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The Influences of Racing Track on Choosing Winglet

Siqi Lin

Chongqing DEPU Foreign Language School, Chongqing, China, 40000

vernoups@outlook.com

Abstract. Since winglet be added on the motorcycle in 2016 first, the extreme speed of the motorcycle competition improve a lot. The engineers of motorcades not only focus on the efficiency of the engine, but also put some of their attention on the design of the aerodynamic kits. This paper is focus on the shape of the racing track to see how it effect the choosing of winglet. Since different surface area of winglet may have some effect on the force provided on the motorcycle. This paper finds that for the racing track which has more strait roads, the motorcycle should reduce the drag force, so that the winglet should has less surface area, vice versa. The research significance is to help motorcades to choose suitable aerodynamic rate and give some suggestion to the rider who want to add winglet on their own motorcycle.

Keywords: motorcycle, winglet, CFD (computational fluid dynamic), Moto GP (grand prix motorcycle racing).

1. Introduction

Aerodynamics is a compound word, “aero” refers to that it searches in something related to air, “dynamics” refers to the motion, and “aerodynamics” refers to the study of how air moves. Good aerodynamics has enabled boats to sail, windmills to spin, and planes to fly [1]. Over the last one hundred years, motorcycles experienced a dramatic improvement. Nowadays some can even reach higher speeds than an average automobile. To improve rider comfort, wind screens and fairings were added on the motorcycle, leading to studies on motorcycle aerodynamics [2].

In 2016, the winglet first be allowed to use in the Moto GP (Grand prix motorcycle racing) and quickly be banned in 2017 since some of the rider mention that they could not get behind the Ducati, the first company who added the winglet on the motorcycle. Although did not have the brakes, the car kept shaking and it felt like it was getting hit by an air cannonball. But this design truly improve the speed of the motorcycles. At May 22th 2016, in Mugello Circuit, one of the Ducati participant create the new speed record-354.9 km/h. After a few years, this will be allowed again with some limits which will be set by Moto GP.

This paper aims to search how the different characteristics of the racing track would influence the choosing of winglet, especially the winglet with different cross-section area. By analyzing the relationship of between surface area and downforce or air resistance, this paper finds out the balance among that. This paper’s research significance is to help motorcades to choose suitable aerodynamic rate and give some suggestion to the rider who want to add winglet on their own motorcycle.

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2. Theoretical background

It's widely known that the lift is caused by the pressure differences, which means the pressure upper the wings of airplane is lower than that under the wings. This caused by the curved streamline with the pressure increasing in the direction away from the center of curvature [3]. However, for the ground vehicles, the positive lift is truly an undesirable force since it will result in the loss of traction, stability and control over the vehicle [4]. As for providing the downforce, it has a little bit change to make sure that the pressure under the winglet is lower than that upper the winglet. The concept for it is to placing winglets on both sides of the motorcycle at a negative dihedral angle [5]. However, the placement of winglet may effects both downforce and air resistance, and these two forces that are fundamental to aerodynamics. That's what should be consider about during the designing of the racing motorcycle.

2.1. The relationship between surface area and downforce

Downforce is the negative lift force on motorcycle produced by distinction between air pressure and performance of the motorcycle [6]. Based on the experiment research, the down force could be calculated by an accompanying equation (1) [7]:

$$D = \frac{1}{2}\rho A C_L V^2 \tag{1}$$

D: Downforce
: Air Density, kg/m^3
A: Surface Area, m^2
: Coefficient of lift
V: Velocity, m/s

Since the coefficient of lift and air density are almost same during the competition, and the velocity is decided by the rider themselves which also almost same for each rider. This gives the information that for the designer of the racing motorcycle, the downforce provided by the winglet is proportional to the surface area. Since racing engineers opted to the use of winglet as a non-electronic based solution for avoiding front wheel leave the ground [7]. When increasing the surface area of the winglet, it may provide larger downforce. A higher downforce at the frontal section of a vehicle shall result in the increase of cornering speed, which makes it suitable for the racing track that contains lots of corner.

2.2. The relationship between cross-section area and air resistance

Similar to the downforce, the air resistance could also be calculated by an accompanying equation (2):

$$F = \frac{1}{2} C \rho S V^2 \tag{2}$$

At this equation, C means the coefficient of air resistance, S means the surface area, and F comes to the drag force. Similar to the coefficient of lift, the coefficient of air resistance is almost a constant. This means the drag force on the motorcycle also directly proportional to the surface area of the winglet. Based on algebra, the most critical defect of the large surface area winglet is the increment of air resistance which reduce the vehicle's speed [8]. Especially when they are on the straight road, the part of the track that asked the rider to reach as fast as possible, this would leads the extreme speed of the motorcycle decrease and effect the final score that get by the competitors.

3. Analysis of the research results

3.1. The results took by others through CFD about downforce

From *Anti-Lift Assessment of Multi-Flap Motorcycle Winglet for Track Usage Via Wind Tunnel Test* [4], this research designs winglet with multi-element wings. The increase of the

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multi-elements provided more surface area that the winglet attack with the air. During that paper's test, it choose the same length of multi-elements and compare 3 types of number of flaps 3, 4 and 5.

Besides the equation that mentioned above to calculate the downforce, the software (CFD) calculated the speed through another equation (3):

$$V = \sqrt{\frac{2(P_t - P_s)}{\rho}} \tag{3}$$

From this test, it show that with the increase of the speed, the downforce provided by the winglet also increase. What's more the winglet with 5 flaps provided more downforce than the one has 3 flaps. Especially at much higher speed. Through the test, when speed is 10m/s, the downforce provided by 5 flaps is 0.18N while that for 3 flaps is 0.05N, with the difference of 0.13N. But when the speed increase to 30m/s, the downforce provided by 5 flaps increase to 1.57N and that for 3 flaps is 0.46N, with the difference of 1.11N. This show that the difference on the number of flaps may effect more when the speed of the motorcycle become higher.

Although the motorcycle used in the Moto GP or some other types of the competition did not allow to use winglets with much multi-elements, it still provides some idea about the decision. From the table in that paper, it could be seen that 5 flaps have an area of 0.016 square meters, while that for 3 flaps is 0.010 square meters. It show that with the increase of the surface area, the downforce would increase and provided more effect when the speed of the motorcycle is very high. This confirm that the assumption that I get from the theoretical equation is true.

3.2. General results

Since motorcycles are essentially the least amount of metal and structure, and the competition may set limits on the weight of the motorcycle, so improvements from weight reduction is unlikely [9]. So to make some improvements on aerodynamically efficient becomes much important. For motorcycle aerodynamic, it's basic is to reach the balance between lots of force that may affect motorcycle's performance. Especially for downforce and the drag force, which are in contradiction [10]. From the front result, it show that with the increase of the speed, the effect by the downforce and the drag force become more and more visible. As the speed during the competition are really high, the aerodynamic kits take a very important part in the designing of the motorcycle. To reduce the drag force appear, the designers add the front fairing on the motorcycle although it seems that is design for the comfortable of the rider [2]. The front fairing makes the attract area with the air become more smooth which could reduce the turbulence that may cause the drag force. Some may even tried to adding the rear fairing for increase the efficiency [9]. For the downforce, the solution is to add the winglet on the motorcycle, with the increase of the surface area, it becomes more and helps the control of the motorcycle.

4. The Influences of Track on Deciding Winglet

As for a car racing competition, its purpose is to become as fast as possible. Figure 1 shows some shapes of the Moto GP racing track.

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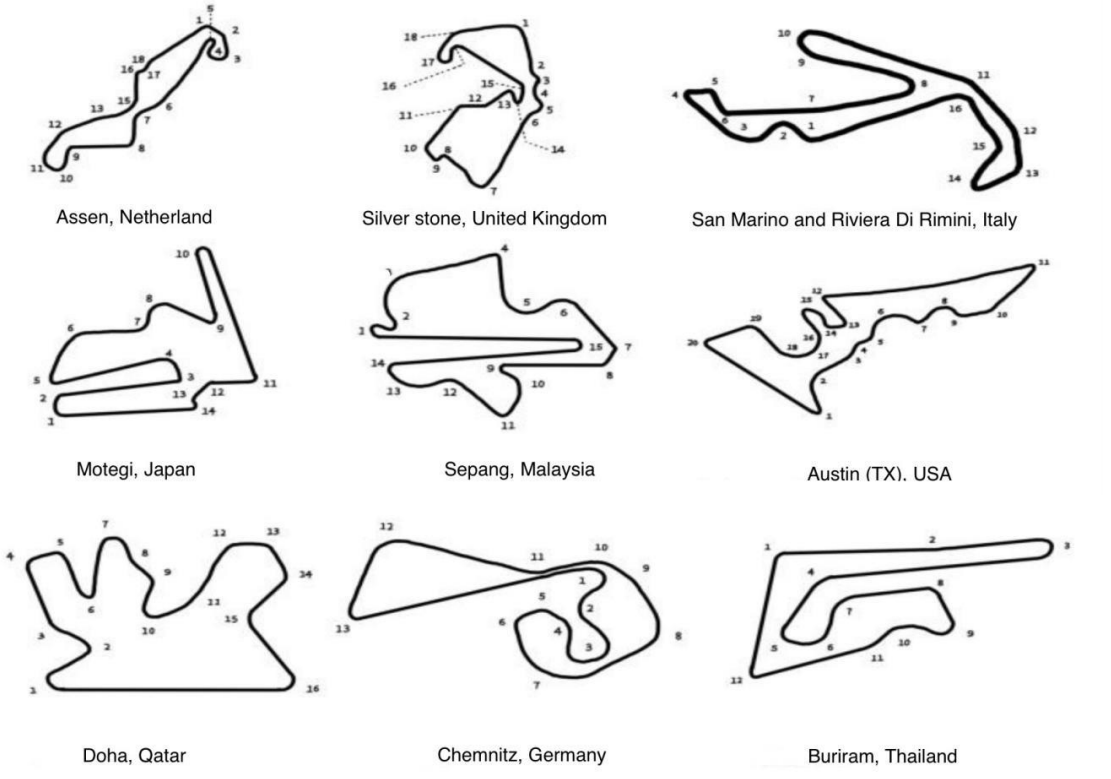

Figure 1. The thumbnail for 9 Moto GP racing track.

It is easily to see that the number and angle of bend for each country are different. This leads the motorcades should find the balance between to focus on the extreme speed on the straight road and to focus on the stability of motorcycle which effect the speed that could be reach at the corner.

4.1. The shape of racing track

Like for the 10th bend of Motegi track, 15th bend for Sepang track and the 3rd bend of Buriram track. It is likely be told as hairpin, which means that the rider must go through the bend with slow speed and a very extreme lean angle. This makes the possibility to low side (one type of fall down which caused by the loss of traction between front wheel and the ground) increase, which is a negative effect and need to increase the downforce to reduce that. However, for the Doha and Chemnitz track, their bend do not have the exaggerated angle and most part of these track are the straight line, which allow the rider to go through with much higher speed. This could also be prove by the track record. For Chemnitz, it needs at least 1’21.442 to finish, while for Motegi, it needs at least 1’45.350 to finish. Through the recorded, it’s true that the shape of track may influence the extreme speed and the special needs for the motorcycle. What’s more, the number of bend on each track are also different.

According to these 9 tracks, the longest one is the Silverstone track in United Kingdom, which is 5.9 km. Since the mileage of the track is long, it only acquire the rider to take 20 turns. For Assen track in Netherlands, it only 4.5 km, so that the rider should take 26 turns. For the track need more turns to finish, the rider should take more bends. This leads the motorcade to put more attention on the performance of the motorcycle during the bends. As for the Buriram track, it only have 12 corner, however that for Austin track becomes to 20. This show that the ability that the track acquire rider to have are also different.

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4.2. Motorcade's decision in real competition

In different racing track, different motorcade's rider may have different performance. Some of the performance may be influenced by the effect of the others. Like in this year's Moto GP-Assen, the fall of Quartararo also influence Aliex Espararo. This effect leads Aliex Espararo only got the 4th in that competition. But in some of the situation, the choosing of winglet may also leads some effect.

For Aprilia (one of the motorcade of Moto GP), the winglet on their motorcycles have the largest surface area. This design helps the rider of Aprilia like Aliex Espararo took high score in some station of the competition. Like the one mentioned in Assen track. From the Figure 1, this track also has lots of bends and the length of this track is short, which means the motorcycle need to have enough downforce for balancing themselves. Since the downforce will facilitate in ensuring enough traction on the frontal section of the motorcycle without having the need of any electronic traction control system or electronic intervention [6]. Without the huge downforce provided by the winglet to avoid him also fell down, he cannot get the 4th in that competition. However, for Honda (another motorcade) their winglet has less surface area, which makes their score on the track which have more straight road may become higher. But for the track which have more bend, their score did not really well. Although it may have some effect caused by their riders.

During the past, there used to have one kind of fairing called Hammerhead Fairing. It could provide large downforce, but it certainly be give up by its designer. Because during the test, it be prove that when back-to-back, this design is approximately 10km/h slower than the conventional design of fairing and top speed in the main straight road. Although it does well in the bend, it did not reach the balance that should reach since it influence the straight road speed a lot.

Nowadays, since the competition allow to use the aerodynamic kit that they used in last competition season, most of the motorcade may prepare kit with different size of winglet. This help the motorcade to use more suitable winglet for different racing track. Since it allow to change the aerodynamic kit between different tracks, this would be one of the influence factor.

5. Conclusion

From the analysis of the racing track, the track could be generally divided into two general types. One is more require the rider to show their ability about the control of their motorcycle during the bend, the other one is to ask them to challenge the extreme speed they could reach.

After the competition allow the use of winglet, motorcades started to design and improve that a lot. Some are designed for speed and other may more focus on the control. Since this match the ability that the competition want, so the type of the racing track also influence the decision of the winglet. For the racing track with much more bend especially with hairpin which force the rider to go through with low speed, the motorcycle with large surface area of winglet may more suitable. Since the extreme speed be cut down, the drag force caused by the air become less. When the lean angle need for cross the bend increase, the winglet design for control may took more important role in avoid rider face some accident. While for the race track with more straight roads, the motorcycle with less surface area become more suitable. Since its average speed during the competition become much higher, the influence of drag force become more feasible and the need for control of avoiding low side decrease.

Generally, it's that more straight roads with less surface area, more bend more surface area. In the future, the design of the winglet which could change the area might be in need for someone which want to refit their motorcycle. It could change by the rider so that they could change during the straight road and bend for much higher overall speed. But this might not allowed for the competition since the competition should not become the totally competition of technology without riders ability. However, there is not in need for most of people, since most of people to refit their motorcycle is only for good looking. Because in their daily life, the winglet cannot show its positive side, the only thing they provide is only the extra drag force. For the future study, it could focus on the angle of the winglet. Since its purpose is to effect the streamline go through that, the angle of the winglet may also effect the performance of that.

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