Drag measurement of an Indian auto-rickshaw model

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Abstract. Indian vehicle auto-rickshaw is considered as the most common and economical mode of transportation for day to day activities. It plays an important role in the automobile sector both in urban and rural areas. The present study is about external aerodynamics of the vehicle considered which was tested in a subsonic wind tunnel. The forces acting on the vehicle especially the drag component was measured for various operating conditions. The drag forces were measured by load balance that consists of a load cell which is calibrated against known loads. The results obtained with the model helps in the understanding of physics of the flow behind it. The results also suggest that the vehicle is moderately bluff to the flow and needs aerodynamics optimization.

1. Introduction
The Indian automotive industry focused primarily on vehicle repair, distribution, financing and maintenance. After independence, the Indian Automotive industry has faced a number of challenges and roadblocks, such as manufacturing capacity, have been limited by the licensing law and cannot be increased, but it still leads to growth and success today. The study of vehicle aerodynamics is highly driven by external aerodynamics of the high-performance vehicle. Targeting the racing industry primarily, the common category vehicles such as auto-rickshaw, open jeeps over are overlooked.

Vehicle aerodynamics is studied to enhance vehicle performance and passenger comfort. The drag is a factor of resistance to the movement of vehicles. Hence to improve the efficiency the resistance should be as less as possible. In this experiment, our primary objective is to study the drag characteristic with respect to velocity. This investigation will comprehend the study of drag for an auto-rickshaw.

2. Literature Survey
Studying the effect of increasing mass and dimension of modern vehicles on the drag coefficient Boran Pikula [1]. gave a detailed report on the influence of increasing mass and dimension for passenger comfort on the drag coefficient with proper experimental setup pictures and graphs plotted by him and other co-authors. Mohd Nizam Sudin [2]. did a study report on different existing drag reduction methods employed to prevent or delay airflow separation at the rear end of the vehicle. This paper includes both active and passive flow control methods and their effect on the drag coefficient. Li Nan [3]. made a report on the analysis of exits methods and gave an overall conclusion about the advantages and disadvantages of each method. There are overall four methods that have been described. The first one is an element floating on water, second is the same method with a mechanical device. The third method using an oil bath instead of water and the last one is with a standard load.
cell. Abdessamed Kacem et al. [4], experimented to determine the drag coefficient of a Toyota car model using the strain gauge method. In this paper, they used a 1:20 scaled Toyota car as the test subject and found out the drag at various velocities using a strain gauge FLA-6-11 type. In conclusion the drag coefficient reduced by 50% from velocity was increased from 21.18m/s to 33m/s. W. H Hucho et al. [5], reported on various techniques to reduce the aerodynamic drag of cars throughout the past. And they indicated a procedure known as detailed optimization that has been developed by Volkswagenwerk AG.

G. M. Le Good et.al [6], presented a paper on comparison of road aerodynamic drag measurements with wind tunnel data. They suggested that the ground is fixed in case of a wind tunnel and there is no wheel effect on the flow hence these configurations do not necessarily produce consistent effects. This paper described the road and wind tunnel derived data. The authors emphasized to investigate on saloon and fastback shapes with underfloor smoothing and its effects on wheel design and tire size. V A Petrushov [7], did experiment to determine the vehicle drag and its relation to the aerodynamics configuration under real atmospheric conditions and road covering using the coast-down method. This paper explains the relationship between time and distance from a new solution of the coast down an equation which is independent of speed and deceleration, this allows us to eliminate measurement error due to temperature alteration, inflation pressure, etc. Simon Watkins et.al [8], wrote a paper on the effect of vehicle spacing on the aerodynamics of a representative car shape. They described drag characteristics due to Ahmed's body for spacing and compared with the body in isolation. In conclusion it was established that the effect of the formed vortex from slant back was the primary reason for drag.

Joachim Currle et.al [9], did a numerical analysis of the flow over Convertibles using STAR-CD and investigated the exterior airflow over convertibles and the internal airflow in the passenger cabin. These investigations were performed on an SLK-class Mercedes with two occupants which provided detailed information about the flow field for understanding the influence of different geometrical modifications like the roof spoiler, variations of the draft stop behind the seat, etc. Mathieu Roumeas, Patrick et.al [10], did a research paper on drag reduction by using flow separation control on a car after body. They carried out a 3d geometry analysis using a load suction system located on top of the rear window for eliminating rear window separation on simplified fastback car geometry. At last, they established that aerodynamic drag reduces close to 17% using this procedure.

3. Experimental Methodology
This segment emphasizes the experimental methods for preliminary investigation of drag measurement of a common Indian road vehicle i.e. an auto-rickshaw.

3.1. Calibration of spring balance
For the calibration of the spring balance, a simple mass of 20 grams was calibrated. The range of the spring-mass system is given from 0 to 50 kg with 5 grams accuracy. The following calibration of 20 grams is shown in Figures 1 and 2.

3.2. Spring Mass System Setup
The spring-mass framework utilized in the present arrangement is a basic low-cost mechanical equipment designed by the corresponding authors for drag measurement. Figure 3 shows the CAD model design of the experimental setup that is constructed to carry out experiments. This particular setup is assembled in Aerodynamics Laboratory, Aerospace Hanger, Department of Aerospace Engineering at SRM Institute of Science and Technology, Kattankulathur. This setup consists of a wooden plank with a hinged shaft with one end connected to a spring-mass system and other end connected to the vehicle. Therefore, when the flow pushes the vehicle back the system pulls the spring-mass system giving a drag value in terms of the kilogram. This setup is placed on the top of the Jet Tunnel with auto-rickshaw inside the tunnel and connected to the shaft. The auto model used in this experiment is the scaled-down version of the actual auto-rickshaw that is used majorly on Indian
roads. This model is having a scale-down ratio of 1:14 as shown in Figure 4. And Figure 5 shows the front view of the whole setup with the auto-rickshaw placed inside the tunnel. The spring-mass system used as shown in Figure 6 is having a minimum sensitivity of 5 grams.

3.3. Anemometer System Setup
The anemometer used in the present study is outright from the laboratory that can measure the flow velocity up to 30m/s. To find the velocity the anemometer was hanged from the top inside the setup as shown in Figure 7. The enclosed space prevented airflow to diverge out and help to guide the flow in a particular direction. In the case of this experiment, the flow velocity is around 19m/s.

![Figure 1. 20 grams weight used for calibration.](image1)

![Figure 2. Spring balance system calibrated with 20 grams weight.](image2)

![Figure 3. Isometric view of the CAD model of the Drag estimation setup.](image3)
Figure 4. The 1:14 scale down version of actual auto-rickshaw.

Figure 5. Front view of the spring-mass system with auto placed in front of the jet tunnel.

Figure 6. Top View of the spring balance experimental setup.
Figure 7. Position of Anemometer for measurement of flow velocity.

4. Results and Discussion

4.1. Drag Value of an Auto-Rickshaw Model
By keeping the auto scale model in the free stream flow in jet tunnel, the estimation of drag was found to be 50 gm in mass by using spring-mass balance system, which in conversion to Newton came to be 0.4905 N. This drag coefficient value corresponding to the flow with velocity of 19 m/sec is calculated below. Auto-rickshaw being an open vehicle, the cavity inside forms a low-pressure region which redirects the external flow to pass through it and mix with the turbulent regime as a result of which the coefficient of drag is obtained higher than that of the sedan which has an approximate \( C_d \) value of 0.3. Aerodynamic drag increments with the square of speed; in this way it turns out to be critically significant at higher velocity. Due to the formation of the high-pressure region on the front end and low-pressure pocket on the back end creating a pressure difference. This formation of a pressure gradient plays a significant role in producing the drag. Pressure drag is dependent on the frontal area hence more the cross area more is the pressure drag. Secondly, the formation of a boundary layer on the roof of the vehicle tends to create a velocity profile in which flow velocity is zero at the surface and accelerates at a free stream which negligibly affects the drag coefficient overall.

\[
C_d = \frac{\text{Drag Force}}{\frac{1}{2} \rho \text{v}^2 \text{cross sectional area}}
\]

Drag Force = 50gm = 50*9.81 = 0.4905N
Density(\( \rho \)) = 1.225kg/m³
Flow Velocity = 19m/s
Cross Sectional Area = 0.0040m²
\[
C_d = \frac{0.4905}{0.5 \times 1.225 \times 19^2 	imes 0.0040}
\]

\[
C_d = 0.5546
\]
Table 1. Drag value obtained from the experiment in a flow velocity of 19m/s.

| Drag (grams) | Drag (Newton’s) | Coefficient of Drag |
|--------------|----------------|---------------------|
| 50           | 0.4905         | 0.55435             |

5. Conclusion
The present study was about an auto-rickshaw model's drag at a given airflow velocity. A spring balance system was used to measure the drag value in terms of kg or gm which was later converted into Newton’s and an anemometer was used to find the flow velocity. The results from the experiment suggest that the drag value of a 1:14 scaled-down auto-rickshaw model is 50 gm or 0.4905 N at a flow velocity of 19 m/s. decreasing the drag coefficient in an auto-rickshaw improves the engine performance of the vehicle in accordance with speed and fuel efficiency.

Acknowledgment
The authors wish to acknowledge the usage of Aerodynamics Laboratory for experiments, the help and constant advice by lab assistants and supervisors.

6. References
[1] Pikula, B Mesic E and Hodzic M 2008 Determination of air drag coefficient of vehicle models International Congress Motor Vehicles & Motors
[2] Sudin M N, Abdullah M A, Shamsuddin S A, Ramli F R, and Tahir M M 2014 Review of research on vehicle aerodynamic drag reduction methods International Journal of Mechanical and Mechatronics Engineering 14 35–47
[3] Nan L 2013 The methods of drag force measurement in wind tunnels
[4] Kacem A, and Abdullah A N 2016 Determination of the drag coefficient for TOYOTA car model (Using Strain Gauge Method) IOSR Journal of Mechanical and Civil Engineering 13 141–45
[5] Hucho W H, Janssen L J, and Emmelman, H 1976 The optimization of body details-A method for reducing the aerodynamic drag of road vehicles SAE Technical Papers
[6] Le Good G M, Howel J P, Passmore A and Garry K P 1995 On-road aerodynamic drag measurements compared with wind tunnel data SAE Technical Papers 41 2
[7] Petrushov V 1998 A Improvement in vehicle aerodynamic drag and rolling resistance determination from coast-down tests Proceedings of the Institution of Mechanical Engineers Part D: Journal of Automobile Engineering 212 369–80
[8] Watkins S, and Vino G 2008 The effect of vehicle spacing on the aerodynamics of a representative car shape Journal of Wind Engineering and Industrial Aerodynamics 96 1232–39
[9] Currle J, and Moos O 2001 Numerical analysis of the flow over convertibles SAE Technical Papers 724
[10] Roumáes M, Gilliéron P and Kourta A 2009 Drag reduction by flow separation control on a car after body International Journal for Numerical Methods in Fluids 60 1222–40