CFD ANALYSIS FOR DRAG FORCE REDUCTION IN INTER-CITY BUSES

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ABSTRACT: *The road transport now a day is becoming uneconomical because of the rising fuel price and strict government regulations. The two essential factors for a successful operation in the competitive world are exterior styling and aerodynamically efficient design for reduction of engine load which reflects in the reduction of fuel consumption. The outer surface and structure of the bus are the precedence's of the bus body building company and ignore the aerodynamic. The aerodynamic exterior design of the present intercity buses is poor. The aim of this project is to modify the outer surface and structure of the bus aerodynamically in order to decrease the effect of drag force of the vehicle which in turn leads to reduced fuel consumption of the vehicle. To reduce the drag force by using CFD the two prototype bus body has been modeled, namely model 1 and model 2. Model 1 is existing intercity bus model and model 2 is modification of existing intercity bus. Model 2 is useful to reduce the drag force by modifying and analyzing by using CFD. Increased performance and reduced the fuel requirement occurs as a result of reduced drag force. The overall aerodynamic drag force is reduced.*

***KEY WORDS*:** *Aerodynamics, drag force, inter-city buses, exterior styling.*

1.INTRODUCTION:

Now days the automotive industries invest significantly in reducing the fuel consumption of their products due to the global climate change. The governments and legislations push the companies at first hand to reduce the emissions of their vehicles. To reduce the emissions there are many approaches and all of them are important for the automotive industry. One approach is to switch to a more environmental friendly fuel. Other way is to base the power train on other technologies such as electric or hybrid. To make the existing technology more efficient a lot of work has been done, such as, internal friction has been reduced; combustion is optimized e.g. direct injection, spark timing etc., along with these downsizing and turbo charging of internal combustion engines has been done. Reduction of the driving resistance of the vehicle is however one of the most effective approaches.

The following expression can determine the required force to propel the vehicle:

Freq = Fd + Fr + Fa + Fg ...(1)

Where,

Fd = 1/2 * V2 aerodynamic drag force

Fr = force due to rolling resistance

Fa = force needed to accelerate the vehicle

Fg = Wsin - climbing resistance due to gravity

Hence the mass, the rolling resistance and the aerodynamics are the parameters that are to be improved by automotive industry.

The rolling resistance and aerodynamic resistance are still equal in around 100km/h generally for a typical passenger vehicle and the aerodynamic drag is the main source of driving resistance at highway velocities while the rolling resistance stays more or less constant.

1.1 OBJECTIVE:

This project aims to employ computer modeling in order to conduct a thorough analysis of current Ashok Leyland bus aerodynamics and for required improvements it provides recommendations too.

- To use solid works CAD modeling software to model an existing Ashok Leyland bus, as a baseline model.
- To perform the flow analysis on the baseline model using CFD tool fluent.
- To design new model of bus with reduced drag force.
- Perform flow analysis on the new models.
- To reduce drag force along with achievement of better fuel efficiency.

2. Model Development:

Race car, sedan aerodynamics were focused by most of the researches than heavy vehicles because of market forces at work and consumer preferences. However, few researches like research conducted by Sachin Thorat and G Amba Prasad Rao in 1999 on "Computational Analysis of Intercity Bus With Improved Aesthetics And Aerodynamic Performance On Indian Roads and drag force reduced by 30%. Edwin j Saltzman and Robert R Meyer in 2007 conducted studies on reduction of drags of buses and trucks. The final model equipped with rounded, horizontal and vertical corners, smoothed under body and a boat tail achieved Cd value of 0,242. (Peterbilt Motors Company, 2009) presents a white paper on Heavy vehicle aerodynamics and fuel efficiency. The aerodynamics drag losses due to which vehicles utilize large capacity engines is reviewd by this paper. In 2007, G Buresti conducted research on methods to reduce drag of bluff bodies and their application to heavy road vehicles which stated that to reduce the drag of bluff body, boat tailing has been applied and this lead to the reduction of base drag to about 5% to 10% respectively. To reduce the drag force further, a device occupies the Tractor- Trailer gap which ensures both drag reduction and easy movement of trailer around the turns without any clashing. Not only the pressure drags of axle but of trailer base is also provided with flow deflection devices and fairings. This paper also points out that wheels of road vehicles are source of significant aerodynamic drag, so wheel housings have been provided to reduce such drag.

In 2004, Mc Callen found that vehicle drag will get down by 4.5% by removal of rear view mirror alone. Flow separation and flow circulation will occur as a result of presence of any gap in the vehicle body. Until the front leading edge radii reaches 150mm drag value gets reduced, revealed in the investigation.

In 2007, a research conducted by Panu Sainio from aalto University on aerodynamics possibilities for heavy vehicles concluded that boat tail approach is a good solution in terms of aerodynamics. The length of the vehicles is significantly increased by classical boat tail but this problem can be overcome by using trailing edge blowing which still has full aerodynamic capacity of long boat tail.

In 2013, E Selvakumar conducted research on "Aerodynamic exterior body design of bus". In order to prove the effectiveness of new concept design, experimental numerical tests were conducted in wind tunnels. New concept reduced the drag upto 30% to 40% than the existing bus and for every 100km 6 to 7 litres of fuel is consumed – evidence from the test result.

2.1 . Methodology:

Numerical simulations of different vehicle configurations are done in this study. Required configurations can be identified by evaluation of baseline stimulation results. The CFD process described below can be performed for each configuration, which includes three steps; pre-processing, solving and post-processing.

2.2 . Boundary Conditions:

Boundary Conditions were applied on meshed model. Only straight wind condition was considered in the stimulation at different speeds of the vehicles up to 100km/hr. In order to replicate the constant wind velocity like wind tunnel test, constant velocity inlet condition was applied at the inlet. With the atmospheric pressure as operating pressure, zero gauge pressure was applied at the outlet.

3.Modeling:

The original model was considered as the model of intercity bus. The dimensions of the bus were considered as to be of intercity bus. The outer body of the bus was designed similarly to the design of the intercity bus.

While designing for the aero dynamical analysis the outer shape of the body plays a vital role and is more responsible for the formation of drag force. Therefore in the modified model the major change has been brought to the outer shape of the body.

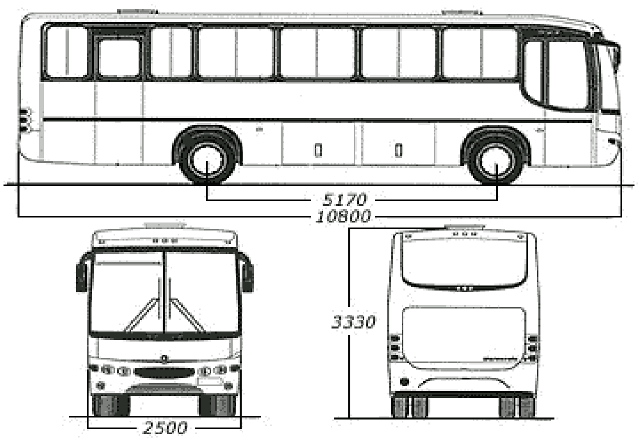


Figure 1 : Outer Dimensions

3.1 Original Model:

The original model which the model of the intercity bus is modeled using designing software and is presented as shown. The isometric view of the intercity bus is modeled in the below figure.

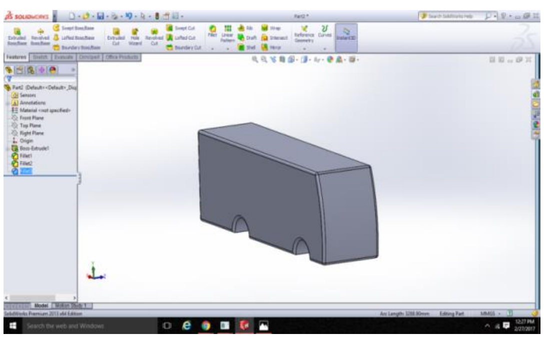


Figure2: Isometric View (Original Model)

3.2 Modified Model:

The above model has been modified in their exterior looks. While designing the aerodynamic aspects and parameters have been taken into consideration.

Modified Aspects:

Frontal Area: The frontal area is curved as compared to the original styling.

Back Area: At a distance from a halfway of the bus the back area of the bus is declined to an angle of 15 degree.

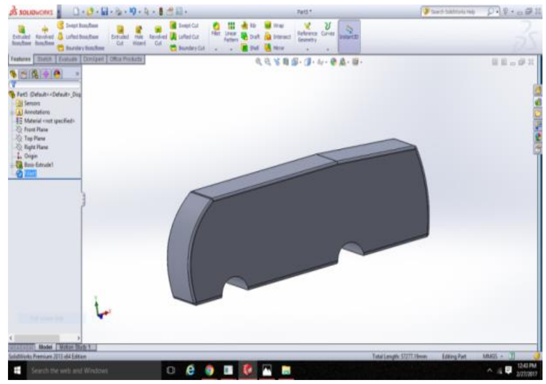


Figure 3: Isometric View(Modified Model)

4.MESHING:-

For the lead to a free with ignored capable to blockage the computational domain is designed , which basically mean box that involve of inlet and outlet as well as roof and a ground surface this domain is occupied almost such that the real –time road condition fulfilled .

The mesh was generated on the surface of the domain and the surface of the geometry of the vehicle .and the computational grid is created between the domain and vehicle .To internment certain area of interest(where the turbulence is high as well as departure might occur)the cell have to be solve complete a vigorous solution and all irregularities. The grid has been reassignment Over the bus, and rear of the bus and specially. the grid has been over the bus and the rear of the body and especially bottom ward. the vehicle has been studied on the concentrating on the under bodies of the guidance of the flow filed

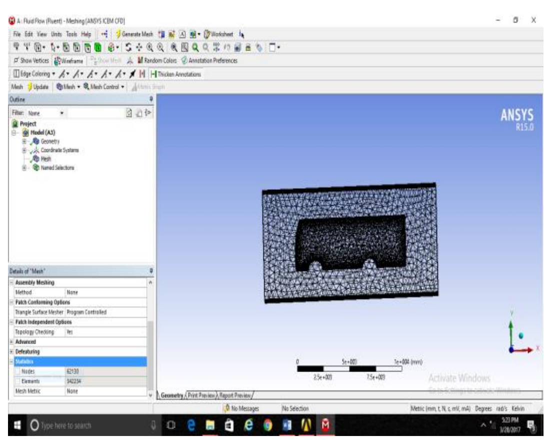


Figure 4: Meshing Model 1

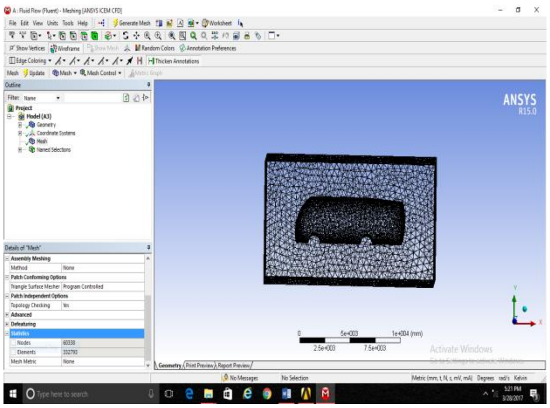


Figure 5: Meshing Model 2

In earlier sections it has described how the air is act and create the boundary layer over the surface of the bus body . to acquisition these flow a depuration region over the revealed surface must be created .this processing area is called prism layer

Its more signification to express the orientation of the surface to make the prim layer in the direction of the normal vector. this layer is required to expect the more accurate flow since the maximum gradient are traced close to wall

4.1Baseline Model

Element Details:

- 342234 tetrahedral cell, zone 2, binary.
- 674594 triangular interior face zone 1,binary.
- 418 triangular velocity-inlet faces , zone 5,binary.
- 416 triangular pressure-outlet faces, zone 6,binary.
- 3158 triangular wall faces, zone 7,binary.
- 972 triangular wall faces, zone 8,binary.
- 14792 triangular wall faces, zone 9,binary.
- 62130 nodes, binary.
- 62130 node flags, binary.

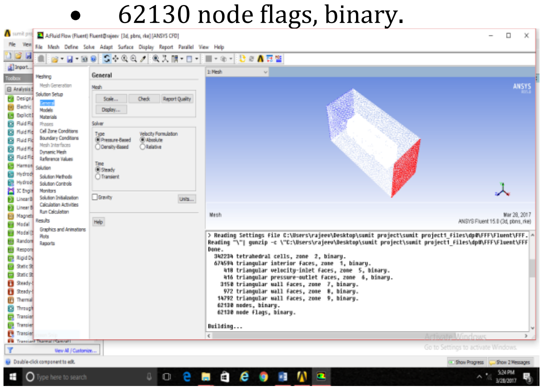


Figure 5: Meshing of Baseline Model

4.2. Modified Model

Element Details

- 332793 tetrahedral cell, zone 2, binary.
- 656155 triangular interior face zone 1,binary
- 2218 triangular wall faces , zone 5,binary.
- 2240 triangular wall faces, zone 6,binary.
- 452 triangular pressure-outlet faces, zone 7,binary.
- 466 triangular velocity-inlet faces, zone 8,binary.
- 13486 triangular wall faces, zone 9,binary.
- 60338 nodes, binary.
- 60338 node flags, binary.

5.Results and Discussion:

We have got different results in various categories like drag force, power resistance, rolling resistance, total resistance and are depicted with the help of a table and graphs.

5.1 Calculation Of Drag Force: F=1/2*ρ AV^2

CALCULATION OF DRAG FORCES IN BASELINE MODEL AND MODIFIED MODEL		
SPEED(KM/H)	BASELINE MODEL(F_D)	MODIFIED MODEL(F_{D1})
10	33.434	22.702
20	132.393	88.049
30	293.031	193.793
40	517.986	340.416
50	805.129	529.017
60	1155.279	755.522
70	1562.937	1020.625
80	2045.478	1326.758
90	2584.061	1674.099
100	3182.435	2059.710

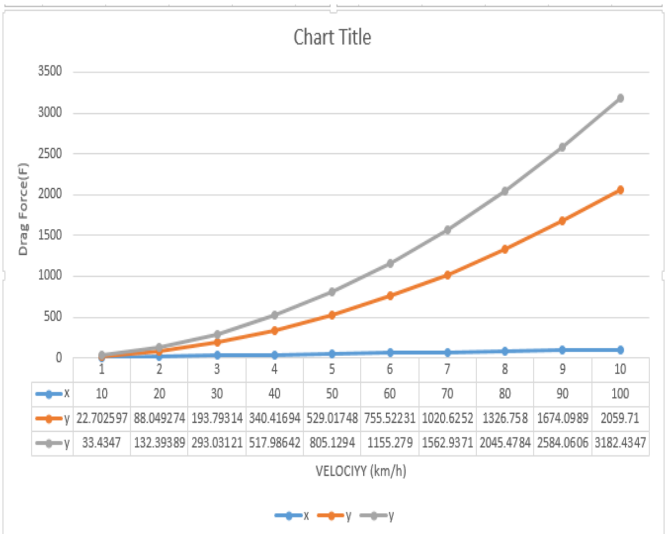
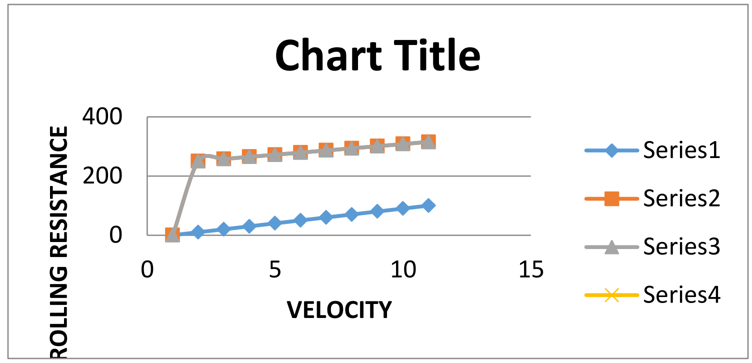


Chart 1: Drag Force

5. ROLLING RESISTANCE (N):

FR=(0.015+0.00016V)*W

ROLLING RESISTANCE AT VARIOUS SPEED		
SPEED(KM/Hr)	BASELINE MODEL(F_D)	MODIFIED MODEL(F_{D1})
10	250.207	250.207
20	257.411	257.411
30	264.591	264.591
40	271.797	271.797
50	279.002	279.002
60	286.208	286.208
70	293.388	293.388
80	300.594	300.594
90	307.801	307.801
100	315.005	315.005



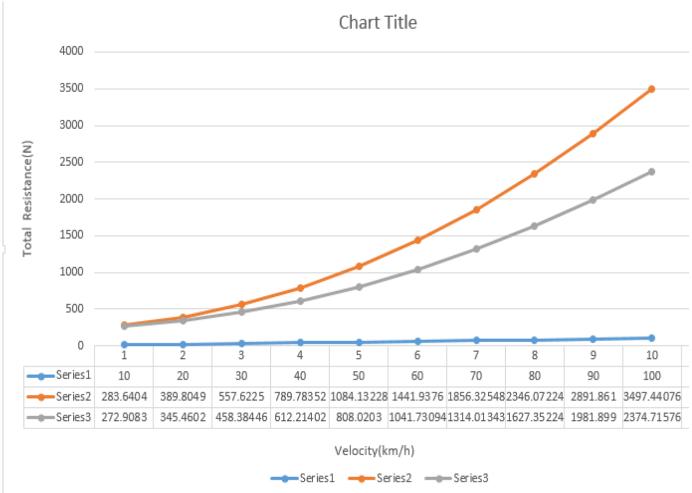
C.TOTAL RESISTANCE (N)

$F_t=F_D+F_R$

F_D :– Drag Force

F_R :- Rolling Resistance

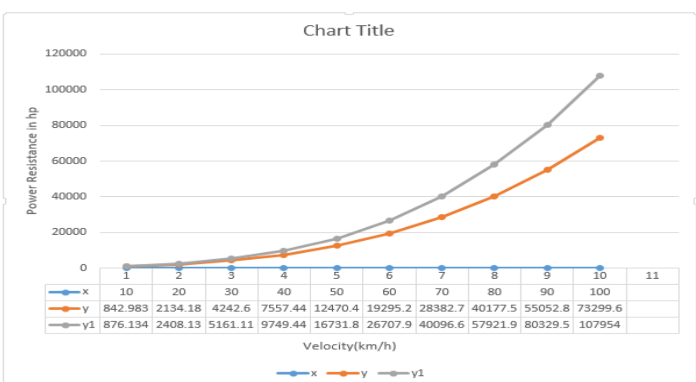
TOTAL RESISTANCES AT VRIOUS SPEED		
SPEED(KM/H)	BASELINE MODEL	MODIFIED MODEL
10	283.640	272.908
20	389.8049	345.460
30	557.622	458.384
40	789.783	612.214
50	1084.132	808.020
60	1441.938	1041.731
70	1856.325	1314.013
80	2346.072	1627.352
90	2891.861	1981.899
100	3497.441	2374.716



D. POWER REQUIRED (hp)

$P= F_T V/n_t$

POWER RESISTANCE AT VARIOUS SPEED		
SPEED(KM/H)	BASELINE MODEL	MODIFIED MODEL
10	876.133	842.983
20	2408.128	2134.176
30	5161.106	4242.603
40	9749.439	7557.442
50	16731.770	12407.452
60	26707.891	19295.178
70	40096.638	28382.690
80	57921.923	40177.521
90	80329.473	55052.750
100	107954.328	73299.560



6. Conclusion:

A complete and detailed computational analysis has been done on the intercity buses that run on the roads of India with some modification in their outer structure which affects the aerodynamics of the bus.

A modified version of the original structure is modeled with the change in the rear and frontal areas of the bus and mathematical analysis has been done using CFD software. There are two types of prototype used 1) Original version of intercity bus 2) Modified version of intercity bus. Calculations and analysis has been done for both the cases.

The maximum velocity that has been considered is 100 km/hr and the drag coefficient for the base line model is 0.7 and it has been decreased in the case of the modified model to 0.58.

By following these criteria the drag has been decreased to approximately 20%.

The drag force has been reduced which leads to the enhancement in the performance of bus and decreases the fuel consumption and hence increases the efficiency of the bus.

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