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AERODINAMIČAN DIZAJN I ANALIZA MOTORISTIČKE KACIGE S VIZIROM PROTIV ODSJAJA

AERODYNAMIC DESIGN AND ANALYSIS OF MOTORCYCLE HELMET WITH ANTI-GLARE VISOR

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Prethodno priopćenje

Sažetak: *Broj motociklističkih nesreća u posljednja se dva desetljeća povećao. Kaciga u određenoj mjeri može zaštititi motocikliste od teških ozljeda koje je moguće zadobiti tijekom prometne nesreće. Prilikom dizajniranja funkcionalne kacige važno je analizirati oblik kacige i veličinu vizira. Iz tog se razloga pokušalo dizajnirati i analizirati novu kacigu uzimajući u obzir tlak otpora zraka i vizir protiv odsjaja. Tlak otpora zraka pritišće kacigu na vratni dio tijela vozača. Oblik aerodinamične kacige može smanjiti pritisak otpora zraka. Kacige sfernog oblika i novog aerodinamičnog oblika izrađene su pomoću Pro-E software-a. Izračunati su tlakovi otpora zraka za oba oblika kacige i napravljena je usporedba rezultata.*

Ključne riječi: *kaciga, tlak otpora zraka, aerodinamičan, indeks loma*

Preliminary note

Abstract: *The number of motorcycle accidents has increased in the last two decades. Helmet can protect the vehicle riders from severe injuries during road accident to certain extent. To design a functional helmet, it is important to analyse the shape of the helmet and visor portion. Therefore, the attempt has been made to design and analyze new helmet by considering the pressure drag and anti-glare visor. The pressure drag resistance presses the helmet against the neck portion of the rider. The shape of an aerodynamic helmet can reduce the drag pressure. The spherical shape and new aerodynamic shape helmets are designed using Pro-E software. Pressure drag is calculated and comparison is made on the basis of drag pressure.*

Key words: *Helmet, drag pressure, aero-dynamic, refractive index*

1. INTRODUCTION

As per the 'Mechanism of head injury', the data collected from the USA shows that many persons lost their lives as they did not wear helmets. The results from various sectors indicate that riders were affected by neck pain in the spherical shape helmet and also in night time riding their vision was impaired through the visor in the helmet. Helmets must provide crash protection, adequate ventilation, and reduced aerodynamic drag. The aerodynamic drag resulting from surface friction is quite low compared to the resulting pressure drag. Therefore, the largest reductions in coefficient of drag can be achieved when the pressure drag is reduced by maintaining low drag coefficient.

2. LITERATURE REVIEW

Several studies have been conducted to evaluate the protective performance of helmets during direct head impact, with constant-rate compression and drop-impact tests which are typically used to investigate the protective contribution of individual helmet components in [1], [2], [3], [4]. In [5] the effectiveness of mandated motorcycle helmet used in Taiwan by applying logit modelling approach was presented and before-and-after comparisons were made. In [6] the helmet design variations in terms of different variables other than headform linear acceleration were presented and suggested that the model had optimized cost, weight and helmet size. The biomechanical characteristics of head impact with both metal form and ABS helmets suggested that the metal form shell performed well compared with ABS helmet [7]. In [8] the rotational and linear acceleration of a Hybrid II headform, representing a motorcyclist's head, in such impacts, considering the effects of friction at the head/helmet and helmet/road interfaces by Finite element analysis was presented. In [9] the simulation models of helmet and human head were used to study the impacts on a protected and unprotected head in a typical motorcycle related collisions. In [10] the simulation method was used to determine the velocity of air flow in the helmet models with pressure and stresses in the brain. In [11] the head injuries by Finite element simulation were presented. In

[14] it can be seen that during a long bicycle time trial or during the cycling portion of a triathlon, 80 to 90 percent of the power developed by the athlete is used to overcome aerodynamic drag. In [15] many of these events are won or lost by only seconds. Small reductions in overall aerodynamic drag can easily save seconds in any of these events, giving the athlete a decisive advantage. In [16] it is said that the helmets must provide crash protection, adequate ventilation, and reduced aerodynamic drag. In air at typical cycling speeds the Reynolds number for an aerodynamic helmet is in the range of 300,000 to 500,000. Reynolds numbers in this range show that the aerodynamic properties will be dominated by inertial effects. In [12] an experimental bird strike tests were conducted on aluminium foam based double sandwich panels. They predicted the failure of structural components with aluminium foam in bird-strike events through a numerical model. In [13] triple layer dielectric systems were investigated, in which the reflection at the main contact surface is decreased due to the interference of the reflected light from each interface, so that the refractive index n(x) is an unknown piecewise constant function. The results from various sectors indicate a very high percentage of injuries can be prevented by using helmet. Even though people wear helmets, due to their inadequate quality, the neck pain was developed and glare in the visor is high.
Hence it is essential to produce standard helmet with proper aero-dynamic shape to reduce the neck pain of the rider in the long journey paraded with anti-glare in the visor. The attempt has been made to design and analyse the aerodynamic shape helmet model by using 'Pro-E' software.

3. MATERIALS AND METHODS

The standard spherical shape helmet model is created in the Pro-E software as per the dimensions shown in Figure 1.

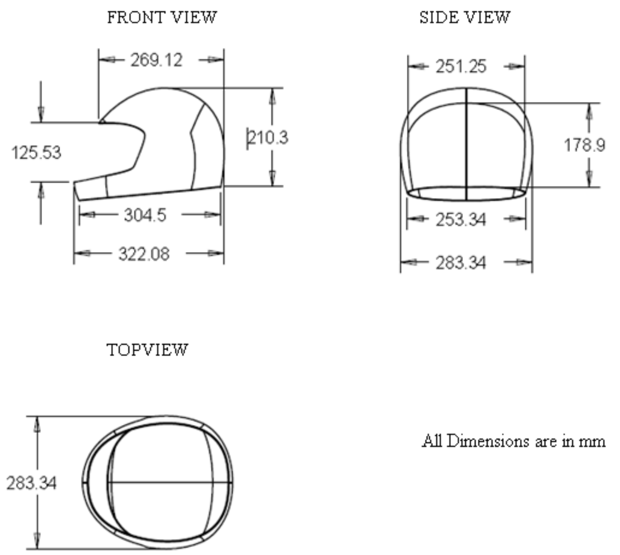

Figure 1. Standard dimension of various parts in helmet

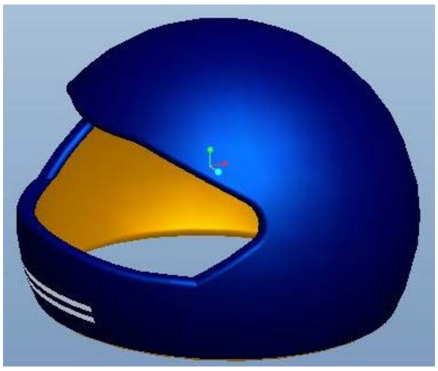

Figure 2. Helmet CAD model

Figure 2 shows the spherical shape helmet model developed in the Pro-E software. This model helmet has created more neck pain during a long journey. So the attempt has been made to redesign the helmet considering the aerofoil profile.

3.1. Selection of an aerofoil profile

The main type of drag acting against a cyclist is pressure drag. It is caused by the air particles being more compressed (pushed together) on the front-facing surfaces and more spaced out on the back surfaces. The drag force depends upon the various shapes and drag coefficients.

Table 1. Drag coefficient values for different aerofoil shapes

S. No.	Shape	Figure	Drag coefficient
1	Sphere		0.47
2	Half-sphere		0.42
3	Cone		0.50
4	Cube		1.05
5	Angled cube		0.80
6	Long cylinder		0.82
7	Short cylinder		1.15
8	Streamlined body		0.04
9	Streamlined half-body		0.09

Table 1 shows the measured drag coefficient values for the different aerofoil shapes. It is clearly shown that the streamlined body shape is having the low drag coefficient compared with other shapes. So this shape is chosen for redesigning the helmet for minimizing the drag force.

3.2. Redesign of Helmet

The spherical shape model helmet is redesigned with the new aerofoil shape of streamline body. Figure 3 shows the redesign model of the helmet considering the aerodynamic concept. In the back side of the helmet, the streamline air flow is considered and the shape has been modified to reduce the drag coefficient.

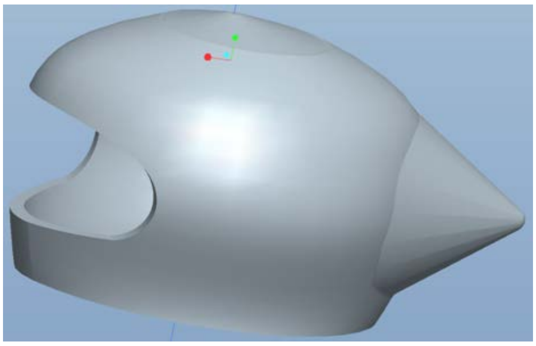

Figure 3. Redesigned helmet (Streamline shape)

3.3 Drag Pressure

The drag force is estimated for the spherical shape helmet model from the Equation (1).

$$F_d = 0.5 \times V \times \rho \times C_d \times A \quad (1)$$

where,

F_d = Drag force in N

V = Velocity of air in m/s

ρ = Density of air in kg/m^3

C_d = Drag coefficient

A = Frontal area of helmet in m^2

Drag Pressure (D_P) = Drag force / Frontal area of helmet (2)

The pressure drag is estimated from the expression (2) for the specifications considered in the spherical shape helmet model.

3.4. Refractive index in the visor without coating

The reflection from any given interface at normal incidence is related to the ratio of refractive index of the materials forming the interfacing and has characteristics by the percentage of reflectance. In optics, the refractive index or index of refraction (n) of a substance (optical medium) is a dimensionless number that describes how light, or any other radiation, propagates through the medium.

$$\text{Refractive index, } n = \frac{C}{V} \quad (3)$$

Where, C is the speed of light in vacuum and V is the speed of light in the substance.

The percentage of reflectance through the visor is calculated from expression (4)

$$2\,[(n_0 - n_s)^2/(n_0 + n_s)^2]\,100 \quad (4)$$

Where, n_0 is the refractive index of the first layer (air) and n_s is the refractive index of the second layer (window).

Thus, for a crown glass window, n_0 = 1 and n_s= 1.52 giving a reflectance at normal incidence of 4.3% per surface, i.e. a total reflectance of 8.6% from the window. In order to minimize or remove this reflectance, a further layer of refractive index (n_1) is coated completely onto the window so that reflections from the air/coating and coating/window interfaces undergo destructive interference to the greatest possible extent.

4. RESULTS AND DISCUSSION

The pressure drag and the coefficient of drag are estimated from the Equation (1) and (2) for the streamline shape of the redesigned helmet with the following specification

Frontal area of helmet = 0.08m^2

Velocity of air = 22.2m/s

Density of air = 1.22 kg/m^3

Drag coefficient = 0.47

Drag force (F_d) = 0.5 x 22.2 x 0.47 x 1.22 x 0.080
= 0.509 x 9.81
= 5N

Therefore, Drag pressure (D_P) = 5 / 0.080 = 62.43 N/m^2

From these calculations, the drag pressure value is estimated at 62.43 N/m^2 in the spherical shape helmet model. The attempt has been made to estimate the drag pressure for the modifying streamline shape helmet. The drag pressure value depends on the drag coefficient of the aerofoil shape. The drag coefficient value for streamline shape is 0.04. From Equation (1) and (2), the Drag pressure (D_P) is estimated for streamline shape helmet is 5.775 N/m^2.

Figure 4 shows the relation between drag coefficient and drag pressure. It is clearly shown that drag pressure increases with the increase of the drag coefficient. The neck pain for the rider increases if there is the increase of the drag pressure. So it is identified that the streamline shape model helmet reduces the neck pain for the rider in the long time journey when compared with spherical shape model helmet.

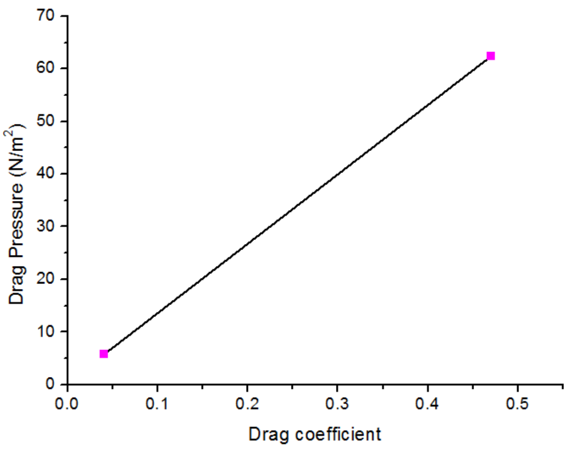

Figure 4. Drag coefficient Vs Drag Pressure

4.1. Anti-glare visor - percentage of reflection with coating

The percentage of radiation glare through the polymer coating is estimated from the Equation (4). In this equation n_o is replaced as n_x, where, n_x is a high refraction index to the polymer coating equal to 1.97.

Percentage of reflection through the visor with coating

$$= 2\,[(1.97-1.52)^2/(1.97+1.52)^2]\,100$$
$$= 33.3\%$$

Comparison of percentage of reflection has been made with and without coating from the visor portion to resist the glare penetrating the rider's eye. The difference in reflection percentage is as follows: 33.3 - 8.6 = 24.7 %.

The polymer coating reduces the headlight glare of 24.7%. The visor made of polymer coating reduces the glare of the rider from the lighting source.

5. CONCLUSION

The design of a helmet shape has been carried out by streamline shape with anti-glare visor. The study has been made for two different aspects. In the first case, an aerodynamic shape has been considered and in the next case the hybrid high refractive index coating in the visor has been studied. The results show that the streamline shape of a helmet is having low drag pressure and reduces the neck pain of the rider for long journeys. The visor portion of a helmet is coated by a polymer and it reduces the refractive index of the visor. This polymer coating reduces the glare of 24.7 % compared with non-coated visor and eliminates the opposite headlight glare for the night time riders.

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