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Original Article

Design Modification of the Horizontal Tail and Performance Simulation of LSU-05NG Drone

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Abstract: LSU-05NG is a drone manufactured and developed by LAPAN. The horizontal tail of the aircraft is used to maintain longitudinal stability, however, there has been no study on a tail modification that could improve the performance. The study of tail modification will examine the impact of modifying the airfoil to NACA 2412 and NACA 63-215. The base model of LSU-05NG uses NACA 0012 as the airfoil profile which is used in the horizontal tail. The performance is measured from the value of the lift coefficient, drag coefficient, and longitudinal stability. The results are obtained using ANSYS CFX software. Based on the study, the modification of the horizontal tail has no impact on the lift and drag coefficient, however, impacts greatly on the pitching coefficient which determines the longitudinal stability. The airfoil profile that produces the highest longitudinal stability is NACA 63-215, followed by NACA 2412, and the last is the basic model using NACA 0012.

Keywords: LSU-05NG; Tail Modification; Airfoil; Performance; CFX ANSYS

1. Introduction

Indonesia is a developing country, especially in its technology. One of the institutions that move to advance the development of technology in Indonesia is LAPAN (Lembaga Penerbangan dan Antariksa Nasional), this institution is engaged in the field of space such as Indonesian-made satellites, and aviation such as drones and aircraft made in Indonesia. Drones that are made are multipurpose drones that can be used as surveillance or SAR (Search and Rescue) and named LSU (LAPAN Surveillance UAV). Until now, LAPAN has developed the LSU to the fifth version named LSU-05NG (LAPAN Surveillance UAV 05 Next Generation) [1,2].

LSU-05NG drone has the same parts as an airplane in general, this includes the fuselage, wing, and tail of the aircraft. The tail on an airplane is divided into horizontal and vertical tails. The horizontal tail has the main function of providing longitudinal stability to the plane. The airfoil on the horizontal tail on LSU-05NG drone uses type NACA 0012 which is a symmetrical airfoil. There has been no modification research that is done using a different type of airfoil. However, there is still a lot of different airfoil type that can be used on the tail of the drone so it can produce higher performance, especially the longitudinal stability of the drone [3]. Performance in this study means the lift coefficient, drag coefficient, and longitudinal stability. Where the lift is the effect of a fluid passing through an object, creating a pressure difference between the top and bottom of the object, resulting in lift force. Drag is a force that opposes the direction of motion of an object, which is caused

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by the resistance of the object. Longitudinal Stability is the moment force of the aircraft during the pitching motion [4-6].

Each profile on the airfoil can produce different performance characteristics. Airfoil can be determined by the number and type of airfoil. The most common type of airfoil is the airfoil developed by the National Advisory Committee for Aeronautics or NACA. The NACA airfoil profile is divided based on the numbering of the airfoil name, for example, there are NACA 0012, NACA 2412, NACA 63-215, and others [7,8].

In this study, NACA 2412 and NACA 63-215 airfoil profiles were used as the modification on the horizontal tail. It will be conducted using ANSYS CFX to simulate its performance and gather the speed contour around the drone. The main purpose of this study is to examine the effects of how the horizontal tail airfoil profile is affecting plane performances.

2. Methods

2.1. Design Modification of the Horizontal Tail

The design of the modification uses SolidWorks to change the profile of the airfoil. NACA 2412 and NACA 63-215 coordinates is gathered from the airfoil database. The coordinates will be converted into a format that is compatible to be read by SolidWorks. The coordinates will replace the horizontal tail of the drone, then will be extruded 775mm onto both sides of the z-axis. Then the model will be saved as STEP in order to be imported to ANSYS CFX. All models designed are shown in Figure 1.

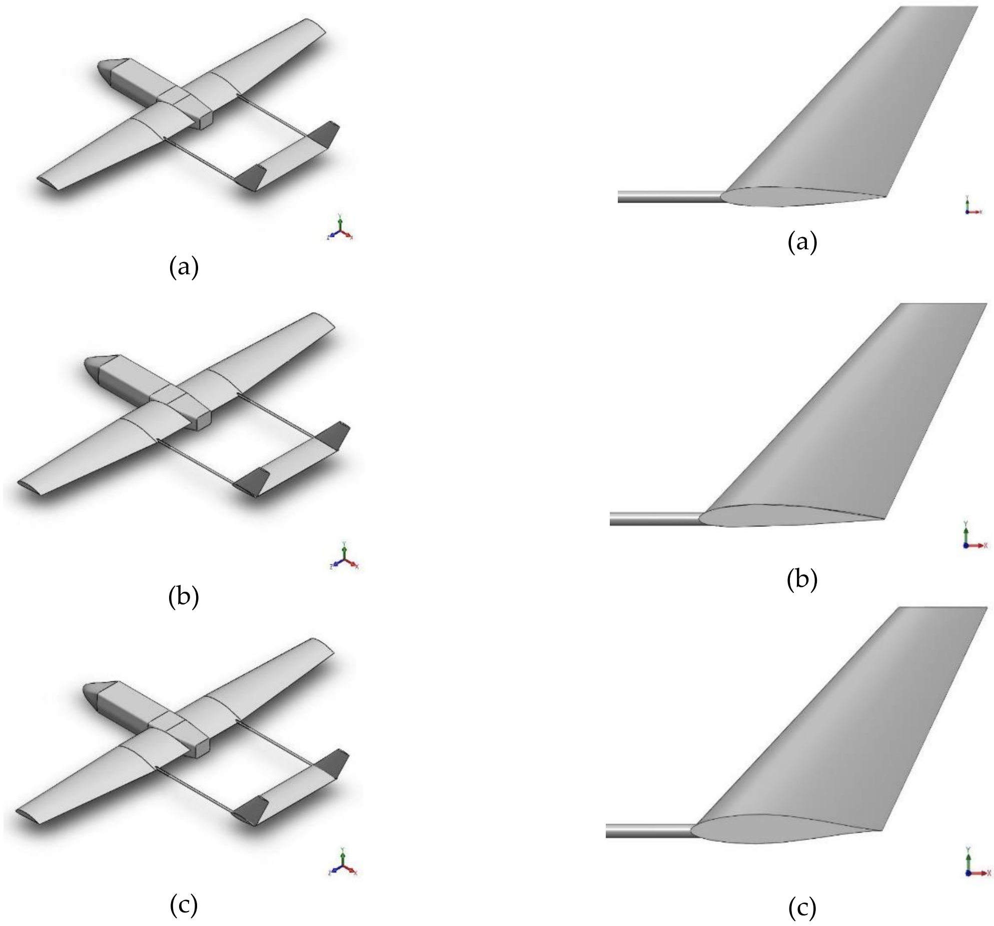

Figure 1. Drone Design (a) Base model using NACA 0012 (b) Modification model using NACA 2412 (c) Modification model using NACA 63-215.

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2.2. Enclosure Design

Using DesignModeler, the model can be first imported using the import geometry option. The study will use two enclosures to help ease the meshing procedure. Then by designing the enclosure around the model referencing Figure 2. and Table 1.

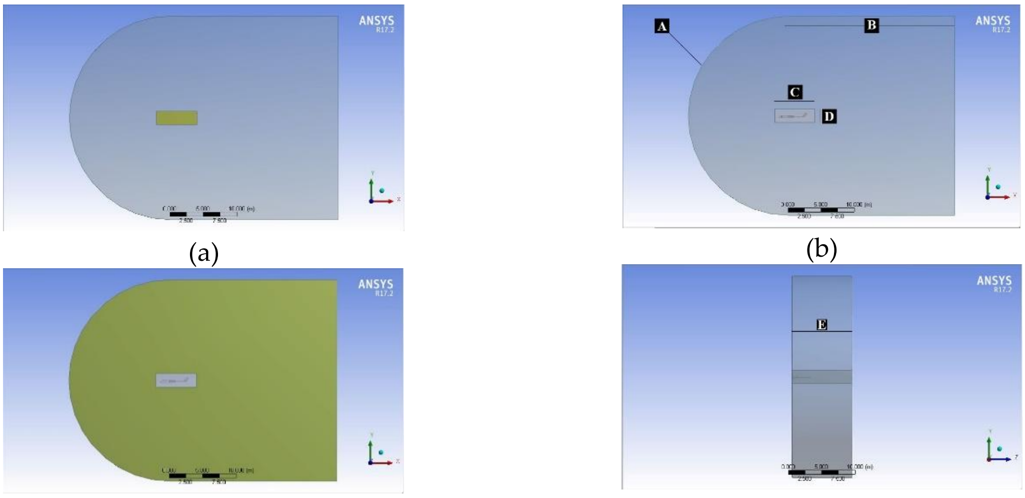

Figure 2. Enclosure Design (a) Inner Enclosure (b) Outer Enclosure (c) Front facing enclosure (d) Side facing enclosure

Table 1. Enclosure size

Section	Size
A	Radius = 15 m
B	25 m
C	6 m
D	2 m
E	9 m

Using Boolean Subtract, the model of the drone can be subtracted from the inner enclosure. This simulation will be using half of the drone's model, as the model have a symmetrical design.

2.3. Meshing

The first step of the meshing process is to name its face geometry, inlet, outlet, symmetry, farfield, and LSU (Drone). Face geometry can be seen in Figure 3.

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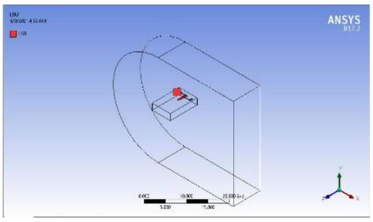
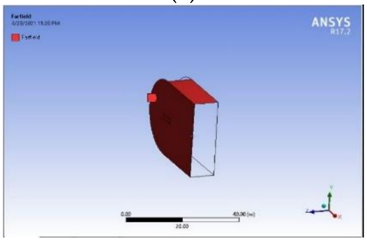
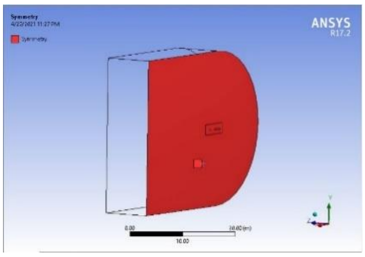


(c)



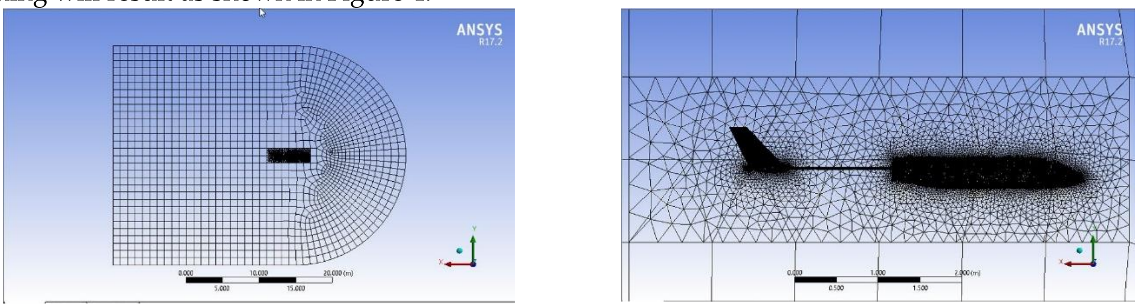
(d)



(e)

Figure 3. Named Geometry (a) Inlet (b) Outlet (c) LSU (d) Farfield (e) Symmetry

For this study, meshing will be using two option, inflation and LSU face sizing. In the end, the meshing will result as shown in Figure 4.



(a) (b)

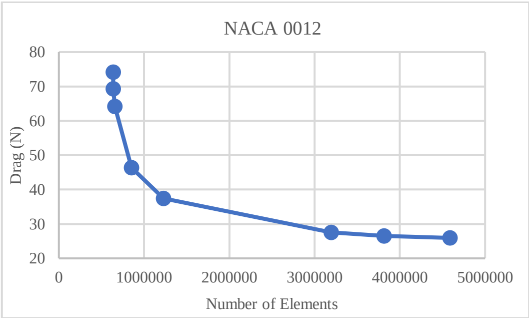
Figure 4. Meshing Result (a) Overall View (b) Drone Area View

2.3. Meshing Refinement

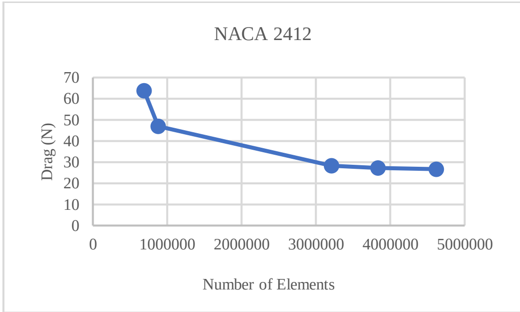
Meshing refinement is a method to determine the most optimum face sizing used, where the results of the force have produced a convergent value compared to the number of element sizes. At this stage, testing is carried out on the basic model with sizes 0.1 m, 0.08 m, 0.06 m, 0.03 m, 0.01 m, 0.009 m, and 0.008 m. It is found that the force starts to converge when the size is 0.01 m, as can be seen in Figure 5a.

For the other two models, tests were carried out on the size of 0.06 m, 0.03 m, 0.01 m, and 0.009 m. It is found that the force starts to converge when the size is 0.01 m as well, as can be seen in Figure 5b and 5c.

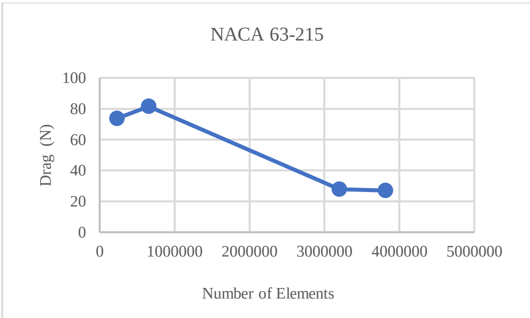
So, it can be concluded that the face sizing used in angle-of-attack simulation is 0.01 m on the three of the drone models.



(a)



(b)



(c)

Figure 5. Meshing Refinement Result Drag Forces vs Number of Elements (a) NACA 0012 (b) NACA 2412 (c) NACA 63-215

2.4. Angle-of-attack simulation

Data gather from previous step, the angle-of-attack simulation will use the meshing generated using 0.01m mesh for all the models. Parameter used in this simulation is, air velocity is $30\ m/s$, fluid density $1.225\ kg/m^3$, reference area $3.22m^2$, reference length $4{,}1945\ m$, and angle-of-attack from -10° to 18° [9]. The simulation will gather lift, drag and pitching moment from ANSYS CFX. Using equation, lift coefficient, drag coefficient, and pitching moment coefficient can be calculated.

3. Results

3.1. Validation

Validation of the data is done by comparing data gained from simulation of the base model (NACA 0012) with data from the LSU-05 model testing using a wind tunnel [10]. The result will be shown from Table 2.

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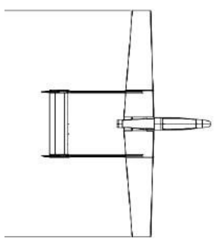
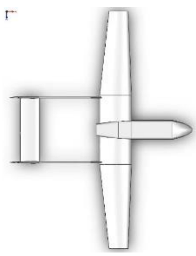
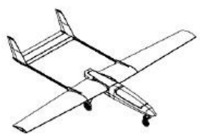
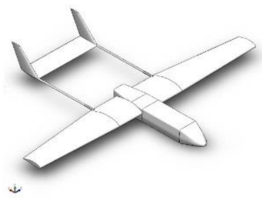
Table 2. Data Validation

α	Experimental Data		Simulation of the base model	
	Lift (N)	Cl	Cl	Error (%)
-8	-52,1	-0,349613747	-0,2659	25,0551
-6	-11,7	-0,078512108	-0,0906	65,1754
-4	44,4	0,297943385	0,12018	70,6166
2	84,3	0,565689806	0,31543	2,22364
0	120,1	0,805923437	0,52797	12,992
2	188,7	1,266259388	0,73537	1,8499
4	225,5	1,513203455	0,93224	7,47817
6	257,4	1,727266383	1,10929	11,2456
8	290,4	1,948710791	1,26916	12,4802
10	312,6	2,097682484	1,40487	14,8905
12	325,4	2,183576072	1,46428	14,9998
14	293,3	1,968171057	1,48539	24,4739

The reason of the high error percentage is because it is compared using different model, the simulation uses LSU-05NG while the experimental uses LSU05 body. The difference is that the design of the fuselage of the plane, Table 3. will show the difference of both models.

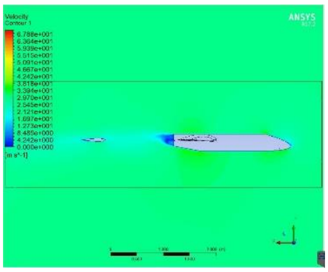
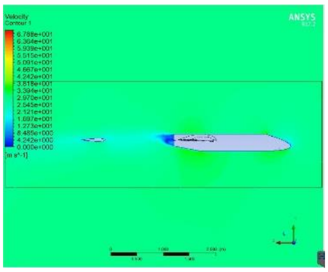
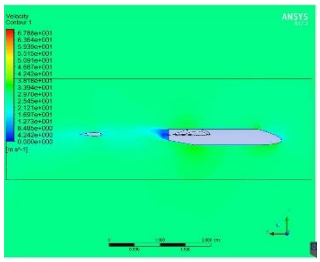
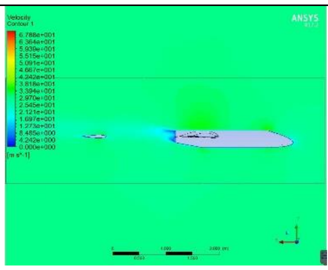
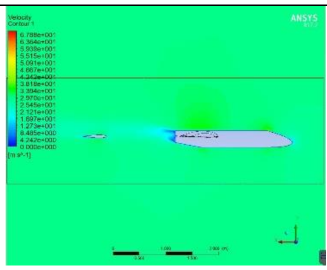
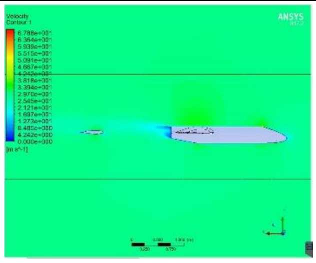
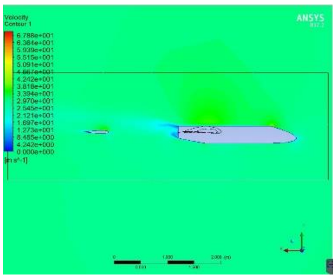
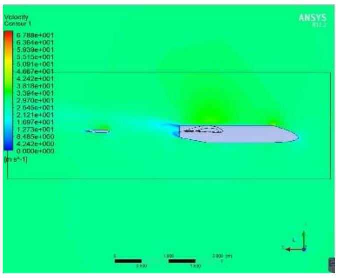
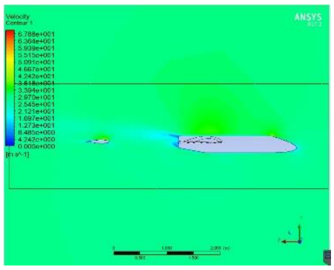
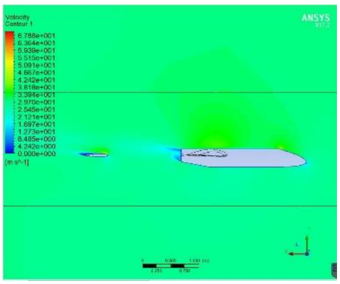
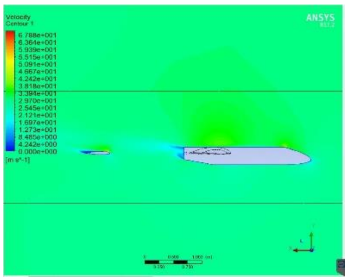
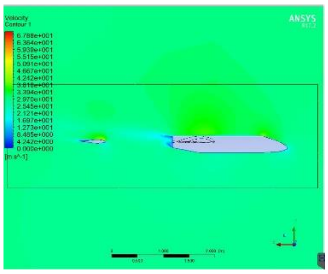
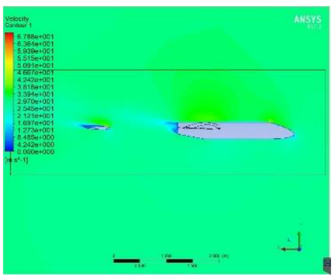
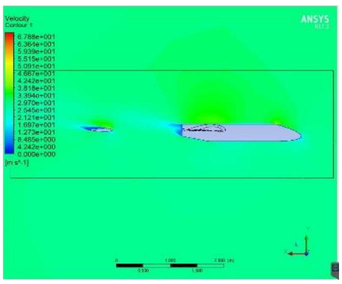
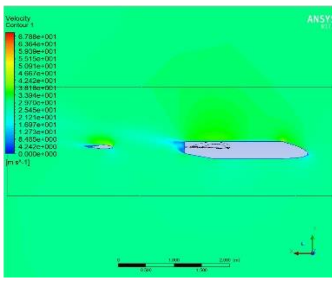
Table 3. Comparison of LSU-05 and LSU-05NG model models

Model		Description
LSU-05	LSU-05NG	
		Top View
		Isometric View
		Realization Model

3.2. *Speed Contour Visualization*

Speed Contour Visualization can be gathered from ANSYS CFX for all three of the models. Table 4. shows the angle of attack on the aircraft which shows important data.

Table 4. Speed Contour Visualization

No	NACA 0012	NACA 2412	NACA 63-215	α
a.				-8°
b.				0°
c.				8°
d.				14°
e.				16°

3.3. Lift Coefficient, Drag Coefficient, Pitching Moment Coefficient

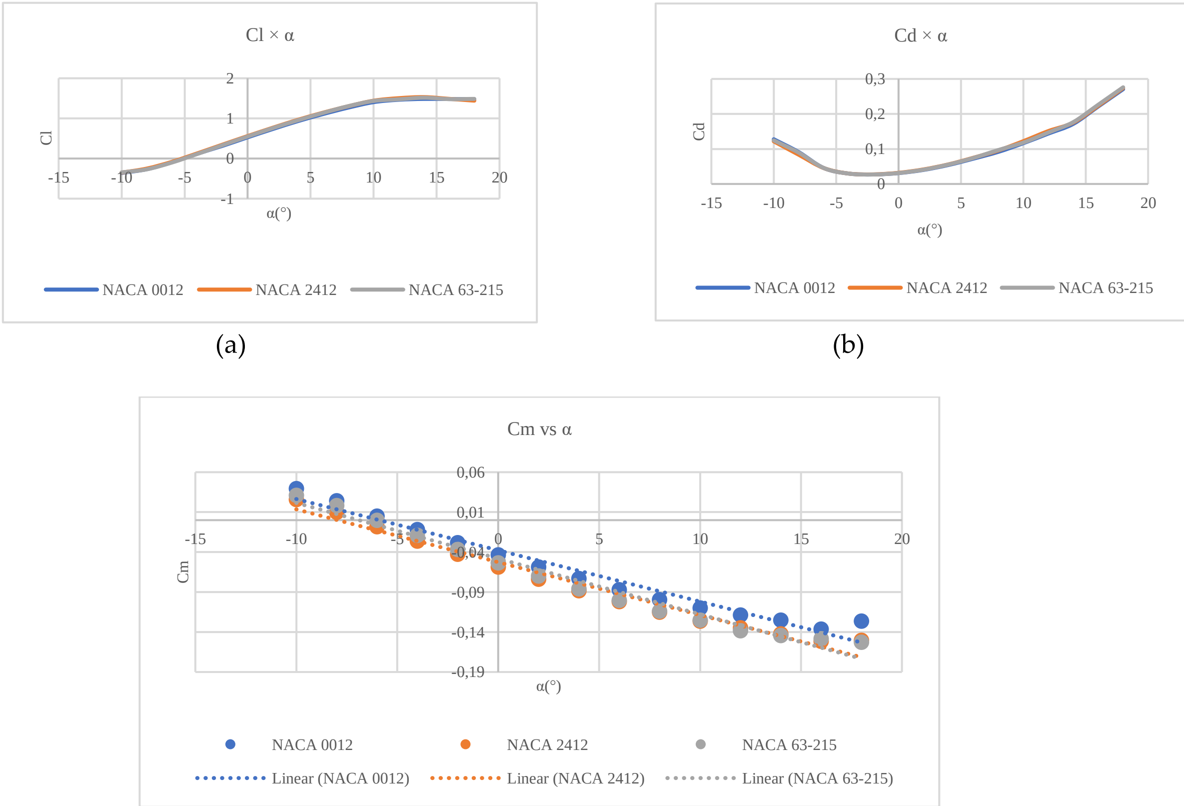
Based on the data gathered from the simulation using following parameters, air density is 1.225 kg/m^3, fluid velocity is 30 m/s, reference area of 3,22 m^2,and reference length of 4.19495 m. The following data are obtained and shown at Table 5, Table 6, and Figure 6.

Table 5. Cl and Cd Simulation Data

α	Cl			Cd		
	NACA 0012	NACA 2412	NACA 63-215	NACA 0012	NACA 2412	NACA 63-215
-10	-0.359809853	-0.351739937	-0.345701628	0.127661537	0.121771439	0.124537401
-8	-0.265901693	-0.250459535	-0.268714952	0.090992872	0.083532195	0.089608734
-6	-0.090578103	-0.0821424	-0.099013805	0.045637828	0.045515299	0.045760357
-4	0.12017569	0.127556441	0.112794938	0.029699451	0.029719102	0.0296798
-2	0.315429165	0.345086609	0.332007799	0.027054438	0.027390893	0.027032218
0	0.527970029	0.558752694	0.547451444	0.03104069	0.031890255	0.031323502
2	0.735371503	0.766776311	0.75739563	0.040147688	0.041539036	0.0408718
4	0.932240503	0.964797621	0.954076177	0.054239236	0.055962528	0.05555429
6	1.109288027	1.143105284	1.137396018	0.072306353	0.074896561	0.074349687
8	1.269158425	1.302528778	1.304777658	0.091701663	0.095672973	0.096888087
10	1.40487174	1.440712127	1.434524755	0.116476006	0.122182811	0.118188966
12	1.464276948	1.503245453	1.475213623	0.143889888	0.150973246	0.146824901
14	1.485390087	1.530080363	1.515560804	0.171561721	0.175209222	0.176602869
16	1.481954757	1.486820156	1.480271146	0.221304416	0.223365554	0.22617953
18	1.478813191	1.442056007	1.485413418	0.27078311	0.274175437	0.276052254

Table 6. Cm and dCm/da Simulation Data

α	Cm			dCm/da		
	NACA 0012	NACA 2412	NACA 63-215	NACA 0012	NACA 2412	NACA 63-215
-10	0.039457	0.025877565	0.031030838			
-8	0.024313	0.00993105	0.018086952			
-6	0.005132	-0.008087142	-0.00015481			
-4	-0.01185	-0.026231037	-0.018971706			
-2	-0.02813	-0.04284904	-0.036577335			
0	-0.04366	-0.058680059	-0.053463934			
2	-0.0587	-0.073882564	-0.069807971			
4	-0.07323	-0.088217506	-0.085773287	-0.006413943	-0.006610983	-0.00696872
6	-0.08723	-0.102085092	-0.100409056			
8	-0.09977	-0.115181808	-0.113895236			
10	-0.10987	-0.126427902	-0.125082239			
12	-0.11878	-0.134896718	-0.138342798			
14	-0.12538	-0.14242545	-0.144407685			
16	-0.13625	-0.151726912	-0.148587031			
18	-0.12657	-0.150394678	-0.152785178			



(a) (b) (c)

Figure 6. Comparison of Simulation Data Result of All Models (a)Lift Coefficient (b) Drag Coefficient (c)Pitching moment Coefficient

4. Discussion

It can be seen from Table 4, the visualization of the fluid experienced by the three models is quite the same so that the modification of the airfoil profile does not have a major effect or change the airflow that passes through the LSU-05NG drone. Starting at an angle of 14º which can be seen from Table 4 number d and e, air separation is visible in the horizontal tail. This air separation indicates the aircraft is starting to stall. This stall is an event where the airfoil cannot produce maximum lift because the fluid during air separation does not have contact with the surface of the airfoil.

Based on the data gathered from the simulation, the modification of the airfoil profile on the horizontal tail of the LSU-05NG drone affects the Cm value or pitching moment coefficient, while the Cl value or lift coefficient and Cd value or drag coefficient are not too affected. It can be seen that the two values have a difference of less than 10%. Meanwhile, judging from the difference in the smallest Cm, the difference has exceeded 10%. Therefore, it can be concluded that the modification of the horizontal tail airfoil profile does not affect the Cl and Cd values but does affect the Cm values [10].

The maximum Cl value of the three models is produced at an angle-of-attack angle of 14º, and starting from that angle, the aircraft condition has experienced a stall where flow separation occurs on the aircraft, this event can be seen in Table 4 in numbers c. It can be seen from the drag coefficient; the three models experienced a higher increase starting from an angle of 14. In Figure 6c, three models have different Cm values. The Cm values can be sorted from high to low, the basic model with the NACA 0012 airfoil, the model with the modified NACA profile 63-215, and the lowest is the model with the modified NACA 2412 profile.

The longitudinal stability of an aircraft can be measured by the gradient of the curve from Cm to the angle-of-attack. Longitudinal stability is intended if the angle-of-attack of the aircraft increases, the aircraft can return to its original position or a stable position. The value of $\partial Cm/\partial\alpha$ is obtained from the ratio of changes in the value of Cm to changes in the angle of attack. Based on Table 6, the simulation results of the three models tested were obtained. So, the model modified using NACA 63-215 produces higher stability with the most negative $\partial Cm/\partial\alpha$ with a value of -0.00696. followed by the NACA 2412 airfoil profile model with a $\partial Cm/\partial\alpha$ value of -0.00661. The last is the basic model of NACA 0012 with a $\partial Cm/\partial\alpha$ value of -0.00641.

5. Conclusions

Based on the study of all models through the CFD simulation carried out, several conclusions can be drawn including that the modification of the airfoil profile on the horizontal tail of the LSU-05NG has little effect on Cl and Cd values but has a significant effect on Cm values. The LSU-05NG drone has a maximum Cl value at an angle of 14° and experience stalling starting from that angle. Modification of the horizontal tail airfoil profile of the LSU-05NG drone has no significant effect on the shape of the airflow that passes through it. From the three LSU-05NG models tested, the airfoil profile that has the highest longitudinal stability is the NACA 63-215 airfoil profile, followed by the NACA 2412 airfoil profile, and finally the basic model using the NACA 0012 airfoil profile.

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