drag coefficient [ $C_D$ ], lift/drag ratio  $\frac{[C_L]}{[C_D]}$  and tip vortices to get the best RGV winglet design. Based on contour plot analysis, the RGV winglet shows lower vortex formation compared to without winglet. The CFD result shows 15% - 30% reduction in drag coefficient and 5% to 25% increase in lift coefficient by using an RGV winglet.

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background Of The Study

The drag produces from an aircraft is one of the primary obstacle that limiting the performance of an aircraft. The local relative wind downward (an effect known as downward) and generated a component of the local lift force in the direction of the free stream caused by the drag stems from the vortices shed by an aircraft's wings. The spacing and radii of these vortices are proportional to the strength of this induced drag (Anderson (2005)). By designing a winglet which creates vortices with large core radii and at the same time forces the vortices farther apart, one may significantly reduce the amount of the induced-drag. An airplane will be more efficient when flying consumes less fuel for an arbitrary distance which produces less drag and less engine power used.

Vortices at the wing tip can cause crash particularly when a bigger airplane flies in front of a small aircraft. The airplane which has created larger vortices can cause accident with the smaller aircraft where this smaller aircraft might lose control. To minimize the separation rule in an airport, lower wake vortex category aircraft must not be allowed to take off less than two minutes behind higher wake vortex category aircraft. The time will be increased to three minutes or more when the highest wake vortex category aircraft take off.

Winglet is the most used in aircraft industry because of its benefit and one of the promising drag reduction device. The possible benefits of modifying wing-tip flow has