

# A comparative pressure analysis of air flow between horizontal and V-Tail of UAV MALE of NACA0012H with speed variation

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**Abstract.** NACA0012H is an airfoil type that could be used for Unmanned Aerial Vehicle Medium Altitude Long Endurance. This experiment was used to analyze stress in the surface of Tail of UAV MALE that was caused by air flow. The experiment was conducted using Computational Fluid Dynamics Software. Two designs of tail, horizontal and V-tail, were considered to simulate pressure occurred on the surface of leading edge, chamber and trailing edge. The simulation was developed varying the speed of the UAV MALE. The results showed that pressure occurred on the surface of horizontal tail higher than pressure on the V-tail.

## 1 Introduction

Unmanned Aerial Vehicles (UAV) simply could categorize as plane which remotely control outside of its plane [1]. Hence, the design of UAV would be identical with the actual aircraft where the ability of UAV to fly determined by the design of its airfoil. This could be understood that the effectivity of the wing of the aircraft or UAV to produce aerodynamic force was determined by the design of air foil [2]. This force is important to obtain optimum process for the aircraft to fly in the air. The airfoil referred to the profile of the wings of the aircraft which obtain by cutting section that was perpendicular to the wing [3]. Therefore, *tail* or *empennage* on a UAV plane has the same function as a full-scale aircraft, which is to provide both longitudinal (pitch) and directional stability (yaw).

The selection of tail geometries is based on mission requirements, as the example for take-off and landing conditions, manoeuvres, payload laying, propeller configurations, drive systems (servo) to aesthetic aspects. The tail design should consider the lightest and strongest material and construction and not disturbance the engine exhaust. The tail could be designed as small as possible to obtain minimum weight.

One variation of the tail has V-shape, known as V-Tail. This is generated combining the vertical fin and stabilizer into a pair of controls. The theoretical advantage of this design is lighter than T-tail and to reduce the interference drag associated with two surfaces [1]. This could be established by simulating the pressure resulted in the design. *Computational Fluid Dynamic* (CFD) could be used to simulate the pressure change especially in the change of the speed of air flow in the tail itself.

In this study, NACA0012H was applied to construct airfoil profile in order to explore the pressure change of horizontal and V-tail design. This was caused that air foil

design from NACA widely used in the airfoil design for aircraft or UAV [3], especially for NACA0012 [4, 5].

## 2 Simulation Methods

In this work, two design of tails, horizontal and V-tails, were simulated using CFD software to analyse the change of its pressure resulted by variation of air flow through its surface. The model simulation was conducted to investigate the change of the pressure in three important region of the tail for both designs. The important areas of the tail are given on Fig.1 [3, 6].

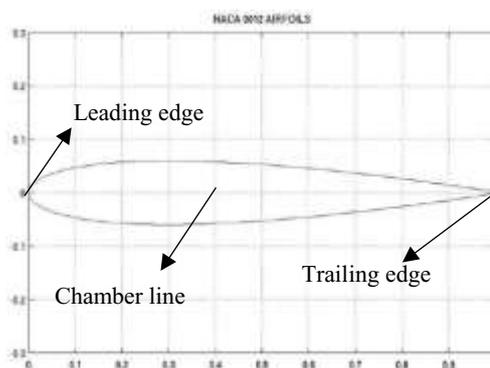


Fig 1. The geometry airfoil of NACA 0012

Pressure which acted in all of the areas had been established as variation speed of the aircraft or UAV. The design of the tail was expected to reach speed of 240 km/h and to carry in till 400 kg payload. This could be categorized as UAV with specification for Medium Altitude Long Endurance (MALE). Four speed variations were selected in order to simulate the change of pressure in the important region of the tail, namely 165 km/h, 195 km/h, 210 km/h and 240 km/h. The results were used to analyse the advantages of either horizontal or V-tail.

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### 3 Results and Analysis

The accomplished CFD simulation had generated two results which would be analysed in this paper. The first result was a general description of the pressure acting in tail of UAV MALE in horizontal and V-tail design. This result would be discussed in Section 3.1 for the horizontal tail and Section 3.2 for the V-tail design. The second result was the pressure variation in the three specific region of tail either in the horizontal and V-tail design. This result would be discussed in Section 3.3.

#### 3.1 Simulation Results on Horizontal Tail UAV MALE

The simulation of air flow in the area of the horizontal tail was conducted in the seven variation speed, namely 150 km/h, 165 km/h, 195 km/h, 210 km/h, 240 km/h. The overall results are given in Table 1.

**Table 1.** Simulation results for pressure of the horizontal tail

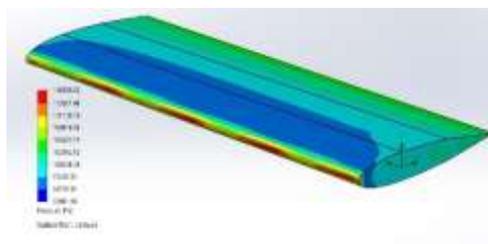
Velocity (Km/h)	Pressure (Pa)		Pressure Range (Pa)
	Maximum	Minimum	
150	113815.75	93627.89	20187.86
165	116595.62	92041.64	24553.98
180	120745.51	89587.19	31158.32
195	124566.19	87941.76	36624.43
210	128310.97	85795.96	42515.05
225	132404.45	82952.14	49452.31
240	136866.99	79445.62	57421.37

Table 1 showed the simulation results for every speed variation. The values of Table 1 showed that the increase of aircraft speed had resulted parallel value with the increase of the maximum pressure. In other hand, the increase of aircraft speed looked contrary with minimum pressure value acting on the surface of the tail. This data showed that the effect of the increase of the speed had different impact between the maximum and minimum working pressure.

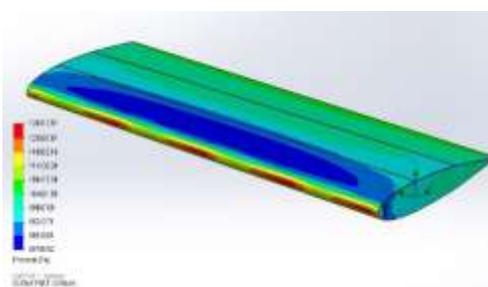
The entire acting pressure on the surface of the tail is given in Fig. 2 and Fig. 3. Fig. 2 showed the simulation results for the pressure acting on the surface of the tail with the speed of 165 km/h where Fig. 3 referred to the simulation for speed of 210 km/h.

Fig. 2 and Fig. 3 show pressure variation acting in the horizontal tail. This result was generated from the pressure acting caused by air flow with assumption that the tail is in the speed of 165 km/h and 210 km/h. Based on the legend, we could conclude that the tail had the

highest pressure in the front side of the tail. They were concentrated in some points. Simulation results for variation speed of 165 km/h and 210 km/h overall had similar region of the pressure acting on the surface of the tail. However, simulation results for the speed of 210 km/h had generated lower pressure in the region which the minimum pressure act.



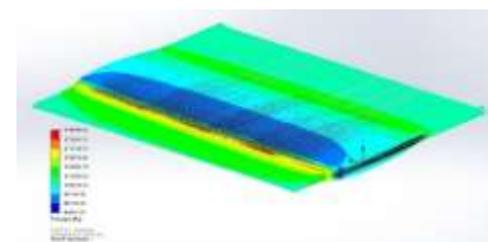
**Fig 2.** Pressure Surface Aerofoil with speed of 165 km/h



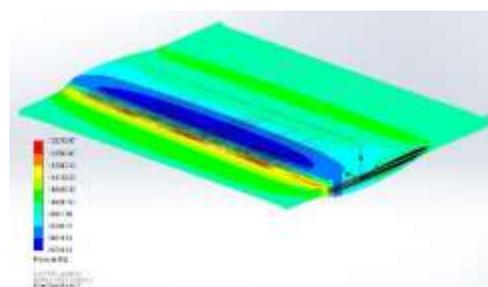
**Fig 3.** Pressure Surface Aerofoil with speed of 210 km/h

However, the pressure caused by the air flow acted in the end of the tail not too much different compare to the pressure acting in the front side. The area of the tail had received the lowest pressure located near to the area that had the highest pressure. This could be ensued due to the pressure of the air flow highly concentrate in some points.

The flow of the air through the tail are given in Fig. 3.



**Fig 4.** Flow Pressure Surface Aerofoil with speed of 165 km/h

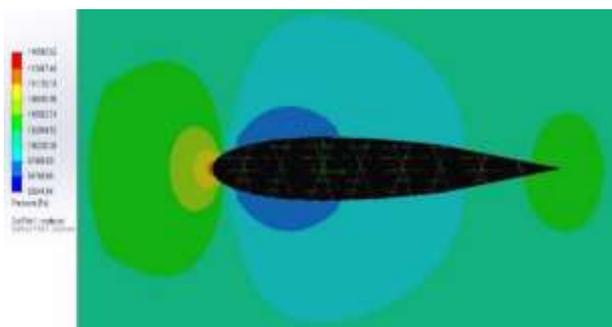


**Fig 5.** Flow Pressure Surface Aerofoil with speed of 210 km/h

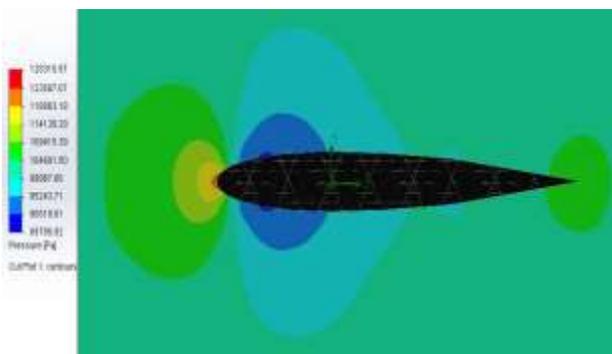
In Fig. 4 and Fig. 5, the air flow was overall described. This results also showed where the area of air around the

tail effected by the acting pressure on the surface of the tail caused by the speed of the aircraft. Those, However, the pressure caused by the air flow acted in the end of the tail not too much different compare to the pressure acting in the front side. The area of the tail had received the lowest pressure located near to the area that had the highest pressure. This could be ensued due to the pressure of the air flow highly concentrate in some points.

The samples contour of aerofoil are given in Fig. 6 for speed of 165 km/h and Fig. 7 for speed of 210 km/h. The pattern drawn of both simulations had quite different especially in low pressure. There is change the area of light blue pattern and the both area of green pattern. This showed the increase of pressure that was parallel with the increase the speed of the tail.



**Fig 6.** Contour Pressure Surface Aerofoil with speed of 165 km/h



**Fig 7.** Contour Pressure Surface Aerofoil with speed of 210 km/h

The other area of the tail had received the pressure evenly distributed. This was shown by the area of each colour pattern. The results of both speed variations in this pressure range had been drawn within similar pattern.

**3.2 Simulation results on V-tail UAV MALE**

Besides the horizontal design, the tail of UAV had been proposed using V-shape or V-configuration [Babbu..]. Therefore, the analysis of NACA00012 aerofoil had been simulated in the V-configuration in this experiment. The overall results V-tail are given on Table 2.

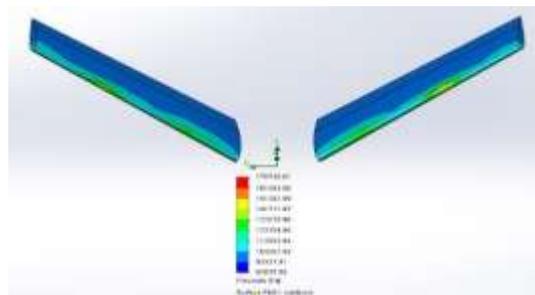
The simulation results of the V-tail as given on the Table 2 showed the similar pattern as the results of the horizontal tail. The increase of the aircraft speed is in line with the increase of maximum pressure and the range pressure acting on the tail. However, this ensued till the

speed 210 km/h. After this speed, there is a reduction of the maximum pressure acting on the aerofoil. The maximum pressure looked decreasing while the speed of aircraft rising from 210 km/h to 240 km/h. The increase speed, in fact, had caused the reduction of the minimum pressure acting on the aerofoil in this configuration.

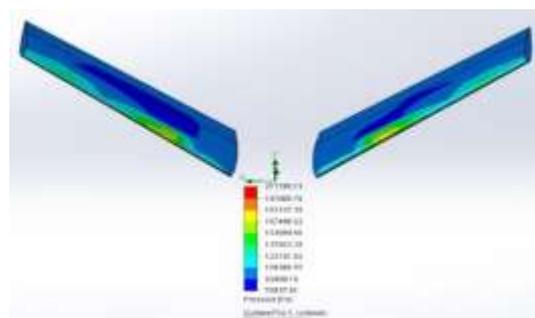
**Table 2.** Simulation results for pressure of the V-tail

Velocity (Km/h)	Pressure (Pa)		Pressure Range (Pa)
	Maximum	Minimum	
150	132984.51	91896.15	41088.36
165	170740.01	83655.90	87084.11
180	162794.92	79706.77	83088.15
195	188658.64	75497.31	113161.33
210	211780.13	78837.81	132942.32
225	187643.06	78571.59	109071.47
240	186030.17	71377.89	114652.28

Description of the working pressure on the tail with specific speed had been simulated as shown on Fig. 8 and Fig.9. Fig. 8 refers to the simulation results for the pressure action on the tail at speed 165 km/h while Fig. 9 refers to the speed of 210 km/s. The pattern resulted from the CFD simulation for both speed variations looked significantly different.



**Fig 8.** Pressure Surface Aerofoil with speed of 165 km/h

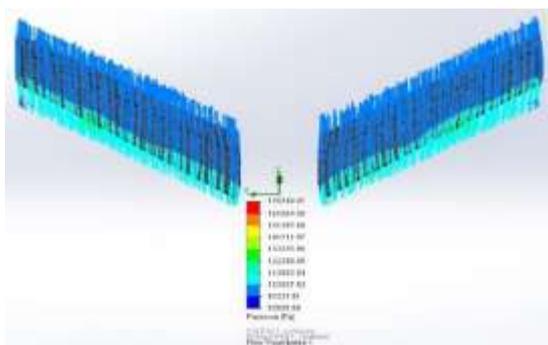


**Fig 9.** Pressure Surface Aerofoil with speed of 210 km/h

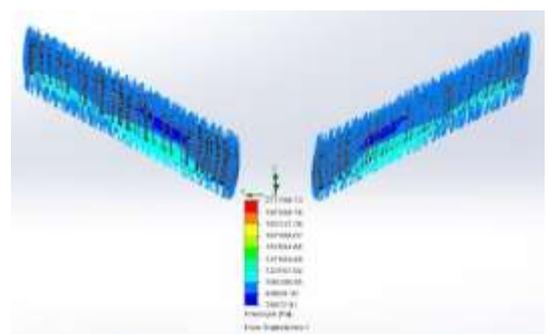
The pattern of simulation results for the speed of 210 km/h had dark blue colour. This colour refers to the lowest pressure acting on the tail. This is not found in the result for speed variation of 165 km/h. The maximum pressure working on the tail also had few desperate in the simulation results as described in Fig. 8 and Fig. 9. The speed variation of 210 km/h had yellow colour. This colour is pointing to the highest value of the pattern in

both Fig. 8 and Fig. 9. This is consistent with the results given on the Table 2.

The description of the value of Table 2 was able to be illustrated with the comparison of the air flow pressure between specific speed value. In this case, simulation results for the speed of 165 km/h and 210 km/h were selected to compare the pattern. This is given on Fig.10 and Fig.11. Both figures visualized the results of lower speed and higher speed. Fig. 10 illustrated the working pressure of the air flow within speed of 165 km/h while Fig. 11 represented the pressure in the speed of 210 km/h.



**Fig 10.** Flow Pressure Surface Aerofoil with speed of 165 km/h



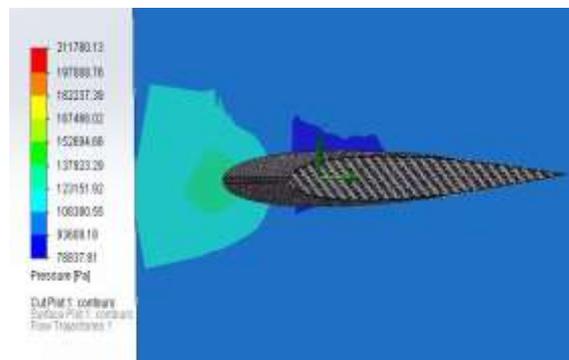
**Fig 11.** Flow Pressure Surface Aerofoil with speed of 210 km/h



**Fig 12.** Contour Pressure Surface Aerofoil with speed of 165 km/h

At a glance, the pattern of flow pressure surface aerofoil with speed of 210 km/h is more complicated compare than the pattern for the speed of 165 km/h. This was supported by the contour pressure surface simulated by CFD as given on Fig. 12 and Fig. 13. Fig. 12 represent the contour pressure surface produced by air flow with speed of 165 km/h and Fig. 13 as the result of speed of 210 km/h.

The contour effected by air flow with speed of 210 km/h had more pattern compared than the area generated by air flow with speed of 165 km/h. This means that the pressure generated by air flow with speed of 210 had higher pressure range than air flow with speed of 165 km/h. The results at speed of 210 km had area with dark blue colour which is refer to the lowest pressure among the pattern in the Fig. 12 and Fig. 13.

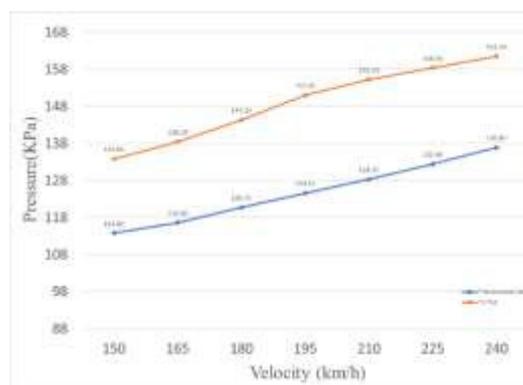


**Fig 13.** Contour Pressure Surface Aerofoil with speed of 210 km/h

At a glance, the pattern of flow pressure surface aerofoil with speed of 210 km/h is more complicated compare than the pattern for the speed of 165 km/h. This was supported by the contour pressure surface simulated by CFD as given on Fig. 12 and Fig. 13. Fig. 12 represent the contour pressure surface produced by air flow with speed of 165 km/h and Fig. 13 as the result of speed of 210 km/h.

### 3.3 Pressure comparison of the tail

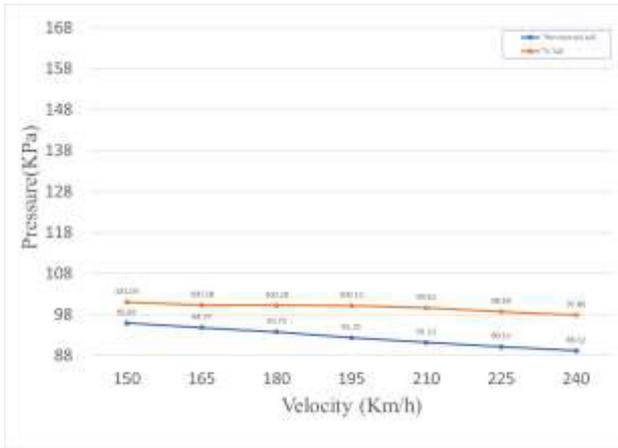
The simulation had also performed to analyse pressure acting in the three important area of the tail. This will be discussed in the form of comparison among the horizontal and V-tail.



**Fig 14.** Pressure comparison in the area of maximum Leading Edge

#### 3.3.1 Pressure comparison on the Leading Edge

Based on the computer simulation, the pressure values on the horizontal and the V-Tail in the area of *Leading Edge* are presented in graphical format shown in Fig. 14 and Fig. 15.

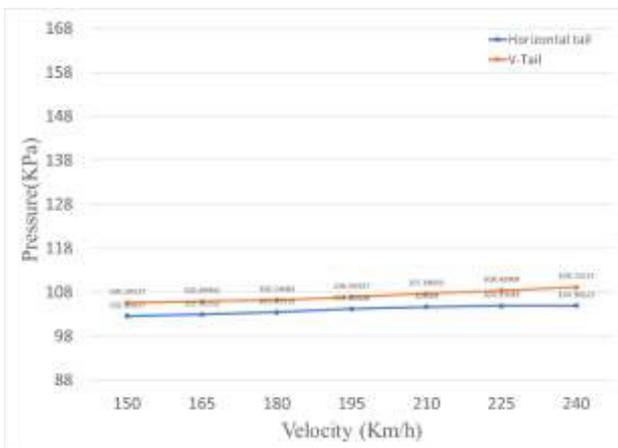


**Fig 15.** Pressure comparison in the area of minimum Leading Edge

Fig. 14 and Fig. 15 has shown the comparative graph of the pressure values occurring in the Leading Edge region of each wing model. Both graphs shown a relatively similar pattern. It appears that the maximum and minimum pressure values occurring on the V-Tail wing model are larger than the horizontal wing model. The pattern for the maximum *leading edge* region looked to have a tendency to decrease with the increasing speed of UAV MALE. In the other side, the trend of the minimum *leading edge* is in contrary tendency.

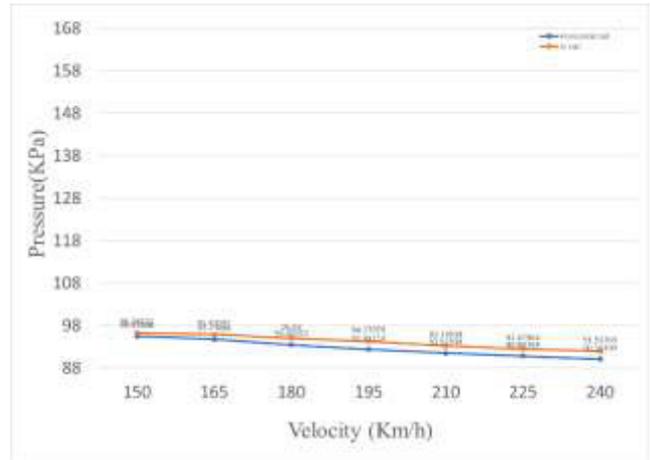
### 3.3.2 Pressure comparison on the Chamber

Results of computer simulation on the *chamber* area are given on Fig. 16 and Fig. 17.

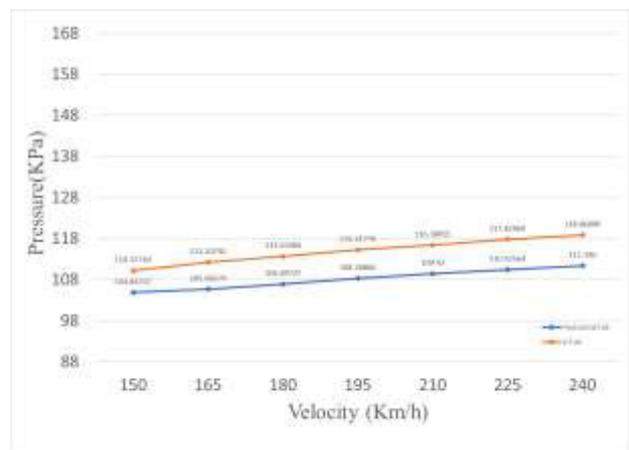


**Fig 16.** Pressure comparison in the area of maximum Chamber

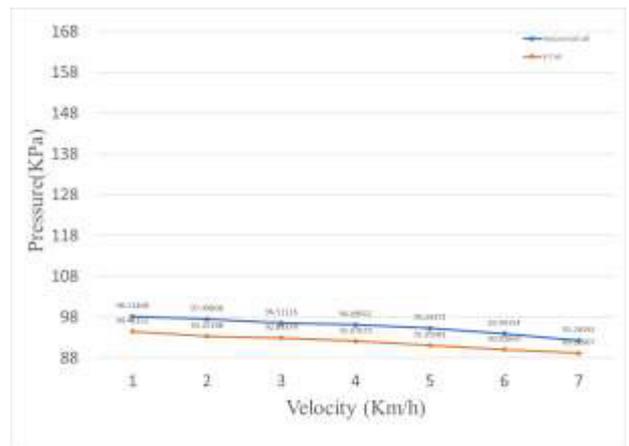
Where Fig. 16 shows the pressure occurred in the maximum *chamber* region and Fig. 17 refers to the minimum *chamber* region. The trend of the pressure change for both horizontal and V-tail have similar tendency in the region of the maximum and minimum *chamber*. However, the pressure trend in the maximum *chamber* area has downward inclination. This is different with the pressure trend in the minimum *chamber* region.



**Fig 17.** Pressure comparison in the area of minimum Chamber



**Fig 18.** Pressure comparison in the area of maximum Trailing Edge



**Fig. 19** Pressure comparison in the area of minimum Trailing Edge

### 3.3.3 Pressure comparison on the Trailing Edge

Results of the computer simulation on the *trailing edge* are given on Fig. 18 and Fig. 19.

In the region of *trailing edge*, the simulation results also demonstrated the adverse profile between maximum and minimum region of the *trailing edge*. This is in line

with the illustration given by the value of Table 1 and Table 2.

## 5 Conclusion

From the CFD simulation results, it can be seen that the maximum pressure arising from the air flow rate is directly proportional to the speed. The faster the speed of the plane, the resulting pressure is also greater, however, the minimum pressure had a contrast condition for both horizontal and V-tail. This condition could also found in the specific geometry for both horizontal and V- tail.

Furthermore, the pressure range will be greater if the rate of aircraft getting faster for both horizontal and V-tail. The pressure range of V-tail was higher than range for the horizontal tail. The highest range occurred in the V-tail with value of 114652,28 Pa. This condition had taken place caused by the minimum pressure acting in aerofoil is hand in hand with its maximum values. However, the highest pressure acting still on the horizontal tail namely the working pressure in the speed of 210 km/h with value of 136866.99 Pa.

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