Design of Streamlined Motorcycle Helmet with Enhanced Head Protection

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Abstract

Two-wheeler is one of the common mode of transportation in India. Being inherently unstable the two-wheelers are more prone to accidents, and account for 10,000 to 15,000 deaths every year. Head hitting the pavement is the main cause of injury and fatality. Hence, use of crash helmet, which reduces the risk of severe brain injury is generally mandated in most of the major cities. To be effective, these helmets have to meet standard impact performance criteria. The resulting discomfort around the head inside the helmet can alleviate the discomfort felt by the rider.

In the present work, Computational Fluid Dynamics (CFD) simulation was used to design improved air flow path inside the helmet to enhance the ventilation around rider’s head. The routing of the grooves was designed to also reduce the drag created by the flow around the helmet.

Impact absorption test, specified by Bureau of Indian Standards (BIS) was simulated for the redesigned helmet. The head deceleration levels were found to be well within the limits specified by the standards.

Key Words: Crash Helmet, Computational Fluid Dynamics, Helmet Impact Test, Helmet Ventilation, Drag Coefficient

Abbreviations

ABS  Acrylonitrile Butadiene Styrene
BIS  Bureau of Indian Standards
CES  Cambridge Material Selector
CFD  Computational Fluid Dynamics
EPS  Expanded Polystyrene Foam
PU  Polyurethane

1. INTRODUCTION

Motorcycle accidents account for about 10,000 to 15,000 deaths every year in India [1]. Fatalities by motorcycle accidents are 14 times higher than by cars. One means of protection for motorcyclist is crash helmet, which reduces the risk of severe head injury. In case of fatal accidents, the rider may hit the ground or other vehicle hard surfaces causing sudden deceleration of the head. The brain is the most sensitive part in the head and is surrounded by high viscous fluid in the skull. Sudden deceleration beyond a threshold limit causes brain injury.

Helmet is expected to provide effective protection from serious brain injury. Hence, it needs to be tested for its performance under impact. The primary requirement of the test specifications for it is the impact absorption test, which measures the shock load on the brain indirectly. The current test procedure is useful for protecting the users to certain level. But the drop test with rigid head form may not model the real dynamic scenario. To achieve accurate results and to check the adequacy of the helmet, an improved head form with brain model is to be used for drop test. Also, to get an accurate measure of brain injury, in addition to the linear acceleration of the head, its rotational acceleration should also be taken into consideration. However, in the present work impact simulation was carried out considering rigid head form to conform to the Indian Standard test procedure. The drop test simulated was to check the rotational acceleration of the Hybrid-III head form along with existing test specification as per IS: 4151. IS: 4151 specifies some more tests for the helmets but for this study shock absorption test was identified as the most important test to check the performance of the helmet.

One of the main disadvantages faced by the users of helmets is the lack of ventilation inside the close fitting helmet. This causes discomfort, especially in the hot and humid conditions of tropical weather. It is essential to provide adequate ventilation to the rider, because heat stress can cause rider discomfort, increasing the chances of driver losing concentration.

As a motorcycle rider is exposed to forced air stream, heat transfer by forced convection is an easy means of providing ventilation inside the helmet. The air motion significantly affects body heat transfer by convection and evaporation [2]. Air flow not only reduces temperature but also reduces stuffiness/humidity. Most favourable air velocity for human comfort is 0.25 m/s, which is generally used for air outlet devices.

To design a more effective ventilation mechanism inside a helmet, simulation tools were used. The geometric model was built in CATIA V5 to model the air flow behaviour in and around the current design of the helmet. Outer profile of motorcycle helmet was generated using reverse engineering. Computational Fluid Dynamics (CFD) analysis was carried out to determine the air flow behaviour in and around the current design of the helmet. Potential promising locations for ventilation grooves inside the helmet lining were identified. These ventilation grooves were incorporated and fine tuned to provide internal ventilation as to reduce wakes in the flow to achieve drag coefficient reduction.

After improving the ventilation by providing grooves, an impact analysis was carried to ensure that the safety standards specified by Bureau of Indian Standard (BIS) are met by the modified design. The simplified geometry of outer shell and liner were used
in the impact analysis. Commonly used materials, ABS for the outer shell of the helmet and EPS foam for the inside liner, were used in the analysis.

2. MODEL CONSTRUCTION – CFD

The selected helmet was reverse engineered using laser scanning and the scanned data was imported to CATIA V5. Local geometry simplifications were made to improve the ease of meshing. Analysis of fluid flow around the selected helmet (baseline analysis) was carried out using FLUENT. The model was modified with the objective of providing ventilation grooves in the inner liner in the helmet to reduce the heat and humidity inside the helmet. In this work, it is assumed that enhanced flow of air will result in cooling of the interior. Hence, only flow analysis has been carried out and thermal analysis is not carried out to estimate the heat dissipated. After the flow analysis around the baseline model was completed, the flow analysis around the helmet with modified design was taken up. The methods and methodology adopted for carrying out the fluid flow analysis, and the results of the modification are discussed below.

2.1 Model Construction and Simplification

The selected helmet was reverse engineered on a non-contact type LASER scanner with an accuracy of 50 µm. The scanned three-dimensional data points were converted to a set of polygonal data consisting of millions of tiny facets with the help of Geo Magic Studio software. This data was converted to IGES format and imported in CATIA V5 where surface model of the outer skin of the helmet was developed. The helmet, along with chin guard, visor, lock and inner foam, was modelled and assembled. The inner foam was simplified by modelling its outer surfaces only.

The geometry of the helmet model, in the chin guard region was simplified by removing the strengthening ribs. Chin guard opening locks, being very small were neglected. Simplified model of the helmet with manikin (top half) is shown in Fig. 1.

2.2 CFD Modelling

For CFD analysis, fluid domain was extracted from the modelled helmet assembly. Taking advantage of symmetry, only half model was considered. For meshing convenience a small fluid domain of 500 x 500 x 400 mm was considered around the helmet assembly along with the manikin model (head and top half of the manikin chest were considered as the region of interest). The grid was generated in HyperMesh and then the fluid domain was extended to a 3000 x 1000 x 1000 mm region. The positioning of the helmet in the flow domain was important, in order to minimise the boundary wall effect. The flow field considered was 3 times of helmet length in the upstream side and 6 times the helmet length in the downstream side. As the region of interest in this study was near helmet surfaces, finer mesh was used there and it was biased towards boundary walls. Tetrahedral elements were used to discretise the flow domain volume.

The grid was imported to GAMBIT where boundary conditions were applied. At the inlet velocity condition and at the outlet, pressure conditions were applied. Symmetry condition was imposed at the midplane and opposite side wall was specified as wall along with the top and bottom wall of the domain. The solver selected was pressure based implicit solver using control-volume based technique. For modelling turbulence, k-ε turbulence model was used. The turbulence intensity and length scale were calculated and specified for the inlet and outlet boundaries. The simulation was carried out for a vehicle speed of 60 km/h.

A total of 3 cases were analysed. Case 1 is referred to as baseline analysis, case 2 contains a groove for air to enter from the sides between the foam and the outer shell and exit at the rear. In case 3, the location of the inlet and exit was modified based on the fluid flow around the manikin and helmet.

2.3 Solution – CFD Baseline Analysis

The drag coefficient calculated from the results was found to be 0.477 for the baseline analysis. To understand the region where inlets and outlets can be provided for the ventilation vents, velocity vectors plotted at different planes were studied. Flow recirculation was observed in the region between chin guard and the face of the manikin, as shown in Figure 2. In actual driving conditions the air exhaled by the rider will recirculate within this area, thus increasing CO₂ content in this region resulting in rider discomfort. The air inhaled or exhaled by the rider is not modelled in the present analysis.

Detached air flow was observed at the rear of the helmet (Fig. 2). This can be attributed to the spherical shape of the helmet. Also, wake formation at the rear of the neck at the bottom edges of helmet and sides of the neck can be observed. This is due to flow separation behind the neck region of the manikin. The other observation is that the cushion pad blocks in the present liner, restrict the flow of air around the head.

Fig. 1 Helmet model

Fig. 2 Case 1 - Vectors of velocity magnitude (m/s) at symmetry plane of the helmet and manikin
High stagnation pressure was found over the visor, neck and chest frontal area and low pressure region on the side of the neck and shoulders, where flow separates and creates vortices. Pressure distribution over the helmet and manikin was used to decide the best location for ventilation grooves (Fig. 3). Inlet ventilation groove was provided on the forehead region since the wake over this region creates a high pressure zone. Negative pressure region on the lower end of side liner is expected to help suction of air from the forehead region and low pressure at the rear end is expected to act as an outlet. Based on these observations, liner was modified to incorporate ventilation grooves on the liner.

A complex air flow pattern was observed at the rear of neck and helmet (Fig. 4). Vortices were generated at the rear of shoulder, rear of neck, helmet rear and bottom corner. Detached flow was observed because of the gaps and sudden shape changes in geometry. At half meter distance the flow was attached again, which indicates less reverse flow resulting in reduced wake and reduced drag coefficient.

At symmetry plane, due to the gap between the chin guard and the face of the rider, air is trapped and vortices are created. These vortices persist as the vehicle speed increases or decreases. Air flows through the gap between the chin guard and the visor. This airflow splits the vortex and allows some air to escape and provides fresh air to inhale to the rider. Velocity vectors in helmet flow field are shown in Fig. 4.

### 3. RESULTS AND DISCUSSION

#### 3.1 Flow Behaviour over Modified Geometry for Ventilation

Velocity vector plot at symmetry plane of case 2 and case 3 are shown in Fig. 4 and Fig. 5 respectively. From these, it can be seen that the presence of ventilation grooves improves flow velocity in the gap between the chin guard and the chin (location 1), as the air flows through the grooves. In case 2, the vortex formation is reduced compared to case 1. Further, reduced vortex formation is also observed in case 3. This increases air circulation, in-turn increasing comfort. The flow at location 2 (vision level) is improved as the vortex created was reduced in case 2 and case 3. This will reduce strains on eyes. A uniform flow was evident and reduced wake was observed. Velocities at different locations compared with baseline simulation are presented in Table 1.

### Table 1 Velocities at different locations

<table>
<thead>
<tr>
<th>Region</th>
<th>Case 1 (Base line)</th>
<th>Case 2 (straight)</th>
<th>Case 3 (Angular)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.57</td>
<td>2.89</td>
<td>3.06</td>
</tr>
<tr>
<td>2</td>
<td>4.67</td>
<td>2.89</td>
<td>3.06</td>
</tr>
<tr>
<td>3</td>
<td>No groove</td>
<td>10.1</td>
<td>1.53</td>
</tr>
<tr>
<td>4</td>
<td>No groove</td>
<td>1.45</td>
<td>4.59</td>
</tr>
<tr>
<td>5</td>
<td>9.32</td>
<td>2.89</td>
<td>4.59</td>
</tr>
<tr>
<td>6</td>
<td>No groove</td>
<td>5.77</td>
<td>1.53</td>
</tr>
</tbody>
</table>

At forehead region, the velocity of air was higher in case 2 than in case 3. Most of the air passed through the side grooves (Region-6) as the suction was at the side outlet. From this analysis velocity and pressure variations were found to be in the range that will cause discomfort to the rider. At location 4 at rear of the head, there are chances of dust accumulation due to low velocity around the step. To remove the effect of possible dust accumulation, the grooves were modified so as to improve comfort and increase velocity. Even with this solution it is recommended to provide an air filter at the vent inlet. But from the flow behaviour, it was evident that the possibility of dust accumulation in case 3 is lower compared to case 2.

One more drawback of providing straight grooves at the sides was that the air flow through outlet vent was perpendicular to the free stream velocity. This results in increase in drag for the helmet. The outlet vent at the rear was also blocking the air flow due to the L - shaped groove. In addition to these disadvantages, it was observed that the airflow strengthens in the rear wake
region, resulting in an increased drag coefficient (0.687). Based on the case 2 observations, the ventilation groove shape, which was defined by the shape of the liner, was now smoothed at the outlet so that the ventilation flow is unrestricted. With these modifications, improved air flow over the head was achieved simultaneously reducing the wake at the rear of the helmet. This also reduced the potential for dust accumulation.

![Fig. 5 Case 3 - Velocity vectors at symmetry plane and middle of groove](image)

At the outlet vent, air flow which was directed towards the neck reduced the wake, resulting in lower drag coefficient (0.442). Fig. 5 shows the velocity vectors in the wake region. The change of flow behaviour was clearly evident in Fig. 4 and Fig. 5.

In case 3, at the middle of the side ventilation groove, the flow pattern improved drastically when compared to case 2. It was observed from Fig. 5 that the air flow was entering from the side vents when compared to case 2 where the air flow was exiting from the side vents. The velocities at different locations are tabulated and shown in Table 1.1.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and other organisations have conducted experiments on different age group to quantify thermal comfort. These experiments provide data for acceptable human comfort values. Most favourable air velocity is 0.25 m/s, which is generally used for air outlet devices. An increase of 0.15 m/s in velocity is required to cool each 1°C rise in temperature [3]. Velocities obtained in this work were higher than comfort standard and this can be reduced by providing air filters at inlet and outlet vents. Providing air filters would help in eliminating dust accumulation and filter density would be controlling factor for air flow velocity.

In case 3, most of the flow is attached compared to case 1 (baseline) and case 2 due to gradual shape transition. As discussed earlier, because of low velocity air flow in case 2 from rear outlet vent, there was an adverse effect on wake resulting in an increased drag coefficient. But in case 3 the situation was different due to flow velocity and direction. A higher flow velocity directed towards the source of the wake i.e. rear of neck region, forced the wake to move out of the region. The presence of ventilation grooves has an advantage that, the wake created was reduced between chin guard and chin. Also, increased comfort level of rider was achieved due to less turbulence and improved air circulation. The improved air circulation reduces CO₂ concentrations drastically and rider can breathe fresh air. The path lines over helmet and man model surfaces are shown in Fig. 6.

3.2 Summary of Aerodynamic Analysis

Through the CFD analysis, the ventilation groove was fine-tuned, thus improving the rider comfort. Summary of results are presented below.

- In case 2, a drastic velocity change and pressure differences were found which will lead to rider discomfort.
- In case 2, at the rear of the head, there would be dust accumulation as the flow velocity drastically drops down.
- The outlet vent at the rear also blocks the airflow due to L-shaped groove in case 2.
- In addition to these disadvantages, the drag coefficient was increasing to as high as 0.687 as the outlet from the groove was adding up to the wake.
- To address these problems the routing of the grooves were fine-tuned to reduce these variations in velocity and improve the rider comfort.
- Based on the case 2 observations, the ventilation grooves were modified to angular grooves and the rear outlet vent was modified with a tangent transition surface.
- With above mentioned improvements, most of the problems seen in case 2 were resolved and a uniform velocity gradient throughout the groove were obtained. Favourable results were achieved by changing the outlet vent to direct the airflow towards the neck, thus reducing the wake region (drag coefficient achieved 0.442).
- Most favourable air velocity is taken to be 0.25 m/s as comfort [3]. The achieved values were higher than this comfort standard. This problem can be solved by providing air filters at inlet and outlet vents. Providing air filters would address another problem, it eliminates dust entering to the grooves.
- In case 2, because of low velocity, air flow from rear outlet vent created an adverse effect on wake.
- In case 3, a higher flow velocity was directed towards the wake i.e. rear of neck region. Hence, attached flow was achieved.

Initially, the project objective was to streamline the outer shape to achieve less drag coefficient. Since, improvement in drag coefficient was achieved by incorporating ventilation grooves itself; the helmet outer geometry was not modified. Consolidated drag coefficient results of all the cases are presented in Table 2.

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Drag coefficient C_D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Baseline</td>
<td>0.477</td>
</tr>
<tr>
<td>Case 2</td>
<td>Straight grooves</td>
<td>0.687</td>
</tr>
<tr>
<td>Case 3</td>
<td>Angular grooves</td>
<td>0.442</td>
</tr>
</tbody>
</table>
4. MODEL CONSTRUCTION FOR IMPACT

The helmet is intended to protect the rider from severe head injury. It is important to ascertain that the present helmet is satisfying the current Indian Standard (BIS) impact test specification. From the literature review, it has been understood that impact absorption test is an important test to assess rider safety provided by the helmet. For the baseline case, FE model, for simulating the mandated IS:4151, BIS test was built. Commonly used materials for helmet were taken into consideration and material properties were obtained from CES software [4]. The chosen material for outer shell was ABS and for the liner was EPS foam. With these considerations, helmeted head impact simulation was carried out. Results from this simulation were compared to those reported in other technical journals. Reasonable correlation was found between the two results. Material property details, inputs and simulation procedure are discussed below.

Hybrid III head form, taken from MADYMO, was considered for the impact analysis, which was used to evaluate occupant (upper interior head impact as per FMVSS 201) and pedestrian injury criteria (Pedestrian safety) [5]. However head form considered as a rigid body, because rigid wooden head form was specified in BIS drop test [6]. In this test specification, deceleration against time is plotted and for adequate design, deceleration should not exceed 300 g. The analysis was carried out in LS-DYNA and results are shown below.

4.1 Model Construction and Simplification

The outer surface of liner was taken to HyperMesh and discretised using shell elements. Solid elements were used to discretise the liner. The impact analysis was carried out considering only helmet outer shell and liner. Since the comfort padding has less influence on impact performance, these pads were not considered. Also, chin guard and visor were not considered in the simulations. To confirm this consideration, the outer shell and liner were constrained and impacted with a moving wall. This check helped to predict the stress regions and elements behaviour and it was found that there is no effect on visor and chin guard. The other advantage of this simplification was that the finite element model building time and simulation time reduced to a great extent. Since checking the injury criterion of skin was not the aim of this simulation, an aluminium head form [7] was considered for this simulation. In the drop test, only deceleration versus time graph was obtained to check it against the results of the physical test specified by IS:4151.

Liner outer surface was taken into HyperMesh and meshed with quadrilateral elements. A few triangular elements were also used to suit the geometry. A 2D element shell layer was considered as the outer shell. Appropriate material and section properties were assigned to these elements. To create the solid mesh for the liner, these 2D elements were offset to a distance of 25 mm (liner thickness) and solid 3D prismatic elements were created. Initially a gap of 1.5 mm was given between shell layer and solid liner elements. A set of node to node rigid connections (1D element) was given between outer shell and liner. These rigid elements showed an adverse effect on results. The load transfer to node was also affected and also the solid elements were distorted locally. In reality, the liner is bonded with outer shell. To model this real situation, the 1.5 mm gap provided earlier was removed. By removing the gap, it was essential that two faying elements share the same nodes. This was ensured while generating the mesh for the analysis. A surface to surface contact interface was defined between head form and liner inner surface. Details of the orientation setup are shown in Fig. 7. The details of results are presented below.

4.2 Material Properties

The materials considered for outer shell, liner and head model were based on the information available in the literature. For baseline simulation, for 25 mm thick PU liner, and 3 mm GE plastic outer shell, properties
given in Table 3 were used. Even though results showed a good trend correlation between literature and simulation results (Fig. 8), an unacceptable sudden increase in deceleration was observed in the simulated results. This variation of deceleration with time was much more uniform in test results [5]. Changing the material for the liner to EPS improved this performance. Both set of material properties are shown in following Table 3 below. In all simulations an aluminium head form, which was found in literature [7] was used.

<table>
<thead>
<tr>
<th>Component</th>
<th>Density (kg/m³)</th>
<th>Yield strength (MPa)</th>
<th>Poisson’s ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head (Aluminium)</td>
<td>2800</td>
<td>72000</td>
<td>0.29</td>
</tr>
<tr>
<td>Liner (EPS)</td>
<td>28 to 32</td>
<td>11.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Outer shell (ABS)</td>
<td>1049</td>
<td>2409</td>
<td>0.4</td>
</tr>
<tr>
<td>Liner (PU)</td>
<td>64</td>
<td>0.55</td>
<td>0.3</td>
</tr>
<tr>
<td>Outer shell (GE plastic)</td>
<td>1390</td>
<td>1870</td>
<td>0.35</td>
</tr>
</tbody>
</table>

4.3 Boundary Conditions

The finite element model of Hybrid – III head form was imported from MADYMO. Only outer skin was considered and all other components, like skull, inner skin, contacts, constraints, etc., were removed. To be able to measure the acceleration at the location of the centre of gravity of the head, as required by BIS test, a stage was created at that location. A set of 2D elements were created from the centre of impact region to centre of gravity location. A mass element, representing the mass of the head, was modelled at the same centre of gravity location, and was connected with rigid elements over boundary edge of head form. To avoid head penetration into liner inner face, a surface to surface contact interface was given between the head and the liner. The outer shell and liner elements were connected through shared nodes.

A rigid wall was created to represent flat anvil to impact helmeted head as specified by BIS. Initial velocity of 7 m/s was given to helmet and head in the direction of the impact. A gap of 1 mm was kept between the helmet outer shell and the wall to which it is impacted.

4.4 Assumptions and Considerations

In the drop test, the helmet is dropped (free fall) from a height of approximately 1.83 m. Since simulation of the free fall will increase the simulation time considerably without providing any useful information, in the simulation the expected impact velocity was assigned to the helmet and the head and the free fall distance was reduced to 1 mm. The helmet is oriented 20° to median plane, as specified in the drop test. Helmet test setup orientation and components are shown in Fig. 7.

The anvil was considered as a rigid wall similar to the steel anvil specified in the IS:4151 test specification. As the yield strength of the steel is much higher than ABS material, there is no deformation of steel anvil taking place. Hence, the assumption of anvil being rigid wall is a reasonable assumption. After preparing the input deck, file is exported and post processed in LS-DYNA.

4.5 Baseline Simulation – 25 mm Thick PU Liner

First, the impact of the model of the existing helmet design was simulated. Behaviour of 25 mm thick EPS liner was observed to be similar to what is reported in the literature (Fig. 8). 40 mm thick EPS liner and ABS outer shell showed better behaviour and the peak deceleration was not crossing the BIS specified limit of 300 g. The validation with physical test and results are discussed below.

![Fig. 8 Comparison of results of baseline simulation with published results](image_url)

5. VALIDATION - BASELINE IMPACT SIMULATION AND PHYSICAL TEST

The baseline impact simulation was carried out with 25 mm and 40 mm thick EPS liner and ABS outer shell. From the analysis, it was found that 40 mm thick liner shows better results than 25 mm thick liner. Similar results are reported by Deb et al. [5]. Correlation of EPS and ABS combination with physical test data was better than that of PU liner and GE plastic outer shell combination. So, further impact simulations were carried out with EPS and ABS combination. The ventilated liner was also analysed to confirm that it meets the standard requirement.

The validation of baseline impact simulation results with physical test results found in literature is discussed below. Two baseline impact simulations were carried out, one with 25 mm thick and another with 40 mm thick EPS liner and ABS outer shell. With 25 mm thick liner the peak acceleration reaches up to 575 g. the behaviour of the material shows uniform deceleration with same time frame. Increased liner thickness (40 mm) shows better behaviour and is relatively close to physical test results. Observed deceleration was uniform and with larger time frame. Also, the peak deceleration of 225 g was less than specified limit of 300 g. comparisons between drop test
(physical test) and baseline simulations are presented in Fig. 9.

![Graph showing comparison of physical drop test and baseline simulations](image)

**Fig. 9 Comparison of physical drop test and baseline simulations**

![Graph showing baseline and ventilation groove simulations](image)

**Fig. 10 Baseline and ventilation groove simulations – 40 mm thick liner**

6. RESULTS AND DISCUSSIONS

The modified liner for ventilation was analysed, to confirm that it meets BIS test specification. As predicted, the peak deceleration was slightly higher (230 g) than baseline simulation (225 g). This slight variation is due to the reduction in the stiffness of the liner because of the presence of ventilation groove. The initial delay was because of local deformation of groove edges and gap between head form and liner. Both baseline and ventilated model showed similar behaviour except for time delay and peak deceleration. Baseline and ventilation groove simulations are presented in Fig. 10.

In CES, the range of EPS foam density is given. To check the material density influence, lower value of given range was considered for simulation. The behaviour was found to be similar to that observed in baseline simulation. Even though there was slight peak deceleration difference, the plateau region was for longer period. This behaviour is expected to provide more safety to the rider.

6.1 Summary of Results

Even though the addition of ventilation grooves increased the peak deceleration its magnitude was still within BIS specified limit. EPS liner and ABS outer shell combination, commonly used materials for motorcycle helmets, showed better correlation with physical data. To incorporate the grooves inside the liner will be a challenge, as the foam breaks during mould extraction process. F.M. Shuaeb et al. [7] studied the suitability of EPP liner material for bead moulding process, which shows ease of mould extraction and multi impact performance because of its resilience properties. A 40 mm thick liner would be sufficient for the safety of the rider. However the physical tests need to be conducted before it comes to an application level. Slight variation of liner material density will have negligible effect on deceleration values.

7. CONCLUSION

Fluid flow analyses were carried out to study the flow behaviour inside a helmet and modifications were proposed to improve the flow within the helmet to improve comfort of the rider. Impact analysis was done to check if the modified helmet meets the BIS impact absorption test specification.

- For the selected helmet, there was insufficient air flow between chin guard and face. Vortices generated in this region results in exhaled air recirculation, which may cause discomfort to the rider.
- The modified helmet with ventilation grooves improves airflow over the head and also the region between chin guard and face.
- The position of the outlet vent of the ventilation groove not only improved the air circulation but also reduced the wake at the rear of the helmet, resulting in reduction in drag coefficient.
- It was observed that air gets stagnant at the rear region of ventilation grooves and it may result in accumulation of dirt during actual tests. This can be avoided by incorporating an air filter at the inlet and outlet.
- Use of air filter would reduce the air velocity and thus improve the comfort further.
- A 40 mm thick EPS liner and 3 mm ABS outer shell are required to protect the rider adequately during an impact.
- Marginal variation in liner material density does not have much effect on brain deceleration criteria.

REFERENCES


