INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF A WING MODEL WITH RGV WINGLET

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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
θ	angle in degree
ρ	Density in kg/m^2
μ	Viscosity, $kg/m.s$
t	time, s
S_m	Source Term
$\bigtriangledown$	Divergence
$\vec{v}$	Flow velocity vector field
p	Static Pressure, Pa
$\overline{\overline{\tau}}$	Stress Sensor
$\rho\vec{g}$	Gravitational body
$\vec{F}$	External body force
I	Unit Tensor
ϕ	Scalar Quantity
ϕ_f	Scalar Face Quantity
$\bigtriangledown\phi$	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 gradents
G_ω	the generation of ω
Γ_k	effective diffusivity of k
Γ_ω	effective diffusivity of ω
Y_k	Dissipation of k due to turbulence
Y_ω	Dissipation of ω due to turbulence
D_ω	cross-diffusion term
S_k	Source Term for k
S_ω	Source Term for ω
T	Static temperature in Kelvin
T_0	Reference temperature in Kelvin
μ_0	Reference Viscosity, $kg/m.s$
S	Effective temperature in Kelvin

LIST OF ABBREVIATIONS

USM	Universiti Sains Malaysia
RGV	Ruppells Griffon Vulture
CFD	Computational Fluid Dynamic
PIV	Particle Image Velocimetry
BL	Boundary Layer
AR	Aspect Ratio
SST	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 = 1.7×10^5] 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 = 1.7×10^5] 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