INVESTIGATION OF AILERON HINGE MOMENT OF NATIONAL TRANSPORT AIRCRAFT BASIC TO NUMERIC METHOD

Dana Herdiana[1], SinungTirtha Pinindriya[1], Ratna Triwulandari[2]
[1]Aeronautic Technology Center - LAPAN
[2]Indonesian Aerospace
dana.herdiana@lapan.go.id, sinungtirtha@gmail.com, ratri@indonesian-aerospace.com

Abstract

Analysis has been done of aileron hinge moment on the aircraft National Transport with numerical methods in 2 Dimension. The analysis was performed to obtain a hinge moment magnitude resulting from the aileron deflections and as input to the flight control team to estimate how much force must be issued by the pilot for deflecting the ailerons to be used to fit the needs. Analysis was performed on four aileron deflection are considered the condition of aileron deflection maximum of 20 degree, -20 degree, 10 degree and -10 degree also analyzed the condition without deflection as a comparison to see the changes. The calculation is performed using numerical methods in 2 Dimension using FLUENT software. From the simulation results , the magnitude of the predictions obtained aileron hinge moment on the National Transport plane at 224.97 lb with the magnitude of the gearing ratio is 2.75 rad/m. The force generated is still too big from 67 lb based regulation FAR 23, hence the need for the addition of servo tabs and settings gearing ratio to reduce the force.

Keyword: Hinge Moment, Aileron, National Transport Aircraft.

1. INTRODUCTION

In designing an airplane, there are some requirements that need to be accounted for numeric particularly from flight control teams who want to estimate how much force must be issued by the pilot for deflecting ailerons. To meet these needs, the flight control team asked a team of aerodynamic coefficients for calculating the amount of the aileron hinge moment. Calculations used there are several ways, namely by theory, numeric, and the wind tunnel test.

The calculations will be done this time is to use numerical methods with software CFD (Computational Fluid Dynamics). CFD software is to determine the flow on the surface of the object and can calculate the force - aerodynamic forces experienced by the object. The model that will be the object to be simulated or calculated is the model of the wing airfoil coupled aileron deflection configuration with 20 degree, -20 degree 10 degree and -10 degree and configuration without deflection. The model to be tested, made in 2-Dimension with angle of attack variation. Which vary the angle of attack is from -10 degree, 0 degree, 5 degree and 10 degree. As can be seen, the nose part of this aileron variant is visibly out of the contour of the wing airfoil even at moderate angles of deflection [1]. The purpose of this simulation is to obtain a hinge moment magnitude resulting from the aileron deflections and as input to the flight control team to estimate how much force must be issued by the pilot for deflecting the ailerons to be used to fit the needs. Hinge moment is a moment that moves the hinge line of control surface that should be able to move the control surface when the pilot moving the rudder [2]. The simulation results will be analyzed by comparing the conditions of aileron without aileron deflection with the deflected condition so they will know the magnitude of the change between the conditions aileron hinge moment without deflection with the aileron deflection. In order to verify the results of the simulation analysis it is necessary to wind tunnel test under the same conditions, ranging from configuration and environmental conditions. The output of the simulation results are hinge moment coefficient (CH) and hinge moment (HM) on each configuration, with a linear shape to be analyzed.

2. METHODOLOGY

The calculation is done in two ways: numerical and theoretical. The calculation is performed by numerical methods using CFD software. The software used in the calculation is 6.3 as a solver FLUENT and GAMBIT 2.4 as the manufacture of meshing. Configuration to be simulated is the deflection 20 degree, -20 degree, 10 degree and -10 degree to -10 degree angle of attack variations, 0 degree, 5 degree and 10 degree.

2.1. Hinge Moment Theory

The approach used to calculate the coefficient of hinge moment is as follows:

$C_{H_A} = C_{H_0} + C_{H_\alpha}\alpha + C_{H_{\delta A}}\delta_A$ (1)

$C_{H_A} = \frac{H_M}{(q * S_A * \bar{c}_A)}$ (2) [3]

Where

C_{H_A} = coefficient hinge moment of aileron

C_{H_0} = coefficient hinge moment with angle of attack of 0 degree

C_{H_0} = aileron drive moment with reference position aileron hinge line on the wing angle of attack

equal to zero. Hinge moment must be divided by the dynamic pressure, aileron area and mean chord aileron hinge moment to get a non-dimensional coefficient

C_{H_α} = changes in the driving torque to the reference position aileron hinge line due to changes in the angle of attack (angle of attack) wing in the linear region. Hinge moment must be divided by the dynamic pressure, aileron area and mean chord aileron hinge moment to get a non-dimensional coefficient.

$C_{H_{\delta A}}$ = changes in the driving torque aileron deflection due to changes in the linear region at an angle of attack equal to zero. Hinge moment must be divided by the dynamic pressure, aileron area and mean chord aileron hinge moment to get a non-dimensional coefficient.

α = angle of attack

δ_A = aileron deflections

H_M = aileron Hinge moment

q = dynamic pressure= ½ *ρ*v^2

S_A = aileron area

$\bar{c}_A$ = aileron mean chord

v = aircraft speed

So, to obtain value of hinge moment obtained from

HM = CH* S_A* $\bar{c}_A$ *q (3)

q =0.5*ρ∗v^2 (4) [4]

Where: VMO = 190 knots =0.29 M

2.2. Simulation Consideration of Hinge Moment

To estimate aerodynamic hinge moment, measurements required during flight, but can also be estimated with simulation predictions. Configuration to be simulated is the deflection 20 degree, -20 degree, 10 degree and -10 degree to -10 degree angle of attack variations, 0 degree, 5 degree and 10 degree. Simulation using FLUENT software as a solver and Gambit as a maker of meshing on the model. To use the model density-based solver and energy, as well as the use of viscous spalart-allmaras models because the model is simulated outflow. Boundary conditions used in the simulation is part of the model and the wall for the outdoor area far field is set as the pressure at the inlet, outlet and far field. Parameters are set as far field pressure is to pressure P = 84307.11 Paskal, velocity V ~ = 0.162 M, temperature T = 303.24 K.

The following is geometry of the wing plus aileron.

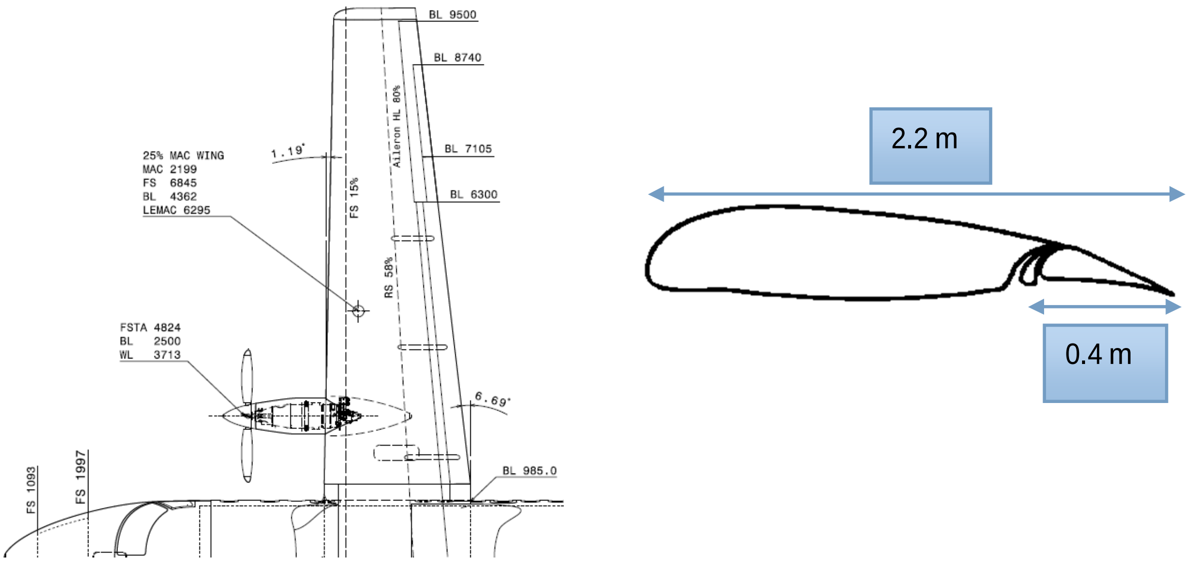

Figure 2-1 Wing Geometri with aileronand airfoil [6]

Orientation movement of the aileron, aileron deflection downwards positive direction and negative direction upward shift at request aileron deflection, shown in Figure 2-2.

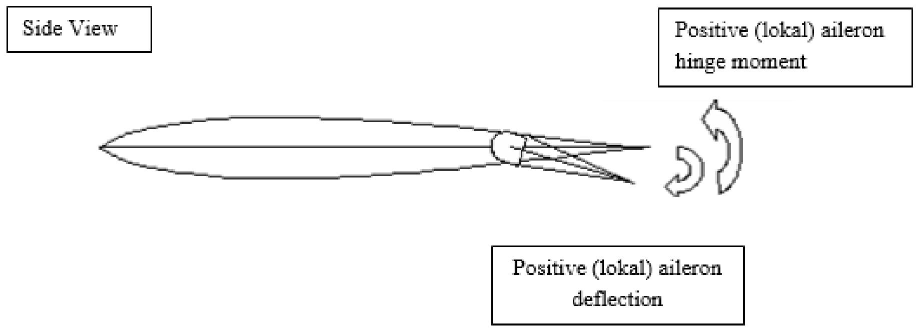

Figure 2-2 Axis System and sign convention

Airfoil geometry models that will be simulated is taken from the wing at the aileron along with the mean chord length of 2.2 m and a mean wing chord aileron at 0.4 m. The airfoil models can be seen in Figure 2-3.

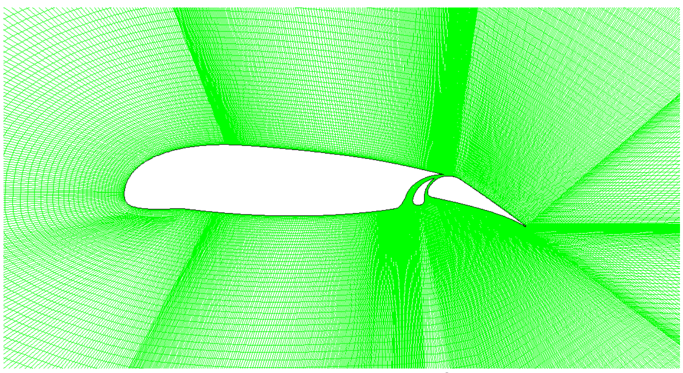

Figure 2-3 Example grid near the wing airfoil models + aileron [7]

3. RESULT AND DISCUSSION

From investigation result in simulation that was done in a variation angle attack from -10 degree, 0 degree, 5 degree, and 10 degree and deflection aileron 20 degree, -20 degree, 10 degree, and -10 degree. The amounts hinge moment is one of the biggest happened in a situation where aileron done deflection in the corner 20 degree and angle of attack at 10 degree.

3.1. Simulation Result

This simulation is calculated using Fluent software and 2D approaches. Parameters are set as far field pressure is to pressure P = 84307.11 Paskal, velocity V ~ = 0162 M, temperature T = 303.24 K. The following is view of simulation results the flow distribution with aileron deflection angle of 20 degree and - 20 degree and the angle changes attack ranging from -10 degree, 0 degree, 5 degree and 10 degree.

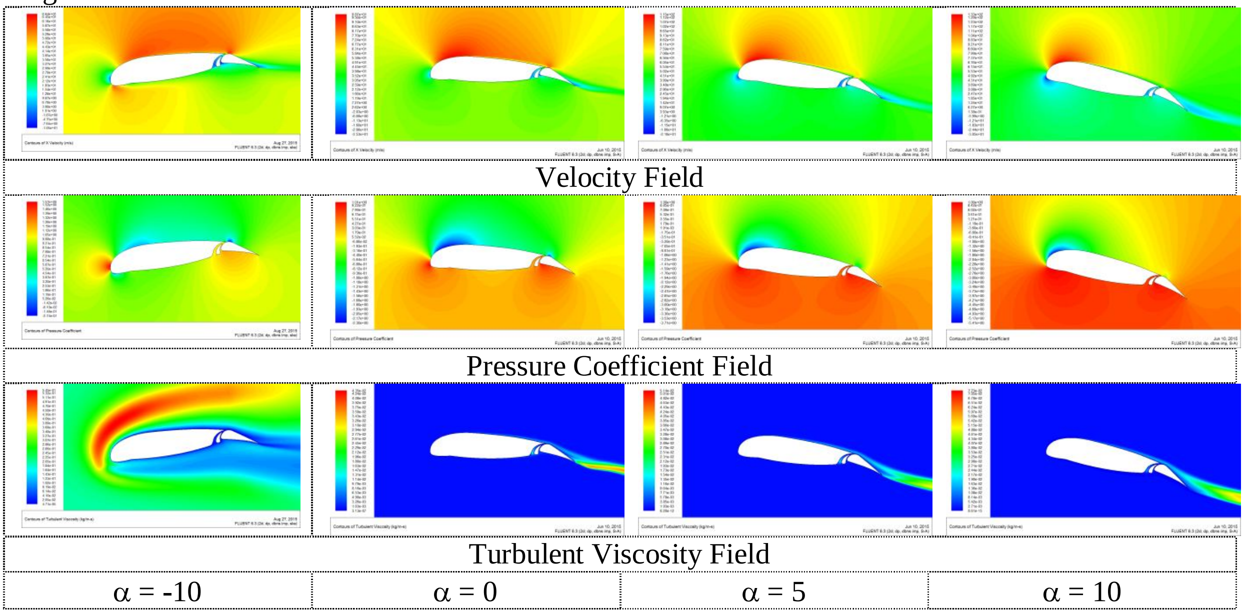

Figure 3-1 Speed Distribution, Coefficient Pressure and turbulent viscosity with aileron deflection 20 degree [8].

From Figure 3-1 visible changes in velocity and pressure distribution coefficient for the deflection of aileron 20 degree, where red color indicates high numbers and low numbers of blue color. For the velocity distribution of the changes seen in the attack angle 10 degree angle of attack surface of the chamber upper section further down stream region of aileron and the greater the pressure distribution means that the amount of hinge moment in the region is great. Hinge moment coefficient is affected by viscous effects and leakage flow between the aileron and the main lifting surface [9]. Distribution of turbulent viscosity seen with increasing angle of attack turbulent flow behind the greater aileron.

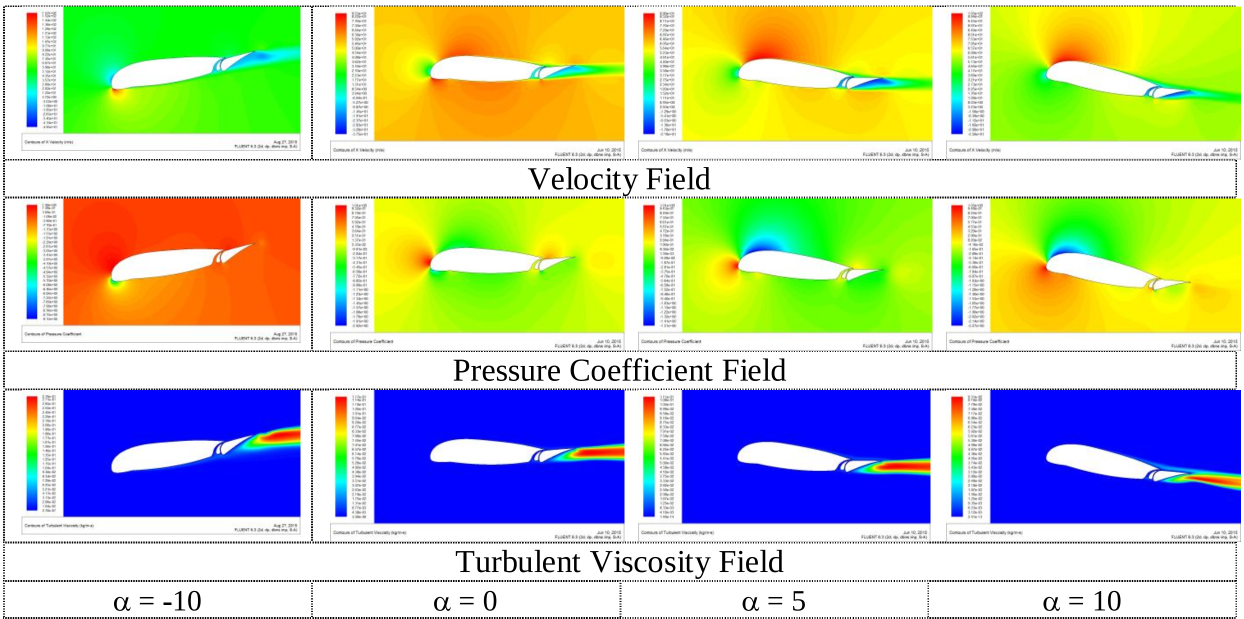

Figure 3-2 Speed Distribution, Coefficient Pressure and turbulent viscosity with Aileron deflection -20 degree.

From figure 3-2 visible changes in the distribution of velocity, pressure and turbulent viscosity coefficient for aileron deflection -20 degree, where red color indicates high numbers and low numbers of blue color. In the deflection angle of -20 degree to look at changes in velocity distribution angle of attack there are changes in the movement of the point of separation that initially were behind to come forward with increasing angle of attack. Coefficient pressure increases with increasing angle of attack. Distribution of turbulent viscosity seen with increasing angle of attack turbulent flow behind the greater aileron.

3.2. Hinge Moment Calculation

Calculations show that the hinge moment when the aileron deflection increases as the angle of attack increases. This indication shows that the separate flow increases hinge moment drag caused by high pressure. It can also interpret the slope of the curve increased hinge moment at a higher angle of attack. This shows a very important from the pressure drag caused by the separation of the boundary layer to properties associated with aileron, rudder and elevator.
These effects cannot be ignored in the design process airfoil this configuration types [10]. Here are the results of the simulation approach.

Table 3-1 Coefficient Hinge Moment at aileron deflection variation.

α/δAileron (degree)	CH				
	δAileron -20	δAileron -10	δAileron 0	δAileron 10	δAileron 20
-10	0.505	0.413	0.311	0.167	-0.101
0	0.034	-0.022	-0.211	-0.376	-0.533
10	-0.406	-0.523	-0.690	-0.865	-0.998

From the table above shows the highest value obtained on condition of aileron deflection 20 degree and 10 degree angle of attack and the lowest value obtained in conditions of -10 degree aileron deflection and angle of attack of 0 degree. The coefficient calculation results above will be used to obtain the magnitude of hinge moments using equation (3). Here are the results of the calculation of the hinge moment.

Table 3-2 Hinge moment ataileron deflection variation

α/δAileron (degree)	HM (Nm)				
	δAileron -20	δAileron -10	δAileron 0	δAileron 10	δAileron 20
-10	825.07	674.73	508.57	272.74	-164.65
0	56.17	-36.11	-345.16	-615.00	-871.32
10	-664.19	-854.90	-1128.55	-1415.10	-1631.92

From Table 3-2 shows that the magnitude of the deflection aileron hinge moment to change the angle of attack is different but to ascertain the magnitude of the hinge moment, its value is made absolute where the condition of the angle of attack is a linear condition. For the greatest value on the hinge moment deflection 20 degree and 10 degree angle of attack of 1631.92 Nm and the smallest at -10 degree and aileron deflection angle of attack of 0 degree at 36.11 Nm.

3.3. Analysis Calculation Result

Aileron hinge moment predicted by pitching moment coefficient with a reference point on the pivot movement of the aileron. This prediction is done with 2D approach and is calculated by FLUENT, assuming if CH = CM at the pivot point aileron.

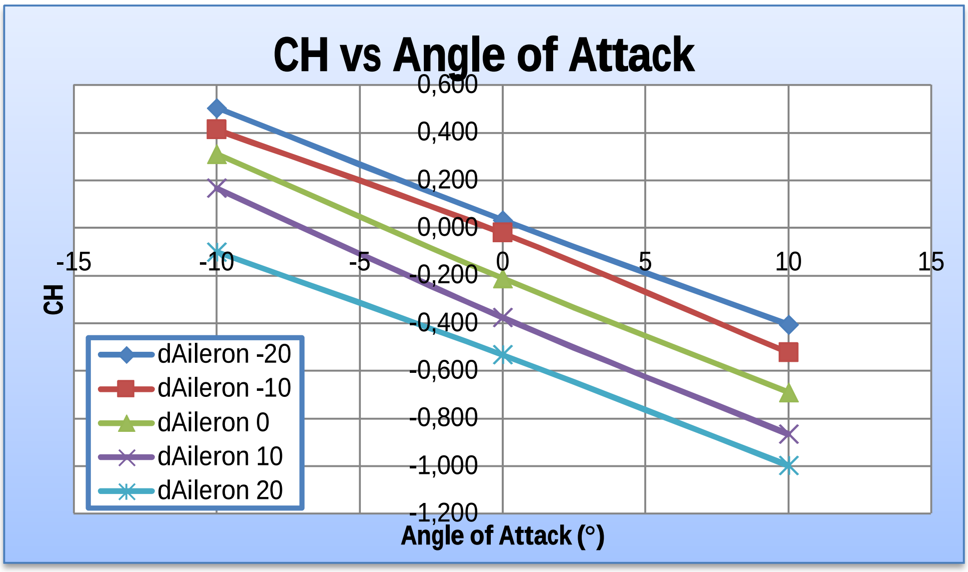

Figure 3-3 Coefficient hinge moment vs angle of attack with changesof aileron deflection angle [11].

Figure 3-3 shows the hinge moment coefficient with change in aileron deflection and angle of attack. The figures show a trend hinge moment coefficient tends to decrease with increasing angle of attack and hinge moment coefficient values will decrease if the aileron deflection positive direction. From Figure 3-3 can be obtained values as follows

CH0	-0.211
CHα	-0.050
CHδA	-0.014

Table 3-3 Hinge moment to estimate the amount of force that must be removed pilot deflecting aileron on the angle of attack of 0 degree.

δA	HMδA (lb)	HMδA (kg.f)
-20	73.45	33.05
-10	-75.76	-34.09
0	-224.97	-101.23
10	-374.17	-168.38
20	-523.38	-235.52

Based on the predicted results can be seen in Table 3-3 that large aileron hinge moment with a deflection of 0 deg at 224.97 lb , with the value of the force generated is still too big of a hinge moment magnitude based regulation FAR 23 is equal to 40-67 lb. From these results it is necessary to recalculate to reduce the force generated by way of added servo tab.

4. CONCLUSIONS

From the results predicted by using simulations show that

a. The maximum value aileron hinge moment on one side is HM δA = 523.38 lb on 20 and aileron deflection angle of attack 0.
b. The magnitude of the predictions obtained aileron hinge moment on the National Transport plane at 224.97 lb with the magnitude of the gearing ratio is 2.75 rad/m.
c. The force generated is still too big from 67 lb based regulation FAR 23, hence the need for the addition of servo tabs and settings gearing ratio to reduce the force.
d. Results of the graph is linear, so with the increase in the value of a particular attack angle hinge moment is absolute and will be enlarged depending on the orientation of the aileron deflection.

5. RECOMMENDATIONS

a. To do simulations by using a better grid so that the results of calculation approximating.
b. To do verification of the simulation results with testing in a wind tunnel.
c. Keep calculation sizing of servo tabs to reduce the magnitude of the force, which the force generated is still too big of restrictions that exist in the regulation of FAR 23.

ACKNOWLEDGMENT

The author would like to say thanks for supporting to Head of Aeronautic Technology Center Drs. Gunawan Setyo Prabowo, M.T and Head of Aerodynamics Technologies Division Ir. Agus Aribowo, M.Eng in guidance paper and to friends from LAPAN and PT Dirgantara Indonesia involved in this research.

REFERENCES

1) Makarov, K.A. and Pavlenko, A.A. "*Numerical Investigation of an Aileron Hinge Moments and Effectiveness ona High Lift Wing Airfoil*". Congress of International Council of the Aeronautical Sciences, Russia, 2014.
2) Hambrick, E.M. and Thomason N.M. "*Conceptual Aircraft Hinge Moment Measurement System*". Degree Bachelor of Science in Aerospace Engineering. Faculty of the Aerospace Engineering Department California Polytechnic State, 2010.
3) Boyd Perry III, "*Control-Surface Hinge-Moment Calculations for a High-Aspect-Ratio Supercritical Wing*", NASA Technical Memorendum 78664, 1978.
4) Anderson, J. D. Jr. "*Fundamentals of Aerodynamics*". Fifth Edition. McGraw-Hill. New York,2010.
5) Mulder M., Lubbers B., Zaal P.M.T., van Paassen M. M., and Mulder J. A., "*Aerodynamic Hinge Moment Coefficient Estimation Using Automatic Fly-By-Wire Control Inputs*". AIAA Modeling and Simulation Technologies Conference, Chicago, Illinois, 2009.
6) CATIA, Software Package, Ver. 5.21, Dassault Systems, 1998 – 2011.
7) GAMBIT, Software Package, Ver. 2.4.6, ANSYS, Inc., 1988-2010.
8) FLUENT, Software Package, Ver. 6.3, ANSYS, Inc., 2011.
9) Caughey D., A., "*Introduction to Aircraft Stability and Control Course Notes for M&AE 5070*", Cornell University Ithaca, New York, 2009.
10) Ylilammi N.,"*Experimental and Computational Study of Two Flapped Airfoils at Low Reynolds Numbers*", Thesis Submitted In Partial Fulfillment Of The Requirements For The Degreeree Of Master Of Science In Technology, Helsinki University Of Technology, 2009.
11) Rassieur W.T., "*Hinge Moments*", Thesis In Partial FulFillment of the Requirements for The Degreeree of Master of Science in Aeronautical Engineering, California Institute of Technology, Pasadena California, 1934.
12) Federal Aviation Administration (FAA), FAR (Federal Aviation Regulations) Part 23, Airworthiness Standards : Normal, Utility, Acrobatic and Commuter Category Airplanes, Update to amendment 55.