Drag Optimization Mechanism for Taylor’s Race Car
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Abstract— The time is one of the most important factor in achieving the destination in a car race. One factor which contributes in reducing the time is drag force. This paper proposes a method to optimize the drag force of a car during the race. An increase in the drag was observed when cooling channel to direct the airflow into the radiator was installed in the car. Simulink was used for real-time simulation of the linear motion of the car to observe the performance of the car by optimizing the drag coefficient. It was concluded that if the drag coefficient of the car is optimized from 0.6702 to 0.5853 or 0.6217 then it is possible to achieve better speed and to cover more distance in less time as compared to the car with fixed value of drag coefficient.

Keywords— Drag Coefficient, Drag Optimization, Cooling Channel, Performance of the Car, Simulink, Airflow, Velocity, Distance.

1. Introduction
Taylor’s University Racing Team (TRT) designed and manufactured and open wheel race car. After the test run it was observed that the temperature of the engine increases gradually due to the blockage of the airflow into the radiator which was placed at the back of the driver seat [1]. It is important to avoid the engine from overheating to improve its efficiency and to prevent its failure [1]. In order to cool down the engine a cooling channel (flat plate) was installed to direct the airflow into the radiator as shown in Figure 1 [1]. An extensive study was conducted by Lee and Al-Obaidi to calculate the drag and its effect by changing the angle of attack of the cooling channel [1]. This resulted in additional drag, having this channel at the given angle is not required but it is required only when the temperature of the engine reach its maximum limit.

![Cooling Channel](image)

Figure 1. Car model with cooling channel [1]

The main objective of this research is to design a control system which adjusts the angle of the cooling channel depending on the temperature of the engine. This involves the study of the effect of an optimization of the drag coefficients (C_d) on the performance of the open wheel race car. For this study the drag coefficient is considered as a variable because the angle of the cooling channel has to be adjusted during the race to provide minimum possible drag when the temperature of the engine is normal and vice versa.

2. Research Methodology
It is important to carry out the real time simulation of the car to study the effect of the drag optimization on the performance of the race car such as the velocity and distance covered in time. Tasora (2008) studied the lateral acceleration and reaction of suspension with respect to time at simulated maneuver by developing the computer based simulator tool for optimizing the design of the car [2]. Bruna and Spiridon (2013) studied the effectiveness of numerical modeling of aerodynamic by adopting the aircraft airfoil on sports car to determine the C_d at different angle of attack and concluded that engineering student can design complex aerodynamic model and obtain accurate results [4, 5]. Lot and Simos (2013) studied the methodology for lap time optimization of a sports hybrid electrical vehicle with give characteristics on a particular track [3]. To study the effect of the drag optimization on the velocity, distance and acceleration with respect to it is important to simulate the car on the race track. This can be achieved through Matlab, Simulink.

2.1 Mathematical Modeling
To simulate the motion of car on the race track a mathematical model was developed. Newton’s second law was used to create the mathematical model as shown:

\[ \sum F = ma \]

\[ \sum F = \sum F_w + \sum F_r = F_d - F_t \]

where, \( \sum F \) represents the forces acting on the car. \( F_t \) is the thrust of the car in Newton, \( F_w \) is the weight of the car in Newton, \( F_d \) is the drag force of the car in Newton, \( F_r \) is the friction force acting on the car in Newton. \( F_r = \mu m g \)

where \( m \) is mass in kg, \( g \) is gravity in m/s², \( \mu \) is friction coefficient, \( C_d \) is drag coefficient, \( v \) is velocity in m/s, \( A \) is reference area in m² and \( p \) is mass density of fluid in kg/m³.

2.2 Simulink
Simulink model is created to simulate the car motion and study the effect of different drag on the performance of the car. This Simulink model is only able to simulate the real-time linear motion of the car. Table 1 shows the main characteristics of the car.

<table>
<thead>
<tr>
<th>Characteristics of Race Car</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of car (m)</td>
<td>250 kg</td>
</tr>
<tr>
<td>Driver and fuel mass (m)</td>
<td>80 kg</td>
</tr>
<tr>
<td>Friction Coefficient(( \mu ))</td>
<td>0.6</td>
</tr>
<tr>
<td>Drag Coefficients (C_d)</td>
<td>0.6702 - 0.5853 - 0.6217</td>
</tr>
<tr>
<td>Maximum Speed (v)</td>
<td>13.8 m/s</td>
</tr>
</tbody>
</table>

The values from the table 1 were used in the Simulink model as shown in Figure 2.

![Simulink model for linear motion of the car](image)
allow the air into the radiator to cool down the engine which would result in additional drag.

3. Results and Discussion

The drag coefficient of the car with the cooling channel at different angle of attack was calculated by Lee and Al-Obaidi as shown in Figure 3 to determine the minimum possible drag coefficient at particular angle of the cooling channel [1].

![Figure 3. Drag Coefficients at different angels of cooling channel](image)

Figure 3 clearly shows that the drag coefficient is higher when the cooling channel is fixed at its original position at an angle of 36° and if the angle of the cooling channel is readjusted a decrease in the drag coefficient was observed which could affect the performance of the car. These drag coefficients were substituted in the Simulink model to determine performance of the car by observing the change in velocity and distance with respect to time. Figure 4 shows the time taken by the car to reach a distance of 5 km when different drag coefficients were used.

![Figure 4. Distance vs. time at different Drag Coefficient](image)

From Figure 4 it can be observed that when the drag coefficient is set as zero it only takes around 100 s for car to reach 5000 m. But when the angle of the cooling channel is adjusted to 36 degree to allow the air into the radiator for the cooling of the engine the drag coefficient is increased to 0.6702 and it takes 880 s to cover a distance of 5000 m. Similarly when the angle of the cooling channel is adjusted to 90 degree the drag coefficient is increased to 0.5853 it takes 820 s to reach 5000 m. This clearly proves that the higher the drag coefficient the more time the car is going to take to complete one full lap.

![Figure 5. Change in Drag coefficient over Time](image)

Figure 6 shows the velocity with respect to time when the drag coefficient is kept constant and as a variable. It was observed that if the cooling channel is kept at its original fixed angle of 36° at a drag coefficient of 0.6702 the maximum velocity attained by the car would be 6 m/s. And if the drag coefficient is changed during the race the change in the velocity with respect to time can be observed. The car started the race at minimum drag coefficient of 0.5853 and achieved a maximum velocity of around 6.5 m/s. Later during the race after 100 s the engine started to heat up and the angle of the cooling channel was adjusted to 54.5° to allow the air into the radiator to cool down the engine this resulted in an increase of the drag coefficient to 0.6217 and decreased the velocity of the car to 6.25 m/s. After 200 s when the temperature of the engine had returned to normal the angle of the cooling channel was readjusted to 90° with drag coefficient of 0.5853 and the change in velocity from 6.25 m/s to 6.5 m/s was observed. At 300 s and increase in the temperature of the engine was observed and the cooling channel was adjusted to its original position of 36° with a drag coefficient of 0.6702 and a decrease in the velocity to 6 m/s was observed. Figure 5 shows the change in the drag coefficient over the time span of 400s during the race. This clearly proves that if the drag coefficient of the race car would be optimized by changing the angle of cooling channel instead of fixing the cooling channel at a particular angle it would decrease the time required for the completion of the one lap due to the continues change in the velocity of the car.

4. Conclusions

Based on the numerical simulation it can be concluded that the drag coefficient plays an important role on the performance of the race car and this could increase or decrease the opportunity of winning the race. If the drag coefficient of the car is optimized during the race it is possible to achieve better speed and to cover more distance in less time as compared to the car with fixed value of drag coefficient.

Future studies include the simulation of the car on a complicated race track with curves and turns to study the effect of the optimization of the drag on the performance of the car. As well as optimizing the angle of the cooling channel and drag to provide airflow into the radiator depending on the temperature of the engine.

References


