A CONCEPTUAL DESIGN OF WIND FRICTION REDUCTION ATTACHMENTS TO THE REAR PORTION OF A CAR FOR BETTER FUEL ECONOMY AT HIGH SPEEDS

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ABSTRACT:

Normally all the car bodies are streamlined for very less wind drag coefficient, but still due to the length of car as constraint the rear portion of the car was not fully streamlined. The present paper objective is to design the wind friction reduction attachments to the rear portion of a car which can be opened and closed depending on the requirement, thereby mileage of the vehicle at high speeds will be improved and the car can travel at higher speeds without increasing the engine capacity. The rear attachments of car can be closed in traffic and parking periods and when the vehicle is travelling on highways at high speed, the attachments are opened. To open and close the wind friction reduction attachments a hydraulic system is designed. The wind friction reduction attachments are designed to be inside the rear door in the closed condition so that there won't be any problem in aesthetic point of view.

Key words: Collapsible wind friction reduction attachments (C.W.F.R.A), Drag force, Coefficient of wind friction, Power consumption, Velocity.

1.0 Introduction:

Normally the cars are used for personal transportation in developed countries. In India the cars were used as luxury items, and the rate of car production also very less. In recent years the car production is increased and utility also increased in India. Earlier the roads in India are narrow and with lot of undulations, so the average speed of the car was very less. But in the recent years the highways and city roads in India were developed to the international standards, so the average speed of the cars on the roads is increased. When the cars are travelling in city traffic, narrow roads, and in parking places, the more the length of the car more will be the problem. So the cars are not completely streamlined at the rear portion to limit the length of the car. Because of this reason the cars wind drag coefficient is around 0.2 to 0.4. The present paper objective is to reduce the wind drag coefficient further by designing the collapsible wind friction reduction attachment at the rear portion bluff body of car.

2.0 Literature Review:

Masaru KOIKE, Tsunehisa NAGAYOSHI, Naoki HAMAMOTO, did research on aerodynamic drag reduction by vortex generators. One of the main causes of aerodynamic drag for sedan vehicles is the vehicles rear end. To delay flow separation, bump shaped vortex generators are tested for application to roof end of a sedan. The overall effect of vortex generators can be calculated by totaling the positive and negative effects. Since this effect depends on the shape and size of vortex generators, those on the vehicle roof are optimized.[1] V.A. Petrushov, presented a new solution of the coast-down equation that is free from speed and deceleration. This enables a considerable group of measurement error sources to be eliminated and coast-down technique sensitivity to be increased; so the small drag alterations due to the changes in vehicle aerodynamic configuration or tyre parameters, such as load, inflation pressure and temperature, can be detected.[2] Pramod Nari Krishnani simulated and optimized by adding Simple external devices like boat tail plate and the foot step to Generic SUV model using commercial software packages like FLUENT, GAMBIT, T-grid and Solidworks.[3] Barry Scanlon designed Collapsible airfoils which reduce wind resistance in their operational positions on the front and rear of a vehicle are moved with a minimum effort to and from collapsed stored positions on the sides of the vehicle such as a truck.[4] Mark A Moore designed a device for reducing air drag on highway vehicles includes a fabric enclosure mounted on the rear end of the vehicle which is self inflated by a pressure differential between the outer and inner surfaces of the fabric enclosure created by the forward movement of the vehicle.[5] Alexander Boynton, and San Antonio, disclosed an atmospheric pressure equalizing means for a vehicle having a windshield arrangement principal object is to shunt the impacted atmosphere from the front end of a rapidly moving vehicle to the rear end thereof, in order to reduce or overcome the partial vacuum ordinarily developed behind the vehicle.[6] Hugh W. Shumaker, disclosed of providing the wind deflectors of a novel form or design, is to force the air currents towards rear end window thus to eliminate the vacuum that is there created by the fast forward travel of the vehicle, and by so doing, to eliminate the great extent the suction that causes dust and road dirt to be sucked up and caused to be delivered against the rear window glass.[7] Donald L. Elder designed an attachment for bluff forward surface vehicles, both to reduce air resistance and air flow separation from the top and sides of the vehicle thus to reduce air drag and increase efficiency of operation.[8]

3.0 Theory:

The engine supplies power to travel the Car on the road, mainly for overcoming the external opposing forces like rolling friction of tires and wind frictional losses. The power required to overcome the rolling friction loss is directly proportional to the coefficient of rolling friction, weight of vehicle and velocity of vehicle.

$$P_r = \mu R_N V \qquad [10]$$

where μ= Coefficient of rolling friction, R_N= Normal load on the tires,
V= Velocity of vehicle.

The power requirement to overcome the wind friction loss is proportional to the Density of air, Coefficient of drag, Frontal area of vehicle and cubic velocity of vehicle.

$$P_w = 0.5\rho C_d A V^3 \qquad [9]$$

ρ= atmospheric air density, C_d=Coefficient of wind friction, A= Frontal area of vehicle, V= Velocity of vehicle.

It means that the power requirement to overcome the wind friction loss increases exponentially with increase in velocity of car. To reduce the power requirement of car, different aerodynamic shapes were designed. In this present work collapsible attachments are designed for the small end cars/SUV rear portion, as a part of rear door to reduce the wind friction drag and thereby to improve the fuel economy.[13],[17]

4.0 Description Of Wind Friction Reduction Attachments To Car Rear Portion:

Fig. 1&2 shows the collapsible wind friction reduction attachments provided at the rear portion of the car bluff body in open condition and closed condition. To the rear door portion of the car a frame is hinged at the bottom portion such a way that when the door is closed the attached frame will be inside the door and parallel to the door. This hinged frame to the rear door of car is opened and closed using the hydraulic system which is under the control of driver. The hydraulic cylinder end is hinged to the door inner side and the piston end is hinged to the bottom hinged frame, so that once the piston rod is extended the bottom hinged frame makes an angle of 60^0 with door. Once the door is opened and the hinged bottom frame is opened then it looks like a v-shaped projection extended at the rear portion of car bluff body. To fill the side gaps between the top and bottom frames of V-shaped projection, a triangle shape frame is hinged to the sides of bottom hinged frame on either side. These side triangle shaped frames also opened and closed by the hydraulic cylinders whose one end is hinged to the bottom hinged frame and other end is hinged to the triangle shaped frames.

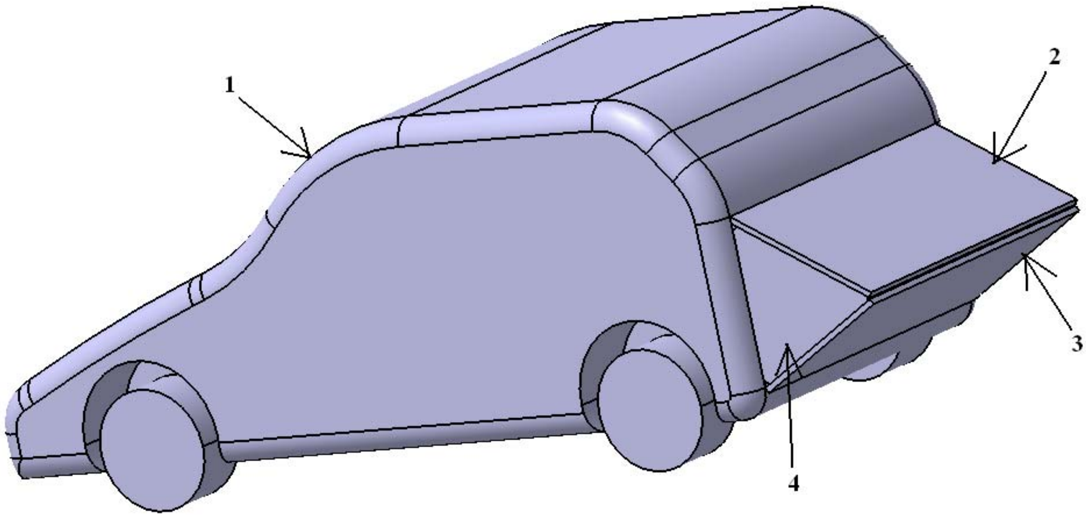

Fig.1. A small end car with collapsible wind friction reduction attachments at the rear portion in open condition.
Parts of Fig.1.Small end car body, 2.Rear end door in open condition, 3.A bottom wind friction reduction attachment hinged at the bottom of rear end door, 4.A side wind friction reduction attachments hinged on either sides of the rear end door.

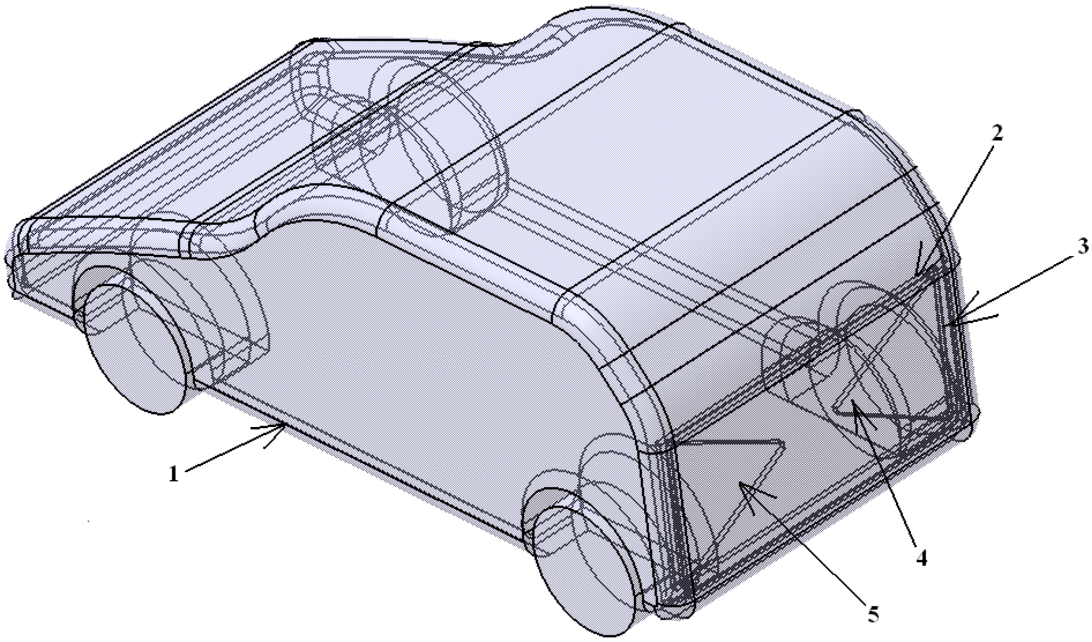

Fig.2.A small end car with collapsible wind friction reduction attachments at the rear portion in closed condition.(Body made transparent to visualize the attachments in closed condition.)
Parts of the Fig.2. 1.Small end car body, 2.A bottom wind friction reduction attachment hinged at the bottom of rear end door(inside the rear door), 3.Rear end door in closed condition, 4.A right side wind friction reduction attachment hinged on the right side of the rear end door (inside the rear door), 5. A left side wind friction reduction attachment hinged on the left side of the rear end door (inside the rear door),
By providing the wind friction reduction attachments to the rear portion of car bluff body, the wind friction drag coefficient can be reduced from around 0.4 to around 0.2. [16] The prototype Bus body with and without attachments is tested by putting the prototype on the moving vehicle and the results shown that the coefficient of wind friction drag without attachments is 0.8 and with attachments is 0.2. [14]

5.0 Power consumption calculations to overcome the wind friction and mileage of vehicle for different wind friction coefficients:

The data for the calculations is taken from conventional vehicle specifications [12].
Maximum width of the Car with wind friction reduction attachments: B_a =1.67 m
Maximum height of the Car with and without attachments: H = 1.49 m
Ground clearance of vehicle: GC = 0.17 m
Frontal area of vehicle with attachments $FA_a = B_a$ (H- GC)
Coefficient of wind friction for the conventional Car: 0.4 [16]
Coefficient of wind friction for the Car with wind friction reduction attachments: C_d = 0.3, 0.25, 0.2, and 0.15
Density of atmospheric air: ρ = 1.227 kg /m^3
Wind friction drag force: $F = ½ \rho C_d A V^2$ [9]
Velocity of the Car: V = 15 m/s to 45 m/s in steps of 5m/s increment
Power requirement to overcome the wind friction force: $P_w = FV= ½ \rho C_d A V^3 = 0.5\rho\ C_d A V^3$ = KW
Dead Weight of Car: 1080 Kg
Pay load: 410 Kg
Total weight of the vehicle: R_n = 1490 Kg =14900 N
Coefficient of rolling friction: μ = 0.01 [11]
Power requirement to overcome the Rolling friction: $P_r = \mu R_n V$ [10]
Total power consumption $P_T = P_r + P_{w\ =\ KW}$
Assumed Vehicle Transmission efficiency from engine to wheels: ή=85%
Data interpolated from Performance curves of a Six Cylinder Four-Stroke cycle Automotive Type CI Engine at constant speed for calculating mileage of vehicle: [15]

S.No.	Speed of Truck(KMPH)	Power (KW)	BSFC(gm/KWhr)	Brake Thermal ή of engine	Overall Vehicle Thermal ή
1.	72.00	7.29	380	21.0	17.9
2.	90.00	12.15	326	24.6	20.9
3.	108.00	19.03	292	27.4	23.3
4.	126.00	28.34	258	31.0	26.4
5.	144.00	40.48	252	31.8	27.1

Assumptions: 1.Mileage of vehicle without attachments and with attachments is calculated using the above overall vehicle Thermal ή.

2. The engine efficiency variation with vehicle speed is not considered.
3. The gradability of vehicle, inertial forces during acceleration and deceleration, cross wind forces, and braking losses which vary from situation to situation are not considered.

Calorific value of Diesel C_v = 44,800 KJ
Mileage of vehicle: M_a or M_c =((C_v/ ((P_Tx100)/ ή))xV)/1000 = KM/Litre
% increase in mileage with attachments = (M_a- M_c/ M_c)100

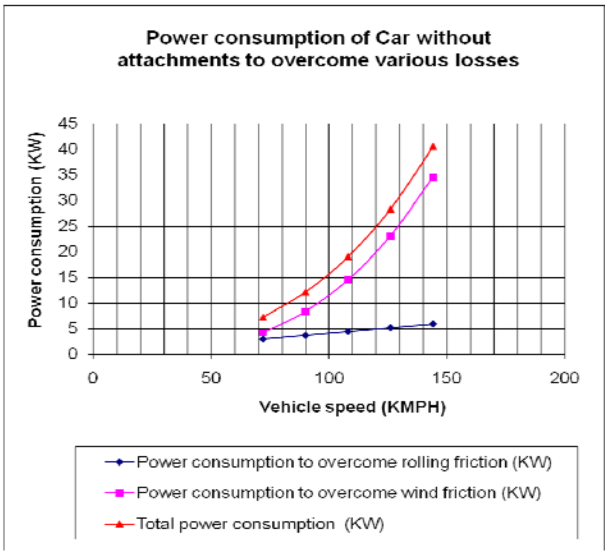

Fig.3. Power consumption of Car without wind friction reduction attachments

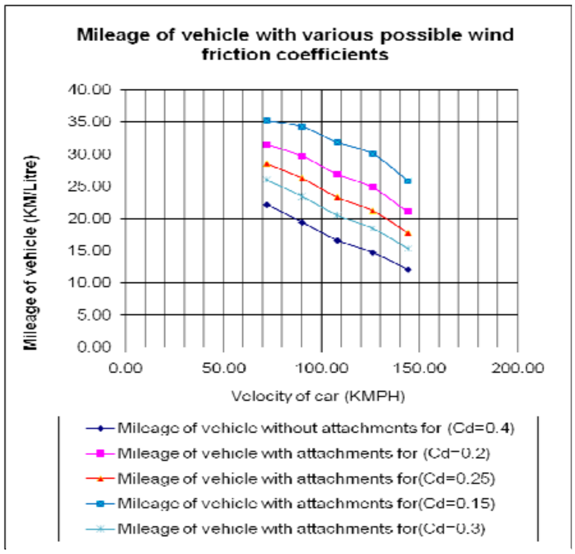

Fig.4. Mileage of Car with and without wind Friction reduction attachments

6.0 Results and Discussion

Fig. 3 shows the power requirement to overcome the wind friction, rolling friction and total power requirement at different velocities to run the Car on a horizontal road. The power requirement at different velocities to overcome the wind friction and rolling friction are calculated using the above mentioned standard equations. The power requirement to overcome the rolling friction is proportional to the velocity of vehicle so it is increased linearly. The power requirement to overcome the wind friction is proportional to the V^3 so it is increasing exponentially. The graph shows that at a speed of 144 KMPH the power requirement to overcome wind friction is around 34.5 KW which is around 5.7 times more than the power requirement to overcome the rolling friction 5.9 KW. The power requirement to over come wind friction at 72 KMPH is 4.3 KW, and at 144 KMPH is 34.5 KW, it means the Cars running at 72 KMPH doesn't require to be streamlined much at rear portion but for high speeds above 108 KMPH the power requirement to overcome wind friction is 14.56 KW which is alarming the need of wind friction reduction techniques. If we reduce the wind friction coefficient from 0.4 to 0.15 then the small end Cars also can travel economically at 144KMPH.

Fig. 4 shows the mileage of the Car at different speeds for both conventional small end Car (C_d = 0.4) and Car with C.W.F.R.A for various possible Coefficient of wind friction (C_d = 0.3, 0.25, 0.2, 0.15). The above graph shows that at a speed of 72 KMPH the mileage of conventional Car is 22.1 KM/Litre whereas the mileage of the Car with C.W.F.R.A is varying from 26.0 KM/Litre to 35.0 KM/Litre. The mileage variation of Car with different Wind friction coefficients for different speeds is showing the same trend of decrease in mileage with increasing Car speed from 72 KMPH to 144 KMPH. The decrease of mileage of Car with increasing speed is mainly due to the exponential increase of power requirement to overcome the wind friction. The above graph shows that at a speed of 144 KMPH the mileage of conventional car is 12.0 KM/Litre whereas the mileage of the Car with C.W.F.R.A is varying from 15.3 KM/Litre to 25.8 KM/Litre. It shows that if the Car with C.W.F.R.A is having C_d=0.15 the mileage will be better even at 144 KMPH. So it means to travel at high speeds on highways on Car, instead of increasing the Car engine capacity we have to provide the C.W.F.R.A. for better fuel economy and less pollution. The graphs show that at 72 KMPH the mileage of Conventional car is 22.1 KM/Litre which is less than the mileage 25.8 KM/ Litre of Car with C.W.F.R.A (C_d=0.15) at 144 KMPH. It means the speed of Car can be increased without decreasing the mileage by using C.W.F.R.A to Car. So the traveling time will be reduced.

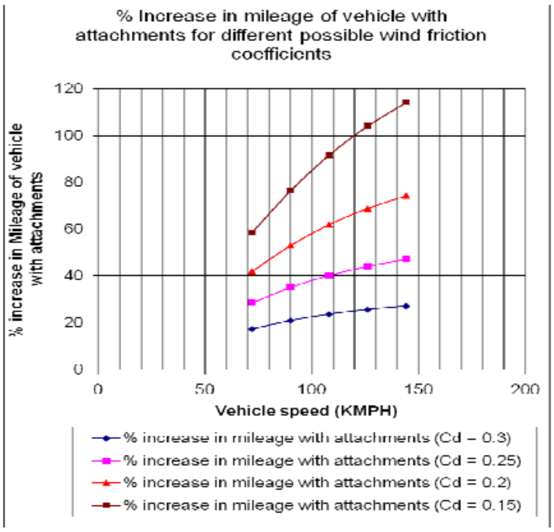

Fig.5. %Increase in Mileage with W.F.R.A

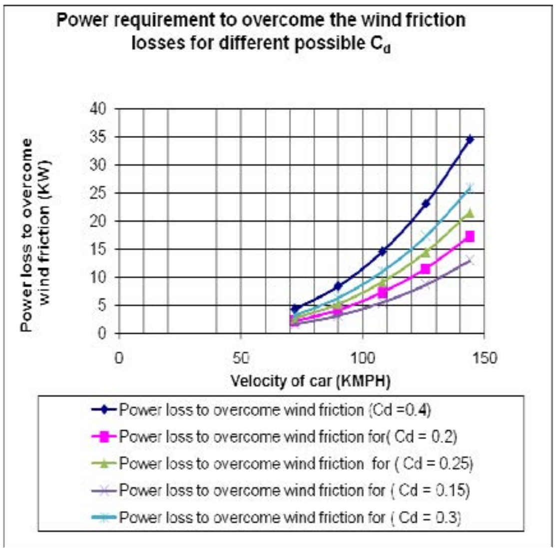

Fig.6.Power required for overcoming wind friction with & without W.F.R.A

with C.W.F.R.A (C_d=0.3, 0.25, 0.2, and 0.15) compared to conventional Car at different speeds. All the graphs show that the % increase of mileage compared to conventional Car is increasing with increasing speed because the difference of power requirement to overcome the wind friction between conventional Car and Car with C.W.F.R.A increases drastically with increasing speed. The % increase of mileage at 72 KMPH varies from 17.3% to 58.6% for different wind friction coefficients, and at 144 KMPH the % increase of mileage varies from 27.0% to 114.0%. The above curves show that the wind friction coefficient should be minimum possible to have the better fuel economy at high speeds on highways.

Fig.6 shows the power consumption to overcome the wind friction at different speeds of the vehicle. The trend of the curves is similar because Power consumption to overcome wind friction is proportional to the V^3 and proportional to the C_d. The power consumption to overcome the wind friction is increasing exponentially with speed, even though the difference between conventional Car and Car with C.W.F.R.A is less at 72 KMPH but is very high at 144 KMPH. So to make the Cars to travel at high speed, instead of increasing engine power and decreasing mileage, it is better to provide the C.W.F.R.A to the Cars without increasing the length of car which creates parking problems.

7.0 Discussion:

The problems arise with the attachments at the rear portion of small end car/SUV and solutions for those problems are discussed below. When the rear wind friction reduction attachments are opened and the vehicle is traveling on high ways, the driver has to be habituated while driving because the length of the vehicle increases so in overtaking and in turnings the rear portion of the vehicle should not touch the other vehicles or objects.

When the car rear wind friction reduction attachments are in closed condition, the luggage space provided at the rare side will be decreased. So to overcome the above problem the rear door with collapsible wind friction reduction attachments can be opened to keep the luggage.

The collapsible wind friction reduction attachments increase the weight of the vehicle around 100 kg. It appears to be an extra weight to be carried throughout the life time of the vehicle and affect the mileage of the vehicle. But fact is, the vehicle travels more distance on highways at high speed, so the above graphs shows that saving of fuel due to reduced wind friction losses is very high at high speed compared to the increased fuel consumption due to increased attachments weight at high speed. At low speeds of the vehicle, the power consumption to overcome the wind friction is very less, but the engine brake thermal efficiency also low at low loads, once the load increases the brake thermal efficiency also increases, thereby the mileage of car will not be affected much at low speeds due to increase in attachments weight.

The rear attachments to Car helps to protect the vehicle by absorbing shock load to certain extent because attachment is damaged when an accident occurs by collision at rear of the vehicle.

8.0 Conclusions:

The proposed innovative idea of Collapsible Wind friction reduction attachments to Car rear portions reduce the wind friction coefficient of the car thereby improve the fuel economy at high speeds and at the same time increase the speed of car for the given capacity of engine. The hydraulic circuit is used to close & open the C.W.F.R.A in sequence and the control button is provided at driver operating area. The Coefficient of wind friction of car varies with shape and size of C.W.F.R.A designed to rear portion of the car. The collapsibility of the C.W.F.R.A provided at the rear of car minimized the following problems.

1. The parking area requirement problem is minimized as the length of car increase in the collapsible condition of C.W.F.R.A. is very less.
2. The traffic problems in the city driving of car with C.W.F.R.A. are very less compared to the car with fixed W.F.R.A provided at the rear.
3. The drivability problem of car in narrow roads and ghat section is minimized as the length of car increase in the collapsible condition of C.W.F.R.A. is very less.

The analysis shows that overdrive gearbox to be modified to increase the velocity of car around 1.3 times compared to conventional car without increasing the engine speed thereby the engine can be operated nearer to maximum load at the given speed where engine efficiency is good. The emissions will be reduced as the mileage of vehicle increases.

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