IJESRT: 8(1), January, 2019 ISSN: 2277-9655

International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)

Impact Factor: 5.164

IJESRT

Website: www.ijesrt.com Mail: editor@ijesrt.com

Correspondence Address: 116, Sukhdev Nagar Ext-1, Airport Road, Indore – 452005, Madhya Pradesh, INDIA

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

AERODYNAMIC PERFORMANCE OF SAAB JAS GRIPEN C-LIKE FIGHTER AIRCRAFT WITH CANARD-WING DELTA

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DOI: 10.5281/zenodo.2532186

ABSTRACT

The aerodynamic performance of an aircraft, especially fighter aircrafts configured with wing canard-deltas, produced a phenomenon of airflow that could form a vortex core which could produce suction giving additional lifts. Wing-canard delta configuration was able to create different lift distribution to the angle of attack where the stall occurred at a higher angle of attack than the conventional wing aircraft configuration. This study investigated the aerodynamic performance of wing canard delta configurations in the Saab JAS Gripen C-like model which had a different wing shape on its wing planform than other fighter aircraft. To obtain values in the form of axial velocity plots along the vortex core, trajectory vortex core, the pressure coefficient distribution CFD analysis utilized ANSYS FLUENT software, where these results were challenging to obtain with water tunnels or wind tunnels. The results showed that the Saab JAS Gripen C-like model stalled at a 40° angle of attack (AoA) with a maximum CL value of 1.431 with a slope of the CL curve of 2.995 / rad. The value of the lift to drag ratio was highest at an angle of 5° with a lift of 11.58 times the drag value. The location of the vortex core height was higher, and the width of the vortex core tended to move away from the fuselage every time the angle of attack increased. In canard vortex core, maximum axial speed increase occurred at an angle of 30° with a value of 1.027 times the speed of the free stream while on the wing vortex core occurred at an angle of 40° for 1.835 times the speed of the free stream.

KEYWORDS: aerodynamics; canard-wing delta; angle of attack; Saab JAS Gripen C-like; vortex; CFD.

1. INTRODUCTION

At present technology is developing so rapidly, including in research on fighter aircraft development. For many countries in the world such as the United States, Russia, Germany, France, China, Sweden has done a lot of research to develop technology specifically on homemade aircraft. This is proven by the fact that their state-made fighter aircraft are able to fill the top ranks of the best fighter aircraft in the world today. In this study, we will observe the fighter aircraft, especially aerodynamic discipline, because this aspect is the dominant discipline in the design of fighter aircraft [1]. The model chosen is the Saab JAS Gripen C-like aircraft. What are the aerodynamic phenomena and the influences from the shape of the wings that Saab JAS Gripen C-like on around the aircraft in various angles of attack?

Various visualization techniques are developed such as wind tunnels, and water tunnels are used to see the flow patterns that occur around the aircraft model. The use of a water tunnel has the advantage of being able to produce visualization in detail due to a higher type of period and a lower diffusion period than the air. However, the use of visualization experiments has difficulty obtaining qualitative data in detail due to the limitations of the measuring instruments used.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Constructing a grid or meshing is the most critical part of the CFD modeling process and is the most necessary part of the effort to get a liable CFD result. Good grid quality, grid suitability with flow patterns, grid resolution right near the surface are requirements of successful CFD simulations [2]. Computational domains are divided into several zones to produce structured grids. Structured grid produces each point with a unique index so that access to adjacent points can run efficiently which will speed up the computational process [2]. Structured grids also offer higher numerical accuracy and fewer data storage compared to unstructured grids.

In addition to the griding aspect, physical modeling in CFD simulation is also important to determine the accuracy of simulation results. The physical flow model in this study is turbulent flow where in the world of engineering most flow phenomena are turbulent for both 2-dimensional and 3-dimensional cases [3]. Turbulent flow has the character of erratic fluctuations in flow variables and fluid properties along the spatial direction in the flow field. The modified Navier-Stokes equation, known as the Reynolds Average Navier Stokes or RANS equation describes the temporary variables / properties in the average value of fluctuating components for turbulent flow. Then these fluctuations are interpreted as statistical quantities at the average time value. Therefore, all temporal scale turbulent fluctuations are included in the mathematical model of the average time in RANS [2].

Most delta wing studies with computational processes generally use the κ-ω turbulent model. As done by Subagyo [4], Saha [2], and Soemarwoto [5], in both studies using turbulent Shear Stress Transport (SST) κ -ω models because the turbulent Shear Stress Transport (SST) κ-ω model is considered to predict flow separation with higher accuracy and is the right choice for delta wing flow phenomena. The three have made several comparisons of computational results and concluded that the simulation results of CFD with turbulent model SST κ-ω show adequate results and there is conformity with the experimental results.

The use of computational fluid dynamics (CFD) methods will be beneficial in presenting data both qualitatively and quantitatively and in better detail. Cost effective CFD methods and sufficient accuracy can be complementary to the experimental approach and have an essential role in simulating maneuver conditions, and this is because many cases cannot be tested in wind tunnels or these conditions are too dangerous to do in real flight tests [6].

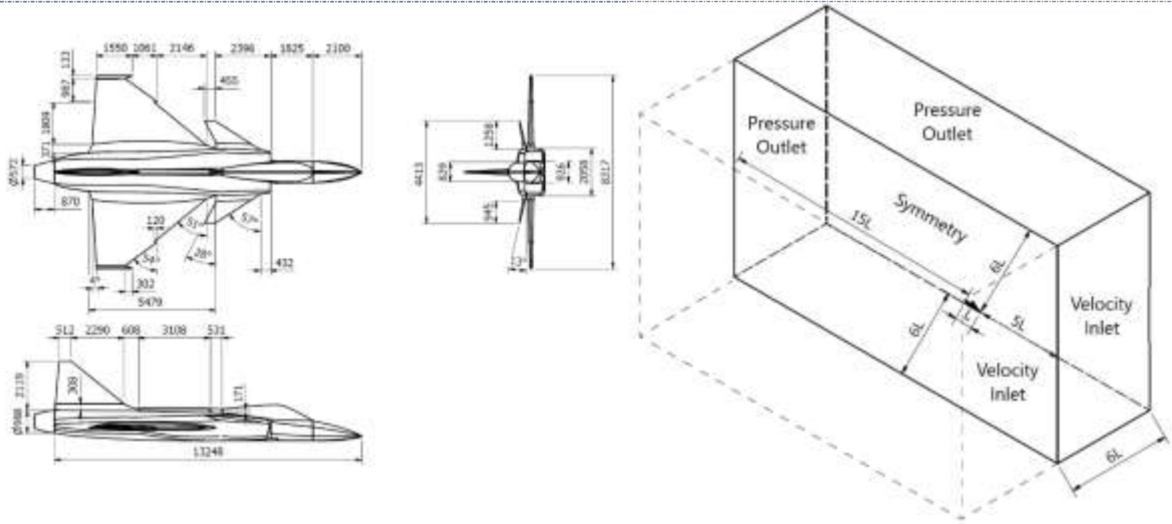
2. METHOD

In this research, the effect of changing the angle of attack on the airflow around the Saab Jas Gripen C-like aircraft was investigated. Simulations were also carried out to obtain the effect of angle of the attack on aerodynamic performance characteristics such as CL, CD, lift to drag ratio, pressure coefficient distribution on canard and wing, axial speed comparison with free streams and trajectory vortex cores. The research also showed the airflow around the aircraft, streamlined results of the interaction between the canard wing and the vortex core region using the Q criterion.

The object considered in this study was a model that resembled the Saab JAS Gripen C-like aircraft which had been simplified in such a way that it was feasible to analyze numerically using ANSYS FLUENT software without eliminating the main flow features, namely flow on the canard, wings and wing interactions canard by ignoring the interaction of aircraft details in the form of detailed intakes, antennas, missiles, radars, sensors, noses and fin pilot tubes so that this model is called Saab JAS Gripen C-like.

After making the CAD model, the mesh fabrication process was then carried out, and the boundaries of computational conditions were determined such as inlet, outlet, symmetry and wing walls. The size of the computational domain was made so large against the size of the model used that it was assumed that the wall area around the model would not affect the flow of the model aircraft. The dimensions of the delta wing and aircraft model and domain configuration were shown in Figure 1.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7



(a) ***(b)***

Figure 1 Geometrical model (a) Saab JAS Gripen C-like (b) computational domain structure.

Griding or meshing was done using the ICEM CFD program which was one of the features in the ANSYS program. The unique ability of ICEM CFD was being able to create a grid or structured grid by dividing CAD models into blocking-blocks with interconnected and regular lines so as to produce a structured grid that had several advantages compared to unstructured grids. The making of net models was selected using the form of structured networks, as structured grids and unstructured grids generally provided almost the same quantitative values, but to identify the vortex structure in detail the form of structured grids had better results than the unstructured grid model. Meanwhile, in the area near the wall, special analysis needed to be carried out regarding the flow phenomena that occurred due to the influence of the boundary layer [7]. At the stage of making this mesh was done giving the number of nodes which initially in the form of 1 block will produce a large number of meshes. This research used a structured grid because it produced points with unique indices so that access to adjacent points could run well and efficiently so that it could accelerate the computational process [2]. So that in the end the results of the structured grid were shown in Figure 2.

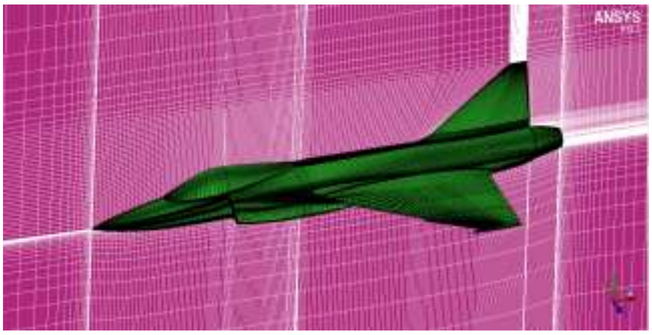


Figure 2 Structured grid SAAB JAS Gripen C like.

This study would be carried out at the angle of attack 10^0, 20^0, 30^0, 40^0, 50^0, 60^0, 70^0, 80^0 dan 90^0. However, to obtain the maximum CL value and lift to drag ratio that was more accurate, additional computation was carried out at the angle of attack (AoA) 0^0, 2^0, 5^0, 35^0 dan 45^0. The choice of more detail angles was to comprehend the more detail influence of the magnitude of the AoA and how the characteristics of the aerodynamic performance on the Saab JAS Gripen C-like aircraft at the low to high angle of attack. Computation was done on ANSYS FLUENT with the settings summarized in Table 1.

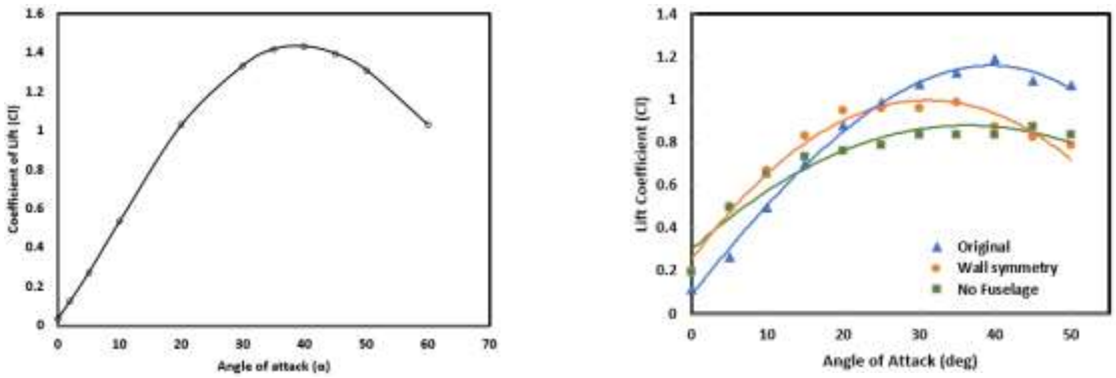
Table 1 Summary of ANSYS FLUENT computational settings

General	Solver Type	Pressure-Based
	Time	Steady
Models	Viscous Model	Transition SST
Materials	Fluid	Air
boundary condition	Body	no-slip wall
	inlet	Velocity inlet (magnitude and direction)
		102.9 m/s
	outlet	Pressure outlet
	Symmetry	Symmetry
Solution Initialization	Standard	From the inlet
Calculation	Number of Iteration	100

In this study, a computer with AMD Ryzen 5 1600G processor specifications would be used with a clock speed of 3.4 GHz, 16 Gb RAM with a rate of 2400 Mhz and with a GTX 1050 Ti GPU. After all data was initialized, the computation process started and produced a residual plot that began to stabilize around 90th iteration with a residual value of about 0.01 for continuity, around 10^{-5} for the speed x, speed y, velocity z, and then around 0.001 for residues of values k and omega, and theta had a residual value of around 0.001, and internites had a residual value of around 10^{-7}. To ensure that the lift and drag calculations produced a stable and convergent solution, a plot of the lift monitor was also made and drag on the number of iterations with results showing lift calculation solutions and drag stabilizing around the 20th iteration.

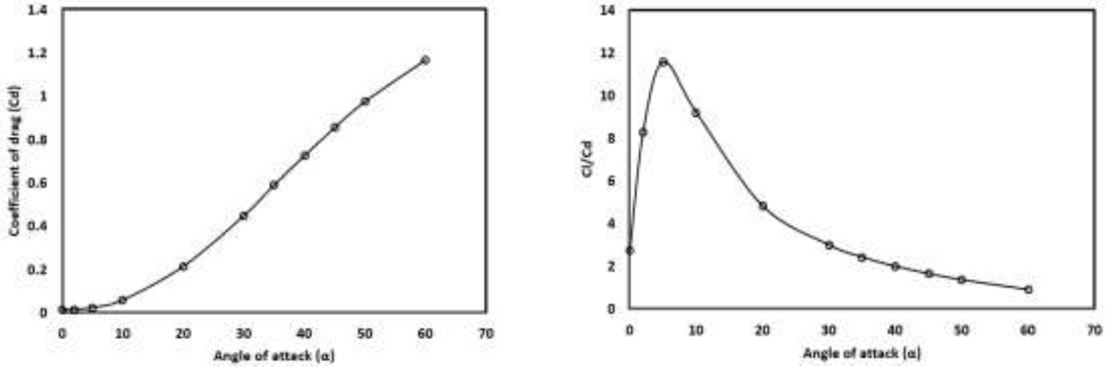
3. RESULTS

The simulation results in the form of Cl, Cd, and lifts to drag ratio was shown in Figure 3 and 4. In Figure 3, the Cl of a) Saab JAS Gripen C-like aircraft were compared with the Cl of b) water tunnel experiment of Chengdu J-10 including without fuselage and with wall symmetry [8].



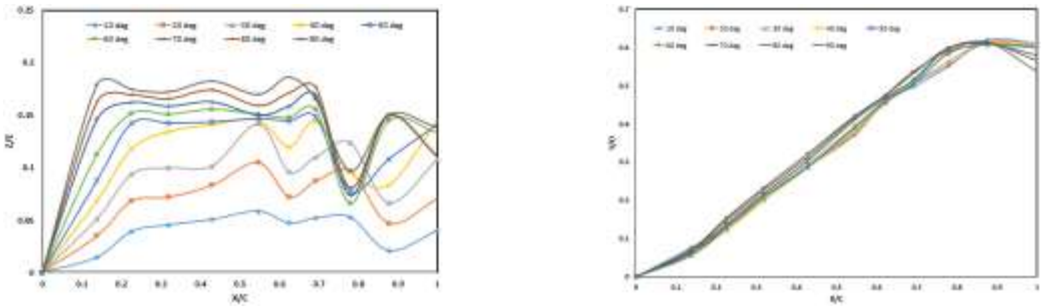
(a) ***(b)***

Figure 3 Distribution curve of (a) CFD simulation of Cl of Saab JAS Gripen C-like aircraft; (b) of water tunnel experiment of Chengdu J-10 [8].



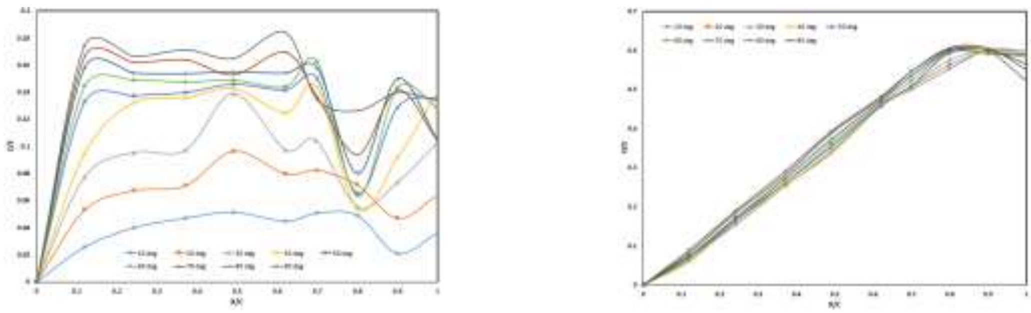
(a) *(b)*

Figure 4 Distribution curve of (a) Cd. (b) Cl/Cd simulation of Saab JAS Gripen C-like aircraft



(a) *(b)*

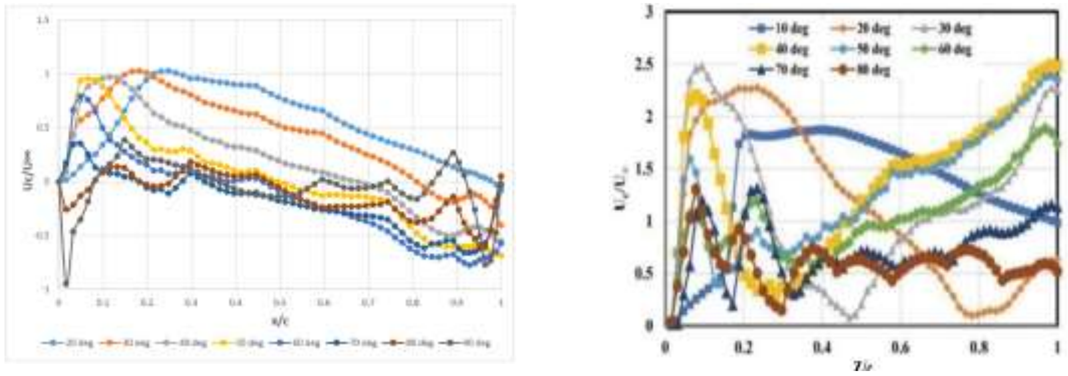
Figure 5 (a) Graphically the height of canard vortex cores to x / c at various AoAs. (b) Graphically the span-wise of canard vortex cores to x / c at various AoAs of simulation of Saab JAS Gripen C-like aircraft



(a) *(b)*

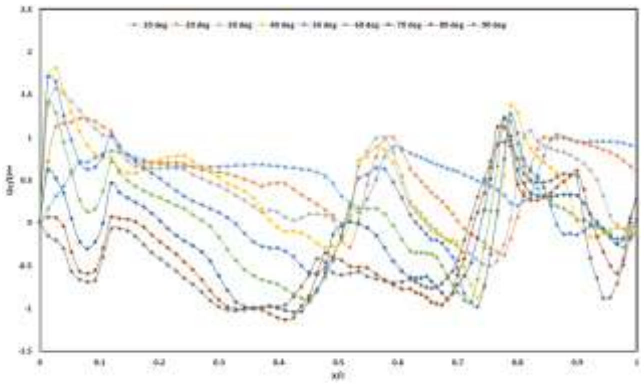
Figure 6 (a) Graph the height of wing vortex core against x / c at various AoAs. (b) Graph the span-wise of wing vortex core against x / c at various AoAs of simulation of Saab JAS Gripen C-like aircraft.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7



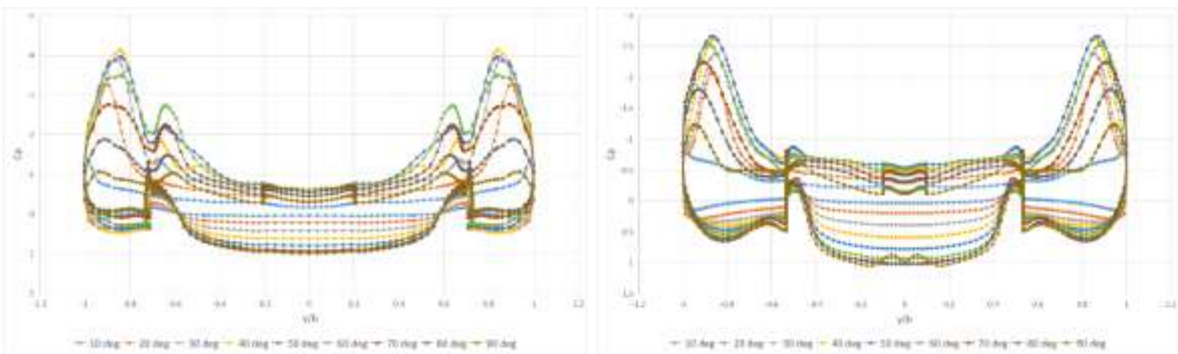
(a) *(b)*

Figure 7 *Uc / U∞ graph along the canard vortex core against x / c at various AoAs a) of Saab JAS Gripen C-like aircraft were compared with b) of Chengdu J-10 (Sutrisno et al., Fig. 4).*



(c)

Figure 8 *Uc / U∞ graph along the wing vortex core against x / c at various AoAs of Saab JAS Gripen C-like aircraft*



(a) *(b)*

Figure 9 Graph of Cp distribution throughout the span at (a) 30%. (b). 60% canard chord, of Saab JAS Gripen C-like aircraft.

ISSN: 2277-9655
Impact Factor: 5.164
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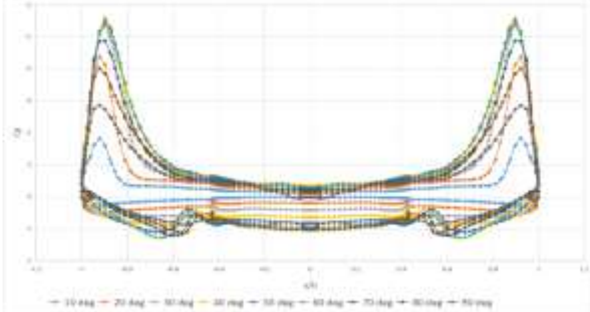
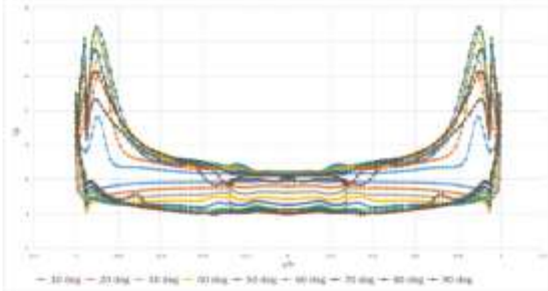
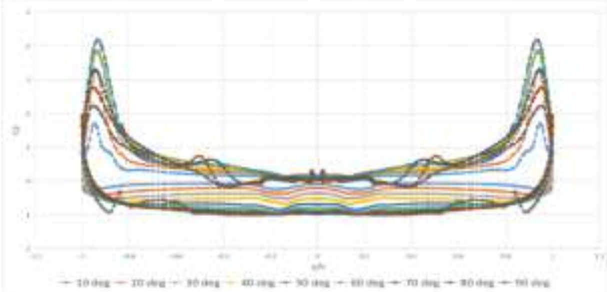


(a)



(b)



(c)

Figure 10 Graph of Cp distribution throughout the span at (a) 30%. (b). 53%. (c) 65% wing chord, of Saab JAS Gripen C-like aircraft.

4. DISCUSSION

In Saab JAS Gripen C-like model, there is a similar phenomenon, namely the appearance of vortex core and vortex breakdown both in the stall canard and in the wing on the Saab JAS Gripen C-like occurs at an AoA of about 40^0 with a maximum Cl value of 1.431. It can also be calculated the slope of the Cl curve on the angle of attack (in radians) in the area near the angle 10^0 for Saab JAS Gripen C-like is 2.995 / rad. Based on the thin aerofoil theory of infinite wings for either thin or chambered aerofoils, the slope of the Cl curve against the angle of attack is 2π / rad = 6.283 / rad [9] so that it can be seen that the Cl curve of the AoA Saab JAS Gripen C like 2.098 times more slope than the slope of the Cl graph towards the angle of infinite wing attack. The slope of the CL curve towards this gentle slope angle is an essential aspect in fighter design because it affects its response to turbulence [10]. Obtained, the slope of the Cl curve to the angle of attack of 2.995 / rad. The higher the AoA, the higher the Cd value. The biggest Cd value at 90^0 angle is equal to 1.332. The lift and drag ratio values increase until the greatest value occurs around the 5^0 angle where the lift value is 11.58 times the drag value.

Based on these data, the Saab JAS Gripen C-like aircraft is capable of maneuvering properly until it reaches its stall angle at an angle of 40^0. With the largest lift to drag ratio at an angle of about 5^0 the lift value is 11.58 times the drag value. With the value of lift to drag ratio reaching almost the same value at an angle of around 60^0, making this aircraft not good is stretched above the angle of attack of 60^0 because the size of the lift has started to be low and many losses due to drag are quite large.

Maximum axial speed increase in vortex core canard for Saab JAS Gripen C-like e model occurs at 30^0 angles with a value of 1.027 times free stream speed. Whereas in the wing vortex core the maximum axial speed increase occurs at an angle of 40^0 with an amount of 1.835 times the free stream speed. The pressure distribution contour on the aircraft surface for the Saab JAS Gripen C-like model shows suction, namely an area with low pressure along the vortex core line. The trend of the length of this suction area is getting shorter with increasing AoA. At the 53% pressure wing contour, it appears that there are 2 vortex cores. The vortex core consists of the main vortex core and secondary vortex core. This is due to the cross-section of the Gripen aircraft which has a different wing configuration in general. The main wing vortex cores are getting weaker with the addition of wing chords, while the secondary vortex core is getting stronger. The transfer of the main vortex core becomes secondary vortex core and secondary to the main vortex core at 53% chord.

In the 65% chord, there is only 1 vortex core, and the secondary vortex core continues to weaken and eventually disappears. The pressure coefficient curve at location 30% and 60% of the canard chord shows a suction peak. The pressure coefficient on the Suction peak for the Saab JAS Gripen C-like model occurs at an angle of 30^0 which is equal to -4.136 at the location of 30% chord and 2.66 at the location of 60% chord. While on the wing occurs at an angle of 40^0 that is equal to -5.586 at the position of 30% chord and -4.424 at the position of 53% chord for main vortex core, -4.0487 for secondary vortex core, then at 65% chord occurs at an angle of 50^0 which is – 4.178.

Increasing the height of the vortex core on the canard and wing increases with increasing AoA. Then the width of the vortex core span is higher with the increasing angle of attack on the canard, but the wing vortex tends to coincide with a position that is almost the same at each angle. With the formation of 2 vortex cores which are the result of the JAS Saab Gripen C-like wing planform, so it can be seen that this aircraft has 2 suction where the suction experiences very low pressure so that the Saab JAS Gripen C-like aircraft has an additional lift force so that it can pull lift value.

5. CONCLUSION

Stall on Saab JAS Gripen C like occurs at an AoA of around 40^0 with a maximum CL value of 1.431. Then, the slope of the CL curve with respect to the AoA is 2.995 / rad. The higher the AoA, the higher the CD value. The biggest CD value at 90^0 angles is equal to 1.332. The lift and drag ratio values increase until the greatest value occurs around the 5^0 the angle where the lift value is 11.58 times the drag value. Maximum axial speed increase in vortex core canard for Saab JAS Gripen C-like model occurs at 30^0 angles with a value of 1.027 times free stream speed. Whereas in the wing vortex core the maximum axial speed increase occurs at an angle of 40^0 with a value of 1.835 times the free stream speed.

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6. ACKNOWLEDGMENTS

The authors would like to express heartfelt gratitude to Dr Bramantya for a fruitful session, useful suggestions, and collaboration. We appreciate the help of our students Zainuri Anwar, Handika, Caesar, and Firdaus, and the lab staff members, Ponimin and Wajiono, for giving their help in construction work and conducting data management, which we gratefully acknowledged.

NOMENCLATURE

u : stream velocity (m/s)
∇u : the deformation tensor = the velocity-gradient tensor

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

α : angle of attacks (AoA) degree
ρ : density (kg/m3)
y+ : dimensionless wall distance
Cl : coefficient of lift
Cd : coefficient of drag
Uc : local velocity
U∞ : free-stream velocity

Subscript, Superscript

d : drag
l : lift
p : pressure
mac : mean aerodynamic chord
u : up
∞ : free stream

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Sutrisno, Pratama, Y. A., Wibowo, S. B., Wega, & Iswahyudi, S. (2019). AERODYNAMIC PERFORMANCE OF SAAB JAS GRIPEN C-LIKE FIGHTER AIRCRAFT WITH CANARD-WING DELTA. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*,*8*(1), 39-47.