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Analysis of Pressure Distribution on Airfoil 65_3-218 Based on Comparison of Suryadarma Low Speed Tunnel with Solidwork Software

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ABSTRACT: The design structure of an aircraft is highly dependent on load factors. The loads acting on the wing of an airplane include aerodynamic loads, fuel weight and loads due to the weight of the wing structure. But of all the loads that work, aerodynamic loading is the largest load that must be accepted by the wing of the entire aircraft structure which is influenced by the pressure distribution. The purpose of this study is to determine the effect of pressure distribution on the NACA 653-218 airfoil at various variations of angle of attack with a comparison using wind tunnel experimental trials using solidwork software simulations. The largest pressure distribution generated based on wind tunnel experimental trials is at an Angle of Attack of 15 ° of 101326.73pa on the Upper Surface Airfoil, while the largest pressure distribution generated based on solidwork software simulations is at an Angle of Attack of 15 ° of 101690.01pa on the lower Surface Airfoil.

KEYWORDS: Airfoil 653-218, Pressure Distribution, SolidWork Software, Wind Tunnel

A. INTRODUCTION

The design of a high-tech product such as a state-of-the-art aircraft is the culmination of various scientific and technological disciplines, each of which is undergoing rapid development, albeit at different rates. The design of a state-of-the-art aircraft is to realize an aircraft that can meet increasingly high and optimal operating requirements, both with regard to the required performance, as well as to meet requirements in increasingly stringent economic and environmental aspects.

In practice, the increased ability of computers to operate highly advanced analysis methods enables optimization in design execution. One method that has been very successfully applied is FEA (Finite Element Analysis), Solidwork, Ansys, and others. In the discipline of aerodynamics, the use of high-performance computers to operate new methods such as FEA, Solidwork is indispensable for carrying out designs related to the areas of flight stability, performance and aerodynamic loading on structures such as aircraft wings.

The wing is one of the main parts of an aircraft that has the basic function of generating the lift required to fly under all operational conditions. So in the implementation of wing design, the criteria applied are closely related to performance issues, operational aspects, flight and control characteristics, structure/construction and "general lay-out design".

In this basic aerodynamic function, the wing is equipped with ailerons for roll steering. To improve its characteristics at low speeds to enable take-off and landing from shorter runways, the wing is equipped with high lift devices (HLD).

So in its implementation, analyze the pressure distribution on the 65_3-218 airfoil based on the comparison of the wind tunnel with solidwork software in Up-Down conditions with the angle of attack of the Up position, namely 5 °, 8 °, 11 °, 14 ° and the angle of attack of the down position, namely -5 °, -8 °, -11 °, -14 °.

B. THEORETICAL FOUNDATION

Wind Tunnel

The wind tunnel is a tool used to determine the flow of air moving through a stationary object where this flow can be adjusted and the object can be changed from various angles of flow direction so that there is interaction between the stationary object and the air flow that moves relatively.

In this wind tunnel consists of a fan that sucks the air flow passing through the stationary object in the test section after that through the Diffuser which is behind the test section which has a function to slow down the air flow after leaving the test section and keep the power loss low, before passing through the stationary object in the test section this air flow passes through the net - the wire mesh that is in the contraction funnel in front of the test section so that the air flow passing through the stationary object can be accelerated so that the flow is formed uniformly with low turbulence and then discharged through the exhaust.

The workings of the wind tunnel can be known by the presence of a test object and the flow that moves relatively through the object, so that the nature of the movement of the air flow passing through the object can be known in the experimental results.

For this can be known in two main ways, namely:

a) The object moves through a stationary stream
b) The flow moves past a stationary object

Gambar 1. Suryadarma Low Speed Tunnel

In the flow that moves through the object is divided into two parts, namely:

1) The flow moves past a stationary object by itself naturally, this is closely related to aerodynamic problems.
2) The flow moves past a stationary object in an artificial way produced by a fan with a suction system, this is also called a wind tunnel (wind tunnel).

Hydrostatic Pressure

Hydrostatic pressure is the pressure caused by a liquid that is in equilibrium or static. When a liquid is in equilibrium or static, every part of the liquid is also in equilibrium or static. Consider a selected liquid element in the shape of a thin cylinder such as a "medicine pill" whose cross-sectional area is A and thickness is dh, the top of which is at a depth of h1 and the bottom of which is at a depth of h2 from the surface of a liquid that is in a state of equilibrium or static.

If the liquid element under review is static, then the resultant force acting on the element is zero in all directions. The resultant force in the horizontal % direction caused by the liquid pressure around the element is zero, meaning that the liquid pressure for each point at the same depth is equal.

The resultant force in the vertical direction is also zero, and it is caused by the difference between the pressure of the liquid at depth h1 on the upper surface of the element whose area is A and the pressure of the liquid at depth h2 on the lower surface of the element whose area is A, and the weight of the liquid element, ρgAdh, so that we can obtain

$$dPA = \rho gAdh \text{..................(1)}$$

If the above equation is integrated, it is obtained

$$P_2 - P_1 = \rho g(h_2 - h_1) \text{......(2)}$$

which means that the hydrostatic pressure at depths h1 and h2 are P1 = ρgh1 and P2 = ρgh2 respectively, or the pressure at a point at depth h from the surface of a static liquid is

$$P = \rho gh \text{..........................(3)}$$

When the surface of a liquid is in direct contact with air, such a surface is referred to as the free surface of the liquid, and the air pressure is P0, then the total pressure at any point at depth h from the free surface of the liquid is

$$P = P_0 + \rho gh \text{..............(4)}$$

The last equation above does not require a specific vessel shape, meaning that it applies to any vessel shape occupied by liquid. It is utilized in the use of a manometer in the form of a U-shaped pipe, therefore commonly referred to as a U pipe, as a tool for measuring pressure.

Aerodynamics

Aerodynamics is taken from the words Aero and Dynamics which can mean air and changes in motion and can also be drawn an understanding that is a change in the motion of an object due to air resistance when the object is speeding up. The object in question above can be a motorized vehicle (car, truck, bus or motorcycle) which is closely related to the development of aerodynamics today. The things related to aerodynamics are vehicle speed and air resistance when the vehicle is traveling.

Aerodynamics comes from two words, namely aero which means part of the air or air science and dynamics which means a branch of natural science that investigates moving objects and the forces that cause these movements. Aero comes from Greek which means air, and Dynamics which means strength or power. So Aerodynamics can be interpreted as the science of the effects caused by air or other gases in motion.

In Aerodynamics, there are several forces that act on an object and more specifically on a car as stated by Djoeli Satrijo (1999; 53).

"Aerodynamic resistance, aerodynamic lift, and aerodynamic nodding moment have a significant influence on vehicle performance at medium and high speeds. Increased emphasis on fuel economy and on energy saving has spurred new linkages in improving aero dynamic performance on highways".

Aircraft Aerodynamics

In principle, when an aircraft is airborne, there are 4 main forces acting on the aircraft, namely thrust T, drag D, lift L, and weight W. When the aircraft is cruising at a constant speed and altitude, the 4 forces are in equilibrium: T = D and L = W. While when the aircraft takes off and lands, acceleration and deceleration occur which can be explained using Newton's 2nd Law (total force is equal to mass multiplied by acceleration).

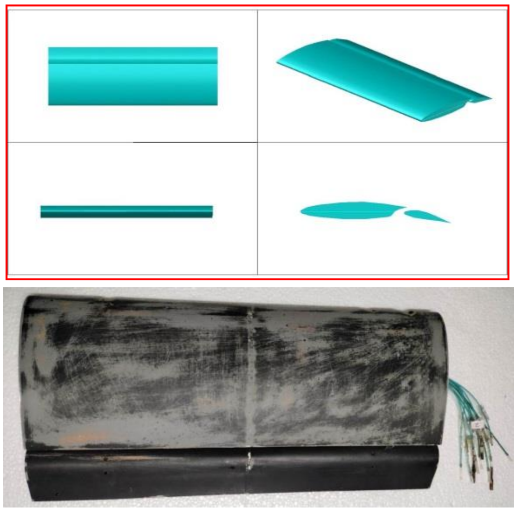
During take-off, the aircraft accelerates in the horizontal and vertical directions. At this time, L must be greater than W, as well as T greater than D. Thus, a large amount of engine power is required at the time of take off. Failure to take off can be caused by a lack of engine power (due to various reasons: mechanical failure, human error, external disturbances, etc.), or system problems in the aircraft.

Airfoil 65_3-218

The airfoil model used in this experiment is a type of NACA 653-218 aerofoil model used on CN 235 aircraft equipped with HLD system. To measure the static pressure (P) at each hole on the surface of the aerofoil model as an experimental model, a water manometer is used. In addition, a pitot tube is also installed in the contraction section, to measure the total pressure (Po) with a water manometer height of H2 and static free stream pressure (P_) with a water manometer height of H1. Thus the dynamic pressure (0.5 ρ V2) can be known by calculating the difference in water level H2 and H1. As a model, the NACA 653-218 aerofoil model is used which is equipped with an HLD system, namely there is a Flap component mounted on the aerofoil with a total of 33 holes consisting of 23 holes on the aerofoil, 10 holes on the Flap. Each hole is connected with a flexible hose pipe to a water manometer, so that the water manometers all total 33 with a variable height of H3. Thus the dynamic pressure $\left(\frac{1}{2}\cdot\rho\cdot V^{2}\right)$ can be known by calculating the difference in water levels H1 and H2.

A system used on NACA airfoils in increasing lift. This airfoil is equipped with parts - parts between others:

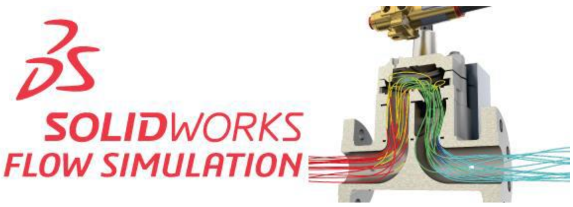
- Aerofoil is equipped with 23 holes that include holes in the upper surface and lower surface.
- The flap is equipped with 10 holes and this also includes the number of holes in the upper surface and lower surface.



Gambar 2. ***Model Airfoil 65_3 – 218***

Software Solidwork

Solidworks is a software used to build aircraft model geometry and used to perform CFD simulations. In addition to building the geometry, in this research, Solidworks software is also used to perform computational simulations of fluid dynamics, with the integrated Flow Simulation feature. The following is a view of the Solidworks software.



Gambar 3. ***Software Solidwork***

C. RESEACH METHODS

A study must use the right research method to produce research that can be accounted for the truth. errors in the choice of research methods used will result in errors in data collection, data analysis, and drawing conclusions from the results of the study. so the accuracy in choosing the research method to be used is a very important factor and must be considered.

According to Sumantri (in Widarmika 2012: 1) the experimental method is a demand from the development of science and technology in order to produce a product that can be enjoyed by the community safely and in learning involves students by experiencing and proving the process and results of the experiment themselves. While the experimental method according to Al-farizi (in Ifzanul 2009: 4) is a method that starts from a problem to be solved and in its working procedures adheres to the principles of the scientific method.

According to Trowbridge and Bybee (in Sarwi 2010: 115), laboratory activities both in the form of demonstrations and experiments (experiments), can be classified into verification laboratory activities (deductive) and inquiry laboratory activities (inductive). Verification laboratory activities are defined as a series of observation or measurement activities, data processing, and drawing conclusions that aim to prove the concepts that have been taught. In inquiry experiments, the learning environment is prepared to facilitate the student-centered learning process. Experiments are not only to achieve the competence of the psychomotor domain, but also the cognitive domain and affective domain.

From the description above, it can be seen that the experimental method is different from the demonstration method. If the demonstration method only emphasizes the process of occurrence and ignores the results, while in the experimental method the emphasis is on the process to the results.

Based on the description above, the method used in this research is the experimental method by conducting laboratory tests by comparing using computer-based software, namely solidwork software.

D. DISCUSSION

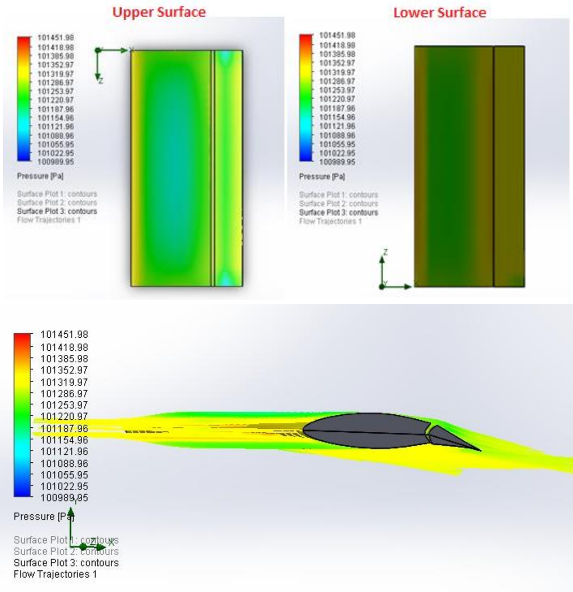
Comparison of Static Pressure Airfoil 653-218 Based on the Use of Wind Tunnel with Solidwork Software.

1) Wind Tunnel and SolidWork

Angle of attack of 5°

Airfoil test with Wind Tunnel

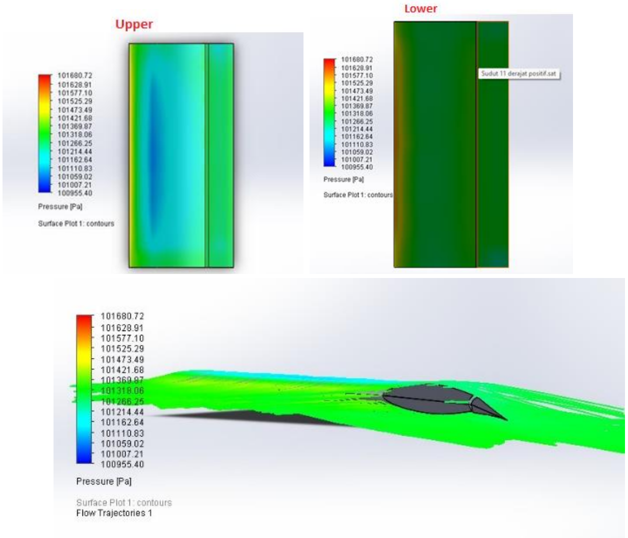
And test with solidwork software



Angle of attack of 11°

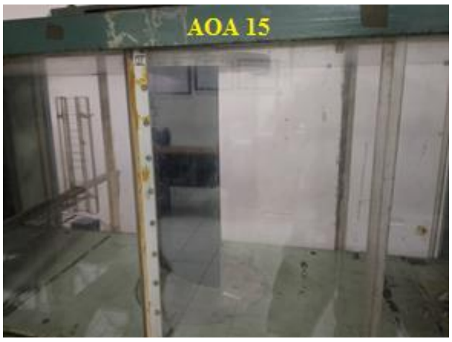
Airfoil test with Wind Tunnel

And test with solidwork software

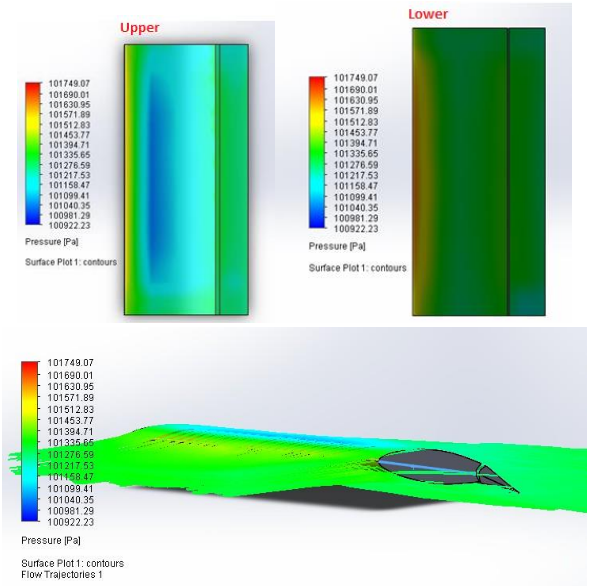


Angle of attack of 15°

Airfoil test with Wind Tunnel



And test with solidwork software



2) Comparison Results Table

Airfoil 653-218					
Angle Of Attack (°)		5°			
No	Hole	Pressure			
		Wind Tunnel		Solidwork	
		Upper (pa)	Lower (pa)	Upper (pa)	Lower (pa)
1	0	101325.88	101325.88	101352.97	101352.97
2	1	101325.13	101325.46	101319.97	101319.97
3	2	101325.22	101325.43	101253.97	101286.97
4	3	101325.28	101326.08	101154.96	101220.97
5	4	101325.35	101326.07	101121.96	101187.96
6	5	101325.46	101325.84	101286.97	101352.97

Flap					
Angle Of Attack (°)		5°			
No	Hole	Pressure			
		Wind Tunnel		Solidwork	
		Upper (pa)	Lower (pa)	Upper (pa)	Lower (pa)
1	1	101325.36	101325.26	101286.97	101286.97
2	2	101325.41	101325.25	101253.97	101319.97
3	3	101325.38	101325.25	101220.97	101286.97
4	4	101325.32	101326.34	101319.97	101286.97
Angle Of Attack (°)		11°			
No	Hole	Pressure			
		Wind Tunnel		Solidwork	
		Upper (pa)	Lower (pa)	Upper (pa)	Lower (pa)
	0	101325.8	101325.8	101525.29	101680.72
	1	101326.2	101325.4	101421.68	101525.29
	2	101325.9	101325.4	101007.21	101266.25
	3	101325.8	101325.1	101110.83	101421.68
	4	101326.2	101325.2	101214.44	101266.25
	5	101325.6	101325.3	101162.64	101318.06

Flap					
Angle Of Attack (°)		11°			
No	Hole	Pressure			
		Wind Tunnel		Solidwork	
		Upper (pa)	Lower (pa)	Upper (pa)	Lower (pa)
1	1	101325.1	101325.3	101266.25	101318.08
2	2	101325.4	101325.1	101214.44	101369.87
3	3	101325.6	101325.1	101162.64	101318.06
4	4	101325.5	101326.1	101214.44	101266.25
Angle Of Attack (°)		15°			
No	Hole	Pressure			
		Wind Tunnel		Solidwork	
		Upper (pa)	Lower (pa)	Upper (pa)	Lower (pa)
	0	101326.2	101326.2	101512.83	101690.01
	1	101326.73	101325.52	101453.77	101571.89
	2	101326.07	101325.53	101276.59	101453.77
	3	101325.85	101325.14	101040.35	101335.65
	4	101325.71	101325.14	101099.41	101276.59
	5	101325.53	101325.23	101158.47	101394.71

Flap					
Angle Of Attack (°)		15°			
No	Hole	Pressure			
		Wind Tunnel		Solidwork	
		Upper (pa)	Lower (pa)	Upper (pa)	Lower (pa)
1	1	101325.36	101325.26	101335.65	101335.65
2	2	101325.41	101325.25	101276.59	101394.71
3	3	101325.38	101325.25	101217.53	101276.59
4	4	101325.32	101326.34	101217.53	101217.53

3) Resumed Comparative Analysis Results

Based on the results of data analysis in the above research by applying the wind tunnel experimental comparison model with solidwork software that has been carried out, where the static pressure generated by conducting wind tunnel experimental trials is much more accurate than using solidwork software but complementary. The value generated by conducting wind tunnel experimental trials has increased compared to using solidwork software.

CONCLUSIONS

1. By conducting Wind Tunnel experimental tests, it is much more accurate than using solidwork software simulations because experimental tests are real tests while simulation tests are only based on software simulations but complement each other.
2. The largest pressure distribution value generated at an angle of attack of 5° is 101352.97 pa on the upper and lower surfaces based on simulation trials while the largest pressure distribution generated in wind tunnel trials is 101325.88 pa on the upper and lower surfaces.
3. The largest pressure distribution value generated at an angle of attack of 11° is 101680.72 pa on the lower surface based on the simulation test while the largest pressure distribution generated in the wind tunnel test is 101326.2 pa on the upper surface.
4. The largest pressure distribution value generated at an angle of attack of 15° is 101690.01 on the lower surface based on the simulation test while the largest pressure distribution generated in the wind tunnel test is 101326.73 on the upper surface.

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