THINK INDIA JOURNAL

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

A Critical Review on The Effect of Spoilers on Lift and Drag Forces in Vehicles

Deven Singh Chauhan*, Danish Khan, Harsh Kumar, NamanSengar, Abhishek Kumar, Jatinder Pal Singh

School of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab

E-mail*:- sdeven1998@gmail.com

ABSTRACT

The spoilers are mostly used in the high speed cars to reduce the drag and lift forces occurred due to the air around the vehicles. The addition of the spoilers in the vehicle body results into decrease in the unwanted forces and wakes formation around the vehicle. The overall performance of the vehicle can be improved with the use of spoilers. The spoilers help to reduce the drag and the lift forces in cars. The reduction in the drag coefficient results in increase in the fuel efficiency of the vehicle. Whereas, decrease in the lift coefficient results into the better stability of the vehicle on the road. The lift and drag are the most important parameters that are taken care during the design of the vehicles. The aerodynamics characteristics of the vehicle are improved by using the spoilers. In present study, the detailed literature review is carried out on the basis of previously reported literature on aerodynamic characteristics of the vehicle.

Keywords:-spoilers, lift, drag, vehicles, aerodynamics, forces

INTRODUCTION

A Spoiler is an aerodynamic vehicular equipment used to reduce the unwanted forces caused by air that hinder the smooth movement of a vehicle. They generally spoil the unwanted motion of air over the body of the vehicle [1]. The main advantage of having a spoiler in a vehicle is reduction of aerodynamic drag that affects the overall performance of vehicle. Spoilers are beneficial in reduction of lift of vehicle which not only improves the traction control but also doesn't add any excessive weight [2]. The braking and overall efficiencyof the vehicle is also increased with the use of spoiler. Usually, spoiler is one of the major components in a racing vehicle.But over period of time, since passenger vehicles come with high speeds, they are also

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

being fitted with spoilers on either the rear or the front end. The spoilers fitted at the front end are termed as air dams. Generally, spoilers are installedat the rear end only [3-4].

The shape of the vehicle takes about 3% of fuel in urban driving, while it takes 11% in highway driving conditions Das et al. [1]. Their research functions upon the design, developments and numerical calculations on using a spoiler in a passenger vehicle. The effect of aerodynamic drag, lift and pressure distributions over the body was studied. A generic vehicle dimensions were taken into account while performing various tests. The spoiler varied at certain angles ranging from -2 to 12 degrees was used in investigation. They reported that smaller angle of attack between the spoiler and air results in higher drag forces. It was also stated that 12-degree inclination is the most optimum. Even it results in increase in drag coefficient by 1.56% but it reduce lift coefficient to a minimum value which is the primary concern. Hu et al. [2] reported the numerical analysis in sedan car with and without the use of spoiler using CFD. The use of CFD(Computational fluid dynamics) software reduces physical testing and prototyping. The standard k-εmodelwas usedfornumerical simulation of external flow field. The attachment position, spoiler shape and clearance variable were the working parameters.A new spoiler is developed by comparing the results, which increased the negative lift and reduced drag by 1.7%. Srivastava et al. [3] performed an analysis on aerodynamic characteristics of BMW X4. The effect of drag and lift was studied by varying speed and temperature. The results shows that increment in speed led to surge of lift and drag coefficient and it was vice versa when it comes to temperature. It was reported that increase in ambient temperature leads to decrease in both drag and lift forces. The magnitude of the aerodynamic forces is depending upon the velocity of the vehicle and density of the air. Shinde et al. [4] investigated the reduction of drag and lift on sedan vehicle with and without the use of spoiler. The results show the reduction in fuel efficiency by improving the aerodynamic effort. The coefficient of drag and lift reduced from 0.555-0.486 and 0.503-0.108 respectively with and without using spoiler. Victor et al. [5]investigated the effect of external aerodynamics and flow over lifting surfaces in a common car. The drag and lift coefficients were determined by numerical code CFD. The maximum values of coefficient of drag and coefficient of lift were determined to be 0.24 and 0.16 respectively. They reported that car design is only acceptable if its form drag is reduced. Kumar et al. [6] performed a numerical study on CAD model of spoiler by varying the speed in range of 70-110 km/hr. The reduction in drag force is observed at 70km/hr whereas increment in lift force at 110km/hr is seen. They reported that the

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

use of spoiler is necessary at 110 km/hr. Dias et al. [7] investigated the characteristics of the wake region behind the car. The spoiler was installed behind the two different car bodies such as hatchback and sedan. They reported that for hatchback and sedan model the drag coefficient was decreased by 0.4 and 0.025 respectively. It was observed from the literature reviews that drag and lift coefficients are the most important parameters to study the aerodynamic characteristics of the vehicle. Also the brake and fuel efficiency of the vehicle is a function of lift and drag coefficients. The use of spoilers either at the rear end or on the front of the vehicle helps to reduce the drag and the negative lift in the vehicles. This helps to increase the vehicle stability and also the fuel efficiency is increased. In present study, a detailed review was carried out on the various parameters of the vehicle stability from the research work reported in the literature.

EFFECT OF SPOILERS ON THE DRAG COEFFICIENT

The drag or drag force is one of the most important parameters in the discussion and determination of aerodynamics characteristics of a body. Drag force (F_D)is described in the form of coefficient of drag (C_d) as both are in relation with each other with the formula as following.

$$F_D = \frac{1}{2} C_d \rho A v^2 \qquad (i)$$

Where ρ is density, A is area of cross section and *v* is velocity.

The aerodynamics characteristics of a body can be improved by keeping the drag force as low as possible, and a research have been carried out in the particular field. Spoiler is one of the components that has been used in the cars because of its inverted aerofoillike shape which helps in reduction in drag force or drag coefficient. Hu et al. [2] examined the behavior of air through the car body itself and car body along with spoiler at the speed of 144 kmph. The result shows that in case of with and without spoiler, the coefficient of drag reduced by 1.74%.Shrivastava et al. [3] conducted their analysis in two parts, first one being determination of drag forces at different speeds (20 & 120 kmph) and second one being determination of drag forces at different temperatures (0°C & 35°C). In 1st part, the result showed that drag force increases with increasing speed, i.e., from 15.23 N at 20 kmph to 546.37 N at 120 kmph. In 2nd part, the result showed that drag force decreases with increasing temperature, i.e., from 64.10 N at 0°C to 56.75 N at 35°C.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

Table 1: Comparison of coefficient of drag reported by various researchers

S. No.	Authors' Name	Year	Body	Percentage Change	Result
1.	Hu and Wong [2]	2011	Sedan	-1.74%	Reduction in drag, i.e., fuel saving.
2.	Shrivastava et al. [3]	2018	SUV (BMW X4)	+34.87% (increased speed) -11.47% (increased temperature)	Drag force is directly proportional to speed, while inversely proportional to temperature.
3.	Shinde et al. [4]	2017	Sedan (Chevrolet Cruze)	-12.43%	Reduction in drag, i.e., fuel saving.
4.	Cernat and Cernat [5]	2017	Compact	$C_d = 0.24$	Drag is experienced by a car in motion.
5.	Kumar et al. [6]	2017	NACA 4412 & NACA 6409	-11.47% (70 kmph) -10.99% (90 kmph) -10.6% (110 kmph)	NACA 6409 is better model than NACA 4412.
6.	Dias et al. [7]	2016	Sedan (Swift Dzire)	-0.04% (fastback) -0.025% (lip)	A fastback type modification resulted in more drag reduction than a lip type spoiler
7.	Kodali and Bezavada [8]	2012	Sedan	-3%	Reduction in drag, i.e., fuel saving.
8.	Sharma and Bansal [9]	2013	Sedan	-2.02%	Reduction in drag, i.e., fuel saving.
9.	Parab et al. [10]	2014	SUV with diffuser	+0.5%	Diffusers result in drag increment and reduction in lift
10.	Rajath and Srivastava [11]	2016	Sedan	-4.5% (wing) -4.49% (surface)	Spoilers help in drag reduction irrespective of their type.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

Shinde et al. [4] conducted their investigation on a Chevrolet Cruze model and they installed it with a spoiler. The final result showed that the coefficient of drag of car without spoiler was 0.555. Whereas, the coefficient of drag of car with spoiler was 0.486.Cernat et al. [5] investigated the numerical study of aerodynamic effects on a compact car considering only external geometry. The maximum coefficient of drag was found out to be 0.24. Kumar et al. [6] conducted study on two different models of spoilers (NACA 4412 & NACA 6409) at different speeds (70, 90 & 110kmph). The results showed that, the reduction in drag forces were 11.47% at 70 kmph, 10.99% at 90 kmph and 10.6% at 110 kmph, taking results from NACA 4412 spoiler. Dias et al. [7] examined the aerodynamic characteristics for a swift dzire car. They did a fastback type modification and a lip type spoiler. The results were obtained at a speed of 144 kmph and it was observed that in 1^{st} case (fastback type modification), the drag coefficient reduced by 0.04% and in 2^{nd} case (lip type spoiler) the drag coefficient reduced by 0.025%.Kodali et al.[8] examined the aerodynamic characteristics of spoiler (NACA 4412) with car speed range of 50-250 kmph. The study was focused to increase the fuel efficiency by reducing drag with spoiler. Their result shows that there is marginal difference of 3% in the reduction of drag, and that it has moderate contribute in the increase of fuel efficiency. Sharma et al. [9] investigated the aerodynamic characteristics of spoiler by keeping it a rack angle of 12°. The results are taken for two cases with and without spoiler. It was observed that the total reduction in drag coefficient was 2.02% by using the car with spoiler. Parab et al. [10] conducted their study by taking a car model and then attaching with a diffuser at different angles of 8°, 10° and 15°. The results were quite significant and it showed that keeping the diffuser at 8° helped in the maximum drag reduction. Rajath et al.[11] investigated the behavior of air by taking a car model and attaching it with two type of spoilers i.e. wing type and surface attached spoilers. The result for wing type showed that the drag coefficient reduced by 4.5%. Whereas for surface attached spoiler showed that the drag coefficient reduced by 4.49%. The outcomes of the literature in context of drag are also listed in Table 1.

EFFECT OF SPOILERS ON THE LIFT COEFFICIENT

Aerodynamic lift is one of the most important parameters regarding overall efficiency and performance of any vehicle. Lift Force F_L or coefficient of lift C_L are the focus for every automobile manufacturer in the market for the optimum aerodynamic stability.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

$$F_L = \frac{1}{2} \times C_L \times V^2 \times A \qquad (ii)$$

Where V is the velocity, A is the frontal projected area and C_L is the coefficient of lift.

Hu et al. [2] investigated the lift characteristics of a high-speed sedan and considering 24 different cases. A new spoiler was designed to reduce the lift by 1.7% which helped in stabilizing the vehicle even more with better handling and cornering capabilities.Shrivastava et al. [3] analyzed lift force with variable speed and variable pressure. At 0kmph no lift forces found and at 20kmph the lift force was noticed as 3.19N. Similarly at 120kmph lift force was found to be 116.83N. The study was also extended to examine the effect of temperature on the lift force. The temperaturewas varied within the range of 0°-35°C.At temperature of 0° and at 35°C the lift force was noticed as 13.5N and 12.12Nrespectively.Shinde et al. [4] investigated the effect of spoiler on the rear end of high-speed sedan car. The numerical simulations were performed on CFD. It was reported in results that rear spoiler helps reducing the drag considerably and helps improving fuel efficiency and performance of the vehicles.Cernat et al. [5] performed a computational fluid dynamics simulation in which they analyzed several pressure and vector fields in parallel to studying the lift coefficient too. It was found that all add on devices on flow can help reducing the lift force and thus enhancing the vehicle's aerodynamics. Kumar et al. [6] investigated the effect of lift coefficient on two spoilers NACA 4412 and NACA 6409. A new modified spoiler was designed on CREO and tested at speed range of 70-110kmph. It was found that the lift force at 110kmph was more in the modified model so it was the better one as compared to the other two models. Dias et al. [7] changed the design of a fastback car slightly and made it more aerodynamic. After doing CFD analysis they found that the lift coefficient decreases which improves the vehicles top speed, stability and also enhances fuel efficiency.Kodali et al. [8] analyzed the effect of the rear spoiler on the lift coefficient. It was observed in the study that the lift force was reduced by 80% with the spoiler. This also results in improvement in the handling and stability of the vehicle. The fuel efficiency was increased moderately.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

Table 2: Comparison of coefficient of lift reported by various researchers

S. No.	Authors' Name	Year	Body	Percentage Change	Result
1.	Hu and Wong [2]	2011	Sedan	-1.74%	Reduction in drag, i.e., fuel saving.
2.	Shrivastava et al. [3]	2018	SUV (BMW X4)	+34.87% (increased speed) -11.47% (increased temperature)	Drag force is directly proportional to speed, while inversely proportional to temperature.
3.	Shinde et al. [4]	2017	Sedan (Chevrolet Cruze)	-12.43%	Reduction in drag, i.e., fuel saving.
4.	Cernat and Cernat [5]	2017	Compact	$C_d = 0.24$	Drag is experienced by a car in motion.
5.	Kumar et al. [6]	2017	NACA 4412 & NACA 6409	-11.47% (70 kmph) -10.99% (90 kmph) -10.6% (110 kmph)	NACA 6409 is better model than NACA 4412.
6.	Dias et al. [7]	2016	Sedan (Swift Dzire)	-0.04% (fastback) -0.025% (lip)	A fastback type modification resulted in more drag reduction than a lip type spoiler
7.	Kodali and Bezavada [8]	2012	Sedan	-3%	Reduction in drag, i.e., fuel saving.
8.	Sharma and Bansal [9]	2013	Sedan	-2.02%	Reduction in drag, i.e., fuel saving.
9.	Parab et al. [10]	2014	SUV with diffuser	+0.5%	Diffusers result in drag increment and reduction in lift
10.	Rajath and Srivastava [11]	2016	Sedan	-4.5% (wing) -4.49% (surface)	Spoilers help in drag reduction irrespective of their type.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

Sharma et al. [9] performed a study on baseline passenger car and tested the lift coefficient with and without a rear spoiler. It was seen that the lift coefficient was reduced from 0.231 to 0.198 with the installation of spoiler. The addition of spoiler results in 14% reduction. In lift force. The rear spoiler helped improving the stability and also the fuel efficiency. Parabet al. [10] investigated the effect of spoiler fitted at the rear end on the lift coefficient. A commercial vehicle having a diffuser at the rear end at an angle of 8˚ is used in the study. The results show 34% reduction in C_L. Rajath et al. [11] performed the aerodynamics analysis on two different spoilers on a passenger vehicle. It was found that the coefficient of lift by spoiler one was reduced from -0.5544 to -0.101 and by spoiler second from -0.5544 to -0.225. It was reported that both the spoilers are enhancing the aerodynamics characteristics of the passenger vehicle and were helping in saving fuel.The outcomes of the literature in context of drag are also listed in Table 2.

EFFECT OF SPOILERS ANGLE ON LIFT AND DRAG COEFFICIENT

Spoilers are known for reduction of drag coefficient as well as lift coefficient. But for obtaining the most favorable output, an optimum angle for the placement of spoiler is very important. For every different angle the spoiler is placed at, there is a different value to both the drag and lift coefficients as well as forces. The effect of angles on a spoiler is tested in laboratories, Computational Fluid Dynamics (CFD) analysis and other different parameters give the most suitable angle for the spoiler functioning. Maximum focus is on reduction of lift coefficient as it helps maintain the vehicle's ground contact or reduces traction effort. Das et al. [1] performed CFD analysis of the passenger vehicle at different angles of the rear end spoiler. The analysis was done at angles of 2, 4, 6, 8, 10 and 12˚. For every angle there is different value of coefficient of drag and coefficient of lift. It was observed that there was a linear decrement in the coefficient of lift but coefficient of lift was observed to having increased slightly on changing the angle of the spoiler. From the experiment, it was calculated that 12˚ angle for the spoiler is most suitable for vehicle as it reduces the lift coefficient on a larger scale and drag coefficient value can be compromised. Parab et al. [10] carried out the experiments for spoiler angle on a production vehicle. CFD analysis for the outcome is done for different angles. It was found out via experiment that on the addition of 8˚ diffuser, there was a reduction (34% reduction) in

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

coefficient of lift and slight increase (0.5% increase) in coefficient of drag. Further incrementation of diffuser angle to 10 anfd15˚ led to even higher reduction in the lift coefficient but there was certain increase in the coefficient of drag as well. So, from this experiment, it was concluded that 8˚ angle on the diffuser will have the optimum impact on the performance of the vehicle. Yuan et al. [12] examined the effect of spoiler angles on a hatchback vehicle. In their research examination of different angles varied from -15, -10, -5, 0, 5, 10 and 15˚. All these spoiler angles were tested on ANSYS software where a 3D model of a hatchback vehicle was tested. Results were obtained from CFD analysis and infinite solver by ANSYS. The results calculated for drag and lift coefficients. The results from the following series of tests conducted indicated that increase in the spoiler angle lead to lowering of the lift coefficient and decreasing of the drag coefficient. Tomar et al. [13] investigated the effect of spoilers at different angles on car body. Various working angles of 10, 20 and 30 degrees were taken into the study. For every case, the outcome of drag coefficient and drag force were different. When the vehicle was tested without spoiler, coefficient of drag and drag force was 0.628759 and 472.838N respectively. On using the spoiler at 10 degrees, these coefficients of drag and drag force were reduced to 0.619300 and 471.159N respectively. For further cases of increased angle, both coefficient of drag and drag force are increased that is not the optimum result.

CONCLUSION

In present study, the detailed literature review is carried out on the basis of previously reported literature on aerodynamic characteristics of the vehicle. It was observed that the use of the spoilers is very beneficial to reduce drag and lift forces in the vehicles. The overall efficiency of the vehicle was also increase by using spoilers. The angle of spoiler also plays an important role in the drag and lift reduction of the vehicle. In most of the cases the lower angle of attack was found as optimum. The increase in the angle of attack of the spoiler results in increase in drag forces. The lower angle of attack was found optimum. The use of spoiler helps to increase the efficiency of the vehicles and also the handling is improved. The aerodynamics characteristics of the vehicles are also improved by using spoilers.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

REFERENCES

[1] Das, Rubel Chandra, and Mahmud Riyad. "CFD analysis of passenger vehicleat various angle of rear end spoiler." Procedia engineering 194 (2017): 160-165.

[2] Hu, X. X., and T. T. Wong. "A numerical study on rear-spoiler of passenger vehicle." World Academy of Science, Engineering and Technology (2011).

[3] Srivastava, Ankit, Deepak kumarsingh and Pranesh Mohan Mishra. "Aerodynamic AnalysisofThe Vehicle Using The Solidwork Flow Simulation." ISSN(online): 2455 – 1457

[4] Shinde, Parashar V., Arshad Shaikh, Saad Mirza, Haidar Khan, and Irshad Shaikh. "Analysis of the Spoiler."

[5] Cernat, Mihail Victor, and AndreeaCernat. "Numerical study of aerodynamic effects on road vehicles lifting surfaces." In AIP Conference Proceedings, vol. 1798, no. 1, p. 020039. AIP Publishing, 2017.

[6] Kumar, MV Sathish, B. Ashwin Rao, and G. Mallaiah. "Design, Analysis and Manufacturing of a Car Rear Spoiler for Drag Reduction." International Advanced Research Journal on Sciences, Engineering and Technology 4, no. 6 (2017): 89-96.

[7] Dias, Gavin, Nisha R Tiwari, Joju John Varghese, Graham Koyeerath. "Aerodynamic Analysis of a Car for Reducing Drag Force." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)

[8] Kodali, Shyam P., and Srinivas,Bezavada. "Numerical simulation of air flow over a passenger car and the Influence of rear spoiler using CFD." International Journal of Advanced Transport Phenomena 1, no. 1 (2012): 6-13.

[9] Sharma, R. B., and Ram Bansal. "Drag and lift reduction on passenger car with rear spoiler." Research and Development (IJAuERD) 3, no. 3 (2013): 13-22.

[10] Parab, Akshay, Ammar Sakarwala, Bhushan Paste, VaibhavPatil, and AmolMangrulkar. "Aerodynamic analysis of a car model using Fluent-Ansys 14.5." International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE), ISSN (2014): 2349-7947.

ISSN: 0971-1260
Vol-22-Issue-17-September-2019

[11] H.R., Rajath and Mrs. Shweta Srivastava. "Aerodynamic Drag Reduction on Vehicle with and without Spoiler." International Journal for Scientific Research & Development| Vol. 4, Issue 06, 2016 | ISSN (online): 2321-0613

[12] Yuan, Cheng See, ShuhaimiMansor, and MohdAzman Abdullah. "Effect of Spoiler Angle on the Aerodynamic Performance of Hatchback Model." International Journal of Applied Engineering Research 12, no. 22 (2017): 12927-12933.

[13] Singh, Akhilesh, AnujPrajapati, Anuj Srivastava, Shubham Srivastava. "CFD Analysis on the Aerodynamic Effects of Spoiler at Different Angle on Car Body." International Journal of Innovative Technology and Exploring Engineering (IJITEE)