CFD Analysis of Automobile Rear Dynamic Spoiler

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Abstract:
Over past few decades automotive industry focuses on aerodynamic characteristics of spoiler. Through this they succeeded running life of all the parts which has been integrated with the automobiles. On this we had designed a rear spoiler in a car that reduces the running distance after applying the break. Keeping in this mind, the present investigation is focused on the study of angular orientation of spoiler in order to reduce the stopping distance using Computer aided Engineering approach. The modeling software CATIA V5.0 is used to model the spoiler for different orientations and ANSYS 12.0 was for dynamic analysis in this current investigation.

Keywords: Spoiler, Car, Speed, Stopping distance, Angle of Attack (AOA), CATIA, ANSYS.

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1. Introduction

In this paper the effect of spoilers on aerodynamic characteristics of an airfoil were observed by CFD. Airfoil section is designed with a spoiler extended at an angle of 20^0 degree with the horizontal.The total aerodynamic package of the race car is emphasized now more than ever before. The use of aerodynamics to increase the cars' grip was pioneered in Formula one in the late 1960s by Lotus, Ferrari and Brabham. Aerodynamics plays a vital role in determining speed and acceleration and thus performance. While drag reduction is an important part of the research, down force generation plays a greater role in lap time reduction. Ground effect aerodynamics of race cars is concerned with generating down force, principally via low pressure on the surfaces nearest to the ground. These phenomena happen when a wing is going near the surface. Airfoils or wings are used in the front and rear of the car in an effort to generate more down force. The front wing of a race car is an important piece to make safety at high speed and produces about 1/3 of the cars down force; it has experienced more modifications than rear wing. The front wing assembly is the first part of the car to meet the air mass. The flow field here is better than at other parts of the car because the air here has been disturbed the least. The wing is designed to produce down force and guide the air as it moves toward the body and rear of the car. Flaps and winglets may also be used. In setting up the front wing assembly, engineers must consider what happens to the airflow as it travels toward the back of the car. (M.H. Djavareshkian, 2011).

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2. THEORETICAL CALCULATION

2.1 Stopping Distance of the Vehicle for Various Speeds (Without Spoiler):

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

If the spoiler not attached, $F_d = 0$

Case (i): If the vehicle moves 150km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}$

$d = \frac{41.667^2}{2(0.7)(9.81)}$, $d = 152.954m$

Case (ii): If the vehicle moves 165km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}$,

$d = \frac{45.833^2}{2(0.7)(9.81)}$, $d = 152.954m$

Case (iii): If the vehicle moves 180km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}$,

$d = \frac{50^2}{2(0.7)(9.81)}$, $d = \underline{182.030}$ m

Case (iv): If the vehicle moves 200km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}$,

$d = \frac{55.556^2}{2(0.7)(9.81)}$, $d = \underline{224.732}m$

Table 1: Stopping distance of the vehicle (without spoiler) in meters

Speed	150 (km/hr)	165 (km/hr)	180 (km/hr)	200 (km/hr)
Stopping Distance in m	126.412	152.954	182.030	224.732

2.2 Stopping Distance of the Vehicle for Various Speeds (With Spoiler):

Table 2: Pressure developed on the spoiler (for various speeds and various AOA)

SPOILER ANGLE/ SPEED	150 Km/hr	165 km/hr	180 km/hr	200 km/hr
8°	821.97	1009.9	1200.5	1486.04
12º	839	1039	1241	1529
15º	884	1065	1268	1570
18º	947	1146	1332	1653
20º	1015.7	1237	1436.71	1797.93
22º	854.6	1030.17	1234.16	1506.46
23º	881	1056.57	1266.84	1561.24
25º	807	965	1152	1432
30º	815.6	986.24	1175.07	1434.23
35º	789	953	1129	1391.78

Table 3: Force developed on the spoiler (for various speeds and various angle of attack) in Newton:

SPOILER ANGLE/SPEED	150 Km/hr	165 km/hr	180 km/hr	200 km/hr
8º	382	469.6	558	690.9
12º	390	483	577.1	710.9
15º	411.1	495	589.6	730.1
18º	440.4	532.9	619.4	768.7
20º	472.3	575.6	668.1	836

22º	397.4	478.9	573.8	700.3
23º	409.7	491	589.1	725.9
25º	375.3	448.7	535.7	665.8
30º	379.3	458.5	546.4	666.8
35º	366.9	443.2	524.9	647.2

2.3 Stopping Distance of the Vehicle for Various Speeds And Various AOA:

1. **If the Angle of Attack (AOA) = 8^0**

Case (i): If the vehicle moves 150km/hr, stopping distance

$$d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$$

Stopping distance, $d = \frac{41.667^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+382}\right)$

$d = \underline{121.7\ m}$

Case (ii): If the vehicle moves 165km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$d = \frac{45.954^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+469.6}\right)$,

$d = \underline{146\ m}$

Case (iii): If the vehicle moves 180km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$d = \frac{50^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+558}\right)$

$d = \underline{172.3\ m}$

Case (iv): If the vehicle moves 200km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$d = \frac{55.556^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+690.9}\right)$

$d = \underline{210.1\ m}$

2. If the Angle of Attack (AOA) = 12^0

Case (i): If the vehicle moves 150km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$d = \frac{41.667^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+390}\right)$

$d = \underline{121.6\ m}$

Case (ii): If the vehicle moves 165km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$d = \frac{45.954^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+483}\right)$

$d = \underline{145.8\ m}$

Case (iii): If the vehicle moves 180km/hr,

$$d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$$

$$d = \frac{50^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+577.1}\right),$$

$$d = \underline{172\ m}$$

3. If the Angle of Attack (AOA) = 20^0

Case (i): If the vehicle moves 150km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$$d = \frac{41.667^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+472.3}\right)$$

$$d = \underline{120.7\ m}$$

Case (ii): If the vehicle moves 165km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$$d = \frac{45.954^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+575.6}\right)$$

$$d = \underline{144.6\ m}$$

Case (iii): If the vehicle moves 180km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$$d = \frac{50^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+668.1}\right)$$

$$d = \underline{170.5\ m}$$

Case (iv): If the vehicle moves 200km/hr,

Stopping distance, $d = \frac{v^2}{2\mu g}\left(\frac{m}{m+F_d}\right)$

$$d = \frac{55.556^2}{2(0.7)(9.81)}\left(\frac{9908.1}{9908.1+836}\right)$$

$$d = \underline{207.3\ m}$$

Table 4: Stopping distance of the vehicle (for various speeds and various AOA) in m.

SPOILER ANGLE/ SPEED	150 Km/hr	165 km/hr	180 km/hr	200 km/hr
8º	121.7	146	172.3	210.1
12º	121.6	145.8	172	209.7
15º	121.4	145.7	171.8	209.3
18º	121	145.2	171.3	208.6
20º	120.7	144.6	170.5	207.3
22º	121.5	145.9	172.1	209.9
23º	121.4	145.9	171.8	209.4
25º	121.8	146.3	172.7	210.6
30º	121.8	146.2	172.5	210.6
35º	121.9	146.4	172.9	210.9

Table 5: Percent of stopping distance reduced by using spoiler (for various speeds and various angle of attack) in %

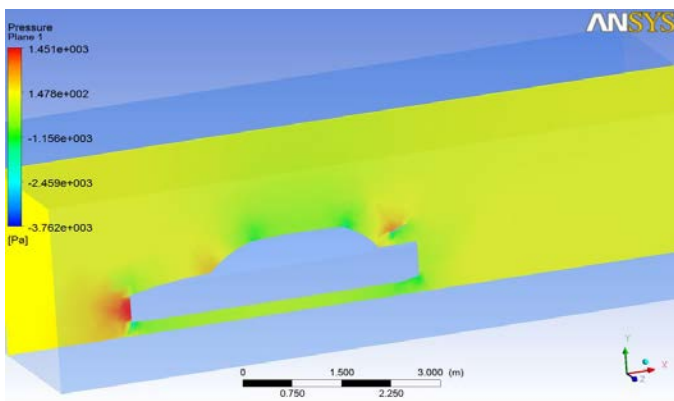| SPOILER ANGLE/SPEED	150 Km/hr	165 km/hr	180 km/hr	200 km/hr
8º	3.73	4.55	5.35	6.51
12º	3.81	4.68	5.51	6.69
15º	3.97	4.74	5.62	6.87
18º	4.28	5.07	5.89	7.18
20º	4.52	5.46	6.33	7.76
22º	3.89	4.61	5.46	6.59
23º	3.97	4.74	5.62	6.82
25º	3.65	4.35	5.13	6.29
30º	3.65	4.42	5.24	6.29
35º	3.57	4.29	5.02	6.13

CFD ANALYSIS

Figure 1: Analysis of spoiler in 20^0 AOA and 150 km/hr speed

From figure 1 the minimum and maximum pressure created is -3762Pa and 1451Pa, the maximum pressure created at spoiler is 1015.7Pa.
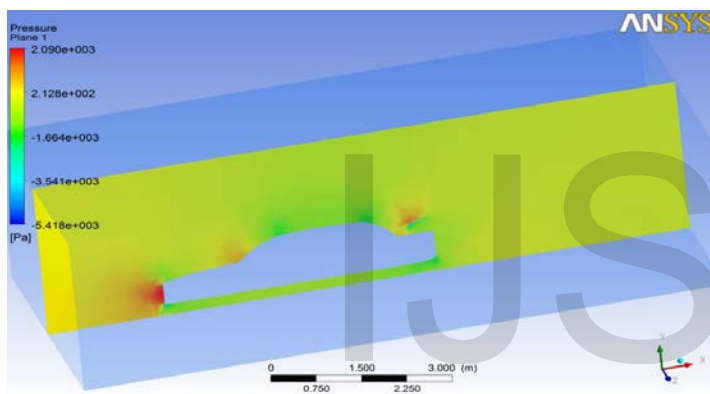

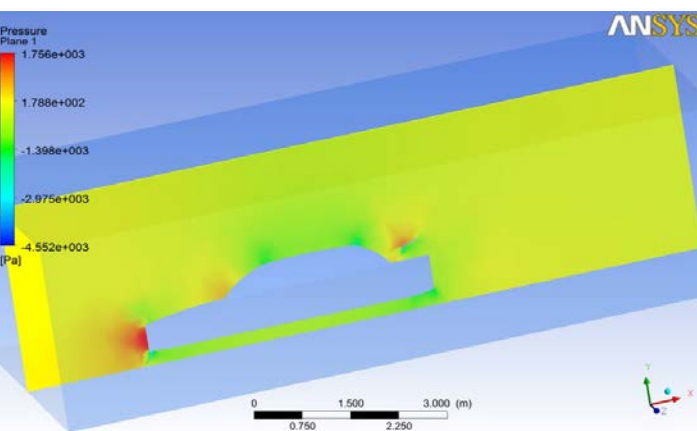**Figure 2:** Analysis of spoiler in 20^0 AOA and 180 km/hr speed

Figure 3: Analysis of spoiler in 20^0 AOA and 165 km/hr speed

From figure 2 the minimum and maximum pressure created is -4552Pa and 1756Pa, the maximum pressure created at spoiler is 1237Pa.

3. Percentage reduction in stopping distance Vs Spoiler angle

The graph below shows the % Reduction in stopping distance Vs spoiler angle. The keeping the reference as stopping distance of car model without spoiler, the percentage of stopping distance for car model with spoiler has been calculated. At angle 20º the percentage of stopping distance is maximum compare to other values.
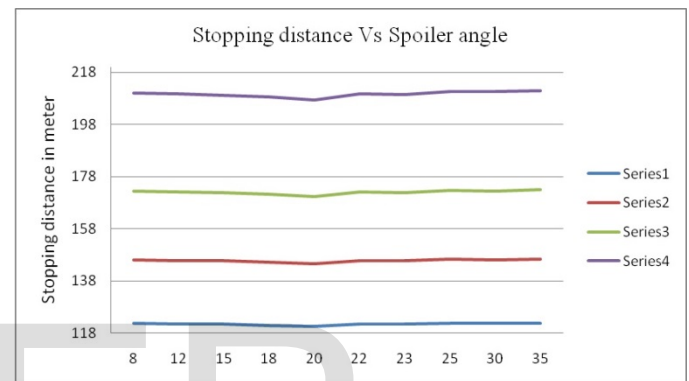

Figure 4: Stopping distance Vs Spoiler angle

The graph above shows the stopping distance Vs spoiler angle. With the help of pressure value which has been found from the analyzed model the stopping distance has been found, by solving the theoretical calculation the stopping distance has been found.
The stopping distance at angle 20º for speed,

- 150 km/hr = 130.7 m
- 165 km/hr = 144.6 m
- 180 km/hr = 170.5 m
- 200 km/hr = 207.3 m

4. CONCLUSION

From the analysis part it is have found that the maximum downward pressure created at an angle 20º and at angle 8º where the minimum pressure has been produced. The stopping distance of the car model with spoiler has been reduced at an angle20º. When the car is in running, at initial condition the spoiler angle kept is 8º and the spoiler moves to angle 20º when the brake is applied which is manually attached to break pedal. The effect of spoiler has become effective when the angle of spoiler increases downward. The stopping distance of car has been reduced to 4.52 % at a speed of 150 km/hr, and the friction between

the tire and road has been increased due to the pressure acting downward which is considered as mass acting on rear of car at particular condition.If this technique is implemented in the day to day life the no of accidents can be prevented and reduced due to stopping distance of the vehicle.

5. References:

[1]. M.H. Djavareshkian "Smart Spoiler for Race Car" World Academy of Science, Engineering and Technology 49 2011

[2]. J. Zerihan and X. Zhang, "Aerodynamics of Gurney Flaps on a Wing in Ground Effect," *AIAA ournal*, vol. 39, pp. 772-780, 2001.

[3]. D. Ueno, G. Hu, I. Komada, K. Otaki, and Q. Fan, "CFD Analysis in Research and Development of Racing Car," presented at the Motorsports Engineering Conference & Exposition, Dearborn, MI, USA, 2006.

[4]. K. Goto and H. Sakurai, "Numerical Study for the Optimal Flap Chord Length of a Two-Element Airfoil," *SAE International Journal of Passenger Cars-Mechanical Systems*, pp. 1-3643, 2006.

[5]. J. Reddy and M. Gupta, "Finding the Optimum Angle of Attack for the Front Wing of an F1 Car Using CFD," in *4th WSEAS International Conference on Fluid Mechanics and Aerodynamics*, Elounda, Greece, 2006, pp. 29-34.