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Computational Fluid Dynamic Analysis to determine Downforce of Motorcycle Winglet

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Abstract

Competitive motorcycling is all about being fast. However, frontal lift (i.e. 'wheelie') has high tendency to occur at high speed of travelling. Frontal lift is when the front wheel is no longer in contact with the ground, thus, results in the loss of traction, stability and control over the motorcycle. These undesired effects could be minimized by increasing the downforce (anti-lift) at the frontal section of the motorcycle. This could be achieved by incorporating a winglet which eliminates the necessity for the integration of electronic intervention. The objective of this study was to determine the downforce generated by a newly developed motorcycle winglet via Computational Fluid Dynamics (CFD) analysis. The CAD model for the winglet was developed via Inventor software and CFD was performed via ANSYS workbench. The analysis was performed on five (5) planes of the winglet. The result however showed a number of inconsistent readings of dynamic pressure gradient and drag pressure for all five (5) planes. It was found that the maximum drag pressure of 194.9 Pa was found on the pressure contour for plane Number 3. This is of course a direct contradiction to the goal of the incorporation of the winglet onto the motorcycle. Conclusively, due to lower dynamic pressure at the top layer of the winglet, the downforce generated is not significant to counter the frontal lift. Hence, the design characteristic of this newly developed winglet is not desired. For future study, the design used in this study could be used as the benchmark for improvement.

Keywords

Motorcycle, Aerodynamics, Downforce, Winglet, CFD Analysis

Introduction

In motorcycle competitions, aerodynamics plays a fundamental role for streamlining purposes (Ma'arof et al. 2018). However, such advantageous design could result in the occurrence of frontal lift at high speed of travelling. Frontal lift or commonly known as 'wheelie' is when the front wheel of a motorcycle is lifted, thus, no longer making any contact with the ground. This in return will results in the loss of front wheel traction, hence, affecting overall stability and

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control over the motorcycle. In short, this is truly not desirable. Therefore, in order to overcome this issue, racing engineers opted to the use of winglet as a non-electronic based solution. Electronic based traction control system does indeed exist, however, the system is complex and requires high frequency of tests in order to attain the optimal or best configuration. Hence, a winglet is much more feasible.

The winglet will be integrated onto the frontal section of the motorcycle to increase downforce or anti-lift. This downforce would facilitate in ensuring sufficient traction on the frontal section of the motorcycle by keeping the front wheel consistently in contact with the ground. For this study, one winglet was designed and tested in order to serve as a preliminary benchmark for a novel Yamaha R25 motorcycle. Different angle of attack (resulting variables) was analyzed for this newly developed design. This single-flap winglet shall be integrated on to Yamaha R25 track-motorcycle via a fastening mechanism.

The aim of this project was to determine the downforce generated by a motorcycle winglet via computational fluid dynamic (CFD) analysis. The downforce will facilitate in ensuring enough traction on the frontal section of the motorcycle without having the need for any electronic traction control system or electronic intervention

Literature Review

Aerodynamics is a major topic of interest in automotive and motorsport – especially, when it involves downforce that has a significant effect on vehicle's stability and overall performance (Dunbar et al. 2018; Ma'arof 2019). Downforce in motorcycling could be simply defined as the negative lifting capacity of which the motorcycle could demonstrate by the distinction between the pneumatic force and the yield of the bike. Moreover, coefficient of lift will be in a negative value for ground vehicle or angle of attack will be counted as zero value (VanDijck et al., 2015). The downforce on a bike is created around the center of the engine towards the front. A higher downforce at the frontal section of a vehicle shall result in the increase of cornering speed, improved acceleration and the reduction of breaking distance (Nascar et al. 2016). Stability is also a critical factor in tackling corners at high speed (Fiddlers et al. 1994). All of these are essential in motorcycle racing. Therefore, in order to achieve such engineering feats, winglet is commonly integrated at the frontal section of the motorcycle as a non-electronic based aerodynamics-add-ons. Based on physics, the downforce generated by a winglet is directly proportional to its surface area. However, the most critical drawback of a winglet with a large surface area is the increment of drag which in return reduce the vehicle's speed (Budiman et al. 2019). Hence, the shape of the winglet shall be a factor of concern due to its geometric restrictions.

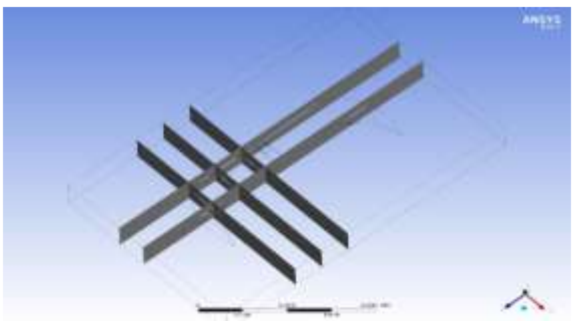
The concept was to increase the downforce by placing wings on both sides of the motorcycle at a negative dihedral angle (Shahzad et al. 2012)**.** The wings are placed at close proximity to the rider for streamlining purposes. The wings are placed at a dihedral angle since when the motorcycle is talking a corner, one of the wings will be in a horizontal position which will generate the downforce and the other in a vertical position which will add the unwanted lateral force (Charles et al. 2002). The lateral force generated by the wing is only partially disturbed, thus, only a small addition is made to the lateral force. The important part is that the wings must be placed on the front fairing after the radiator inlet and at the front of the rider's knee. The rider shall act as the movable interference device.

Currently, generating downforce is one of the most attainable and cost-effective method to improve vehicle performance for most series with restrictive engine, tire or chassis regulations (Jacuzzi et al. 2020). Therefore, determining the downforce generated by a motorcycle winglet via computational fluid dynamic (CFD) analysis can be economical and reliable in present and future and this is especially true in reviewing the study by Sedlak et al. (2012). In short, these literatures shall be the benchmark for this study in developing the motorcycle winglet.

Methodology

For this study, the computer-aided-design model for the winglet was developed via Inventor software as shown in Figure 1. The CFD was performed via ANSYS software. There are 5 planes of analysis for the simulation. Each plane will be viewed as colored contour. The values of these colored contour are given as dynamic pressure in Pascal. This dynamic pressure is the pressure which pass through the winglet design in the simulation. A higher pressure on the top layer in comparison to bottom layer is a key indicator for a desired winglet design. The model for bike wings is exclusive and specifically designed for the Yamaha R25 track-motorcycle. This is unique in comparison to other studies such as by Ma'arof et al. (2019) who did their study based on the winglet that could be incorporated on a Ducati 1198SP.

a) Winglet tested for this study



b) Top View of Planes in Design 1

Figure 1. Winglet Tested.

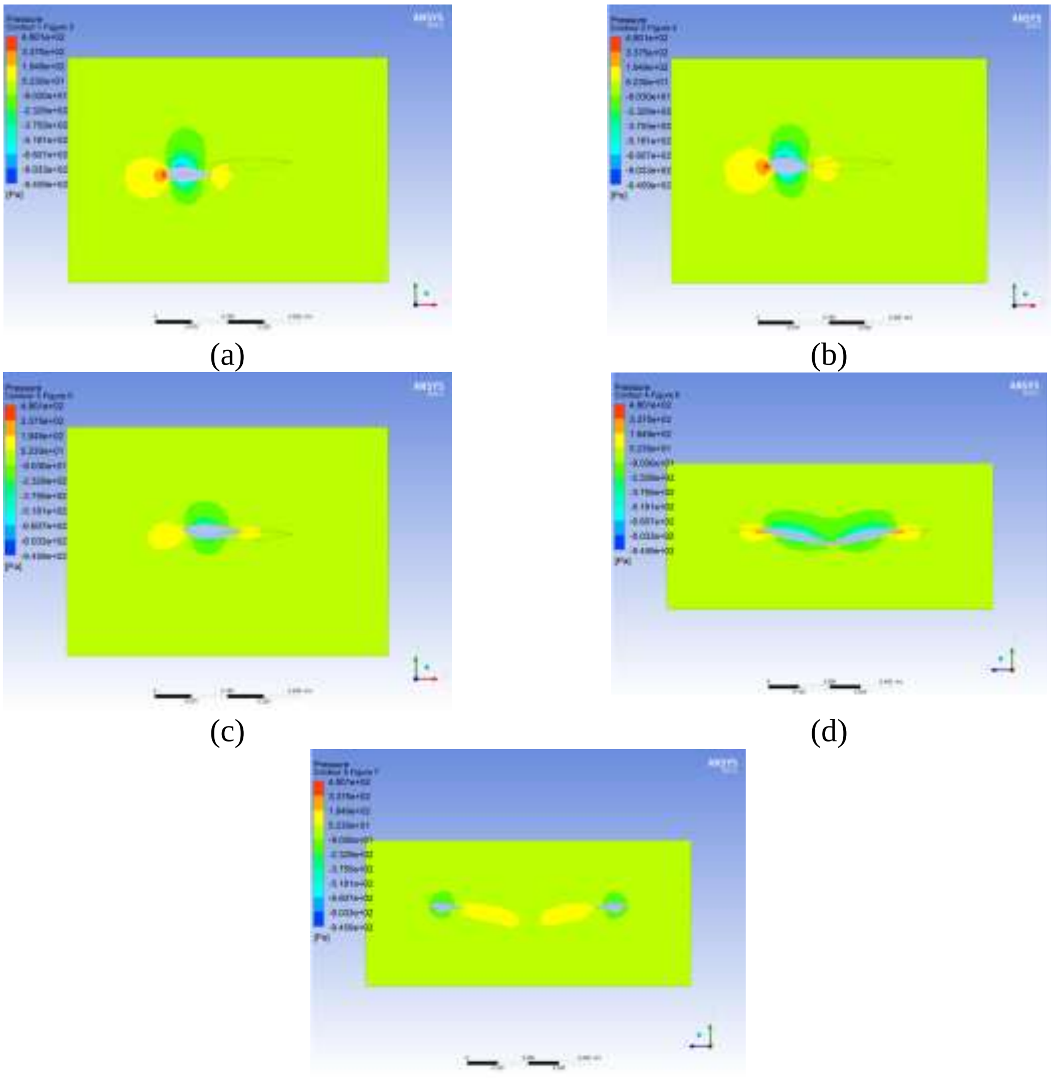
The downforce can be determined on the accompanying equation:

$$D=1/2\rho AC_L v^2 \quad (1)$$

D: Downforce
ρ: Air Density, kg/m3
A: Surface Area, m^2
C_L: Coefficient of lift
v: Velocity, m/s

Results and Discussion

Figure 2 shows the five (5) planes which was tested for the Winglet Design 1 and it is done to gain specific details from simulation at the particular area. These planes will be seen as contour in simulations. Contour and ISO surface plots are utilized in post-processing to picture scalar amounts and fields in ANSYS simulation results. The assessment for this study is made with respect to Figure 2.



(a) (b) (c) (d) (e)

Figure 2. Pressure contour for the Plane tested (a) Plane 1, (b) Plane 2, (c) Plane 3, (d) Plane 4, (d) Plane 5

In Contour 1 of winglet, the airflow was from left to right. From here, it was evidence that the top layer of the winglet had lower dynamic pressure gradient of -803.3 Pa in comparison to bottom layer which indicates a higher dynamic pressure gradient of -518.1 Pa. The frontal area of the winglet showed the maximum drag pressure of 480.1 Pa. Theoretically, lower drag pressure will produce higher top speed. In simpler term, this is the same as DRS system in F1. However, in Contour 1 of winglet, due to lower dynamic pressure in top layer there has less downforce to counter frontal lift.

In Contour 2 of the winglet, the airflow was from left to right. The simulation clearly indicated that top layer of the winglet had lower dynamic pressure gradient of -660.7 Pa in comparison to the bottom layer which had higher dynamic pressure gradient of -518.1 Pa. The frontal area of the winglet showed the maximum drag pressure, which was 480.1 Pa. However, in contour 2 of the winglet, due to lower dynamic pressure at the top layer, it can be concluded that again, downforce was only minimally exerted.

In Contour 3 of the winglet, similarly, it was apparent that the top layer of the winglet had lower dynamic pressure gradient (-518.1 Pa) in contrast to the bottom layer which recorded a much higher dynamic pressure gradient (-232.9 Pa). Though, it should be noted that these readings had shown moderate increment in comparison to Contour 1 and Contour 2, from overall point of view, it was still not the desired result. In addition, the frontal area of the winglet showed the maximum drag pressure, which was 194.9 Pa. However, in retrospect to Contour 3 of winglet, the downforce generated was still to complement the design goal.

In Contour 4 of the winglet, the side profile of the winglet had recorded a lower dynamic pressure gradient (194.9 Pa) on top side and had higher dynamic pressure gradient (337.5 Pa) on bottom side. Although the data attained were an improvement than to that of Contour 1, Contour 2 and Contour 3, it was still indicative of low downforce generation. Furthermore, the frontal area of the winglet shows the maximum drag pressure, which is (-232.9 Pa). Hence, there has less downforce to counter frontal lift at this particular contour.

In Contour 5 of winglet, the side profile of the winglet had indicated a lower dynamic pressure gradient (52.3 Pa) on top side and higher dynamic pressure gradient (-90.3 Pa) on bottom side. Although, these values were indeed better in comparing to the data generated by Contour 1, Contour 2, Contour 3 and Contour 4; downforce was not sufficiently produced. Furthermore, the frontal area of the winglet shows the maximum drag pressure, which is (194.9 Pa). Yet again, downforce generated was not to the readings which are desired.

In summary, the simulation showed that winglet does not exhibit overall downforce. At all five (5) contours of the winglet, low dynamic pressure was simulated at the top layer, whilst, higher dynamic pressure was attained at the bottom layer. Each contour has shown the increment and decrement in the values, though, Contour 3 exhibits the maximum drag pressure at 194.9 Pa. Hence, the data attained from the newly designed winglet does not meet the objective in generating downforce. Therefore, improvements could be made based on this design for future studies.

Conclusion

In this study, computational fluid dynamics analysis was performed to determine the downforce generated of a newly designed motorcycle winglet. From the simulation it was apparent that due to lower dynamic pressure at the top layer of the winglet, the downforce generated is not significant to counter the frontal lift. Hence, this design characteristic is not desired and does not coincide with the goal of the integration of winglet onto the racing motorcycle. Henceforth, for future study, the design used in this study could be used as the benchmark for improvement.

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