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Analysis of drag coefficient when subjected to design change in automobile

R Ajay Aravind
(Student, Department of Mechanical Engineering, St.Joseph's College of Engineering, Chennai, India)

Abstract : *In contemporary industrial age, there exist plenty of analytical methodologies with fine and precise estimation of automobile performance. Especially after the design process, the profile generated is meticulously evaluated through various simulations. In this article, the drag coefficient and drag force are analyzed based on the changes made on the side and rear profile of a conceptually built automobile, in specific term, the segment used for this research is a sedan type.*
Keywords: *Drag coefficient analysis, automobile performance, aerodynamics, car profile, automobile CAD*

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I. INTRODUCTION

Automobile profile development starts from sketching and ends with renders that are dimensioned. The background works for the generation of such industrial prototype requires craftsmanship as well as engineer's diplomatic approach towards design and safety that are intended while making the base construction. Everything starts with a base design which in other words, can be called as sketching. Sketching the model with all features and views would help the designer to brainstorm the ideas that are associated to raise the desired car in a pragmatic way. Post sketching work consists of 2D drafting of various views in CAD software like AutoCAD, where the draftsman would give all the perspectives with constrained dimensions. Followed by that, 3D model is made by aligning the curves with all the related views thereby bringing out the realistic model virtually. After rendering the generated design using software like Alias and VRED, the analysis is to be done on the profile of the car. The analysis in this case, is to find drag coefficient and drag force which could help in determining the stability of the vehicle when subjected to wind flow while running on road. Generally, drag analysis is done through simulation software like Autodesk CFD, Siemens Star CMM+ and Flow Design. Moving on to practical performance, they developed prototype is then subjected to laminar as well as turbulent wind strips over its surface through a wind tunnel to estimate the actual performance.

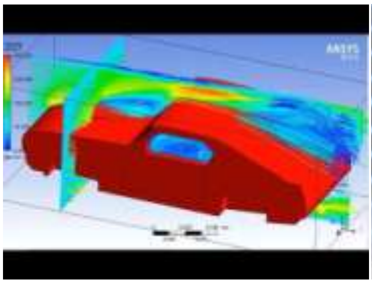


Fig.1 Drag Simulation

Fig.2 Wind tunnel testing

II. CONCEPTUAL DESIGN

Conceptual design which is developing the prototype through series of creative models that could meet the exact requirement of finished complete product. Here, in this article the model constructed comes under sedan category with base dimensions as per Audi A6 which is comes under four doors and a long cabin with sophisticated interiors and an audacious design. The basic frame of that vehicle is been generated through Alias Speed form and is been analyzed in Flow Design. The car sculpted is made of stainless steel with satin finish respectively. With various versions of the models developed accordingly drag coefficient and drag force are determined accordingly.

III. COMPUTER AIDED DESIGN OF CAR MODELS

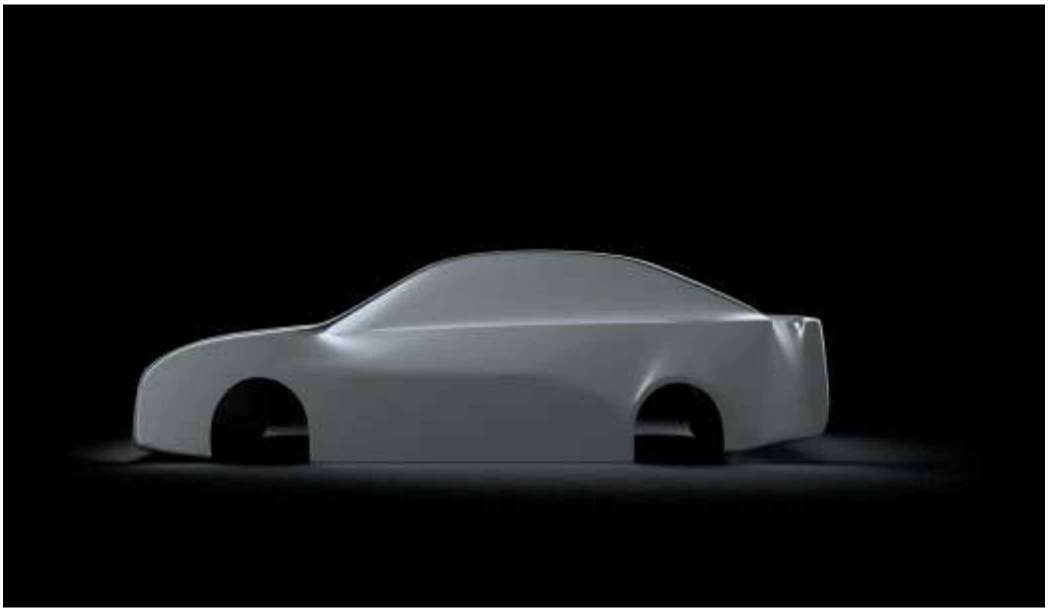


Fig.3 Sedan Version 1

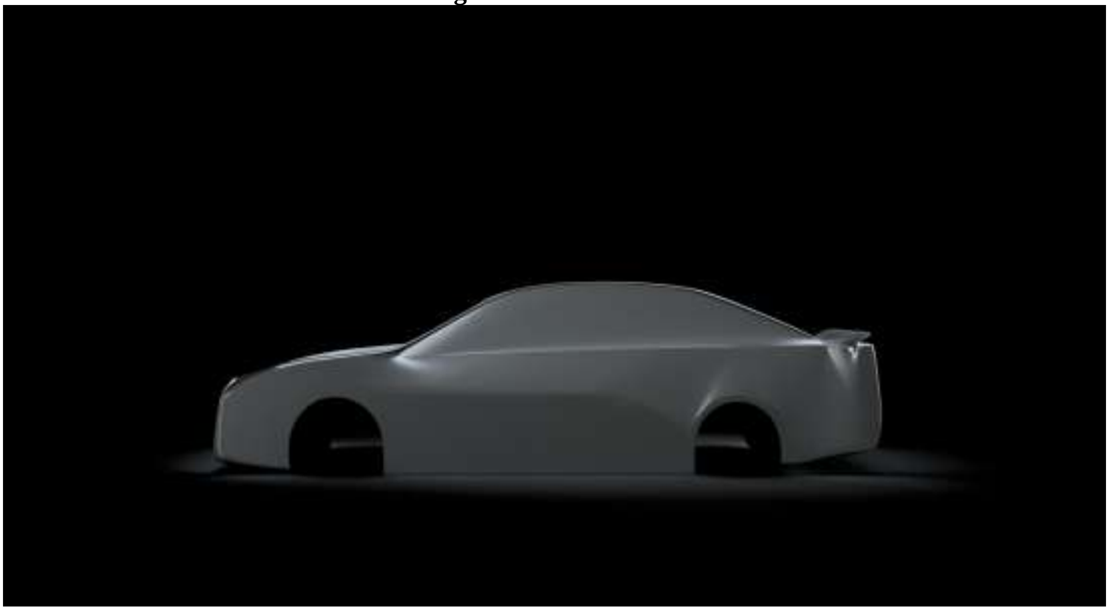


Fig.4 Sedan Version 2

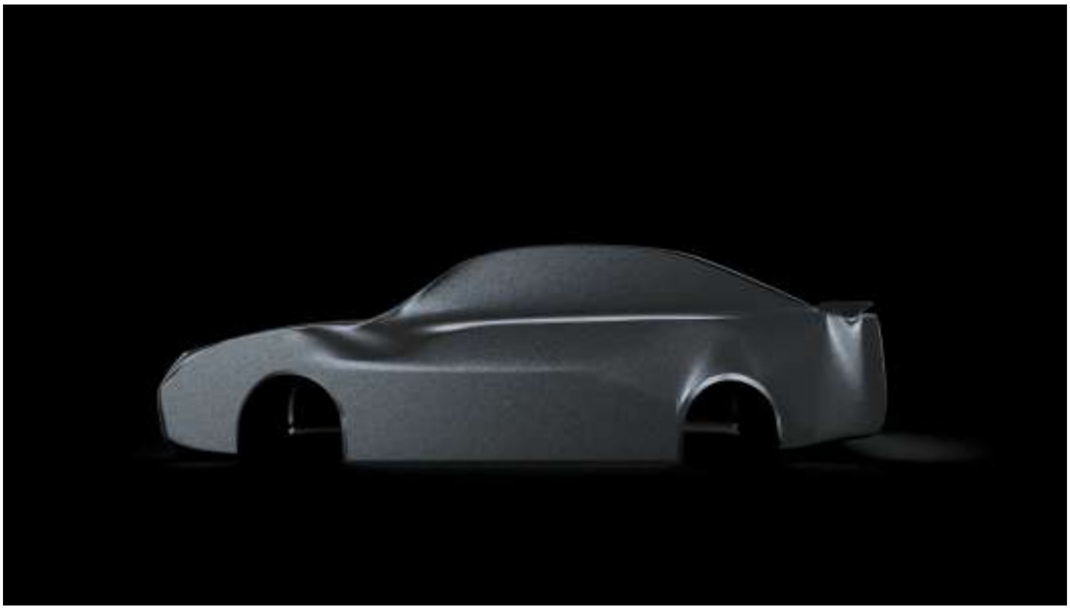


Fig.5 Sedan Version 3

Fig.6 Sedan Version 4

IV. DESIGN SUMMARY

From the above versions of the generated sedan, the design summary enumeration can be done with concepts of front area and rear spoiler application which can help the wind to get pierced with less drag coefficient and also with low lift force.

With the general formula for drag force, it can be explained how significant is deign profile by considering the aerodynamic performance of the vehicle.

General formula for coefficient of drag:

$$\mathbf{D = 0.5C_D \times \rho V^2 \times A}$$

Where, D = Drag Force (N)

C_D = Drag coefficient

ρ = Density of air (kg/m^3)

V = velocity of vehicle relative to air (m/s)

A = Frontal area (m^2)

Version 1:

D = 1434.79 N

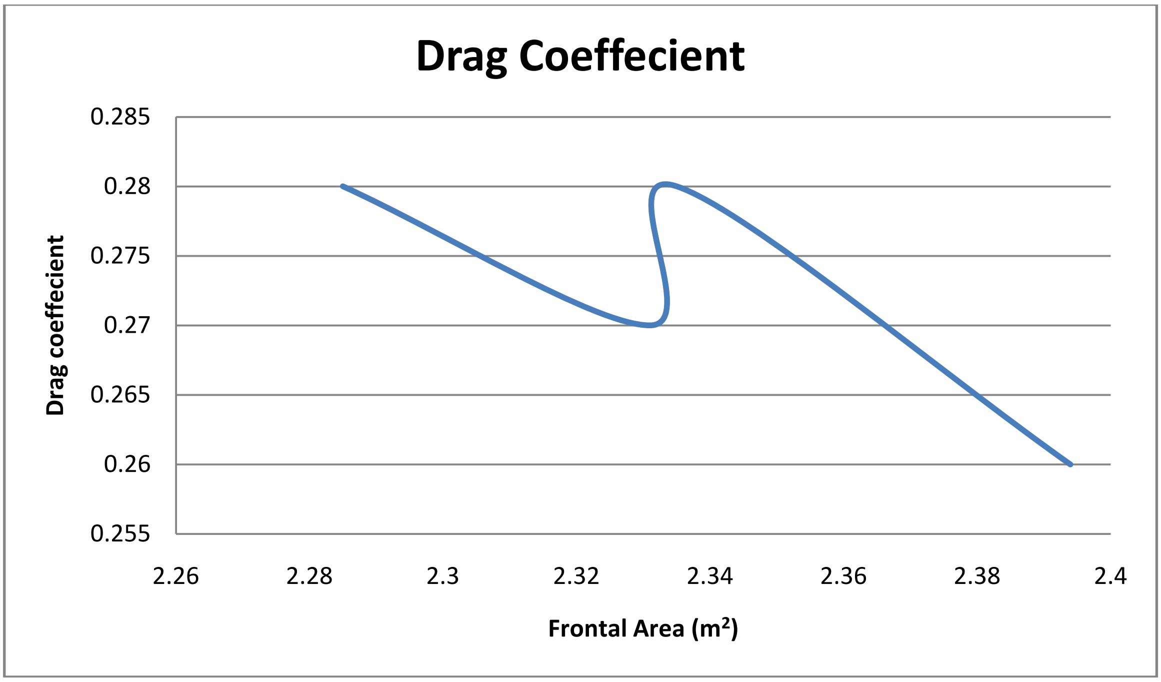
$\rho = 1.225\ kg/m^3$ (constant for air)

V = 61 m/s (constant for all the versions)
A = 2.331 m^2
$C_D = D / (0.5\ \rho V^2 \text{ x } A)$
$C_D = 1434.79 / (0.5 \text{ x } 1.225 \text{ x } 61^2 \text{ x } 2.331)$
C_{D1} = 0.27

Version 2:
D = 1458 N
ρ = 1.225 kg/m^3 (constant for air)
V = 61 m/s (constant for all the versions)
A = $C_D = D / (0.5\ \rho V^2 \text{ x } A)$
$C_D = 1458 / (0.5 \text{ x } 1.225 \text{ x } 61^2 \text{ x } 2.285)$
C_{D2} = 0.28

Version 3:
D = 1490.07 N
ρ = 1.225 kg/m^3 (constant for air)
V = 61 m/s (constant for all the versions)
A = 2.335 m^2
$C_D = D / (0.5\ \rho V^2 \text{ x } A)$
$C_D = 1490.07 / (0.5 \text{ x } 1.225 \text{ x } 61^2 \text{ x } 2.335)$
C_{D3} = 0.28

Version 4:
D = 1418.84 N
ρ = 1.225 kg/m^3 (constant for air)
V = 61 m/s (constant for all the versions)
A = 2.394 m^2
$C_D = D / (0.5\ \rho V^2 \text{ x } A)$
$C_D = 1418.84 / (0.5 \text{ x } 1.225 \text{ x } 61^2 \text{ x } 2.394)$
C_{D2} = 0.26



Graph.1 C_D vs Frontal Area

It can be inferred from the graph which is plotted between frontal area and drag coefficient of vehicle, that there is a gradual reduction in drag while increasing the frontal area, however there seems a dip in between

2.32 m^2 and 2.34 m^2, which is because of the change in feature lines and alignment of the surface that is to be elaborated in latter part of this document.

V. Analysis of models

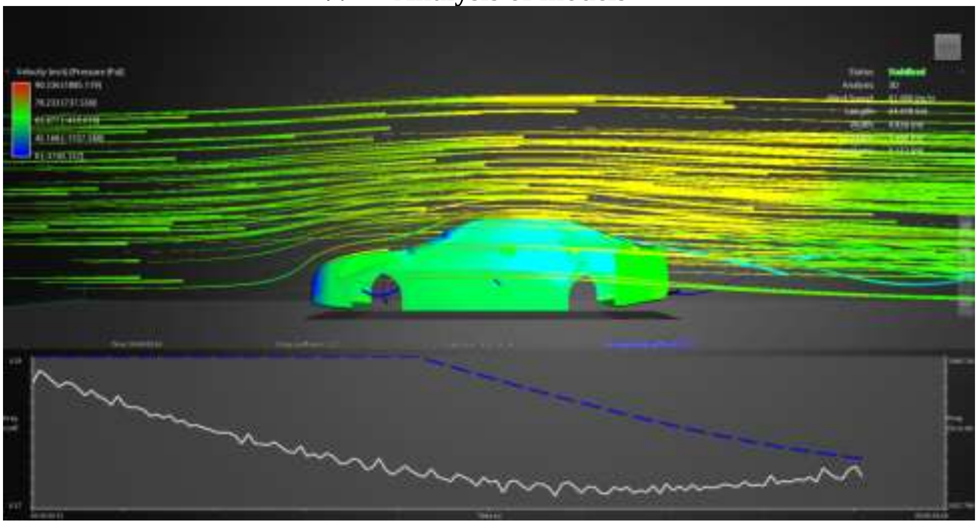


Fig.7 Drag analysis: Version 1 C_d = 0.27

` From fig.7 it can be inferred that the 3D model of version 1 is been meshed and is analyzed with turbulent wind analysis that is done with flow design with velocity set at 61 m/s and with proper housing of the model with the ground, set at the middle of the wind direction, so that there will be uniform shoot of wind over the surface of the automobile. Similarly rest of the model versions are analyzed with the same setting and their performance results are hence then tabulated to find the concurrent changes that are made which has a great impact from the design aspect.

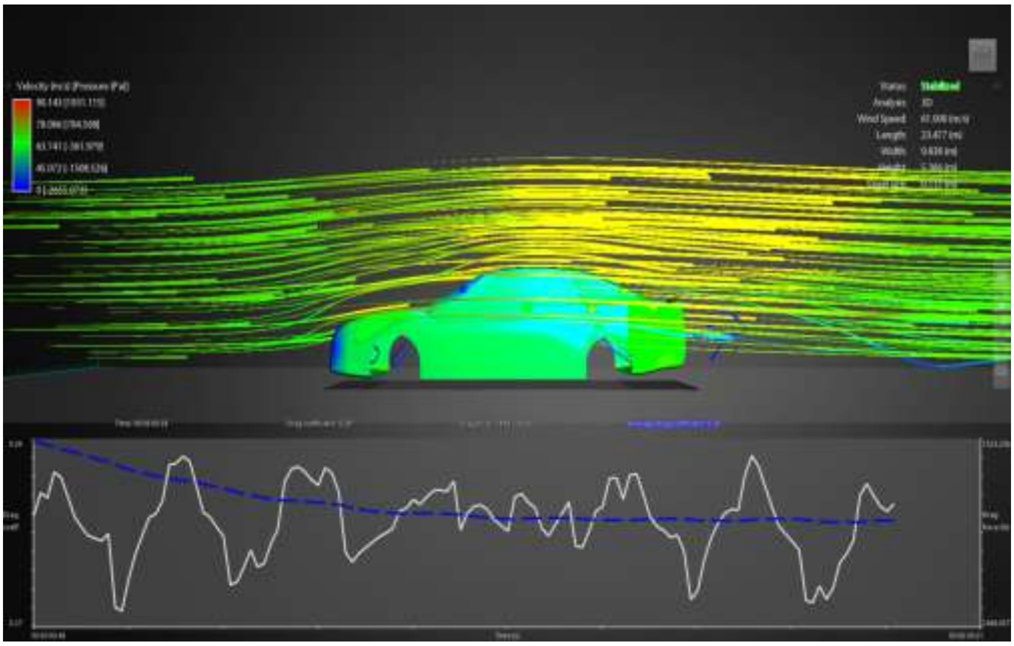


Fig.8 Drag analysis: Version 2 C_d = 0.28

In this version, the introduction of spoiler and changes in bonnet and shoulder line, made a significant rise in drag coefficient value as well as drag force which is a downfall but in aesthetic view, version 2 got few updates compared to prior version.

Also in the next version there seems to be improvisation of profile alignment with appropriate creasing and surface flattening, it gave a rise in C_d as well as in drag force but it helped in increasing the down force so that the stability of the vehicle is ensured by precluding pitching effect.

In case of version 4, the complete refurnishing of overall design with spoiler improvements and crease alignments in frontal region, helped in widening the cross section, thereby reducing the drag coefficient by 7 percent along with aesthetical contour.

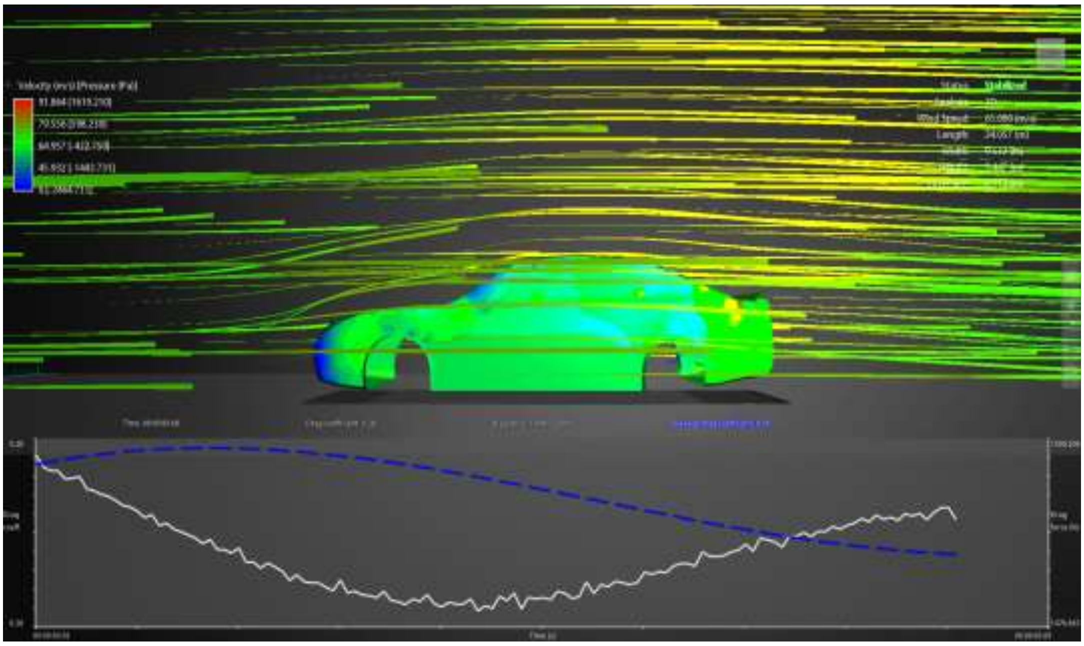


Fig.9 Drag analysis: Version 3 C_d = 0.28

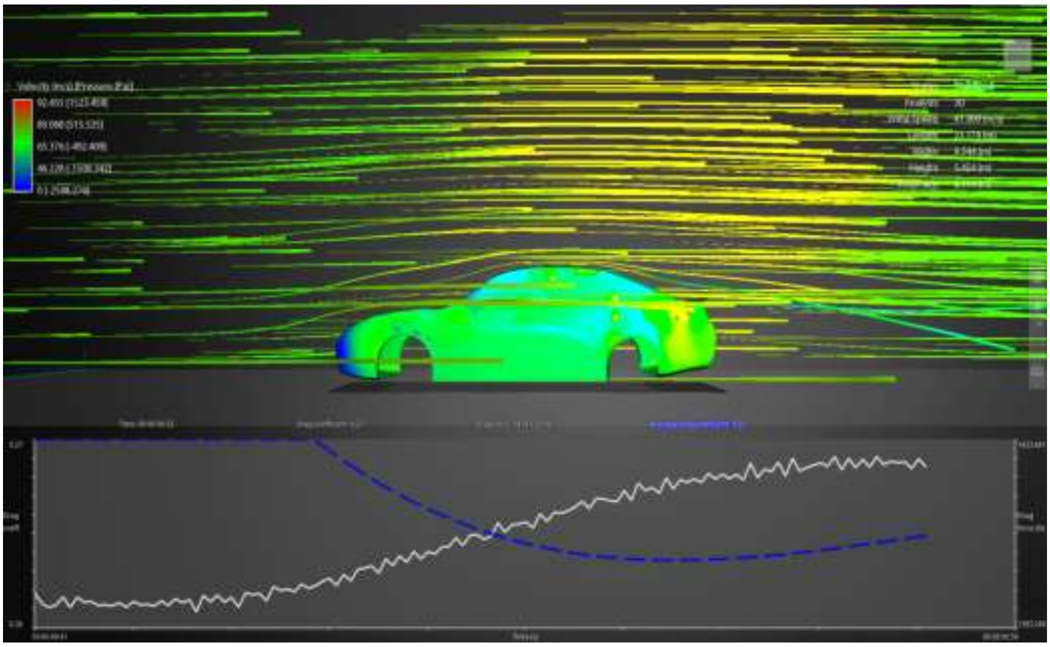
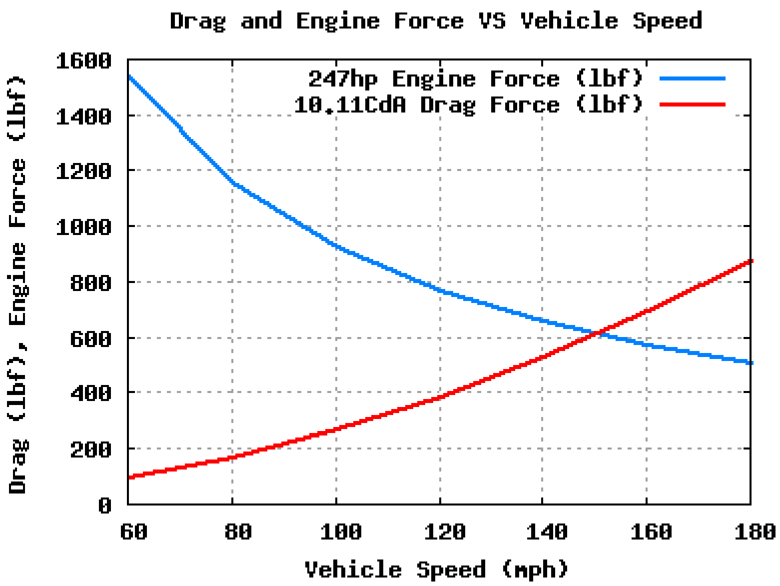


Fig.10 Drag analysis: Version 4 C_d = 0.26

VI. Conclusion

In the analysis of various developed versions, it can be concluded that with supportive featuring of bonnet with additional spoilers in front part as well in rear could help in reducing the drag force, moreover the frontal area increment will definitely reduce the drag coefficient, lower the C_D greater will be the ability of the automobile to overcome the air resistance by piercing through the thick turbulent wind flow that the car faces.
As the drag force is suppressed, faster will be the vehicle through the engine's propulsion through wind.



Graph.2 Drag force vs Vehicle speed

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