ISSN XXXX XXXX © 2016 IJESC

Research Article **Volume 6 Issue No. 12**

Analysis on Bus Body Aerodynamics & Fuel Efficiency in City Buses

S.Gowtham Raj[1], S.Mahesh Kumar[2], C.Sakthivel[3], R.Tamilmaran[4], B.Saravanan[5], V.Kondusamy[6], Saravanan. B[7]
UG students[1,2,3,4], Assistant Professor[5,6,7]
Department of Automobile Engineering
Karpagam College of Engineering, Coimbatore, India[1,2,3,4,5,6]
Dr. Mahalingam College of Engineering and Technology, Pollachi[7]

Abstract:
The rising fuel price and strict government regulations makes the road transport uneconomical now a days. In recent times, due to better road the intercity buses cover large distances on highways at speeds of over 120km/hr. The fore body, under body, roof and trailing end of the bus has to be locally fine tuned to get better aerodynamic performance. The tear drop shape is an ideal aerodynamic shapewhich is largely used in submarine hull and aircraft body designs to reduce the drag. The present intercity buses have a poor aerodynamic exterior design.

I. INTRODUCTION

The overall aim of this project is to modify the outer surface and structure of the bus aerodynamically in order to reduce the effect of drag force of the vehicle which in turn results in reduction of fuel consumption of the vehicle.

II. THE VEHICLE DRAG

A. DRAG

A simple definition of aerodynamics is the study of the flow of air around and through a vehicle, primarily if it is in motion. To understand this flow, you can visualize a car moving through the air. It takes some energy to move the car through the air, and this energy is used to overcome a force called Drag.

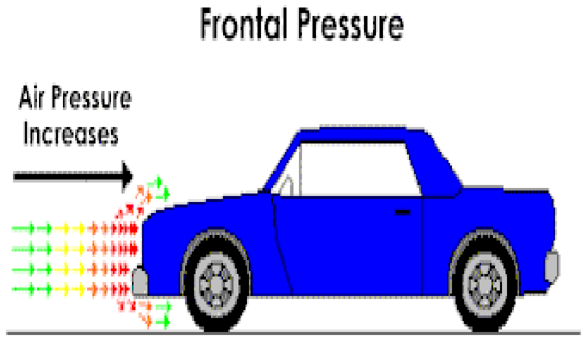


Figure.1. Frontal Pressure

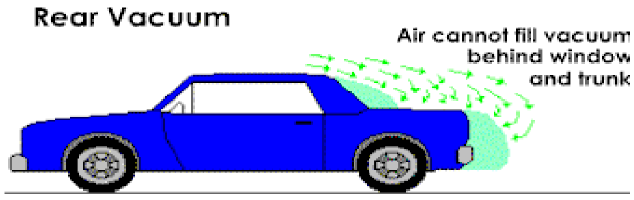


Figure.2. Rear Vacuum

B. FACTORS AFFECTING DRAG

Factors affecting drag force are
(a) Those associated with the object,
(b) Those associated with the motion of the object through the air,
(c) Those associated with the air itself.

C.PROPERTIES OF THE AIR

Drag depends directly on the mass of the flow going past the aircraft. The drag also depends in a complex way on two other properties of the air: its viscosity and its compressibility. These factors affect the wave drag and skin friction, which are described above.

III. SHAPE EFFECTS

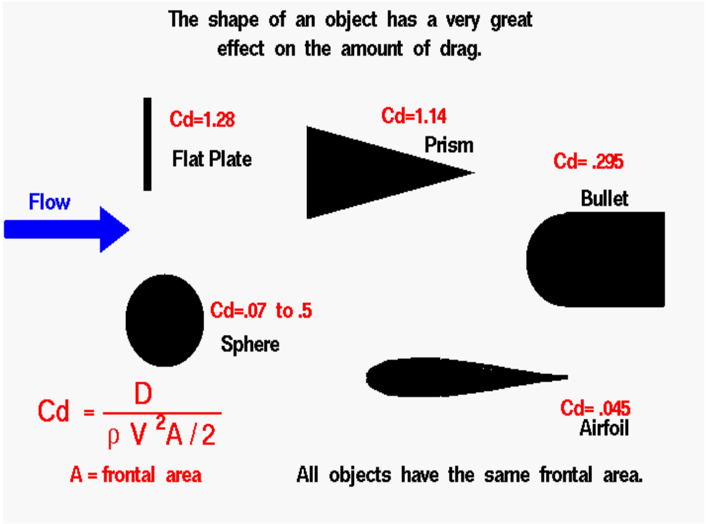


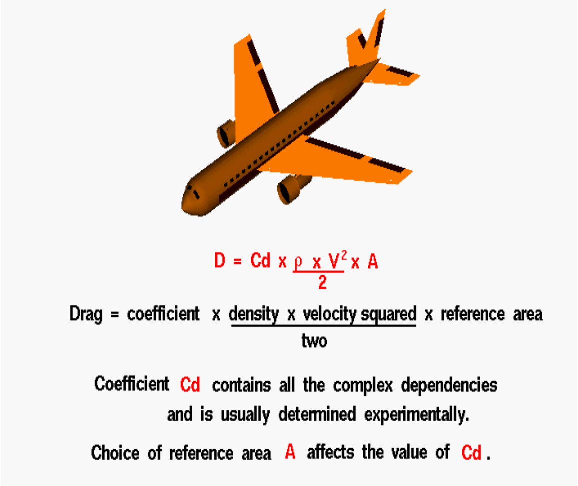
Figure.3. Shape effects of drag

IV. DRAG CO-EFFICIENT

The drag coefficient is a number which aerodynamicists use to model all of the complex dependencies of drag on shape, inclination, and some flow conditions.

$$Cd = D / (.5 * r * V^2 * A)$$

V. DRAG EQUATION



$$D = Cd \times \frac{\rho \times V^2}{2} \times A$$

$$\text{Drag} = \text{coefficient} \times \frac{\text{density} \times \text{velocity squared}}{\text{two}} \times \text{reference area}$$

Coefficient Cd contains all the complex dependencies and is usually determined experimentally.

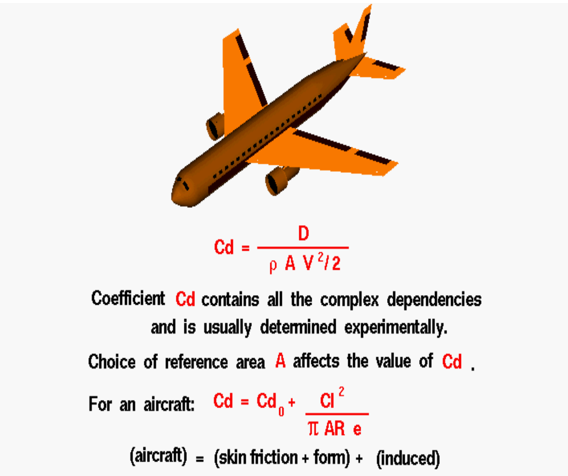
Choice of reference area A affects the value of Cd.

Figure.4. Drag Equation

Drag depends on the density of the air, the square of the velocity, the air's viscosity and compressibility, the size and shape of the body, and the body's inclination to the flow. In general, the dependence on body shape, inclination, air viscosity, and compressibility is very complex. One way to deal with complex dependencies is to characterize the dependence by a single variable. For drag, this variable is called the drag coefficient, designated "Cd." This allows us to collect all the effects, simple and complex, into a single equation.

$D = Cd * A * .5 * r * V\text{^}2$

DRAGCOEFFICIENT



$$Cd = \frac{D}{\rho\ A\ V^2/2}$$

Coefficient Cd contains all the complex dependencies and is usually determined experimentally.

Choice of reference area A affects the value of Cd.

For an aircraft: $Cd = Cd_0 + \frac{Cl^2}{\pi\ AR\ e}$

(aircraft) = (skin friction + form) + (induced)

Figure.5. Dragcoefficient

The drag coefficient is a number that aerodynamicists use to model all of the complex dependencies of shape, inclination, and flow conditions on aircraft drag. This equation is simply a rearrangement of the drag equation where we solve for the drag coefficient in terms of the other variables.

$Cd = D / (A * .5) * r * V\text{^}2$

The quantity one half the density times the velocity squared is called the dynamic pressure.

$Cd = D / (q * A)$

AERODYNAMIC DEVICES

A.SCOOPS

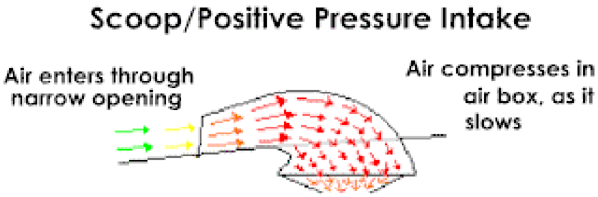


Figure.6. scoop\ positive pressure intake

B. NACA DUCTS

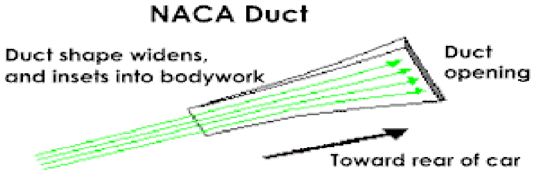
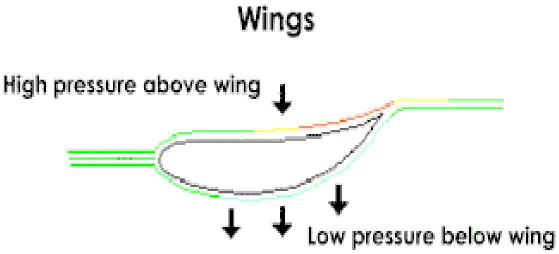


Figure.7. NACA Duct

C. SPOILERS

Figure.8. Spoiler

D. WINGS



FINGURE.9. WINGS

BUS BODY SPECIFICATIONS

The city bus that we considered for our analysis is **TATA Marcopolo – Star Bus54.**

The Tata Star 54 bus comes with an assurance of safety and comfort and is the perfect choice for travelers and operators at the same time. Its superior performance has the stamp of excellence from Tata Marcopolo Motors Ltd.The Specifications of the bus been mentioned in the table.

Table .A. TECHNICAL SPECIFICATION

Chassis Platform	*LPO 1512 BS III Diesel; 54 seater*
Engine	*Cummins 6BT 5.9; Water cooled direct injection Turbo charged Diesel Engine*
Maximum Power	*101 kw (135 HP) at 2400 rpm*
Maximum Torque	*490Nm at 1400-1600 rpm*
Gear Box	*TATA G-600; 6 Forward 1 Reverse*
Clutch Diameter	*330 mm; Dry Single Plate*
Suspension	*Semi elliptical leaf spring at front and rear; Hydraulic double acting telescopic type at front and rear; Anti-roll bar - front only*
Tyre Size	*9.00 x 20 -14 PR Diagonal Ply*
Steering	*Integral hydraulic power assisted steering*
Brakes	*Dual circuit,full air S-cam brake system with EEB fit-ment*
Fuel Tank Capacity	*250 litres*
Wheelbase	*5334 mm*
Front Overhang	*1185 mm*
Rear Overhang	*3200 mm*
No. of Seats	*54*
Max Width	*2600 mm*
Passenger Door	*One front and one rear door on co-driver side*
Overall Length	*9716 mm*
Overall Height In Laden Condition	*3250 mm*
Turning Circle Diameter	*20100 mm*
GVW	*14860 kg*
Electricals	*Battery: 2x12 Volts, 150 Ah; Alternator Capacity: 45 Amps*

AERODYNAMIC MODELLING

A. *PRESENT MODEL OF BUSES*

Figure.10. present model of buses

a) FRONT VIEW / b) SIDE VIEW

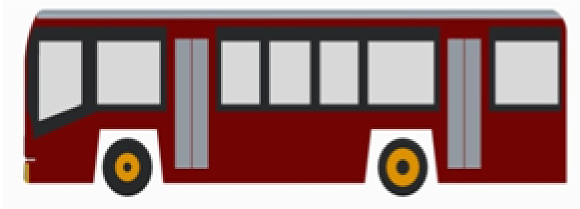


Figure.11. a) front view, b) side view

B.PROPOSED MODELS OF BUSES:

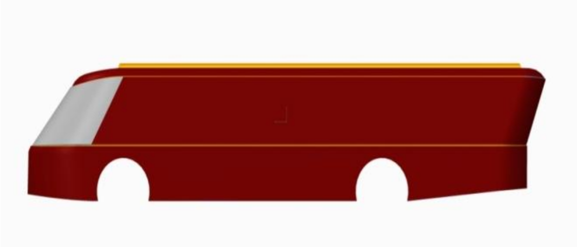


Figure.12. proposed models of buses

a) FRONT VIEW b) TOP VIEW / c) BACKSIDE VIEW

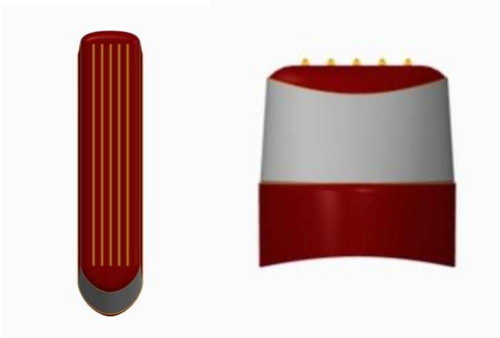


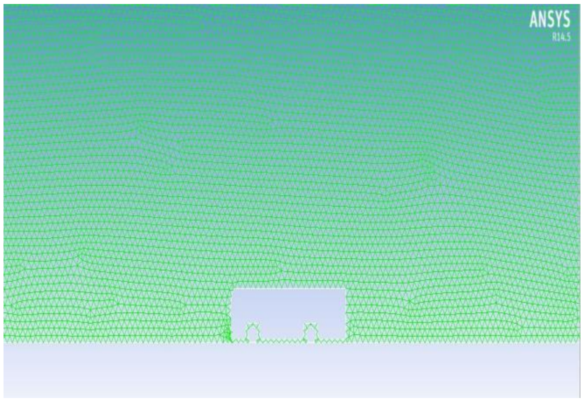
FIGURE.13. A) FRONT VIEW B) TOP VIEW C) BACK SIDE VIEW

VI. EXPERIMENTEL ANALYSIS

The Experimental analyses of our models were done by using ANSYS ICEM meshing software.

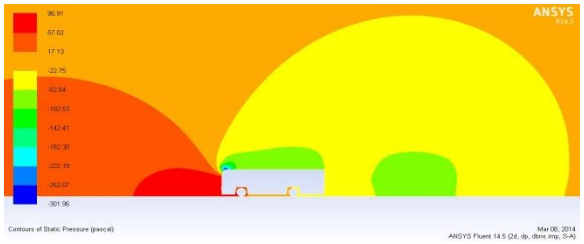
ANSYS ICEM CFD meshing software starts with advanced CAD/geometry readers and repair tools to allow the user to quickly progress to a variety of geometry-tolerant meshers and produce high-quality volume or surface meshes with minimal effort.

A.PRESENT BUS BODY



STATTIC AND DYNAMIC PRESSURE CONTOUR

FIGURE.A.1CONTOUR OF STATIC PRESSURE



Contours of Static Pressure (pascal)
Mar 08, 2014
ANSYS Fluent 14.5 (2d, dp, dbns imp, S-A)

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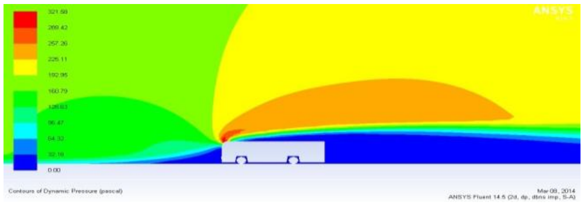
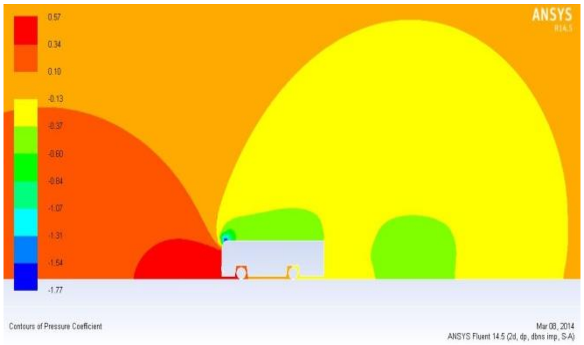
A.2.CONTOUR OF DYNAMIC PRESSURE



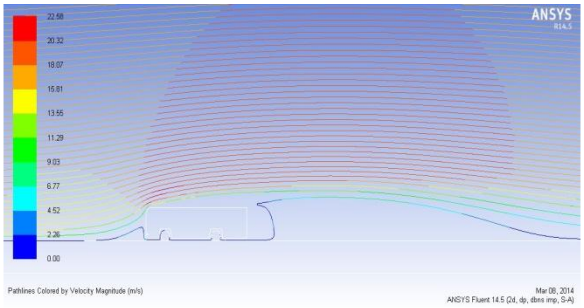
Contours of Dynamic Pressure (pascal)
Mar 08, 2014
ANSYS Fluent 14.5 (2d, dp, dbns imp, S-A)

A.3.CONTOUR OF PRESSURE COEFFICIENT



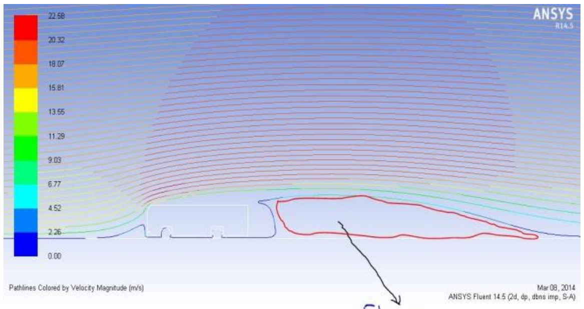
Contours of Pressure Coefficient
Mar 08, 2014
ANSYS Fluent 14.5 (2d, dp, dbns imp, S-A)

A.4.PATHLIES COLOURED BY VELOCITY MAGNITUDE



Pathlines Colored by Velocity Magnitude (m/s)
Mar 08, 2014
ANSYS Fluent 14.5 (2d, dp, dbns imp, S-A)

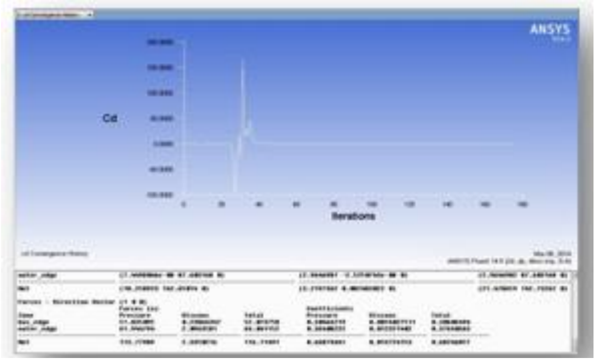
A.5.FLOW SEPERATION



Pathlines Colored by Velocity Magnitude (m/s)
Mar 08, 2014
ANSYS Fluent 14.5 (2d, dp, dbns imp, S-A)

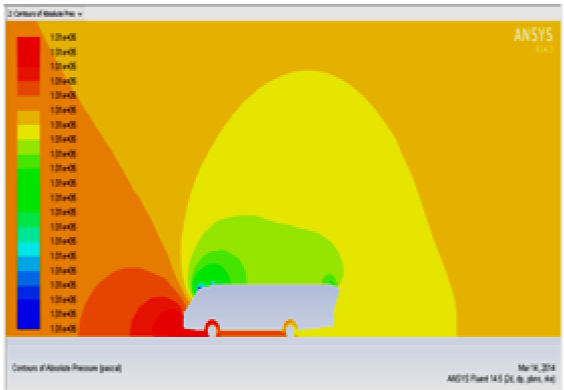
Flow Separation Region

A.6.CONVERGENCE IN CD VALUE



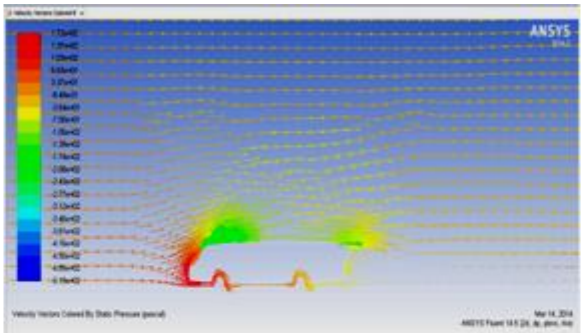
B.PROPOSED BUS MODEL

B.1.PRESSURE CONTOUR- ABSOLUTE PRESSURE



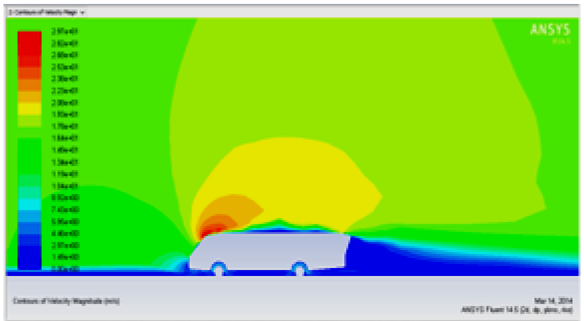
Contours of Absolute Pressure (pascal)
Mar 14, 2014
ANSYS Fluent 14.5 (2d, dp, dbns imp)

B.2.STATIC PRESSURE



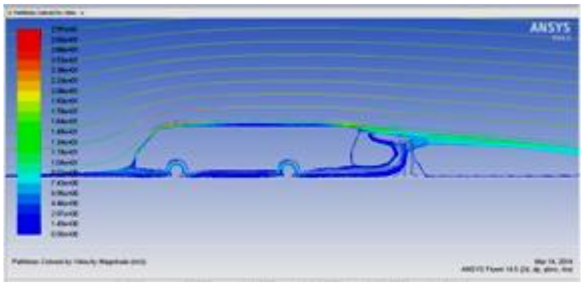
Velocity Vectors Colored By Static Pressure (pascal)
Mar 14, 2014
ANSYS Fluent 14.5 (2d, dp, dbns imp)

B.3.VELOCITY MAGNITUDE



Contours of Velocity Magnitude (m/s)
Mar 14, 2014
ANSYS Fluent 14.5 (2d, dp, dbns imp)

B.4.PATHLINES COVERED BY VELOCITY MAGNITUDE



B.5.CONVERGENCE IN CD VALUES

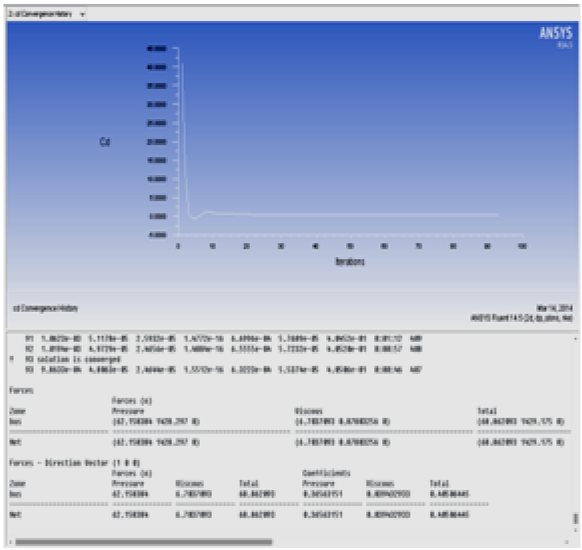


TABLE.B. COMPARISION OF DRAG FORCES AND DRAG CO-EFFICIENT

Bus	Drag force (N)	Drag coefficient
Present model	*116.11*	*0.68*
Proposed model	*68.86*	*0.40*
% of Reduction	*40.69*	*41.17*

FUEL EFFICIENCY

A.TABLE: PARTICULARS FOR CALCULATING FUEL CONSUMPTION

S.No.	PARTICULARS	VALUES
1	*Frontal Area, A*	*7.74 m2*
2	*GVW*	*14860 kg*
3	*CRR – coefficient of rolling resistance*	*0.008(approx.)*
4	*Fuel energy density(Wh/US gal)*	*43055.55*
5	*Engine efficiency*	*0.93(approx.)*
6	*Drive train efficiency*	*0.38(approx.)*
7	*Air Density (kg/m3)*	*1.184*

The calculated fuel efficiency of all the two buses at three different speeds is tabulated.

B.TABLE: FUEL CONSUMPTION PER100 KM

Bus	40 kmph	60kmph	At 80 kmph
Present model	*10.84*	*15.18*	*19.19*
Proposed model	*9.36*	*11.39*	*13.26*
Fuel saving for100Km in litres	*1.48*	*3.79*	*5.93*
% of reduction in fuel consumption	*13.65*	*24.96*	*30.90*

It is evident from the above table that by the 40% deviation in drag force, fuel consumption of about 13% to 30% can be reduced from 40 kmph to 80 kmph.

VII. CONCLUSION

Two different prototypes have been modeled for performing experimental analysis using CFD software. The first model is the existing model; the second one is the model with the modification infront and rear end. The two models have been separately tested for optimizing how each modification is contributing towards the drag force. The experimental test which we have conducted gives us a clear idea that there has been a considerable reduction of drag force on the models which we have created. It was found that the least drag force was acting on the proposed model, as expected. The percentage reduction in drag force of proposed model from present model is found to be 0%. By the 40% deviation in drag force, fuel consumption of about 13% to 30% can be reduced from 40 kmph to 80 kmph. It is evident from the test result, that there has been a considerable reduction in drag coefficient of about 41% from the existing bus to the new concept and up to 5 to 6 litres of fuel consumed for the every 100Kms is saved. This improvement in fuel efficiency will have a high impact on the reduction of annual fuel consumption, which will greatly influence the Government regulations, making the road transport more efficient. Hence, our aim has been achieved.

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