

PAPER • OPEN ACCESS

Numerical Investigation of Flow past an Uberhood at Low Velocity

To cite this article: Swastika Palit and M.B. Shyam Kumar 2019 *J. Phys.: Conf. Ser.* **1276** 012009

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the [collection](#) - download the first chapter of every title for free.

Numerical Investigation of Flow past an Uberhood at Low Velocity

Swastika Palit¹ and M.B.Shyam Kumar¹

¹School of Mechanical and Building Sciences, VIT Chennai, Vandalur – Kelambakkam Road, Chennai – 600127, Tamil Nadu, India

Corresponding Author: shyamkumar.mb@vit.ac.in

Abstract. Uberhood is an aerodynamically designed structure offering protection for the rider from sun and rain. In this paper, a preliminary attempt is made to design an uberhood for motorbikes followed by fluid flow analysis using Computational Fluid Dynamics (CFD). In this study, the $k-\omega$ turbulence model was employed to simulate a three dimensional flow past an uberhood. Comparison between flow past motorbike with rider and motorbike with uberhood along with rider are presented at two different angles of attack. The results in terms of the aerodynamic force coefficients namely the lift and drag coefficients, pressure contour, velocity contour, streamlines and turbulence kinetic energy obtained using the above turbulence model have been presented and discussed. Based on the height and velocity of motorbike with rider and motorbike with uberhood along with rider the Reynolds number was taken as 1.9 million and 2.2 million respectively. It was observed that with the increase in angle of attack the coefficient of drag decreases. Results show that a lower coefficient of drag value for the designed uberhood. This paves way for the use of uberhood in a motorbike which provides safety for the riders together with experiencing lower drag force.

1. Introduction

Uberhood is a structure which protects the motorbike riders from rain and sunlight. One of the problems faced by the motorbike riders over car drivers is direct exposure to sunlight, rain, and insects which can be avoided by using an Uberhood. There are around 200 million motorbikes around the world [1]. Using an Uberhood will increase the safety of the motorbike riders which will help in reduction of motorbike accidents. Many studies are reported related to a motorbike. The motorbike along with the rider encounters distinctive aerodynamic forces and moments while traveling. Studies reported that changes in the rider's aerodynamic performance will play an imperative factor in lessening fuel utilization and enhancing motorbike mobility [2]. A portion of the studies is accounted regarding the impact of the crosswinds on the dependability of the motorbike and rider, because of the aerodynamic forces [3]. Notwithstanding the detailed number of accidents because of the impact of crosswinds, studies identified with crosswinds are constrained [4-6]. Some of the experimental studies have also been reported related to a motorbike. Researchers have conducted wind tunnel experiments to investigate the stability and the motorbike's aerodynamic performance and on a considerable lot of their



individual components [7-9]. Ubertini and Desideri [10] have experimentally measured and reported the aerodynamic forces and moments on a bike and rider at various yaw points up to 10° . Computational Fluid Dynamics (CFD) assumes a critical part in studying the aerodynamic characteristics of the motorbike [11]. For instance, it has been utilized to do the examinations with respect to characteristics of flow inside engines of motorbike [12-13]. Other than this, enhancement of individual designing segments is finished utilizing CFD to enhance the efficiency and to decide the impact on aerodynamic forces due to the changes in the local geometry of motorbike. Investigations were carried out to study the pattern of airflow around a motorbike with the standard $k-\varepsilon$ Reynolds-Averaged Navier-Stokes (RANS) simulation neglecting the crosswind effects for the enhancement of the aerodynamic performance [14-16]. As it is observed that many studies are reported for motorbikes but none of the studies is reported for the use of uberhood. The aim of this study is to propose an uberhood model for motorbikes so that the motorbike riders are protected from sunlight, rain and insects thereby, the safety of motorbike riders will be increased. In this context, we have carried out CFD analysis of flow past a motorbike with rider along with uberhood and without uberhood at two different angles of attack namely, $\alpha = 0^\circ$ and 15° . Numerical computations using the $k-\omega$ turbulence model is employed with 1.9 million and 2.2 million as Reynolds number based on the stature and velocity of a motorbike without and with uberhood respectively.

2. Geometrical Model

A trace of the Yamaha R1 motorbike with rider and Yamaha R1 motorbike with rider fitted with the designed uberhood (Figure 1a and 1b) is considered for the present investigation. These are modeled using CATIA. The front view of the geometry of motorbike along with uberhood and motorbike with uberhood along with rider is seen in Figure 1c and 1d respectively. The designed uberhood has a height of 0.9 m so that the rider of standard height can sit without any hindrance, a width of 0.68 m which is standard width of motorbikes and length of 2.04 m which is a standard length of a motorbike. The height of the motorbike with rider and the motorbike with uberhood along with rider is 1.35 m and 1.5 m respectively. But the length and width of both the models are taken as 2.04 m and 0.68 m respectively. The proposed model is covered from all the sides. It consists of foldable transparent curtains on both the sides and a glass in the front. Here some of the subtle elements of the motorbike namely the bolts and spokes of wheels are not considered. Hereafter the motorbike with rider model is mentioned as motorbike and motorbike with rider along with uberhood is mentioned as motorbike with uberhood. Rider is not visible as the rider is covered under uberhood.

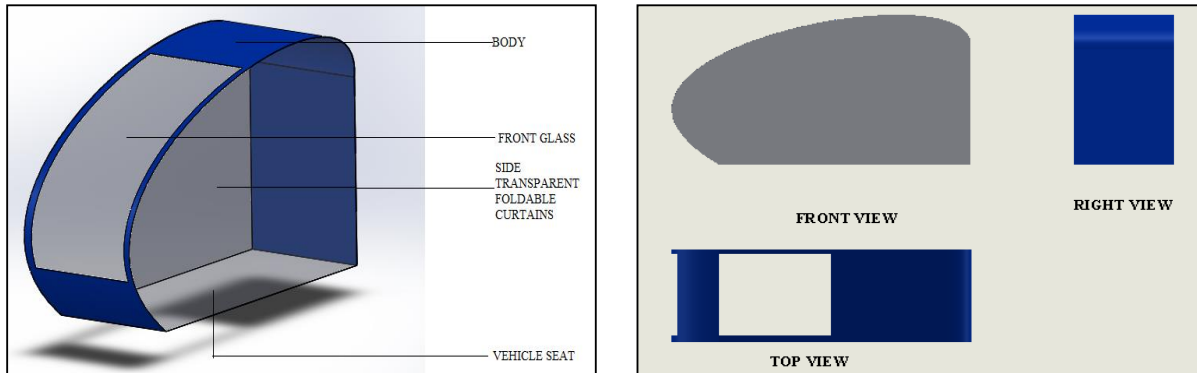
3. Numerical Method

The velocity and pressure of fluid flow are governed by the Navier-Stokes Equation. The $k-\varepsilon$ turbulence model is the most generally perceived model used in computational fluid dynamics (CFD) for analyzing mean stream attributes for turbulence stream conditions. It is a two-equation computational model that gives a portrayal of disturbance by means of two transport equations (PDE's). The $k-\omega$ turbulence model is another regularly utilized two-condition equation model that is utilized as a conclusion for the Reynolds-averaged Navier-Stokes equations (RANS equations). The model endeavor's to foresee turbulence by two partial differential equations for two factors, k , and ω , with the primary variable being the kinetic energy (k) while the second (ω) is the particular rate of dissipation. As these equations are difficult to solve using analytical methods, one employs the numerical techniques such as finite difference and finite volume methods that convert these complex partial differential equations into simple algebraic equations that are easy to solve.

4. Boundary Conditions and Computational Domain

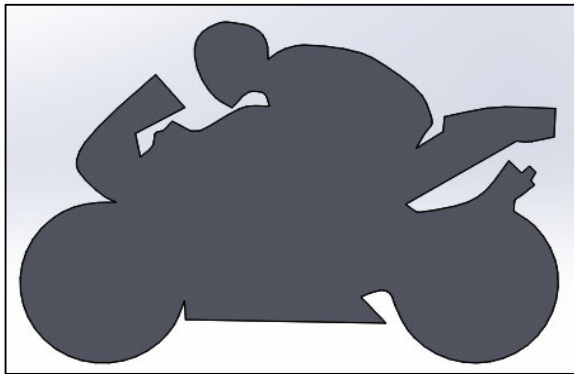
A computational domain was used for this study (Figure 2a and Figure 2b). The velocity was taken as 25m/s. The choice of velocity 25m/s has been taken as in this paper uberhood is considered for the motorbike, so for all the cases the velocity is taken according to atmospheric condition. 6H is the total length in the direction of Y and for X and Z directions the total length is kept as 33H and 20H

respectively. Here H is considered as the height of the Motorbike with Uberhood. The ground surface was imposed with a no-slip boundary condition. Specific shear was applied to all the other walls except the inlet, outlet and ground surface.

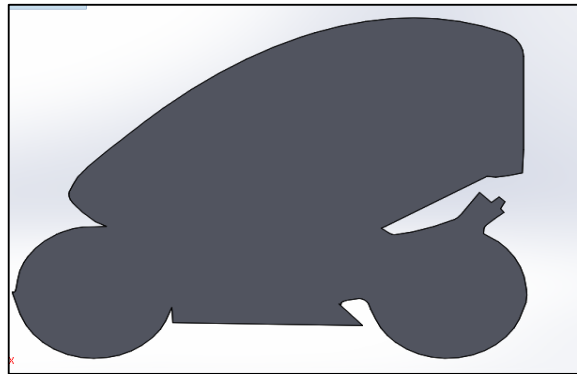


a). Proposed Uberhood Model

b). Front, Right and Top View of Uberhood



c). Front view of t motorbike with rider

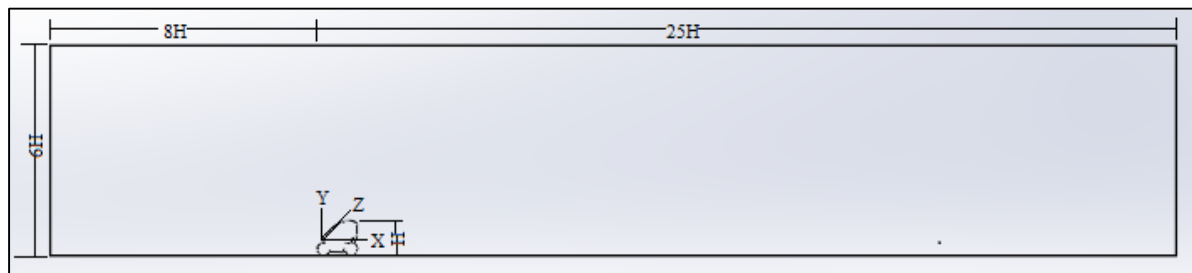


d). Front view of a motorbike with uberhood

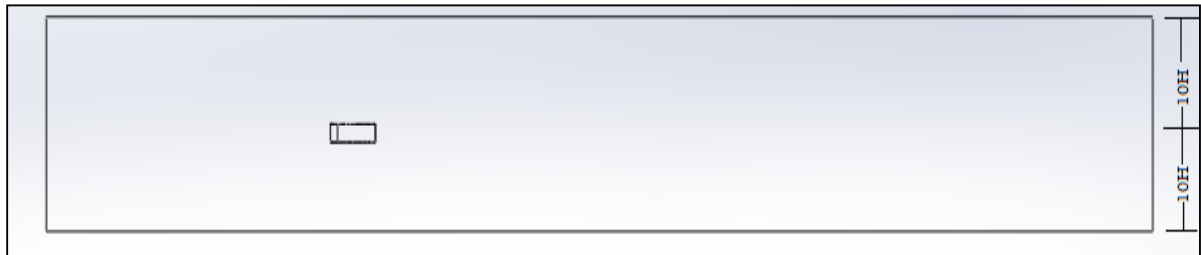
Figure 1.

5. Meshing

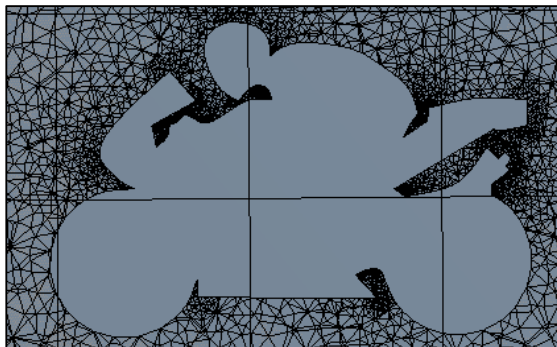
Meshing involves dividing the geometry into grids and small finite volumes. The sizes of these grids are such that the solutions to the Navier-Stokes equations can be reasonably approximated in the volume. The differential equations are solved using numerical methods in these small nodes and a general picture of the simulation is developed. Naturally, the finer the mesh size and smaller the volume of the grid, the more accurate will be the solution obtained. Hence the coarse meshing was chosen. The meshing was created with ICEM CFD. 85% and 90% of cells of the surface mesh are hexahedra cells for motorbike and motorbike with uberhood respectively and the remaining 15% and 10% of cells are polyhedral and prism cells for motorbike and motorbike with uberhood respectively. We can observe the image of meshing of motorbike with uberhood and motorbike in Figure 3a and 3b respectively. In the $k-\omega$ simulations, a coarse mesh is evaluated. There are in total of 17 and 20million cells in the fine mesh of motorbike and motorbike with uberhood respectively. Along with that refinement of the mesh is done around the motorbike and uberhood in the direction of wake flow to obtain the details more specifically.



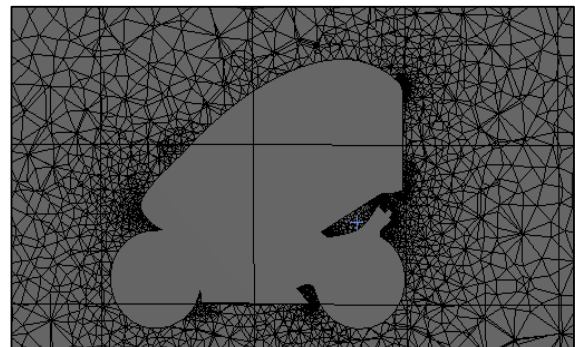
(a) Front View of the domain



(b) Top View of the domain

Figure 2.

(a) Meshing of Motorbike



(b) Meshing of Motorbike with Uberhood

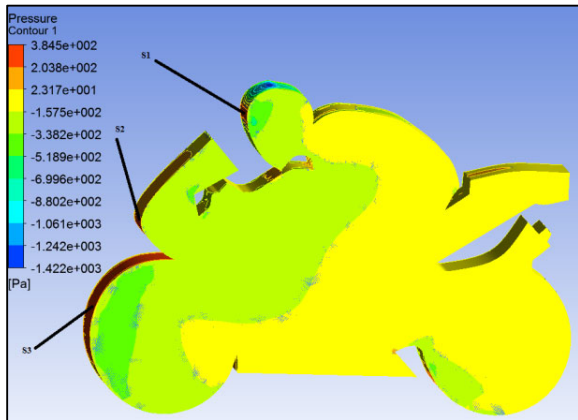
Figure 3

6. Results and Discussion

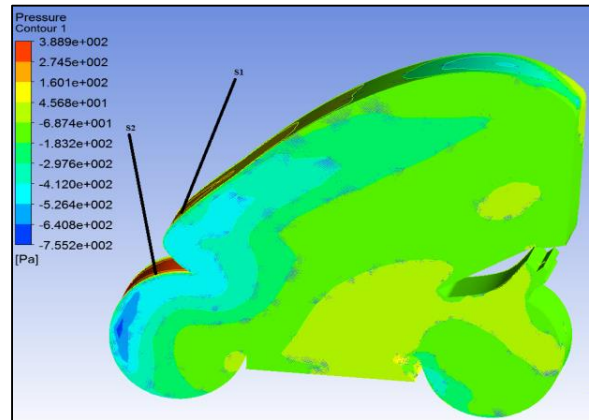
A three-dimensional transient ($t=50$ s) fluid flow analysis at a velocity of 25 m/s has been carried out at $\alpha = 0^\circ$ and 15° for the motorbike and motorbike with uberhood and the following results were obtained.

6.1 Time-averaged Flow Characteristics

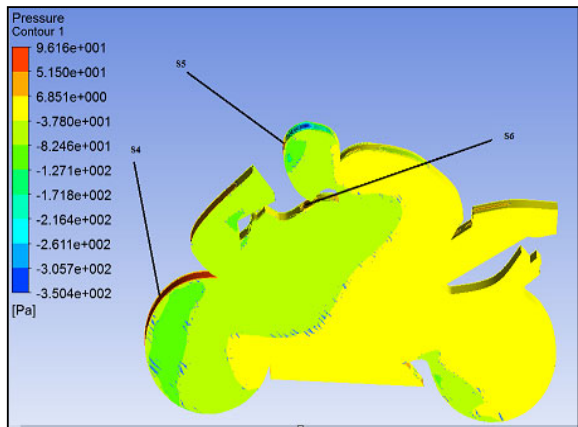
Figure 4, Figure 5, Figure 6 and Figure 7 depict the Pressure Contour, Velocity Contour, Streamlines and Turbulent Kinetic Energy for motorbike with and without Uberhood.



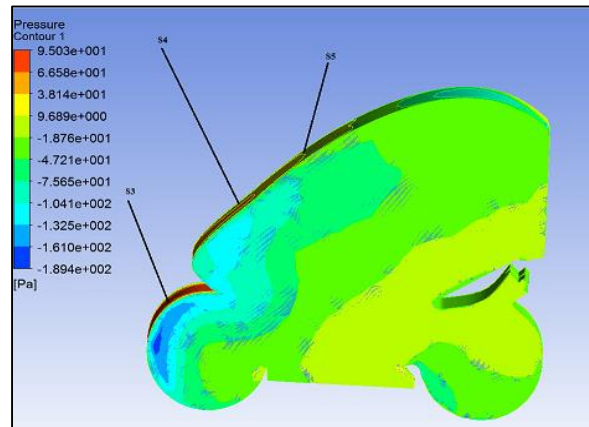
a). Pressure contours for motorbike at $\alpha = 0^\circ$



b). Pressure contours for uberhood at $\alpha = 0^\circ$

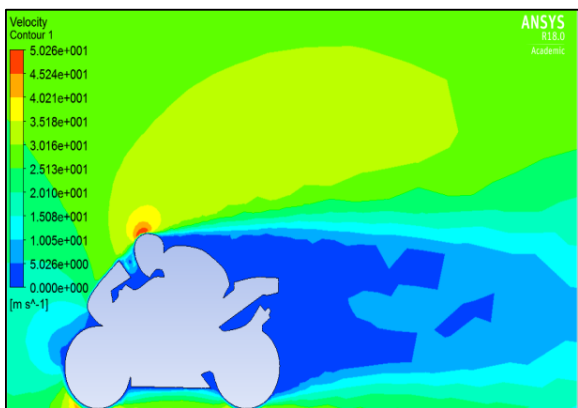


c). Pressure contours for motorbike at $\alpha = 15^\circ$

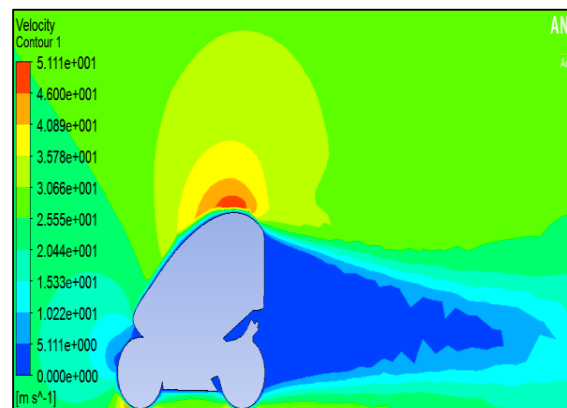


d). Pressure contours for uberhood at $\alpha = 15^\circ$

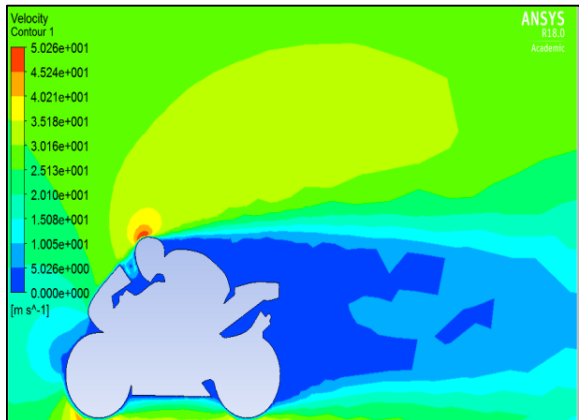
Figure 4. Pressure contours



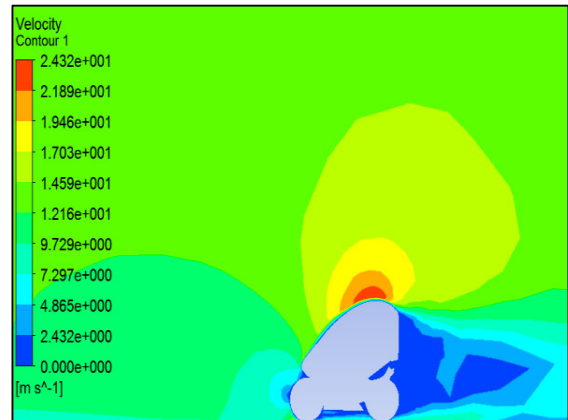
a). Velocity contours for motorbike at $\alpha = 0^\circ$



b). Velocity contours for uberhood at $\alpha = 0^\circ$

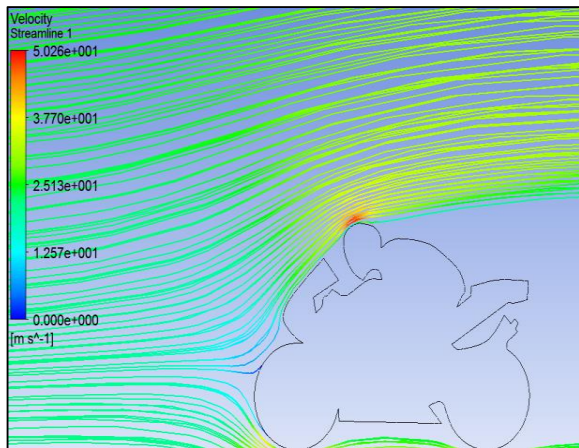


c). Velocity contours for a motorbike at $\alpha = 15^\circ$

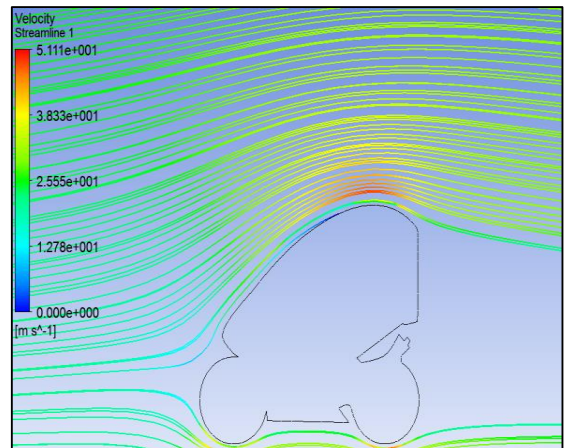


d). Velocity contours for uberhood at $\alpha = 15^\circ$

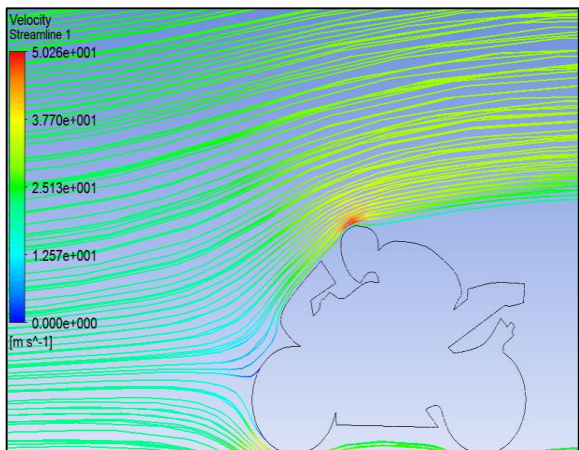
Figure 5. Velocity contours



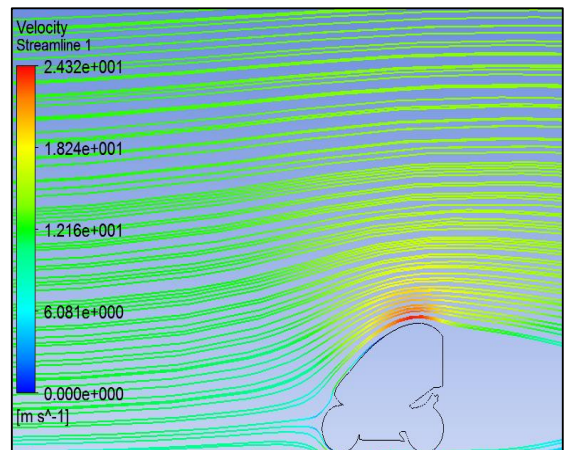
c). Streamlines for motorbike at $\alpha = 0^\circ$



d). Streamlines for uberhood at $\alpha = 0^\circ$



c). Streamlines for motorbike at $\alpha = 15^\circ$



d). Streamlines for uberhood at $\alpha = 15^\circ$

Figure 6. Streamline plot

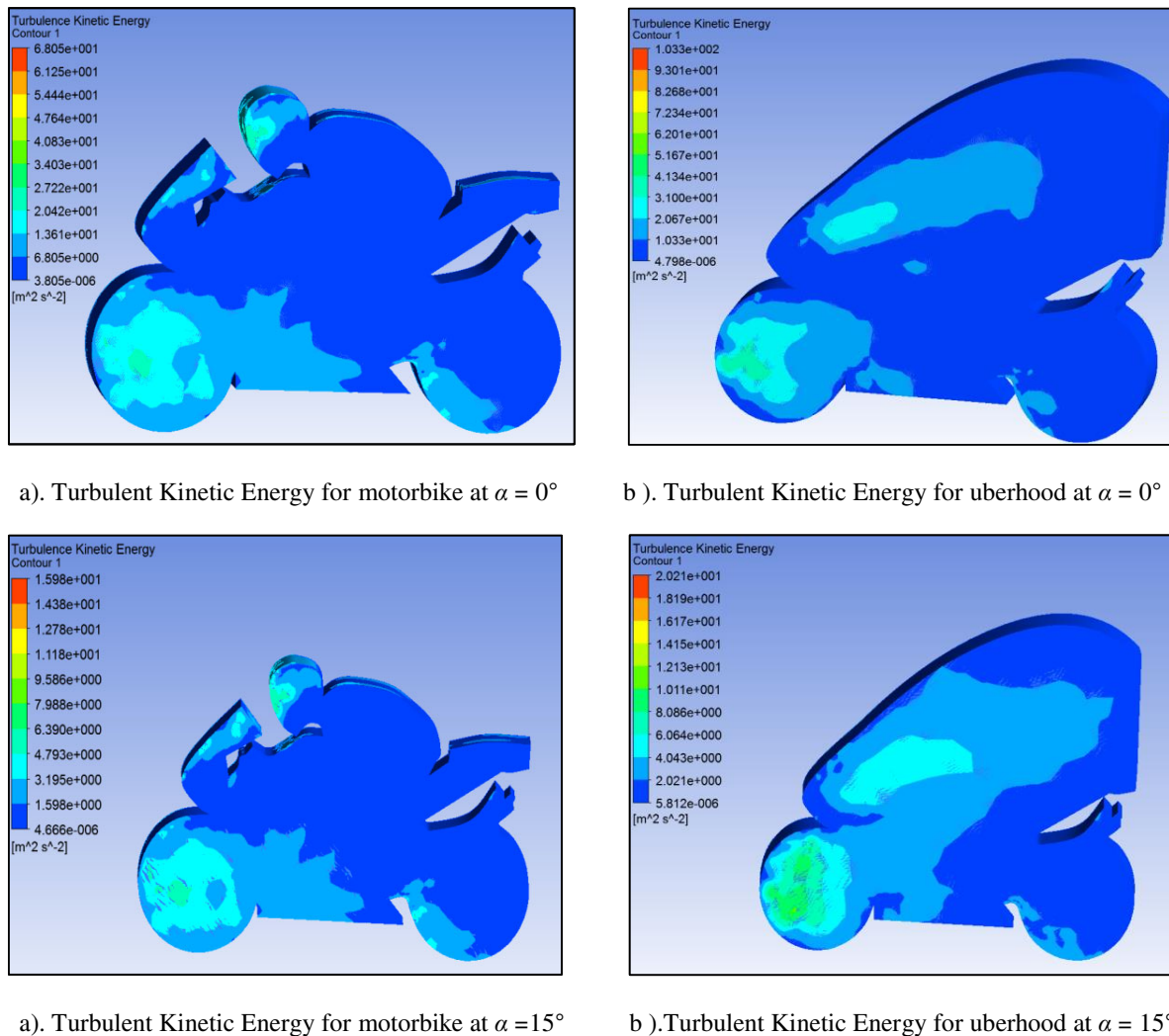


Figure7. Turbulent Kinetic Energy

In Figure 4a the high magnitude areas and stagnation points were observed near the helmet (S1), in the front of the wheel (S2) and near the windshield (S3) and in Figure 4b it was seen at the front of the wheel (S2) and windshield (S1). For the angle of attack of $\alpha = 15^\circ$ in the Figure 4c for motorbike the high magnitude pressure areas and stagnation points were achieved at front of the wheel (S4), windshield (S5) and near the left shoulder (S6) whereas for motorbike with Uberhood in the Figure 4c it was observed at the front of the wheel (S3), near the windshield (S4) and at the front of the Uberhood (S5). Figure 5 depicts the velocity contour on a plane parallel to the sidewalls at a distance of $z/W=0.5$, here W is the width of a motorbike for Figure 5a and 5c and W is the width of the motorbike with Uberhood for Figure 5b and 5d. The width for motorbike and motorbike with Uberhood was considered to be the same as predefined.

Figure 5a and 5b depict the velocity contour at $\alpha = 0^\circ$. In Figure 5a it was observed that around the motorbike the velocity was 0 m/s and high magnitude velocity was observed near the helmet due to the acceleration of flow. From Figure 5b we can observe that around the motorbike and Uberhood the velocity was 0 m/s and high magnitude velocity was achieved at the top part of Uberhood due to the sudden change in shape and acceleration of flow. For Figure 5c and 5d that is for $\alpha = 15^\circ$ similar trends of velocity contour for both motorbike and motorbike with Uberhood, like that at $\alpha = 0^\circ$ was observed.

Figure 6 depicts the streamline plots on a plane parallel to the sidewalls at a distance of $z/W=0.5$. Here W is the same as considered and predefined in the case of velocity contour. Figure 6a and Figure 6b depict the streamline plots for motorbike and motorbike with uberhood respectively for $\alpha = 0^\circ$ and Figure 6c and Figure 6d depicts streamline plots for the motorbike and motorbike with uberhood at $\alpha = 15^\circ$ respectively. In case of the motorbike for both the angles of attack, we can observe the magnitude of velocity is high on the top of the motorbike and similarly in case of the motorbike with uberhood it was observed that the magnitude of velocity is high on the top of the uberhood. Figure 7 depicts the turbulence kinetic energy for motorbike and motorbike with uberhood at two different angles. Figure 6a and 6b depicts the turbulence kinetic energy for both the models for $\alpha = 0^\circ$ and Figure 6c and 6d depicts turbulence kinetic energy for both the models for $\alpha = 15^\circ$. For motorbike models for both angles of attack, it was observed that the turbulence kinetic energy was very low but near the wheel, it was comparatively high. For motorbike with uberhood at an angle of $\alpha = 0^\circ$ it was observed that turbulence kinetic energy was low throughout the body but it was comparatively high near the wheel and on the side part of uberhood. With the increase in the angle that is for $\alpha = 15^\circ$ for motorbike with uberhood an increase in the high turbulence kinetic energy area in comparison to the previous case of $\alpha = 0^\circ$ was observed.

6.2 Aerodynamic Force Coefficients

The force that acts in the opposite direction of the vehicle's motion is the drag. It is unfavorable to the vehicle performance since it increases the efficiency of fuel. Reducing drag in road vehicle has led to increasing the speed of a vehicle, improving the fuel efficiency handling, and acceleration. C_d is called the coefficient of drag. Force acting perpendicular to the road surface is lift. Similar to C_d , C_l is called the Coefficient of Lift. For a super-sportive motorbike, C_d values were reported between 0.45 and 0.6 by Araki and Gotou [10] of the Yamaha Motor Corporation. From Table 1 we can observe that the C_d values obtained for Motorbike and Motorbike for both the angles of attack lies in the range and it lies nearer to the upper limit of the range reported for a super-sportive motorbike. It was observed that with the increase of angle the C_d and drag force decreases and the magnitude of C_l and lift force also decreases. It was observed C_l for both the cases comes out to be negative. The negative sign indicates that uberhood provides a downward thrust which prevents any tendency of the motorbike to lift. As it was observed that the C_d of the motorbike with uberhood comes out to be less and in the range reported for the super-sportive bike. This paves way for the use of uberhood in a motorbike which provides safety for the riders together with experiencing lower drag force.

Table 1. Aerodynamic Force Coefficients

Models	C_d	Drag Force(N)	C_l	Lift Force(N)
Motorbike at $\alpha = 0^\circ$	0.49	188.82	-0.20	-77.94
Motorbike with Uberhood at $\alpha = 0^\circ$	0.59	226.12	-0.29	-113.89
Motorbike at $\alpha = 15^\circ$	0.47	47.52	-0.19	-20.02
Motorbike with Uberhood at $\alpha = 15^\circ$	0.56	53.68	-0.24	-23.54

6.3 Validation

The current analysis simulated using FLUENT 16.0 was validated by comparison with studies reported by D. Fintelman et al [17], in which at different yaw angles they have investigated the flow around motorbike with the rider when subjected to crosswinds we validated their paper for the case of yaw angle $\alpha = 15^\circ$. In Figure 8 it was observed that stagnation points for pressure contours were achieved at similar points as their results that are near the helmet (S7), near the windshield(S8) and near the left shoulder(S9) and also the C_d and C_l values obtained by our simulation were similar to the values obtained by them. From table 2 it was observed that the percentage error comes out to be very less that

is 2.9% and 1.6% for C_d and C_l respectively. Thus our works were compatible with the works reported in their studies.

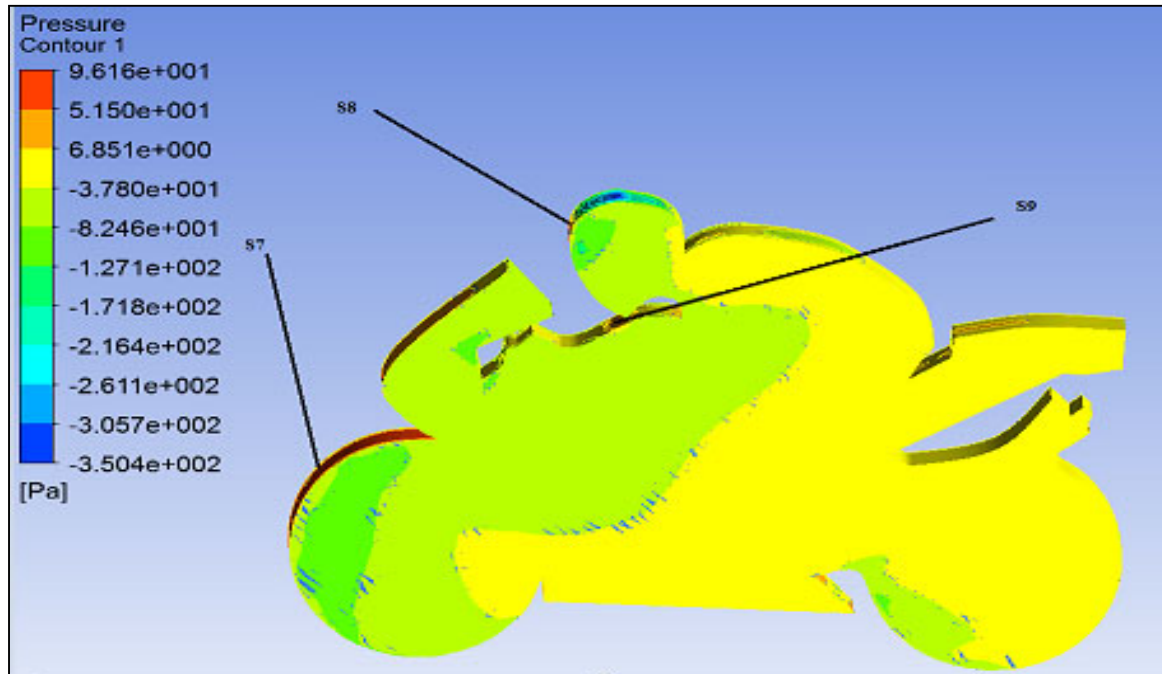


Figure 8. Pressure contours obtained from the validation study.

Table 2 : Aerodynamic Coefficients for validation

Model	C_d	C_l	Percentage Error C_d	Percentage Error C_l
Our Model	0.550	-0.020	2.9 %	1.6%
Model in their paper[17]	0.567	-0.024		

7. Conclusion

A three-dimensional transient ($t=50$ s) fluid flow analysis at a velocity of 25 m/s has been carried out for Motorbike with Uberhood. The Reynolds Averaged Navier Stokes equations were solved using k-Omega turbulence models. It was observed that in all the four cases of pressure contour some stagnation points were obtained at some similar locations and some were obtained at different locations. Velocity in all four cases of velocity contour obtained was 0 m/s around the model. The drag force and C_d come out to be very less and within the range for all four cases. From results, it was observed that with the increase of angle the C_d and drag force decreases and the magnitude of C_l and lift force also decreases. It was observed C_l for both the cases comes out to be negative. The negative sign indicates that uberhood provides a downward thrust which prevents any tendency of the motorbike to lift. The results show that the Coefficient of drag value for motorbike with Uberhood comes to be very less and for both cases, it is in the range of the C_d value reported for a motorbike without uberhood. This paves way for the positive utilization of Uberhood for a motorbike as without much significant difference in drag and thus the safety for the motorbike riders is accomplished.

8. References

- [1] Shuhei A 2006 Fuel cell powered motorcycles *Journal of the Society of Automotive Engineers of Japan* **60(1)** 90–93
- [2] Scibor-Rylski, A. J., Sykes and D. M. 1984 Road vehicle aerodynamics (2nd ed.). Plymouth: Pentech Press.
- [3] Cheli F., Boccione , Pezzola M and Leo E 2006 Numerical and experimental approaches to investigate the stability of a motorcycle vehicle *Proceedings of the 8th Biennial Conference on Engineering Systems Design and Analysis*, Turin, Italy.
- [4] Carr A 2011, 12 August 2013 Fatal motorcycle crash, wind gust causes Sherman wreck Retrieved from <http://www.post-journal.com/page/content.detail/id/583501/Fatal-Motorcycle-Crash.html?nav=5192>
- [5] Donell S 2010 Wind blamed in fatal motorcycle accident, NBC Washington Retrieved from <http://www.nbcwashington.com/news/local/Weather-Blamed-in-Freak-Fatal-Motorcycle-Accident-91433499.html>
- [6] Gauger W 2013 Fatal motorcycle crash in Waupaca Co Retrieved from http://www.fox11online.com/dpp/news/local/fox_cities/fatal-motorcycle-crash-inwaupaca-co
- [7] Cooper K. R. 1983 The effect of handlebar fairings on motorcycle aerodynamics. *SAE Technical Paper* 830156. doi:10.4271/830156
- [8] Bridges P and Russell J.B 1987 The effect of topboxes on motorcycle stability *Vehicle System Dynamics* **16(5–6)** 345–354.
- [9] Araki Y and Gotou K 2001 Development of aerodynamic characteristics for motorcycles using scale model wind tunnel. *SAE Technical Paper* doi:10.4271/2001-01-1851
- [10] Ubertini S and Desideri U 2002 Aerodynamic investigation of a scooter in the university of perugia wind tunnel facility Retrieved from <http://dx.doi.org/10.4271/2002-01-0254> doi:10.4271/2002-01-0254
- [11] Angeletti M, Sclafani L, Bella G and Ubertini S 2003 The role of cfd on the aerodynamic investigation of motorcycles *SAE Technical Paper* doi:10.4271/2003-01-0997
- [12] Chu L, M Chang, M H Hsu, H. C. Chien, W T and Liu, C H 2008 Simulation and experimental measurement of flow field within four-stroke motorcycle engines. *Journal of the Chinese Society of Mechanical Engineers* **29(2)** 149–158.
- [13] Gentili R., Zanforlin S and Frigo S 2006 Numerical and experimental analysis on a small GDI, stratified charge, motorcycle engine *Proceedings of the 8th Biennial Conference on Engineering Systems Design and Analysis* Turin, Italy.
- [14] Takahashi Y , Kurakawa Y, Sugita H, Ishima T and Obokata T 2009 CFD analysis of airflow around the rider of a motorcycle for rider comfort improvement *SAE Technical paper* doi:10.4271/2009-01-1155
- [15] Watanabe T, Okubo T, Iwasa M and Aoki H 2003 Establishment of an aerodynamic simulation system for motorcycle and its application *Jsae Review* **24(2)** 231–233
- [16] Sakagawa K, Yoshitake H and Ihara E 2005 Computational fluid dynamics for design of motorcycles (Numerical analysis of coolant flow and aerodynamics) *SEA Technical Paper* doi:10.4271/2005-32-0033
- [17] D Fintelman, H Hemids, M Sterling and F X.Li 2015 A numerical investigation of the flow around a motorbike when subjected to crosswinds *Engineering Applications of Computational Fluid Mechanics* **9(1)** 528-542