An improved motorcycle helmet design for tropical climates

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Approximately 20% of all fatal traffic crashes in India involve riders of motorized two-wheelers. Head protection of two-wheeler riders is therefore a very important issue. This paper reports the results of a survey of patterns of motorcycle helmet use in Delhi, and the design details of a more comfortable helmet. The survey results were used as guidelines for designing a safer helmet, with a better ventilating system, to promote wider use. In the new design additional protection is provided on the sides of the helmet, since our earlier studies showed that more head injuries occur on the side of the head than on the top. A low-cost locking device has also been developed with which the helmet can be secured to the vehicle when not in use. All these design features are incorporated into a stylized product form. The new design is being marketed by a Delhi-based manufacturer and has received a very favourable response in the market.

Keywords: Helmet, motorcycle, safety, comfort

Introduction

Anecdotal evidence suggests that helmets are unpopular among riders of motorized two-wheelers (MTWs) in India because of the discomfort they caused in tropical climatic conditions. The Indian Motor Vehicles Act requires all MTW riders to wear helmets, but the law is not being enforced in all states of India because enforcement of traffic regulations is state-dependent (Mohan, 1989). There is a small but vociferous anti-helmet lobby in each state. They have been effective in delaying the enforcement of this Act. As a result, most states have not yet enforced rules for mandatory helmet use, but a few large cities (including Delhi) are enforcing the law for riders of MTWs.

In India, open-face (half-mask) helmets are more commonly used than full-face (full-mask) helmets. The outer tough shell of the helmet is generally made from fibre-reinforced plastic (FRP) by a simple hand-laying technique because it is most suitable for batch and small-scale production. The inner shock-absorbing cap is made of expanded polystyrene (EPS), but the density and thickness of the material vary from helmet to helmet (10–25 mm). Though different head sizes are specified by the Bureau of Indian Standards (BIS), only two sizes of helmet are generally available for economic reasons: mainly because most helmets are manufactured by small-scale industries that are unable to maintain large inventories. Only the large manufacturers are marketing their helmets in four sizes: small, medium, large and extra large. Selling prices of the helmets vary from US $2 to $10 for open-face helmets and from $10 to $18 for full-face helmets.

It is not mandatory for the manufacturers to have their helmets certified by the BIS, and a large number of helmets are sold without BIS certification. The standard requires the helmet to be tested for shock absorption properties, penetration resistance, strength of retention system, flexibility of peak, rigidity of the helmet shell, corrosion resistance of metal parts, audibility and peripheral vision.

This paper reports a study of motorcycle helmet design, particularly for use in tropical climates. It was carried out at the Indian Institute of Technology, Delhi and the National Institute of Design, Ahmedabad, and was sponsored by Full Power Works, a Delhi-based small-scale helmet manufacturer, and by the Delhi Police.

Methods of study

Helmets of different brands were obtained and studied from the perspective of safety, comfort and convenience in use. Surveys were conducted to obtain a better understanding of riders' behaviour and their attitudes toward helmets as a safety measure. Technical tests of helmet characteristics related to safety were also carried out.
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Surveys
Two different surveys were conducted in Delhi during February 1987 to gauge helmet users' reactions to helmet use from the perspectives of safety, comfort and functionality. The first survey was conducted at various roadside locations to provide quantitative data regarding the types of vehicles on the road, the types of helmet in use, the types of different helmet accessories, the colours of vehicles and helmets, use of the helmet and strap, and the age and sex of the riders. A total of 200 observations were made, at ten different locations at different times of day. Observations were noted on a specially developed recording sheet for every passing two-wheeler at 1 min intervals. Locations were selected in such a way that there would be no obvious bias in traffic; for example, away from residential locations or industrial sites.

The second survey was conducted by circulating a questionnaire to obtain information on riders' views about helmets in relation to safety, comfort and convenience. Questionnaires were given randomly to MTW riders at different locations in Delhi, until a sample of 100 returns was obtained. Items covered in the questionnaire are summarized in the Appendix.

Impact tests
Shock absorption tests were performed on a total of ten different types of open-face helmet. This included a new helmet produced in part on the basis of the results of the survey. Two different tests were performed on these helmets.

Shock absorption test on front and rear of helmet A mass of 5 kg was dropped through a free fall of 2500 mm ( guided by two metal wires) on the helmet positioned onto a headform as prescribed in the BIS standard 4151: 1982 (BIS, 1982). The test set-up for the front and rear impact tests is shown in Figure 1. The forces were measured by a Kistler dynamic force transducer which has a frequency response of 10 kHz. The force curve was plotted on a Hioki 8803 FFT Hi Corder and recorded on a Jiwatsu digital storage scope type SS-5802. All the tests were performed at room temperature. All helmets were first tested on the front and then the test was repeated on the back of the same helmet. The permissible limit of 20 kN (as per BIS standard) impact force in these tests was considered the maximum permissible limit.

Helmet drop test on side of helmet A steel surface with a covered upper face was fixed on top of the force transducer (Figure 2) and the helmets on their head forms were dropped on to this surface (radius 40 mm) from a height of 1500 mm such that the centre of gravity of the headform was aligned with the centre of the force transducer. The transmitted force was recorded on a Kistler dynamic force transducer for each test and plotted on a Hioki 8803 FFT Hi Corder. The tests were performed on one side and then the same test was
repeated on the other side of the helmet. This test is not prescribed in the BIS standard. However, since most impacts in two-wheeler crashes are sustained on the sides of the helmet (Mohan et al, 1984), we consider this to be an important test.

Results

Figure 3 shows the proportion of different types of motorized two-wheelers found on the streets of Delhi from our survey. We have no reason to suppose this does not represent the true picture in Delhi, but the proportions may be different in other cities of India. Of those wearing helmets, 92% used half-mask helmets and only 8% used full-mask helmets. Of the helmets, 73% did not have any kind of eye protection (visor). Out of the total riders, 69% had their helmets strapped properly, 5% had helmets unfastened, 24% had straps that were loose and 2% had helmets with no straps at all. Pillion riders accompanied 27% of the MTW riders. A majority (55%) of the MTW riders were in the age group of 26–50 years, because in India MTWs are generally used as family and commuting vehicles rather than for leisure purposes.

Riders did not have major complaints about the size and weight of helmets. It was found that 84% of the riders carry their helmets with them after parking their vehicles and 93% of the riders complained about the resulting inconvenience (Table 1). A majority of the riders (72%) reported that helmets cause discomfort due to heat in the summer months.

Product analysis and development of a new helmet

Helmet of different types and makes were studied from the technical, ergonomic and aesthetic points of view. After discussions with a manufacturer, broad guidelines were established for the development of a new design of helmet. As the manufacturer owned a small-scale enterprise, the technical limitations of the small-scale manufacturing process and low product cost were the prime considerations in the development of the new design.

Though we recommended different helmet sizes, as specified by the Bureau of Indian Standards (headband circumferences of 520, 530, 540, 550, 560, 570, 580, 590 and 600 mm), the present manufacturer is marketing the newly designed helmet in one size only (590 mm) owing to financial constraints. His distributors and retailers are unable to stock the helmets in different sizes; in their limited space they prefer to stock as many brands and models of helmets as possible, but of different colours rather than of different sizes.

Figures 4 and 5 show the new design of the open-face helmet in which ventilation is provided by slits in the front, back and sides. These vents can be closed easily in winter by a snap-on plastic fitting or by a cotton wool plug from inside. With marginal increase in cost, the vents can be made adjustable for controlled air circulation. The helmet can be locked by looping a strap through the slot provided on the sides of the helmet and around any fixture on the vehicle (Figure 6). In the new design, additional safety padding is provided on the sides of the helmet as our earlier studies showed that more head injuries occurred to the sides of the head than to the top (Mishra et al, 1984; Mohan et al, 1984). The side padding also gives protection against the small flying insects which very often get trapped inside the ears, by filling the gap between the helmet and ears. These design features were incorporated into a stylized product form, which is being manufactured by a Delhi-based small-scale industrial enterprise. It is being marketed at the price of US $8.50 and has received a

Table 1 Results of the behavioural study of helmet users

<table>
<thead>
<tr>
<th>Riders' views on helmet storage at parking lots</th>
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<tbody>
<tr>
<td>1. Riders always carry their helmets with them</td>
<td>38%</td>
</tr>
<tr>
<td>2. Riders carry their helmet only if there is no proper parking place</td>
<td>46%</td>
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<tr>
<td>3. Riders lock their helmet in helmet storage compartment of their scooters</td>
<td>7%</td>
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<tr>
<td>4. Riders secure the helmet strap in strap lock</td>
<td>5%</td>
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<td>5. Riders lock the helmet strap under toolbox cover</td>
<td>4%</td>
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<tr>
<th>Riders' views on carrying their helmets</th>
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<tbody>
<tr>
<td>1. Very inconvenient, but they are forced to carry in absence of a reliable helmet locking system</td>
<td>64%</td>
</tr>
<tr>
<td>2. Inconvenient to some extent</td>
<td>29%</td>
</tr>
<tr>
<td>3. Convenient</td>
<td>7%</td>
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<th>Riders' reactions on helmet discomfort due to heat, especially in summer months</th>
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</thead>
<tbody>
<tr>
<td>1. Uncomfortable</td>
<td>72%</td>
</tr>
<tr>
<td>2. Comfortable</td>
<td>28%</td>
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<th>Riders' measures to alleviate the discomfort due to heat</th>
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<tr>
<td>1. Riders remove the helmet for some period while riding</td>
<td>8%</td>
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<tr>
<td>2. Riders take small halt to remove the helmet and then start again</td>
<td>30%</td>
</tr>
<tr>
<td>3. Riders avoid using the helmet until they are forced to use it</td>
<td>12%</td>
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<tr>
<td>4. Other solutions</td>
<td>13%</td>
</tr>
<tr>
<td>5. No answer</td>
<td>37%</td>
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</tbody>
</table>

Figure 3 Proportion of different types of two-wheelers on Delhi roads.
An improved motorcycle helmet design for tropical climates

A favourable response in the market; at least three other manufacturers have copied the design.

Impact tests results

Test results of shock absorption tests performed on nine different types of open-face helmet (1 to 9), and on the new helmet, are shown in Figures 7 and 8. Helmets numbered 2, 3 and 4 were BIS certified. Figure 7 shows the comparative ranking of all helmets in descending order for their performance in the shock

![Figure 4 New design of helmet](image)

![Figure 5 Technical features of the new design. Key: 1 – FRP shell; 2 – EPS cap; 3 – inner lining; 4 – neck padding; 5 – clearance padding; 6 – locking slot; 7 – side padding; 8 – chin cushion](image)

![Figure 6 Helmet-locking device](image)

![Figure 7 Front impact forces in shock absorption tests (open-face helmets)](image)

![Figure 8 Side impact forces in helmet drop tests (open-face helmets)](image)
absorption test on the front of the helmet. It shows clearly that the new design of helmet performed better than most of the helmets, including the BIS certified helmets. Figure 8 shows the comparative performance ranking of the helmets in the shock absorption tests on the sides of the helmets. This shows that the provision of the extra padding on the sides of the new design of helmet has improved the shock-absorption properties of the helmet. This is shown also in Figure 9 where the impact force-time curve of the new helmet is compared with three BIS certified helmets (numbers 2, 3 and 4). The curves show that the new helmet records lower peak forces than two of the leading brands. This is because the impact forces are dissipated over a longer time period for the new helmet as compared with the other two. Helmet number 3 performed better than the new design, but we are unable to provide a definitive explanation for this difference, because the padding in helmet number 3 is not better than that in the new design. It appears that the performance of helmet number 3 is the result of the particular combination of shell and padding.

Conclusions

- Motorcycle helmet users all over the world have resisted the imposition of compulsory helmet use laws. It is therefore necessary to understand the reasons for their resistance in each specific situation.
- This study shows that a careful analysis of users' perceptions and behaviour can lead to a better understanding of their needs for the design of helmets, especially from the ergonomics point of view.
- Our study shows that direct and close collaboration of biomechanics and ergonomics researchers with a helmet manufacturer resulted in a product development process which combined the theoretical with the feasible. The motorcycle helmet produced through such a process is not only competitive in the market but also performs better than similarly priced products in respect of its biomechanical and ergonomics characteristics.

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Appendix: Survey 2 questionnaire

The second survey questionnaire contained the following items:

1. age and sex of the riders;
2. type of their vehicle;
3. type of their helmet and its cost;
4. subjective questions on helmet comfort, size and its weight;
5. type of security measures they adopt for their helmets after parking their vehicles: whether they carry their helmets along with them every time or they secure with their vehicles. If they secure, what type of locking methods they use;
6. riders' views on carrying their helmets;
7. type of retention system of their helmets;
8. riders' reactions to helmet discomfort due to heat, especially during the summer;
9. type of remedial measures that riders adopt to alleviate the heat discomfort;
10. riders' reactions on mandatory helmet wearing law for MTW riders.

All questions had options to choose from and the riders were asked to select one or more appropriate options for each question.

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