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International Journal of Applied Arts Studies

IJAPAS 8(3) (2023) 07–14

Bicycle Helmet Design Using Gyro Technology

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Received 12 July 2023; accepted 06 August 2023

Research Article

Abstract

Medical evidence shows that skull injuries and brain injuries are the most important cause of death in cycling accidents. Due to the growing acceptance of bicycles as transportation within and outside the city, it is necessary to use a hat. A helmet prevents severe head injuries in the event of a fall or accident. In this article, an attempt has been made to design a new helmet that has a different structure compared to other helmets. The final helmet is designed with the inspiration of the car airbag system, and its performance is such that when a person crashes and falls, it opens like a car airbag and prevents the cyclist from head injuries. The helmet's electronic system uses a multi-axis gyro sensor and the helmet is filled with a compressed gas capsule. The working method in this article is descriptive-experimental. By observing and examining the hats available in the market and registered patents, laboratory observations and reviewed articles, article analysis was done. The results of the research showed that the designed helmet has more protection than the old helmets, and the new design and its use bring more comfort and visibility to the cyclist.

Keywords: Helmet; Cyclist; Gyro Technology; Design

1. Introduction

A bicycle is a device that can be easily accessed and because the user uses his physical strength, it has a great effect on the physical and mental health of people. On the other hand, because the bicycle does not consume any fuel, it can reduce energy consumption and reduce air pollution and ultimately reduce traffic. While cycling has many advantages, due to the lack of protection for the

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cyclist's body and head, it is a relatively dangerous means, so injuries, injuries and deaths of cyclists have been reported in different countries of the world (Wegman, Zhang and Dijkstra, 2012). Although about a third of the accidents around the world are related to pedestrians and cyclists, only 68 countries have adopted policies for the safety of pedestrians and cyclists (Siman-Tov, Jaffe and Peleg, 2012). Most of the accidents related to cyclists were between the ages of 9 and 15 years old, and usually male cyclists have twice as many accidents as female cyclists (Kiss et al., 2010). The amount of bicycle use is different in different regions. In America, while only one percent of intra-urban and suburban transportation is done by bicycle, about 51,500 accidents and 800 deaths occur due to bicycle riding. Head injuries account for 75% of these injuries. All cyclists, whether beginners or professionals, must use the most essential safety equipment. One of the most essential equipment for cycling is having a helmet. Using a helmet can reduce the possibility of brain damage by 90% (Hamann and Peek-Asa, 2013). It is estimated that bicycle accidents cost the US economy about $5 billion from 2005 to 2010 (Naumann et al., 2010). In our country, due to the presence of cyclists in the passages, streets and roads that are used for the passage of motor vehicles, the number of accidents and deaths caused by cycling, especially among children and young boys, is high (Karkhaneh et al., 2008).

A helmet is one of the most important safety and personal protection equipment that has a variety of uses, including industrial activities, construction, workshops, factories, and sports. The main function of a helmet is to protect the head against falling objects, throwing objects, falling debris, electric shocks and accidents. The straps inside the helmet are very user-friendly and distribute its weight evenly. Safety helmets are also used for working at height, rock climbing and sports that are considered high.

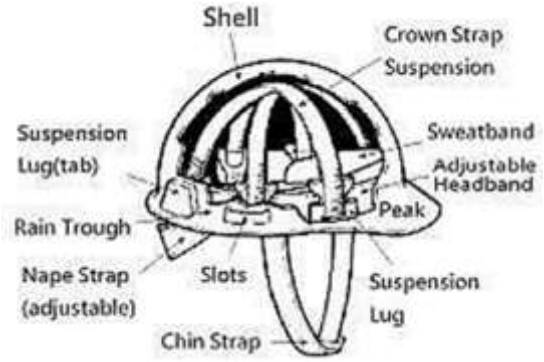

Fig 1 The overall structure of the helmet

There are different types of helmets, which include specialized sub-categories. Among the types of helmets, the following can be mentioned: engineering helmets, industrial helmets, construction helmets, workshop helmets and sports helmets.

The tests that are performed on helmets according to the EN 397 standard are as follows:

Impact absorption test: In this test, a 5 kg spherical object is placed on the hat from a height of one meter and dropped on an artificial head. The maximum force applied to the head should not exceed 500 dyne. This test is repeated at -10oC and +05oC and in humid air.

Penetration resistance test: In this test, a three-kilogram rod with a diameter of 100 mm is hit at an angle of 60 degrees to the hat, so that the tip of the rod should not pierce the hat.

Resistance to ignition test: In this test, the hat is exposed to a burning flame for 10 seconds, the fuel of which is propane and the flame diameter is 10 mm. After removing the cap from the flame, the burning of the outer surface should not continue for more than 5 seconds.

Electrical resistance (insulation) test: In this test, a cap filled with NaCl solution is placed in a tub filled with the aforementioned solution. The amount of electrical discharge is measured at a voltage of 1200 volts and 50 Hz, and the discharge current should not be more than 1.2 milliamps.

Resistance test against metal lava: This test is carried out in iron and steel industries. For this purpose, 300 grams of molten metal with a temperature of 1400oC is poured on the shell of the hat.

Today, the word sensor refers to elements or parts that have the ability to sense and convert a quantity into electrical signals (regardless of whether the signal is digital or analog). A smart sensor is a sensor that has two important parts: 1- Separate processing unit 2- Network communication unit. One of these sensors is a gyroscope. Knowing the position and angle of the object and its angular velocity is essential in all moving devices, because without knowing the position of the object, it is impossible to control it towards the target and it seems impossible. Gyroscopes are sensors that we use to obtain angular velocity and angular position. By processing this information, the overall position of the object can also be obtained based on calculations. Gyroscope is the main member of inertial guidance systems.

In this article, an attempt has been made to design a helmet with an airbag so that it is more efficient and has more freedom of action for the user in its design (Hauptman, 2008).

2. Materials and Methods

In order to choose the right fabric for the airbag, two fabrics, polyester and nylon 66, were examined. According to Table 1 and by examining the characteristics of both fabrics, the advantage of nylon 66 is its low density. On the other hand, fabrics made with threads of the same diameter show that polyester is 20% heavier than fabric made of nylon 66.

Table 1 Comparing the characteristics of nylon 66 and polyester

Specification	Nylon 66	Polyester
Density (kg/m^3)	1140	1390
Specific heat capacity (kJ/kg/K)	1.67	1.3
melting point (°C)	260	258
softening point (°C)	220	220
Melting energy kJ/kg	589	427

According to the aforementioned characteristics and features, nylon 66 fabric was used to prepare the appropriate fabric. The sewing was done using HIGHLEAD industrial sewing machine model GC1188_MZY. Helium gas is due to the small size of its molecules, which causes rapid penetration into empty spaces. The inertness of helium gas prevents the process of surface absorption in objects, and helium can also be considered an ideal gas. Due to the lack of access to very small size helium capsules in the Iranian market to fill the air bag, 16 grams compressed air cartridge containing 16 grams of carbon dioxide gas was used instead of helium gas. The advantage of these capsules compared to helium gas is the cheap price, easy access and easy recharging. At this stage, the amount of gas needed to fill the air bag has been calculated, and by calculating the amount of gas required, how much carbon dioxide gas capsule is needed. Here, taking into account the design of the parts of the hat in the form of a cylinder with an oval cross-section, the volume was calculated.

Calculating the volume of a cylinder with an oval tank:

The volume of a cylinder with an oval cross-section = The height of the cylinder × The area of the ellipse

The formula for calculating gas pressure:

$V_1P_1 = V_2P_2$

After obtaining the chamber pressure, we come to the conclusion that not all the gas in the capsule is needed to fill the chamber, and the solenoid valve system should be adjusted so that a sufficient amount of gas is released from the carbon dioxide capsule.

The sensor used in the project is a gyroscope sensor with part number MPU6050. This sensor has the ability to measure angle and acceleration in three axes and exchanges its information with the microcontroller through I2C serial communication.

Arduino UNO board has an AVR microcontroller with part number m328p. This chip has a maximum working frequency of 16 MHz and has 26 input/output pins and 6 analog inputs.

3. Results and Discussions

In this section, the production process and pattern of the helmet, the initial plans to produce the best suitable model according to the standards and ergonomics of the helmet are discussed. Also, how the gyro sensor works and the components required for production and how the electronic system in the helmet is described.

3.1. Initial Design

After the reviews and researches, the design of the helmet should be designed considering the ergonomics of the helmet and the features of the airbag.

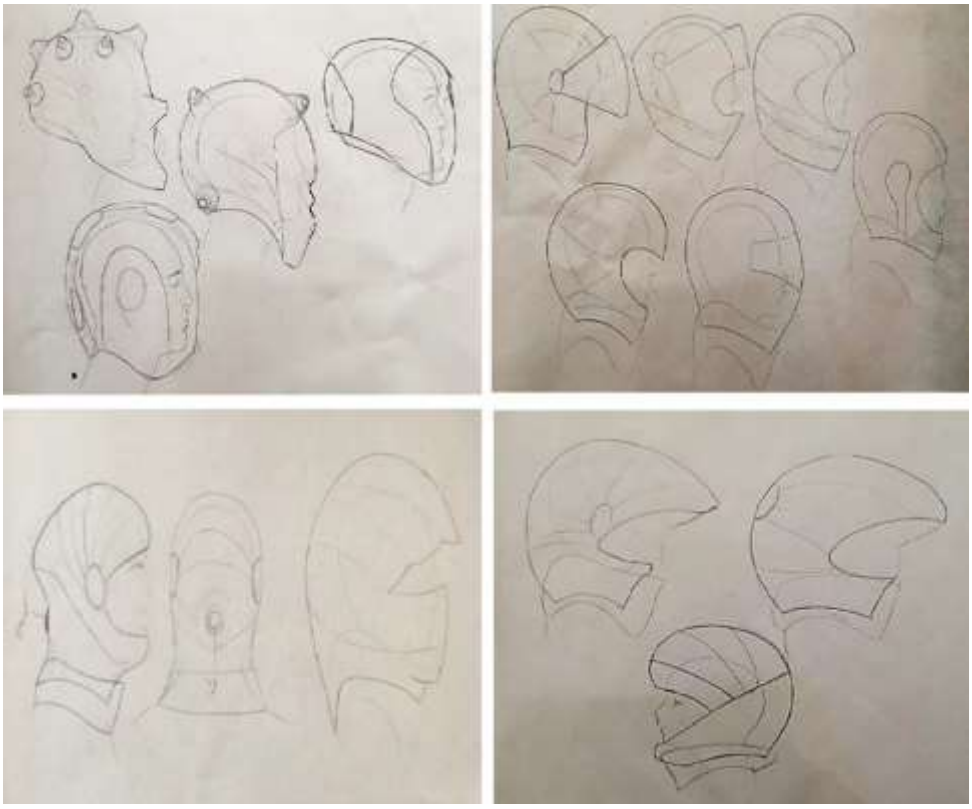

Fig 2 Sample prototypes

Figure 2 (top left): The initial designs were such that the airbag would cover the entire face after inflation and include full head protection. After the investigations, we came to the conclusion that in these designs, more gas is needed to fill the airbag and provide head protection, and it takes more time to fill, which is a problem.

In other designs, by creating a conical design on the cap, it creates a greater distance from the impact point. The problem with this design is that when the hat is opened from the collar, it becomes difficult to inflate these surfaces.

Figure 2 (upper right): In the completed designs, an attempt has been made to create a design with the minimum amount of fabric to produce hats so that the final weight of the work can be minimized.

Figure 2 (bottom left): Preliminary plans have been made for the best points for cutting the fabric and the appropriate location for the gas to enter the hat.

Figure 2 (bottom right): A detailed examination shows the place of cutting the fabric from the back of the head and in the ear area. Cutting the fabric from the ear area requires a larger number of patterns, which creates problems in the field of pressing and sewing. Cutting the pattern is important in this work, because when the airbag is placed in the collar, it should be easy to fold and it should be possible to open it quickly.

3.2. Final Designs

The final design was approved due to having the following features: 1- Protection and more area of the head and neck, 2- The amount of fabric used is low to reduce the overall weight of the hat, 3- The final design can be placed better on the collar, 4- Low amount of helium gas in the chosen design to reduce the overall weight of the hat, 5- Low amount of helium gas to fill the cap faster, 6. The ability to cover with any type of headgear and hairstyle.

The design of the pattern was done after choosing the final design. The pattern is designed in such a way that it has two inner and outer layers. The design of the pattern is done with the help of an example of a motorcycle helmet. Then the patterns were designed and according to the necessary sizes, the amount of fabric needed for use was estimated to be 4651 square meters.

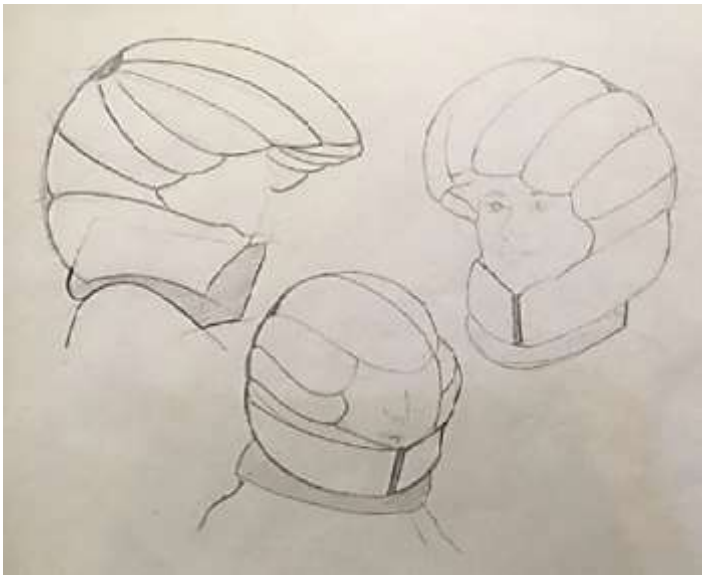

Fig 3 The final design of the helmet

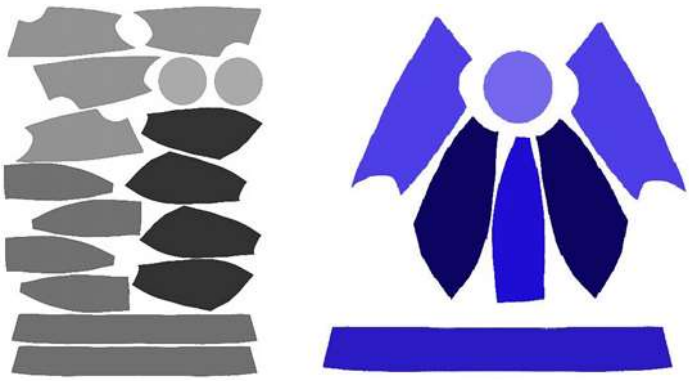

Fig 4 Pattern arrangement of outer layer (right), pattern arrangement of all parts (left)

Only one size has been considered for airbag sizing, and only the collar that wraps around the neck has sizing so that all consumers have enough comfort when wearing it and there is no problem in the neck area.

The collar is sized in three sizes: small (S) (for neck size less than 36 cm), medium (M) (for neck size between 34 and 42 cm) and large (L) (for neck size between 38 and 45 cm).

After obtaining the pattern, a sample of the hat was sewn with ordinary fabric (cotton) and filled with glass wool fibers to remove any defects in the design, and its size was checked on the head. The stitches were made in such a way that there is a chamber in each section so that gas can penetrate into each section by means of an air capsule. The circular part of the back of the hat only connects the patterns and air does not go inside.

Fig 5 Sample of sewn hat fabric

Also, the sample of the prepared fabric was cut into 20*3 centimeters and tested for strength. According to the obtained results, the average force for tearing the fabric is 313N with an increase in length of 34 mm. This amount of force is suitable for a large amount against the rupture of the airbag due to impact with the ground or point impact and has sufficient protection.

Considering the electronic system on the screen, the installation of the dam and the input and output of the device were specified. To place the system in the collar, a small box was considered

behind the collar, which was placed on the end of the neck, and then this box was connected to the collar. This collar is designed to hold both sides of the airbag and the airbag is placed inside it in a compressed manner. The compressed air bag is placed in such a way that there is no obstacle or entanglement in the bag so that it comes out easily. It is installed on the back of the box where the electronic system is located. The electronic system is protected by foam. In the front part, the zipper is sewn to the airbag itself, and then the prepared collar is attached to it.

To connect the airbag to the collar, a kind of glue is used so that no needle holes are created on the airbag. The electronic connections for gas criticism are connected to the air bag through the connecting hose, which is pressed into the air bag at the back of the air bag.

3.3. Test

The helmet test was done in such a way that after putting on the helmet and closing the zipper, the head moves forward as fast as possible. The angle of deviation in the electronic programming of the hat is considered to be 35 degrees from each x, y and z axis. The acceleration measured by the accelerometer in the gyro sensor is considered to be 1.2 m/s in the programming. After deviating from this required angle and speed, the board transfers the steering to the solenoid valve and the cap starts to fill with gas.

Fig 6 Procedures for testing an airbag helmet

4. Conclusion

In the designs made, due to the flexible surface of the airbag, the point of impact and the contact pressure are distributed on the surface of the helmet and a larger area so that the force is not concentrated on a specific area of the skull, which reduces the damage to the head and neck. Therefore, in these designs, better shock absorption is provided than other helmets. The performance of the airbag helmet is such that it reduces the speed of the movement of the skull and therefore the movement of the brain is controlled during an accident. The air in the helmet absorbs some impacts and as a result the head hits the helmet slowly, which means that the brain does not hit the skull with much force. The unique design of this helmet is such that it expands in case of an accident and is stronger and softer than traditional helmets, reducing the risk of stroke up to eight times and almost eliminating the risk of skull fracture. Another advantage of the design of this hat

is its completely natural view because there is no interference or restriction on the head. Meanwhile, the biggest disadvantage of existing helmets is that the visibility of the cyclist and motorcyclist is reduced, and this reduced visibility is a great danger. Another advantage of the designed hat is that it can be easily used with most hairstyles. It can be used even for people who use scarves, shawls, hooded sweatshirts, all kinds of hats such as knitted hats, with or without a mask. Only for this purpose, the collar that is tied around the neck should be used on a shawl or scarf. The use of glasses is also allowed.

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