

CERTIFICATION OF APPROVAL

Experimental and Numerical Investigation on 2-D Wing-Ground Interference

by

A K Kartigesh A/L Kalai Chelven

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

(AP Dr Hussain H Al-Kayiem)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

A K KARTIGESH A / L KALAI CHELVEN

ABSTRACT

The wing collision is a practical aerodynamic problem. All aerodynamics characteristic of the wing are changing in the collision phenomena. In the present project, the collision of 2-D airfoil section with ground will be investigated experimentally and numerically. The study includes a series of wind tunnel experiments to investigate the 2-D wing influence under collision. Numerical simulation by CFD has been carried out using FLUENT software in order to identify the changes of aerodynamics characteristics during the wing collision. The 2-D wing section selected for the study is NACA 4412 airfoil. The investigation has been carried out at different Reynolds Number ranging from $(0.1 \times 10^6$ to $0.4 \times 10^6)$, different angles of attack (-4^0 to 20^0) and different height above the ground.

Based on take off and landing fly stages the boundary conditions for the experimental and numerical analysis are determined. An experimental set up was designed and constructed to simulate the collision phenomena in a subsonic wind tunnel. The results of the airfoil characteristic are presented in non-dimensional form as lift, drag and pitching moment coefficient.

ACKNOWLEDGEMENT

My sincere appreciation goes to Universti Teknologi PETRONAS (UTP) and all individuals that have contributed to the continued development and refinement of this dissertation of Final Year Project (FYP) in order to complete my partial fulfillment of the requirement for the Bachelor of Engineering (Hons) Mechanical Engineering.

My special thanks to my supervisor, Assoc. Prof. Dr. Hussain H. Al-Kayiem for his supervision and his confidence in me through out this project. Also for his tremendous support, advices, and information. Thanks to lab Technician, Mr. Zailan for his comments, advices and technical assistance.

Last but not least, thank you for those who are contributed directly and indirectly to the success of this project. Special recognition to my beloved family, father - Kalai Chelven, mother - Periyanyaki, Sister - Sumathi for their endless love and support through thick and thin in leading life.

TABLE OF CONTENTS

CERTIFICATION OF APPROVAL	. . . . .	i
CERTIFICATION OF ORIGINALITY	. . . . .	ii
ABSTRACT	. . . . .	iii
ACKNOWLEDGEMENT	. . . . .	iv
TABLE OF CONTENTS	. . . . .	v
LIST OF FIGURES AND TABLES	. . . . .	vi
NOMENCLATURE	. . . . .	viii
CHAPTER 1:	INTRODUCTION	1
	1.1 Background of Study	1
	1.2 Problem Statement	3
	1.3 Objectives and Scope of Study	3
	1.4 Scope of study	3
CHAPTER 2:	LITERATURE REVIEW AND THEORY.	4
	2.1 Literature Survey	4
	2.1 Principle of Ground Effect.	5
	2.2 Theory	8
CHAPTER 3:	METHODOLOGY	13
	3.1 Analysis Method	13
	3.2 Project Flow Chart	13
	3.3 Gantt Chart	16
CHAPTER 4:	RESULTS AND DISCUSSION.	17
	4.1 Phase 1(NACA 4412 Coordinates).	17
	4.2 Phase 2(Experimental).	21
	4.3 Phase 3(Simulation)	29
	4.4 Discussion	48
CHAPTER 5:	CONCLUSION AND RECOMMENDATION	49
	5.1 Conclusion	49
	5.2 Recommendation	50
REFERENCES	. . . . .	51
APPENDICES	. . . . .	53

APPENDIX A: AIRFOIL MODELS.	53
------------------------------------	----

APPENDIX B: FUNDAMENTAL FLUID MECHANICS	53
--	----

LIST OF FIGURES AND TABLES

Figure 1.1: Phenomena of ground effect	1
Figure 2.1: Wingtip Sketch	5
Figure 2.2: Airfoil Sketch subjected to airstreams	6
Figure 2.3: Graph of normal induced drag against % of wingspan	7
Figure 2.4: Effective Span	10
Figure 2.5: CFD Results	11
Figure 2.6: Boundary Condition for Airfoil modeling in ground effect	12
Figure 3.1: Project Flow Chart	15
Figure 3.2: Gantt chart	16
Figure 4.1: Naca 4412 Model Cconstructed using the Laser Digitizer Data	17
Figure 4.2: 100 Coordinate points of Naca 4412 Model	18
Figure 4.3: Critical Zone for Experimental Analysis	21
Figure 4.4: Experimental Arrangement	22
Figure 4.5: Subsonic Wind Tunnel	22
Figure 4.6: NACA 4412 Airfoil Model	23
Figure 4.7: Test section floor as ground	23
Figure 4.8: Sample arrangement of the airfoil closer to the ground	24
Figure 4.9: Graph of AOA against Coefficient of Lift, Drag and Moment	25
Figure 4.10: Graph of Re Number against Coefficient of Lift and Drag	26
Figure 4.11: Graph of Re Number against Coefficient of Pitching Moment	27
Figure 4.12: Graph of H/C Ratio against Coefficient of Lift and Drag	28
Figure 4.13: NACA 4412 Vertexes plotted on GAMBIT	29
Figure 4.14: NACA 4412 Edges plotted on GAMBIT	29
Figure 4.15: Boundary Model	30
Figure 4.16: Boundary Model for H/C= 0.1 and angle of attack $\alpha = 0^\circ$	31
Figure 4.17: Boundaries applied in GAMBIT	32
Figure 4.18: Stretched meshing of the flow field	32

Figure 4.19: Pressure Coefficient against the position	33
Figure 4.20: Contour of static pressure around the Airfoil	34
Figure 4.21: Contour of dynamic pressure around the Airfoil	35
Figure 4.22: Contour of velocity magnitude around the Airfoil	36
Figure 4.23: CL vs AOA at H/C = 0.1, Re =0.4 e+6	37
Figure 4.24: CD vs AOA at H/C = 0.1, Re =0.4 e+6.	38
Figure 4.25: CM vs AOA at H/C = 0.1, Re =0.4 e+6	38
Figure 4.26: CL vs Re at AOA = 4, H/C = 0.1	39
Figure 4.27: CD vs Re at AOA = 4, H/C = 0.1	39
Figure 4.28: CM vs Re at AOA = 4, H/C = 0.1	40
Figure 4.29: CL vs H/C Ratio at different Re and AOA	41
Figure 4.30: CD vs H/C Ratio at different Re and AOA	41
Figure 4.31: Comparison Graph of H/C Ratio against CL and CD	42
Figure 4.32: Comparison of Experimental work with previous work	44
Figure 4.33: Comparison of Simulation work with previous work	46
Figure A1: Airfoil Models	53
Table 2.1: Turbulence Flow for NACA 4412 in Ground Effect results	4
Table 4.1: NACA 4412 Coordinates (published data) [10]	19
Table 4.2: Comparison of coordinates	20
Table 4.3: Boundary conditions	21
Table 4.4: Angle of Attack against Coefficient of Lift, Drag and Moment	24
Table 4.5: Reynolds Number against Coefficient of Lift, Drag and Moment	26
Table 4.6: Height to Chord Ratio against Coefficient of Lift and Drag	27
Table 4.7: Angle Of Attack	33
Table 4.8: AOA against CL, CD, and CM	37
Table 4.9: Re against CL, CD, and CM	39
Table 4.10: H/C Ratio against CL and CD	40
Table 4.11: Error between the Experimental data and Simulation data	43
Table 4.12: Error between Experimental work and previous work	45
Table 4.13: Error between Simulation work and previous work	47

NOMENCLATURE

NACA 4412	Aircraft Wing Section Model
CFD	Computerized Fluid dynamics
Re	Reynolds Number
α	Angle of Attack
ρ	Density of Air
μ	Viscosity of Air
V	Fluid Velocity
C_L	Lift Coefficient
C_M	Moment Coefficient
C_D	Drag Coefficient
C	Chord Length
L	Lift Force
M	Pitching Moment
D	Drag Force
H	Height (between the Chord Line and the Ground)
S	Projected Area
L / D	Lift to Drag Ratio
H / C	Height to Chord Ratio
SDGE	Span Dominated Ground Effect
CDGE	Chord Dominated Ground Effect
B or b	Span
H / B	Height to Span Ratio
B^2 / S	Geometric Aspect Ratio
X_p	Centre of Pressure
e	Span efficiency
AR	Aspect Ratio
AOA	Angle of Attack

