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PUNA Aircraft Static Stability Simulation Using XFLR5 Software

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ABSTRACT

Currently the development of Unmanned Aircraft is experiencing a very rapid increase. This is demonstrated by the large number of uses of Unmanned Aircraft in several sectors, one of which is for monitoring traffic density. On this mission, the aircraft will carry a payload in the form of a camera used to record or display the existing traffic situation. This mission requires aircraft with good stability capabilities to be able to provide good monitoring results. Thus, it is necessary to analyze the static stability in longitudinal, lateral, and directional motion. Static stability simulation was carried out with the help of XLFR5 software. The simulation results are then compared with the parameters that are a requirement for longitudinal, lateral, and directional static stability.

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1. INTRODUCTION

Aviation technology in Indonesia is developing very rapidly, not only in commercial and military aircraft, but also in Unmanned Aircraft (PUNA) technology. This aircraft is capable of flying without a pilot accompanying the aircraft during the flight. The control can be carried out by the pilot remotely at the ground-station or can fly independently based on a pre-programmed flight plan or a more complex automated system. For these advantages, unmanned aircraft are usually designed to fulfill certain functions or carry out special missions, one of which is to monitor traffic density.

In previous studies, the initial design of PUNA aircraft for traffic density monitoring missions as a replacement for helicopters was carried out [9]. Using PUNA will be cheaper in terms of cost and easier to operate. However, the dimensions are smaller and the weight is lighter than helicopters or manned aircraft in general, making it easy for PUNA to enter an unstable state when disturbed. In addition, the low flying altitude and the pilot's control which is far from the aircraft also makes PUNA easily unstable so it is prone to flying accidents. Based on its weight and performance, PUNA is included in the small UAV category. In designing PUNA, it is necessary to pay attention to the configuration and placement of aircraft components because it can affect their static stability. So that in a PUNA design process before entering the production stage, it is important to do an analysis of static stability [3,4,5,7]. The aspect of flight stability is an important aspect that must be considered in the aircraft design process. If an airplane is made too stable, it can reduce its ability to maneuver. Conversely, if the aircraft is made with a low level of stability, it will be very easy to maneuver. However, this will make the aircraft very difficult to fly or have poor flight stability. Therefore, to support operations, they can carry out missions properly. PUNA aircraft are needed which have stable flying characteristics and are easy to control. Seeing the importance of the aircraft stability function, it is necessary to analyze the static stability of the PUNA aircraft. Aircraft flight stability can be determined by performing a stability analysis using XFLR5 software.

2. RESEARCH METHOD

2.1. Static Stability

Static stability is the initial tendency of an airplane to return to an equilibrium position after being disturbed. An airplane is said to have static stability if, after a disturbance, forces and moments arise which can make the airplane tend to return to its equilibrium condition. Static stability characteristics must be sought for an equilibrium condition in which all the moment forces are in a balanced condition. Analysis of static stability is divided into 3 namely longitudinal static stability, directional static stability, and lateral static stability.

2.2. Longitudinal Static Stability

Longitudinal static stability relates to the motion of the aircraft in a symmetrical plane, namely the plane formed by the x axis and the z axis with the y axis of motion. So that in this stability, the airplane is seen from the side and the motion observed is the pitch motion. In this stability, it will be seen how disturbances cause changes in the angle of attack (α) (or lift efficiency (C_L)) and pitch moments that occur in airplanes. An airplane is said to have static stability if $C_{m_0} > 0$ dan $C_{m_\alpha} < 0$ (atau $\frac{dC_m}{dC_L} < 0$).

2.3. Directional Static Stability

Directional static stability relates to the motion of the aircraft in the plane formed by the x axis and the y axis with the z axis of motion. So that in this stability, the aircraft is seen from above or below and the motion observed is yaw motion. In this stability, it will be seen how the disturbance causes a change in the side slip angle (β) and the yaw moment that occurs in an airplane. An airplane is said to have static stability if $C_{n_\beta} > 0$.

2.4. Lateral Static Stability

Lateral static stability relates to the motion of the aircraft in the plane formed by the y axis and the z axis with the x axis of motion. So that in this stability, the airplane is seen from behind or in front and the motion being observed is roll motion. In this stability, we will see how the disturbance causes a change in the side slip angle (β) and the roll moment that occurs in an airplane. An airplane is said to have static stability if $C_{l'_\beta} < 0$.

2.5. PUNA modeling

PUNA modeling was carried out using XFLR5 software. This software was chosen because it can analyze aerodynamics and stability. The first step is to analyze the aerodynamics of the airfoil that will be used for the wing and tail (horizontal stabilizer and vertical stabilizer). After that, the wing model, horizontal stabilizer, vertical stabilizer and fuselage were made.

(a) (b)

Figure 1. (a) wing, (b) horizontal stabilizer

(a) (b)

Figure 2. (a) vertical stabilizer, (b) fuselage

The next step is to combine all the models that have been made.

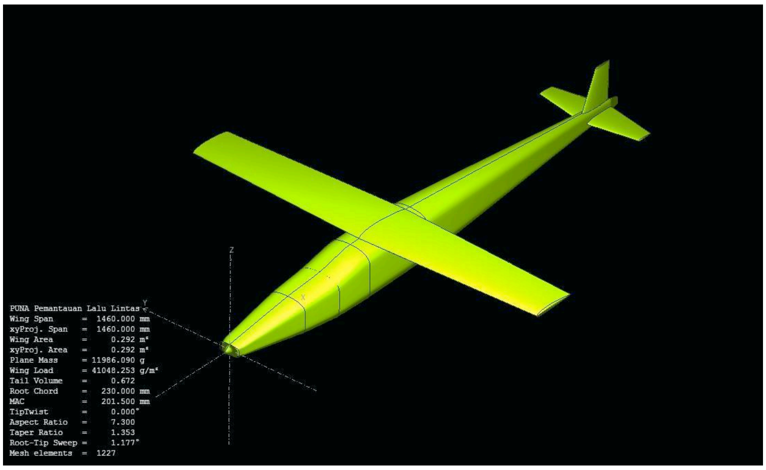

Figure 3. PUNA Aircraft Models

After the models are combined, the next step is to input the mass of each model or system component contained in the PUNA aircraft and then carry out a static stability simulation.

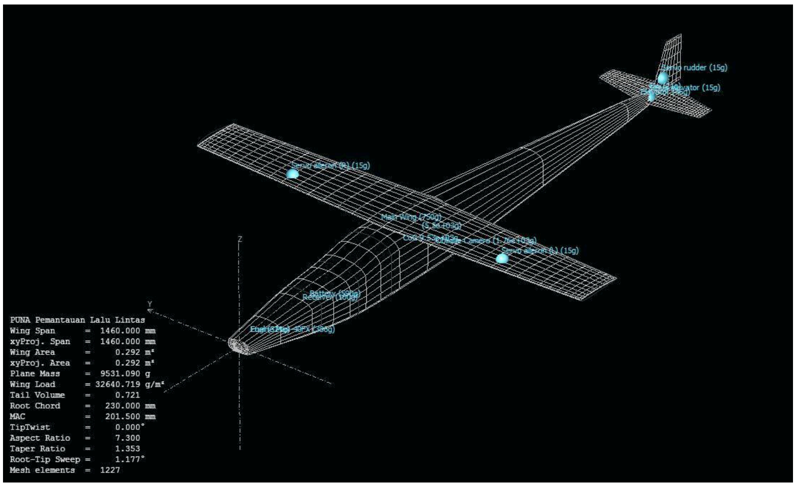

Figure 4. Mass input results on the PUNA model

3. RESULTS AND ANALYSIS

This stability simulation is carried out at a height of 1 km and a speed of 25 m/s. These conditions are adjusted to the altitude and cruising speed when the PUNA aircraft is operating.

3.1. Longitudinal Static Stability Simulation

In this longitudinal static stability simulation, it uses variations of the angle of attack from 1° to 10° with 1° intervals. Relationship between C_m and C_L can be seen in the following figure.

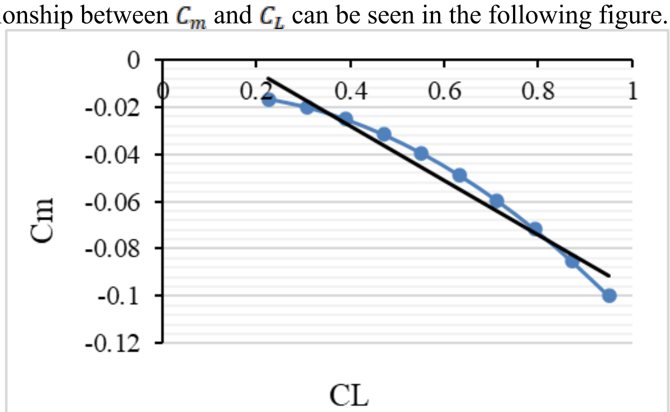

Figure 5. Relationship between C_m and C_L

By using a linear approach, Figure 5 gives the result that the relationship is inversely proportional between C_m and C_L where the greater C_L value, the smaller C_m value. The linear approximation of Figure 5 is $C_m = -0.1147C_L + 0.0178$. This equation indicates that the value $C_{m_0} = 0.0178$ and $\frac{dC_m}{dC_L} = -0.1147$ have a relationship with C_m. So, it can be said that the value of $\frac{dC_m}{dC_L} < 0$ is in accordance with one of the requirements for longitudinal static stability. While the values $C_{m_0} > 0$ is in accordance with one of the requirements of longitudinal static stability. The results of this simulation show that the aircraft being analyzed complies with the required longitudinal static stability criteria.

In the aerodynamic analysis it was found that the value of $C_{L_\alpha} = 0.0815$ /deg and the value of $C_{m_\alpha} = -0.0093$ /deg. The results of this simulation show that the aircraft being analyzed complies with the required longitudinal static stability criteria which is $C_{m_\alpha} < 0$.

3.2. Directional Static Stability Simulation

In this directional static stability simulation, it uses sideslip angle variations from -15^o to 15^o with 3^o intervals. The relationship between C_n and β can be seen in Figure 5.

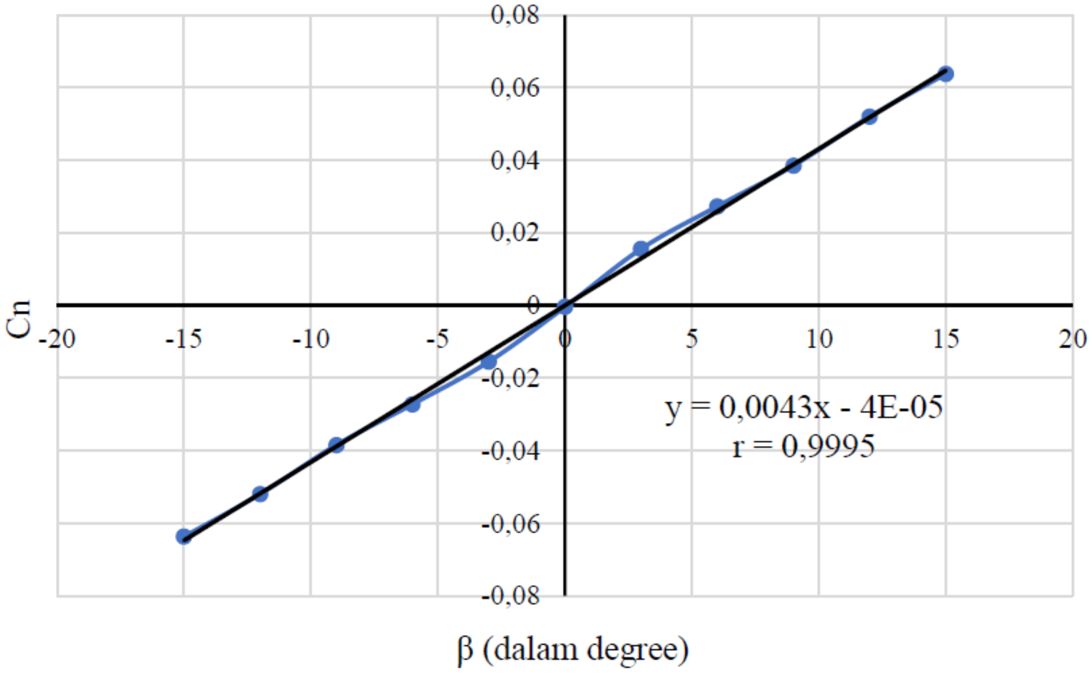

Figure 6. Relationship between C_n and β

By using a linear approach, Figure 6 gives the result that the relationship between C_n is directly proportional to β where the greater the value of C_n, the greater the value of β. Thus, it can be said that the values of $C_{n\beta} > 0$ is in accordance with the requirements for directional static stability.

3.2. Lateral Static Stability Simulation

In this lateral static stability simulation, it uses variations of the sideslip angle from -15^o to 15^o with 3^o intervals. The relationship between $C_{l'_\beta}$ and β can be seen in Figure 6.

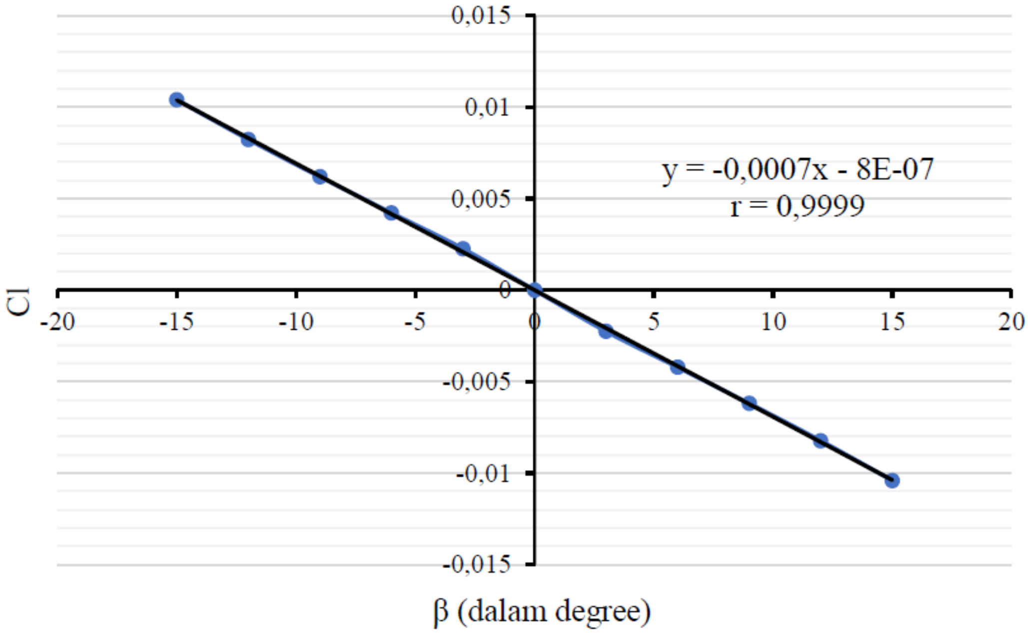

Figure 7. Relationship between $C_{l'_\beta}$ and β

By using a linear approach, Figure 7 gives the result that the relationship between $C_{l'}$ is inversely proportional to β where the greater the value of β, the smaller the value of $C_{l'}$. Thus, it can be said that the value of $C_{l'_\beta} < 0$ is in accordance with the lateral static stability requirements.

4. CONCLUSION

The static stability simulation of the PUNA aircraft has been successfully carried out using the XLFR5 software. The simulation shows that the PUNA aircraft already has longitudinal static stability. However, it is necessary to look more deeply at the trim condition of the aircraft in analyzing on how the C_L value is in accordance with the needs of flying. If the C_L value has not been met, the changes can be made to the horizontal tail tide angle and of course still be followed by a stability analysis. Directional and lateral static stability on the PUNA aircraft complies with the applicable requirements.

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