Mekanika: Majalah Ilmiah Mekanika

CFD Modeling of Narasena Bengawan UV Team Quickster UAV Wings with Addition of Vortex Generator to Aerodynamic Performance

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Keywords:
Taper ratio, vortex generator, CFD, ANSYS

This research is based on obtaining the best possible aerodynamic performance for the Quickster Narasena Bengawan UV Team UAV aircraft wing design. One of the factors that greatly affects the flying performance of a UAV is the wing. The wing on the Quickster Narasena UAV aircraft uses an MH33 airfoil, because MH33 is specifically for high-speed UAV aircraft. This research will discuss the comparison of the performance of a wing without a vortex generator with a wing with a vortex generator. Variations in the positioning of the vortex generator on the wing of the Quickster Narasena UAV will also be discussed in this study. The method used in this research is the CFD (Computational Fluid Dynamics) method. The simulation process will use the ANSYS Fluent 19.0 application with the K-Omega SST method with the Reynolds-Averaged-Navier-Stokes (RANS) equation as the basis. The purpose of this study is to obtain the results of the coefficient of drag, lift, and the contour of the turbulence that will occur. The simulation results that have been done are the geometry of the wing with the addition of a vortex generator can reduce the drag coefficient and can increase the lift coefficient.

1 Introduction

Unmanned Aerial Vehicle (Unmanned Aerial Vehicle) is a flying vehicle that is controlled remotely by the pilot or is able to move automatically according to the parameters that have been entered in the control system [1]. The use of UAVs has been widely used in several fields to facilitate human work. In the field of education, UAV itself has begun to enter and develop among universities in the world, and it has even become a competition between universities [2].

Bengawan UV Team is an unmanned vehicle research team focused on UAVs and USVs at Sebelas Maret University which aims to research, design and build unmanned vehicles for any mission required. Every year the Bengawan UV Team participates in the KRTI competition, besides that the Bengawan UV Team has also been involved in the business of photo mapping and monitoring services in an area.

Therefore, it is necessary to consider the initial design phase related to the emphasis on the aerodynamics of the drone that will be made [4]. In considering the aerodynamic aspects of UAV aircraft, it is influenced by fuselage design, wing design, stability and control studies, empennage design and cooling

https://dx.doi.org/10.20961/mekanika.v20i2.50736

Revised 28 April 2021; received in revised version 29 August 2021; Accepted 9 September 2021
Available Online 30 September 2021

2579-3144

inlet, all of which are included in his consideration [3]. By considering the initial design phase, it can shorten the processing time and reduce the trial and error phase and get the desired goal.

Vortex Generator (VG) is a small fin-shaped component placed on the wing surface which aims to modify the flow around the surface which creates a boundary layer to delay flow separation and stall [5]. Vortex generator is one type of turbulent generator that can controlling turbulent boundary layer separation [9]. They are designed to produce a streamwise vortex that energizes the near wall laminar flow to overcome the adverse gradient [8].

In previous studies discussing the addition of a vortex generator and the influence of the placement and height of the vortex generator on the development of the turbulent boundary layer so that it can improve wing performance [6]. The airfoil used is NASA LS-0417 with Re 1.41×10^5 on AoA 16^o and the type of vortex generator used is counter rotating. Then the parameters used are the variation of the height of the vortex generator (h), namely at h = 1mm, 3mm and 5mm and the variation in the placement of the vortex generator from the leading edge (x/c), namely 0.1; 0.2; 0.3; and 0.4. Overall, the results of this study are that the most optimal vortex generator variations are x/c 0.3 and h = 1 mm where the CL / CD value has increased by 14.337%.

This research will focus on developing the wing design of the Quickster Narasena Bengawan UV Team UNS aircraft. The development of the wing design in this study includes a part of the wing configuration that will be used to add a vortex generator with a variation of the position of the vortex generator on the Quickster Narasena Bengawan UV Team UNS aircraft wing. With this development, it is expected to get good aerodynamic results.

2 Experimental Methods

In making the Quickster Narasena Bengawan UV Team UNS aircraft, an initial design was needed as a start and in order to support the success of winning the race. Then in the selection of airfoils, in this study using an MH33 airfoil. This is because MH33 airfoil is specifically for UAV aircraft at high speed. In this paper will discuss 6 variations of wing, wing without VG; wing with VG 0,1 x/c; wing with VG 0,2 x/c; wing with VG 0,3 x/c; wing with VG 0,4 x/c; and wing with VG 0,5 x/c. The following is the geometry of the Quickster Narasena Bengawan UV Team UNS aircraft wing:

Table 1. Quickster Wing Geometry

Geometri Wing of UAV Aircraft Quickster Narasena	
Parameters	**Value**
Chord Root	369 mm
Chord Tip	111 mm
Wing Span	1400 mm
Wing Area	336000 mm²
Aspect Ratio	5.83
Taper Ratio	0.3
Configuration	High Wing

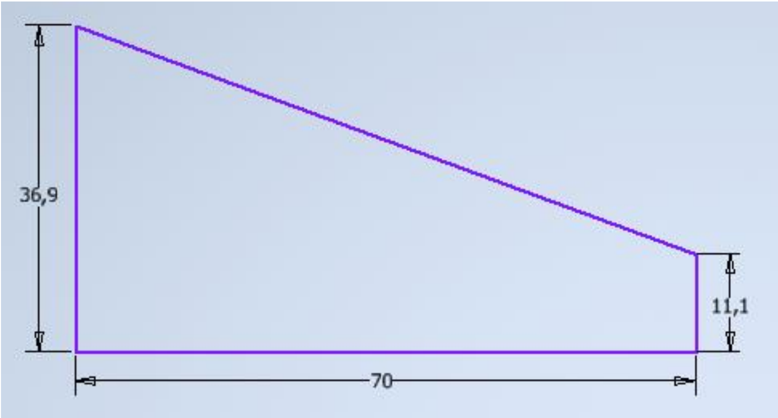

Figure 1. Quickster Wing Geometry

This study also uses the addition of a vortex generator design. The choice of vortex generator design is based on research conducted by Ulul Azmi [6]. In a study conducted by Ulul Azmi [6], a counter rotating vortex generator has a better efficiency than other vortex generators. The following is the geometry of the vortex generator that will be used:

Table 2. Vortex Generator Geometry

Vortex Generator Geometry	
Parameters	**Value**
Fin spacing of VG (d)	5 mm
Length of VG (l)	7.5 mm
Orientation Angle to the Free Stream Velocity	10°
Height of VG (h)	1 mm
Width of VG	1 mm

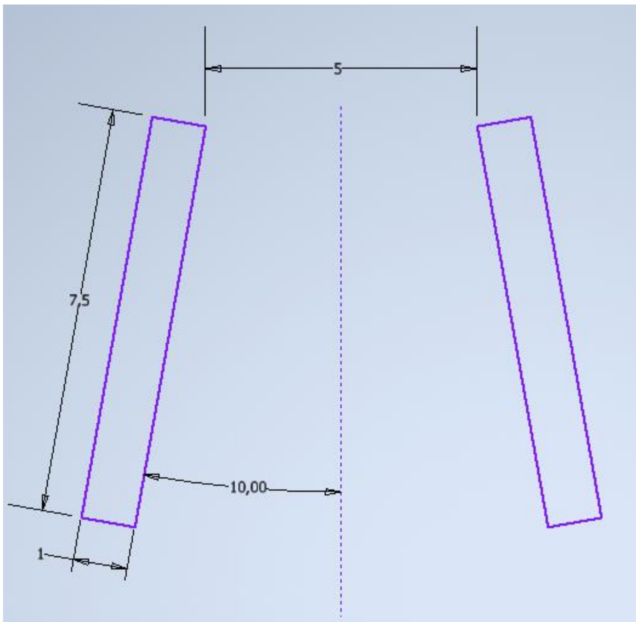

Figure 2. Vortex Generator Geometry

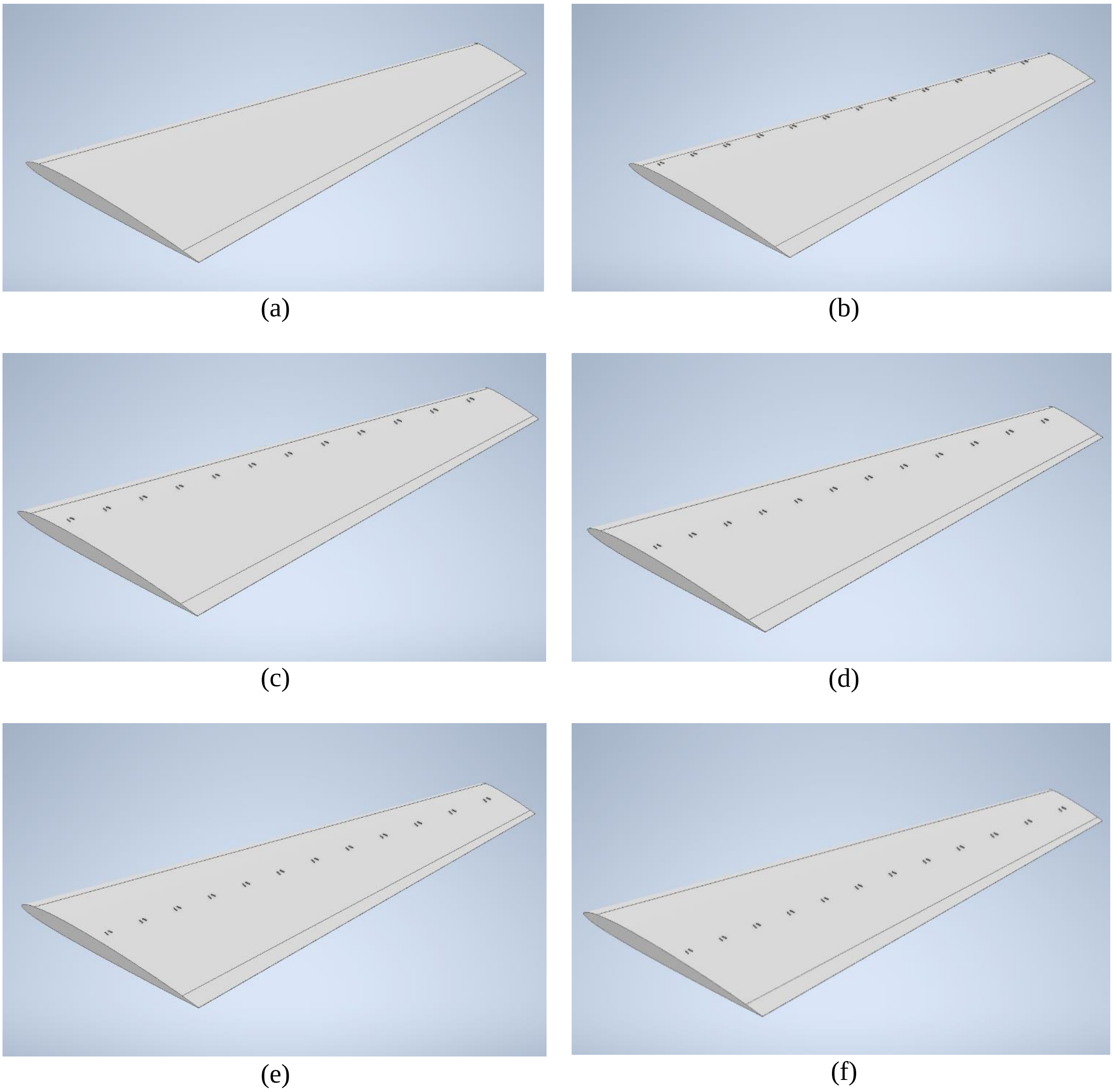

Figure 3. 3D Modelling Quickster Wing (a) No VG, (b) VG 0.1 x/c, (c) VG 0.2 x/c, (d) VG 0.3 x/c, (e) VG 0.4 x/c, (f) VG 0.5 x/c

In this paper, the fluid flow will be assumed to be steady flow, viscous, incompressible and isothermal using the Reynolds-Averaged Navier-Stokes (RANS) equation. Then for the calculation method to complete this research is the turbulence model with the k-omega SST method, because the k-omega SST method can capture turbulence and vortex phenomena better than the spalart-allmaras method.

2.1 Steady Flow

The fluid flow which is assumed to be a flow*steady* is when all *properties* in the flowing fluid does not change with time (t) [13].

$$\frac{\partial V}{\partial t} = 0 \text{ atau } V = V\ (x, y, z) \tag{1}$$

2.2 Incompressible Flow

Flow in which the density value (ρ) is constant is called incompressible flow or cannot be compressed along the flow.

$$\frac{\partial \rho}{\partial x} = 0 \; ; \; \frac{\partial \rho}{\partial y} = 0; \; \frac{\partial \rho}{\partial z} = 0 \tag{2}$$

2.3 Continuity Equation

The assumptions are related to steady flow then the amount of mass in the control volume will be constant or constant.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \tag{3}$$

2.4 Conservation of Momentum

The law of conservation of momentum is expressed by the Navier-Stokes equation which is an equation derived from Newton's second law. In this study, it is assumed that the fluid flow is in steady flow and incompressible flow conditions so that it can be simplified as follows.

$$\begin{aligned}
x;\; \rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right) &= -\frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)\\
y;\; \rho\left(u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right) &= -\frac{\partial p}{\partial y} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right)\\
z;\; \rho\left(u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right) &= -\frac{\partial p}{\partial z} + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right)
\end{aligned} \tag{4}$$

Enclosure in this study using a half-bullet shape often called the c-type domain refers to research conducted by Wonjin Jin [14]. By using the following boundary conditions:

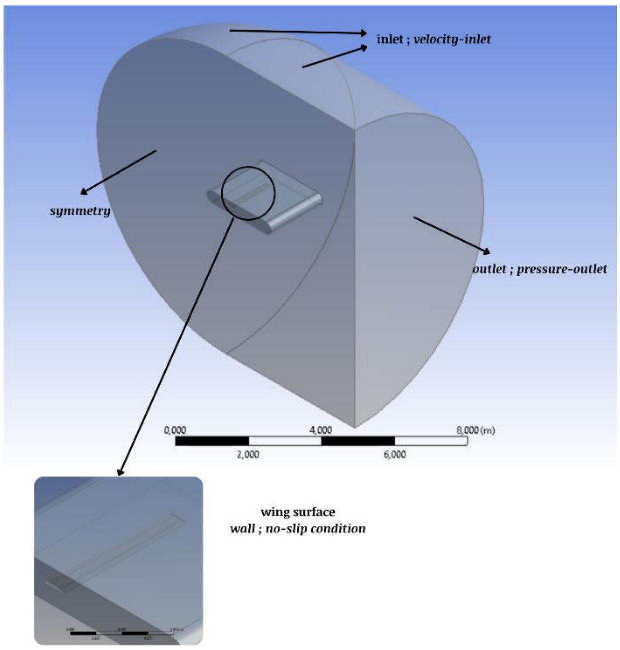

Figure 4. Boundary Condition

In this paper, the validation method refer to Gautham Narayan [7]. The result of this validation, the error percentage level obtained is 6-7%. These results were obtained after going through the Grid Indenpendency Test (GIT) process which was carried out in order to find a method that could be more efficient and produce the smallest error. M3 was chosen as the method to be used as the basis for validation. Furthermore, the methods that have been carried out at the validation stage will be used in finding the results of the research to be carried out.

Table 3. Grid Indenpendency Test Validation

Meshing	Element	CL	CL Error (%)	CD	CD Error (%)
Base	-	0,47	-	0.022	-
M1	5022451	0.50202	6.8128%	0.02362	7.3591%
M2	3553180	0.51483	9.5383%	0.02216	0.7318%
M3	6942034	0.5047	7.3830%	0.02336	6.1636%
M4	7445462	0.50439	7.3170%	0.02342	6.4409%
M5	5932933	0.50259	6.9340%	0.02358	7.2000%

Table 4. Quality of Meshing

Quality of Meshing		
Parameters		**Value**
Nodes		2445434
Element		6942034
Orthogonal	**Min**	0,09635
	Average	0,77287
	Max	0,99942
Skewness	**Min**	0,00017
	Average	0,22653
	Max	0,90365
Aspec Ratio	**Min**	1,1684
	Average	2,2469
	Max	19,343

3 Result and Discussion

The addition of vortex generators includes 5 placements, namely at 0.1 - 0.5 x/c with 0.1 intervals. Then the speed that will be used is the average maneuver speed, which is 135 km/h and at AoA 8°. This is because to get the effect of adding an efficient vortex generator [10]. At this stage, it is to get the right location for the addition of the vortex generator to be applied to the Narasena Bengawan UV Team Quickster UAV aircraft.

3.1 Lift and Drag Coefficient Analysis

In this lift coefficient analysis, it is hoped that the addition of a vortex generator can increase the wing lift coefficient without a vortex generator. Then the drag coefficient has become a consequence with the addition of the vortex generator to increase the drag [11], but with the right placement can make the drag coefficient decrease.

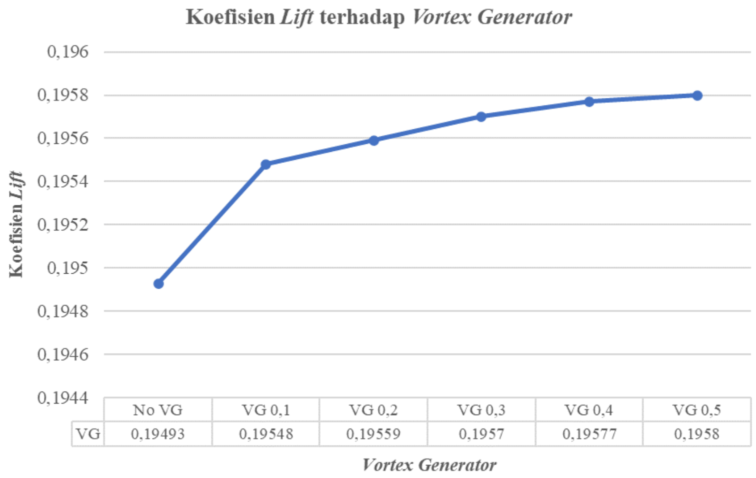

Figure 5. Graph of Lift Coefficient to Vortex Generator

In the results of the lift coefficient above, it is found that the addition of a vortex generator can increase the lift coefficient [11]. Then along with the increase in the location of the vortex generator placement, the lift coefficient also increases. This proves that the use of a vortex generator on an MH33 airfoil with a high angle of attack can increase the lift coefficient. These results are consistent with the research conducted by Ulul Azmi [6] with the addition of a vortex generator that can delay air flow separation [12], so that the lift coefficient on the wings increases at high AoA.

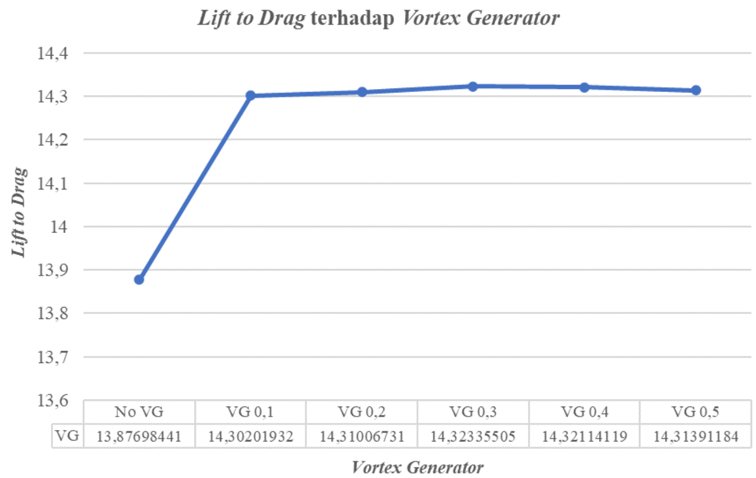

Figure 6. Graph of Drag Coefficient to Vortex Generator

The drag coefficient graph in Figure 4 above shows that with the addition of a vortex generator there is a decrease in the drag coefficient [6]. In the addition of a vortex generator, the largest drag coefficient lies at the position of 0.5 x/c and the smallest at the position of 0.3 x/c. From these results it proves that the most appropriate placement to get the smallest drag coefficient is at the position of 0.3 x/c. This is supported by the research of Ulul Azmi [6], that the placement of the vortex generator which produces the smallest drag coefficient is at 0.3 x/c.

3.2 Analysis of the Contour of Turbulence on the Wing

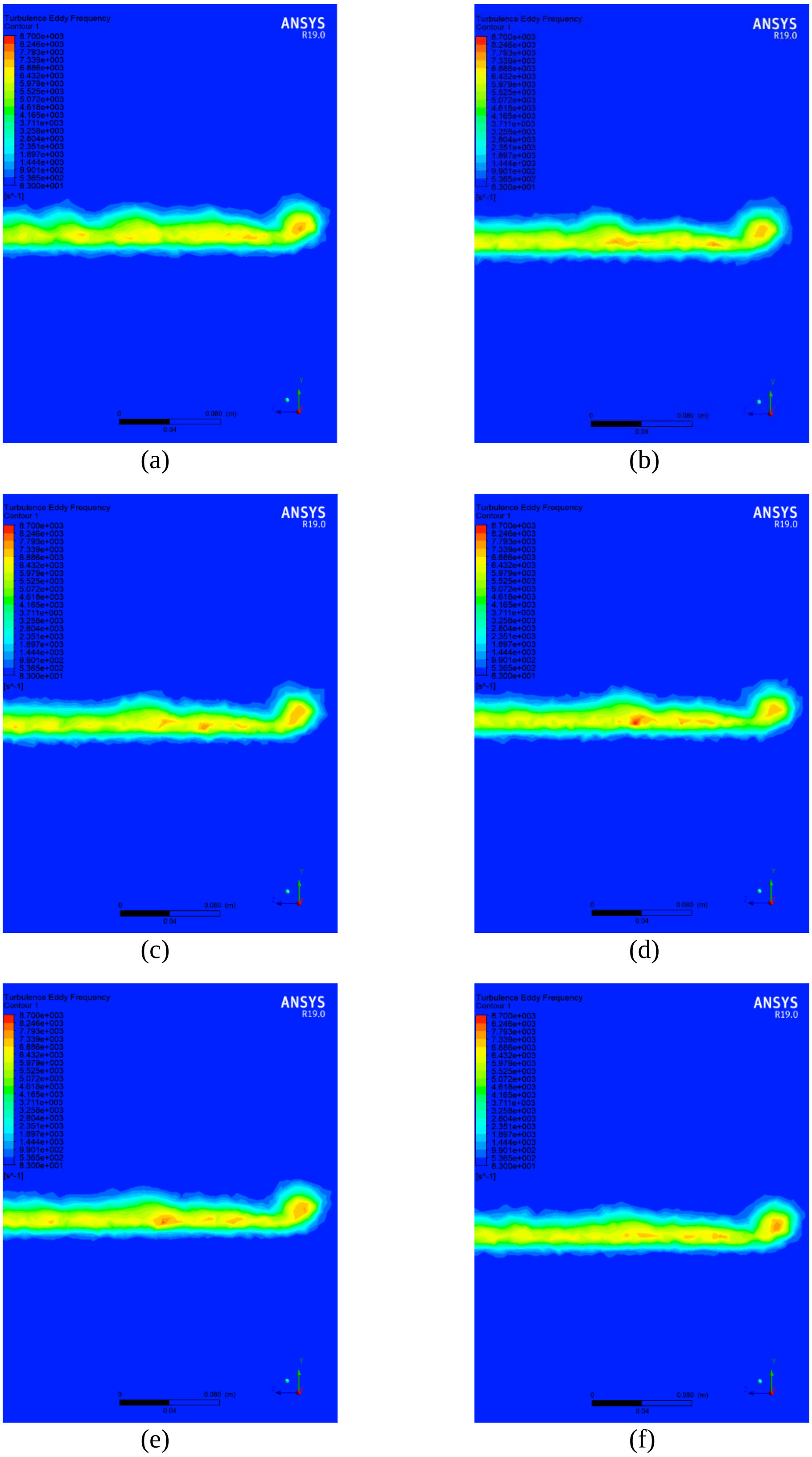

Figure 7. Contour of Turbulence Eddy Frequency on AoA 8^o (a) No VG, (b) VG 0.1 x/c, (c) VG 0.2 x/c, (d) VG 0.3 x/c, (e) VG 0.4 x/c, (f) VG 0.5 x/c

Figure 5 above shows the difference in turbulence contours between the wings without a vortex generator and the addition of a vortex generator with variations in placement. On wings without vortex generators tend to have large turbulence only at the wing tips. The wing with the addition of VG can increase the turbulence along the wing [12]. This indicates that the effect of the vortex generator makes the air flow that was previously laminar and separated, forced into turbulence [6]. So that in this turbulence contour, the wing with the addition of a vortex generator has red dots (high turbulence) in several parts of the wing.

Of the five placements vortex generator, vortex generator 0.3 x/c has the highest turbulence contour. This indicates that the most appropriate placement of the vortex generator for this wing is at 0.3 x/c, supported by the best lift to drag results obtained at 0.3 x/c placement.

4 Conclusion

The addition of a vortex generator at all locations can reduce the drag coefficient and increase the lift coefficient on the wing at AoA 8^o. The best placement of the vortex generator at 0.3 x/c is indicated by the results of the largest lift to drag and the smallest coefficient of drag obtained. As well as having the largest turbulence contours, it proves that the placement of the vortex generator is correct. The addition of a vortex generator can also reduce the moment coefficient because the flow separation on the wing can be delayed.

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