Design And Fabrication Of Adaptive Spoiler For Go - Kart Vehicles

K.S. Karthi Vinith, P. Sathiamurthi

Abstract: The vehicle accident also occurs due to over speed in the cornering, particularly in high speed cars (formula cars). The main objective of project is to replace the DRAG REDUCTION SYSTEM (DRS) in formula cars. The DRS system cost over 2 to 5 lakhs depends upon the formula Race type. On fixing of adaptive spoiler in formula cars it reduces cost and increase the performance and Drag during turning. The major source to reduce the speed of the vehicle is braking system. Another source that can be utilized to decelerate the vehicle on high speed travelling is aerodynamics. Adaptive Spoiler is one major solution for decelerating the vehicle using aerodynamics. Adaptive Spoiler serves to be efficient when compared with conventional spoiler. However, the use of adaptive spoiler with compact and cost effective design is rare in vehicles. The operation of Adaptive Spoiler is based on hydraulic motors and sensors are one of its major drawbacks and it’s not yet equipped in economic passenger cars. The use of adaptive spoiler in super cars is much costlier and does not fall in the economic category. The tilting operation will be controlled by the steering wheel using cable mechanism. The Adaptive Spoiler is pivoted at the center, using a C-clamp. When the steering wheel rotates, the 2 cables attached at both ends of the steering column will push and pull the cables at specific ends in order to tilt the spoiler. The rotation of the steering wheel towards the right will push the cable at the right end and pull it from the left end tilting the spoiler anti-clockwise and vice-versa. The simulation of the Adaptive Spoiler is first done two dimensionally and modeled in SOLIDWORKS 2016 and RHINO software, then analyzed for safe design and stability at various scenarios using ANSYS software. The use of cable will be economical and the whole system will be designed for feasibility, simplicity and best performance.

Keywords: increasing down force at rear wheels, reduced skidding and rolling, increased stability.

I. INTRODUCTION

A. Background Information
Vehicle accident can also occur due to over speed cornering at turns, particularly in high speed cars. The major source to reduce the speed of the vehicle is braking system. Another source that can be utilized to decelerate the vehicle on high speed travelling is aerodynamics. Adaptive Spoiler is one major solution for decelerating the vehicle using aerodynamics. Adaptive Spoiler serves to be efficient when compared with conventional spoiler. However, the use of adaptive spoiler with compact and cost effective design is rare in vehicles. The operation of Adaptive Spoiler is based on hydraulic motors and sensors are one of its major drawbacks and it’s not yet equipped in economic passenger cars. The use of adaptive spoiler in super cars is much costlier and does not fall in the economic category. The use of adaptive spoiler in vehicles will be normally activated only above 45 kmph speed. While a vehicle cornering at a speed of 45 kmph and above, the opposite wind force or drag force will be more effective in the operation of adaptive spoiler which increases the traction at the rear wheels which in turn reduces the skidding of the vehicle at the rear end. When a vehicle turns towards right side, the steering angle will tilt the spoiler anti-clockwise. This will cause more drag at the right end of the vehicle thus increasing the down force at the right wheel. The down force is much necessary at the right wheel because the mass of the vehicle will shift towards the left during a right turn and vice-versa.

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The above same operation actuates at left turn to tilt the spoiler clockwise and the left wheel will get more down force. The tilting operation will be controlled by the steering wheel using cable mechanism. The Adaptive Spoiler is pivoted at the center, using a C-clamp. When the steering wheel rotates, the 2 cables attached at both ends of the steering column will push and pull the cables at specific ends in order to tilt the spoiler. The rotation of the steering wheel towards the right will push the cable at the right end and pull it from the left end tilting the spoiler anti-clockwise and vice-versa. The simulation of the Adaptive Spoiler is first done two dimensionally and modeled in SOLIDWORKS 2016 and RHINO software, then analyzed for safe design and stability at various scenarios using ANSYS software. The use of cable will be economical and the whole system will be designed for feasibility, simplicity and best performance.

B. Statement of the Problem
The problem statement in this thesis work are high cost adaptive spoiler for stability complicated operating mechanism of adaptive spoiler in super cars, decreased efficiency at normal operating speeds above 45 kmph. This system focuses on reducing the operating complication of adaptive spoiler using mechanical linkages, minimizing the manufacturing cost and increasing the efficiency by utilizing the aerodynamic forces.

General objective
To design and fabricate a spoiler which adapts and tilts according to the steering wheel.

C. Specific Objective
- To eliminate the use of high cost active spoiler to increase down force during cornering.
- To increase the stability and traction during cornering.
- To eliminate the usage of electronic equipment(s) and achieve reverse engineering.
- To increase the usage of active spoiler in commercial vehicles.
- To fabricate the spoiler for the dimensions calculated.
D. Scope of the study
Design and fabrication of high efficient, low cost active spoiler
Even by small scale industries across the globe and India in particular.

E. Methodology
- Adaptive spoiler is mounted with help of C-clamp at its
center to enable its right and left tilt.
- At steering rod, a gear mechanism is used as in to
reduce the extra circular motion of the steering wheel to
reduce the unwanted rotation of the cable.
- In the steering rod, a rectangular bar is welded and
holes are made at both sides of the bar.
- The one end of the two cables are fixed in the both end
of the bar holes.
- From the bar holes the cable is joined to the spoiler at
the both sides of spoiler as parallel.
- By use of the spring in the spoiler retraction get to it
original position easily and the driver effort get reduced.
- When the driver has turn the steering towards clock vice
then the spoiler tilt anti clock vise due to cable
connection in the parallel manner.

II. LITERATURE REVIEW

A. Introduction
German Opel engineers describe SPOILER as the future of
reducing aerodynamic drag in cars. Adaptive spoiler is the
process of minimizing the lift force which involves change of air
direction towards upwards. When a vehicle turns towards right
side, the steering angle will tilt the spoiler anti-clockwise. This
will cause more drag at the right end of the vehicle thus
increasing the down force at the right wheel. The down force is
much necessary at the right wheel because the mass of the
vehicle will shift towards the left during a right turn and
vice-versa. The above same operation actuates at left turn to
tilt the spoiler clockwise and the left wheel will get more down
force. The tilting operation will be controlled by the steering
wheel using cable mechanism. The Adaptive Spoiler is pivoted
at the center, using a C-clamp. When the steering wheel
rotates, the 2 cables attached at both ends of the steering
column will push and pull the cables at specific ends in order to
tilt the spoiler. The rotation of the steering wheel towards the
right will push the cable at the right end and pull it from the left
end tilting the spoiler anti-clockwise. The rotation of the
steering wheel towards the left will push the cable at the left
end and pull it from the right end tilting the spoiler clockwise.

B. Historical background of Spoiler
In the late 1920s, German Opel engineers were designing the
world’s first rocket-propelled car called the Opel RAK 1.
Unfortunately, being rocket cars, they kept taking off. To deal
with this issue, they strapped some big ol’ wings on the side,
and carried on. This kept the rocket car on the ground as it
reached speeds north of 45 mph. Later iterations tripled that
speed, and the wings became very important. However, for
whatever reason, the idea of putting upside-down wings on a
car never really took off - at least not until the 60s. McLaren
briefly experimented with wings on their F1 cars in the early
1960s, but the idea was dropped. It was the Lotus 49 that
finally gave downforce some lift. In 1967, Lotus that made its
Formula One debut of the Lotus 49, the first F1 car to use aero
foil wings. The original wing design had the rear wing miles
above the car, and driver Jim Clark won in its debut race. The
Lotus 49 went on to win 12 Grand Prix races. After many
near-fatals involving the failure of the wing mounts,
sky-high wings were banned, and F1 cars were required to
have their wings mounted on the body. Regardless, Formula
One was changed forever. Since the debut of the wing in that
late 60s, automotive wings and aerodynamic downforce have
been a staple of successful F1 design. At one point or another,
you have probably wondered why some cars have a big wing
on the back. Is it for coolness, or is there a practical purpose?
Who first decided to take advantage of downforce? The wings
on an airplane are designed to take air flowing across them
and produce a vertical force that lifts them off the ground. Since
the airplane is hopefully attached to the wings, the plane takes
off. That’s of course unless a passenger suddenly becomes ill
and forces the plane to return to the terminal, and everyone on
the plane waits while the passenger is escorted off and the
baggage people find that passenger’s baggage, and all this
takes so much time that the pilot misses the window of time on
the runway and you are forced to wait an hour and you miss
your connecting flight in Reno and you miss Thanks giving. On
a race car, the same principle is applied, but upside down. As
the car moves, air speeds over the wing, and a downward force
is produced. This downforce helps keep the car glued to the
ground. In a straight line, that’s great. As the engine spins the
wheels, the wheels are less likely to slip. But around a corner
it’s even better. That downforce increases the friction force,
and that means you can go faster around corners without
spinning out and crashing into an orphanage. Downforce has
an effect similar to putting a load of bricks in the car, but without
forcing the engine to have to work hard enough to get all those
bricks moving.

C. Review of Spoiler
The car wing reviews state that you get to choose from the two
color options in this product. The distance between two
brackets is 62.5cm/24.61" and the length of this one is
135cm/53.15 Inch. The car wing reviews also opine that the
adjustable angels give customizable usages, appearances and
efficiencies. It is made up of durable yet lightweight aluminum
alloy. The wings are adjusted to tailor the needs of your
vehicle. The product dimensions are 53 x 8.1 x 4.2 inches and
the item weight is 5.6 pounds. It is also designed to improve the
aerodynamic qualities of your car like lowering the drag.

D. Effect of Spoiler on rear
A spoiler is an automotive aerodynamic device whose
intended design function is to ‘spoil’ unfavorable air movement
across a body of a vehicle in motion, usually described as
turbulence or drag. Spoilers on the front of a vehicle are often
called air dams. Spoilers are often fitted to race and high-
performance sports cars, although they have become common
on passenger vehicles as well. Some spoilers are added to
cars primarily for styling purposes and have either little
aerodynamic benefit or even make the aerodynamics worse.
The term "spoiler" is often mistakenly used interchangeably
with "wing". An automotive wing is a device whose intended
design is to generate downforce as air passes around it, not
simply disrupt existing airflow patterns. As such, rather than
decreasing drag, automotive wings actually increase drag.
E. Review on parameters affecting Spoiler

When the vehicle is moving at a considerable speed, there are several forces applied to vehicle in different directions.

- Rolling Resistance
- Drag
- Lift Force
- Gravity
- Normal

F. Rolling Resistance

There are two kinds of friction important for wheels. “Static friction” is what keeps two non-moving bodies from slipping against each other when you apply an external force. We sprinkle sand on icy sidewalks to increase the static friction, so that people don’t slip. The force of “kinetic friction” on the other hand is what you’d need to apply to keep two surfaces moving relative to each other. Think of static friction as a thin layer of glue that has a breaking point that allows motion, and kinetic friction as the “stickiness” that you have to push through to keep moving. A person who leans back while standing on ice starts to slip if the forward force he’s applying to his foot exceeds the static frictional force that would keep him standing. He keeps slipping and falls on his behind only if the force he’s applying to the ice also exceeds the kinetic frictional force. Now, you can derive some scientific insight from the observation that generally, people who start to slip on ice do fall on their behinds. That tells you that in a given system, the coefficient of kinetic friction is usually less than that of static friction. Once you “break through” the static friction and start moving, you keep moving.

G. Drag

Aerodynamic drag, also called wind resistance, is a retarding force exerted on a vehicle by the air through which it moves. As a truck travels forward, it breaks up the flow of air, creating an area of low air pressure behind the body or trailer (the wake). The high pressure air surrounding the wake then moves into the low-pressure area, exerting a force that pulls the vehicle backwards. Low pressure areas created in the gap between the tractor and the trailer, and underneath the truck, similarly contribute to aerodynamic drag and the fig 2.1 discusses it.

![Fig 2.1 Horsepower required to overcome aerodynamic drag](image)

H. Lift Force

Lift is the force that directly opposes the weight of a car and holds the car in the air. Lift is generated by every part of the car, but most of the lift on a normal airliner is generated by the ground clearance. Lift is a mechanical aerodynamic force produced by the motion of the car through the air. Because lift is a force, it is a vector quantity, having both a magnitude and a direction associated with it. Lift acts through the center of pressure of the object and is directed perpendicular to the flow direction. There are several factors which affect the magnitude of lift.

I. Gravity

Aerodynamic involves two major problems, overcoming the air force of an object by some opposing force, and controlling the air in moving. Both of these problems are related to the object’s weight and the location of the center of gravity. The dream remains that, if we could really understand gravity, we could create anti-gravity devices which would revolutionize travel through the road. Unfortunately, anti-gravity devices only exist in science fiction. Machines like airplanes, or magnetic levitation devices, create forces opposed to the gravitational force, but they do not block out or eliminate the force.

J. Review conclusion

The above mentioned contents give a brief idea on introduction of Spoiler on to the market, the components involved in Spoiler and the parameters involved in designing a Spoiler. Though the contents were contrary among various authors, the core design remains to be the same. The contents from the above mentioned reviews are taken into consideration for the design and development of Adaptive Spoiler.

III. DESIGN AND ANALYSIS OF ADAPTIVE SPOILER

A. Understanding the spoiler

A spoiler is an automotive aerodynamic device whose intended design function is to “spoil” the unfavorable air movement across a body of a vehicle which is in motion, usually described as drag. The main objective is to optimize the drag, increase the downforce and decrease the lifting force. Spoilers on the front of a vehicle are often called air dams, because in addition to directing airflow they also reduce the amount of air flowing underneath the vehicle, which generally reduces aerodynamic lift and drag. Spoilers are often fitted to race and high-performance sports cars, although they have become common on passenger vehicles as well. Some spoilers are added to cars primarily for styling purposes and have either little aerodynamic benefit or even make the aerodynamics worse. But still spoilers are added to the cars in general. The goal of many spoilers used in passenger vehicles is to reduce drag and increase fuel efficiency. Passenger vehicles can be equipped with front and rear spoilers. Front spoilers, found beneath the bumper, are mainly used to decrease the amount of air going underneath the vehicle to reduce the drag coefficient and lift. Sports cars are most commonly seen with front and rear spoilers. Even though these vehicles typically have a more rigid chassis and a stiffer suspension to aid in high-speed maneuverability, a spoiler can still be beneficial. This is because many vehicles have a fairly steep downward angle going from the rear edge of the roof down to the trunk or tail of the car, which may cause airflow separation. The flow of air becomes turbulent and a low-pressure zone is created, increasing drag and instability. Adding a rear spoiler could be considered as making the air “see” a longer, gentler slope from the roof to the spoiler, which helps to delay flow separation and the higher pressure in front of the spoiler can help reduce the lift on the car by creating down force. This may reduce drag in...
certain instances and will generally increase high-speed stability due to the reduced rear lift. Due to their association with racing, consumers often view spoilers as “sporty”. And they also give a stubble look which is called as “sporty look”.

B. Determination of spoiler material

Material: Aluminium
A spoiler made of aluminium will be of excellent properties and also cheaper in price as our objective is also to reduce the cost of the system. Aluminium is light in weight which will make the whole system lighter and also easier to move while steering. Aluminium naturally generates a protective thin oxide coating which keeps the metal from making further contact with the environment. Aluminium has excellent thermal conductivity so to dissipate the heat that has been generated due to air friction. Aluminium is ductile and has a low melting point and density. It can be easily processed in several ways in a molten condition, and when it cools aluminium shows increased strength when the temperature drops. Aluminium is non-magnetic, non-toxic and non-sparking. It is also an excellent sound absorber. Also it is not only cheap but can also be easily recycled. Also 100% recycled aluminium is identical to the virgin or raw aluminium.

C. Dimensions of Spoiler
The Spoiler was designed for the following vehicle specifications.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Unit</th>
<th>Value</th>
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<tbody>
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<td>Vehicle length</td>
<td>(mm)</td>
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<td>1390</td>
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<td>Vehicle’s rear track width</td>
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<td>Vehicle’s top speed</td>
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<td>Minimum turning radius</td>
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Considering the above specifications from table 3.1, the spoiler was designed to meet the required needs. The dimensions of the spoiler are found in such a way that the lift force is minimized and the drag force is optimized. The spoiler can either be smaller than the width of the vehicle or be larger than the width of the vehicle. But it’s better to be within the vehicle’s body for safety purposes as it will be actuated whenever turning. The angle of spoiler will also determine how much the coefficient of lift is decreased and how much the coefficient of drag is increased. It has been seen that for high speed vehicles the absolute and most effective spoiler angle will be 12.5 degrees from the horizontal axis with the rear part lifted and the front part at the origin.

**Spoiler dimensions**
The length of the spoiler, L varies from 0.8 D to 1.1 B, where B is the vehicle’s breadth. Let us consider L = 0.9B.

\[
L = 0.9 \times 1390 \approx 1251 \text{ mm} 
\]

Therefore, L = 1251 mm ~ 125cm Hence, the length of the spoiler (L) = 1250mm. The thickness of the spoiler is the highest at the middle when compared to both the front and rear ends. To reduce the overall weight, the spoiler is hollow inside. The maximum thickness is 2cm at the middle. The breadth of the spoiler is found to be efficient at 120mm. Hence, the breadth of the spoiler (b) = 120mm. The top area is the most important as it is the part which is exposed to the air and deflects it.

**Spoiler top area** = Length × Breadth

\[
= L \times b = 1250 \times 120 = 150000 \text{ mm}^2 = 1500 \text{ cm}^2
\]

Therefore, Spoiler length = 1250 mm and Breadth = 120 mm.

D. Design of spoiler
The aluminium sheet is exposed to higher temperatures to make it easier to mould. It is then bent and folded in a die to meet the required shape. It is then cooled and with decrease in temperature the strength of the aluminium will increase.

**Table 3.1 Specifications of the implemented vehicle**

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**Design calculation for drag and downforce**
The difference between the downforce and the lifting force should be fairly high so that the drag is optimized to the maximums. The downforce should be high and the lifting force should be low. The formula for drag in general is given by

\[
D = \frac{1}{2} \rho \times v^2 \times C_d \times A
\]

where \( \rho \) is the density of air, \( V \) is the relative velocity between the spoiler and the air hitting it, \( C_d \) is the coefficient of drag, \( A \) is the frontal area of the vehicle. The maximum recommended frontal area for a go kart is 0.6 m² and thus the coefficient of drag will be 0.8 (with wings or spoiler). The density of air in general is 1.2 kg/m³. If one assumes the relative velocity of air to be 25m/s,

\[
D = \frac{1}{2} \times 1.2 \times 2.5^2 \times 0.8 \times 0.6 = 180 \text{ N}
\]

And for vehicle without spoiler, the coefficient of drag is 0.5.
\[ D = \frac{1}{2} \times 1.2 \times 2.5^2 \times 0.5 \times 0.6 = 112.5 \text{ N} \]

We can see that the drag force with spoiler is increased by 60% than the one without spoiler.

The lift force is given by,

\[ L = \frac{1}{2} \rho \times v^2 \times C_L \times A \]

if one assumes the coefficient of 0.2 for a vehicle with spoiler,

\[ L = \frac{1}{2} \times 1.2 \times 25^2 \times 0.2 \times 0.6 = 45 \text{ N} \]

And for a vehicle without spoiler, the coefficient of lift will be 0.4,

\[ L = \frac{1}{2} \times 1.2 \times 25^2 \times 0.4 \times 0.6 = 90 \text{ N} \]

We can see that the lift force is reduced greatly just with the addition of a spoiler.

**E. Components of the system**
- Spoiler
- C-Clamp (pivot point)
- Cables
- Cable stopper
- Steering column
- Steering wheel

**IV. CONCLUSION AND RESULTS**

This study shows the role of spoiler in vehicle handling and its contributions in cornering. It is found that the use of Adaptive spoiler contributes a lot in minimizing the drag and increase the vehicle stability that occurs in a vehicle under dynamic conditions especially during cornering and it is shown in table 4.1. Though the Adaptive spoiler minimize the drag of the vehicle effectively, they couldn’t help much in terms of slow speed cornering, keeping both the vehicle in high speed and comfort in consideration the Adaptive spoiler system is developed which allows the drag to act independently during any cornering and also minimizes the body roll of the vehicle actively and in a way more effective than the passive spoiler systems. Hence it is concluded form the above study that the use of Adaptive spoiler in the vehicles minimizes the drag of the vehicle at the high speed cornering to a great extent and of about 67.28% which when compared to the vehicle without spoiler. The system also proves to be 42.41% more efficient than the passive spoiler and it is experimented as shown in fig 4.1

**Table 4.1** Result

<table>
<thead>
<tr>
<th>Condition</th>
<th>Drag Force (N)</th>
<th>Lift Force (N)</th>
</tr>
</thead>
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<td>With Spoiler</td>
<td>180</td>
<td>45</td>
</tr>
<tr>
<td>Without Spoiler</td>
<td>112.5</td>
<td>90</td>
</tr>
<tr>
<td>% increase with spoiler</td>
<td>60%</td>
<td>Lift Force is greatly reduced.</td>
</tr>
</tbody>
</table>

**V. REFERENCES**


[10]. Abd Munir, F., Mohd Azmi, M. I., Razali, N., Mat Tokit,


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