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# Development of an integrated cooling system for motorcycle helmet by physical study of temperature variations and heat transfer

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**Abstract.** In Colombia, the most widely used means of transport today are motorcycles, which have become increasingly numerous, bearing in mind that they are subject to laws and regulations imposed by the country's mobility, transit and transport agencies, the use of helmets is mandatory for drivers and passengers, safety measures are monitored, the hull must be certified and meet the required technical standards; whereas its role is to protect people in the event of accidents, regulations require that the helmet be completely closed to protect the entire head and chin; the design of the helmet allows air entry and there is no concentration of temperature inside, all this is done by implementing air inlet and outlet ducts, which circulate air when the motorcycle is in motion, unfortunately this does not happen due to the accumulation of temperature in the back of the helmet that makes the user feel tired and uncomfortable. This research proposes the development of a prototype portable cooling system for motorcycle helmets by the physical principle of heat transfer, by using Peltier cells, to have low production cost, optimal operation, and low energy consumption thanks to natural air flow.

## 1. Introduction

In Colombia, statistics from "Asociación Nacional de Empresarios de Colombia (ANDI)" and "Federación Nacional de Comerciantes (FENALCO)" confirm that sales of motorcycles at the national level in Colombia are increasing, in such a way that compared to the years 2020 and 2021 an increase of 44% [1], this indicates that the number of motorcycles circulating is much higher; therefore, in order to become a creditor of any motorcycle-type vehicle, the rules established by the "Ministerio de Transporte", Colombia, for circulation within a given territory must be complied with [2].

Helmets must comply with the technical regulations specified in "Norma Técnica Colombiana (NTC)" NTC 4533 [3], which dictates the minimum parameters that the helmet must have to be fit in circulation and not be fined for infringing the established law [4]. Within these specifications are that they should be closed helmets that protect the entire skull and chin [5,6]. On the other hand, the "Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia (IDEAM)" [7], show in their statistics how a substantial increase in temperature is seen at the national level, especially in tropical and warm zones, this triggers the motorcycle population to be more exposed to solar radiation, which means interacting with excessive heat and sweating, causing a feeling of despair in the upper part of the head

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due to the accumulation of heat in this area of the helmet, caused by the deficiency of the ventilation systems they bring, causing the temperature to rise in various areas and achieving a bad experience in the motorcycle driver [8,9].

To build the air conditioning device for motorcycle helmet, you have to take into account many of the principles that govern the exchange of heat, several authors have put forward various theories based on Peltier effects devices and specifically on heat pumps, so that the first helmet in the world with air conditioning works with one of these pumps, based on such simple concepts as heat; which is a form of energy exchange between the system and its surroundings due to a temperature difference, heat-free thermodynamic systems, possess energy, and one of the ways in which they exchange this energy is heat.

Heat transfer, which is a process through which energy is exchanged in the form of heat between different bodies, or between different parts of the same body that are at different temperatures. Peltier effect; its functionality is produced when a current is passed through a circuit composed of different materials whose joints are at the same temperature, an inverse effect is produced, in this case, heat is absorbed in one joint and the temperature is released in the other and finally, which is a physical magnitude that determines or reflects the amount of heat of an object, of the environment or of a body [10]. This research proposes the development of a prototype test of a portable cooling system through the physical study of temperature variations for laboratory tests at scale to provide the basis for the construction of a final prototype reproducible on a larger scale and giving the user a sense of comfort when moving in this mode of transport, where the perception of heat inside the helmet decreases, without neglecting the low cost, optimal performance and low energy consumption with the use of Peltier cells and the use of natural air flow when driving the motorcycle [11].

## 2. Methodology and materials

For the construction of the prototype of the integrated cooling system for the motorcycle helmet, the following methodology shown in Figure 1 is proposed, which contemplates the phases of the process to be followed to achieve the realization of the prototype.

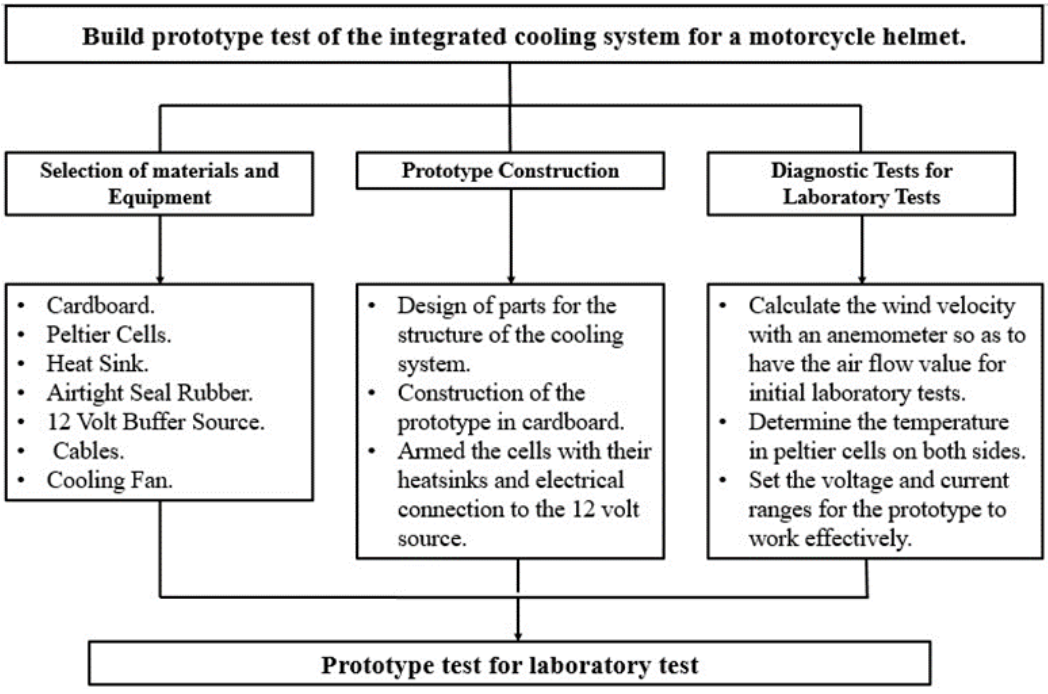


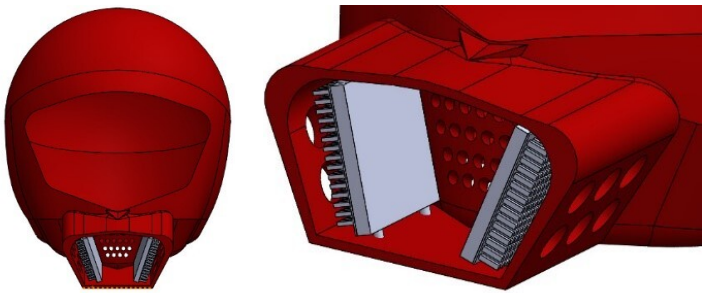

**Figure 1.** Methodology for the construction of the prototype air-conditioning test for motorcycle helmet.

This research will be carried out in 3 stages as detailed in Figure 1; the first thing that will be carried out is the selection of the materials and equipment necessary to be able to carry out the test prototype, among which we have: cardboard for the base and structure of the system, Peltier cells for cooling the air entering the hull, heat sink allowing heat transfer from the hot part of the cell, airtight seal rubber to prevent leakage, 12 volt regulating source for power supply to the system, cables for electrical connections and cooling fan.

The second stage is the prototype construction that will be carried out from the previous design in the SolidWorks software [12], where each of the components that will be part of the system structure will be drawn in cardboard, Next to this will be installed Peltier cells and heat sinks to the 12 volt source and all electrical connections; Finally, diagnostic tests for laboratory tests, consisting of the calculation of the wind speed to have the air flow value for initial laboratory tests, shall be carried out in stage three; as it is to determine the temperature in the Peltier cells on both sides, and to set the voltage and current ranges for the prototype to function effectively.

## 3. Results

Figure 2 shows the initial prototype designed and assembled in SolidWorks, Figure 2(a) show front view, Figure 2(b) show side view, including its location on the rider's helmet, considering that a portable system is proposed, ergonomic that generates a state of comfort in the pilot when driving and economical with the use of Peltier cells [13].



(a) (b)

**Figure 2.** Integrated cooling system prototype design for motorcycle helmet; (a) front view; (b) side view [12].

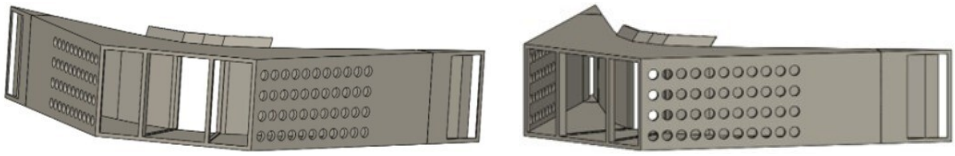
The whole process was based on the application of physical study that includes the behavior of air flow temperatures as it enters the hull, in the same way the heat transfer to enable Peltier cells to carry out what was originally intended, which is to be able to reduce the air temperature at the entrance of the hull, factors such as the generation of heat on the opposite side of the cell were also taken into account so as not to affect the air-conditioning system, However, there are sufficient grounds to be able to start carrying out laboratory tests leading to the final construction of the prototype taking into account all these variables mentioned above.

After adjustments to make it a system that can be used in the largest number of helmets on the market, changes were made to the prototype design to fulfill this function, the new design in the SolidWorks software can be seen in Figure 3, Figure 3(a) show front view, Figure 3(b) show side view, which will be the model for the construction of the test prototype and make small-scale laboratory tests before configuring final details as hot temperature variables produced by Peltier cells. The prototype test already built can be seen in Figure 4, Figure 4(a) show front view, Figure 4(b) show side view, was made of cardboard and was conditioned Peltier cells with their respective heat sinks and rubber to prevent leaks in the integrated air conditioning system.

Figure 5 shows an air flow simulation in the SolidWorks software that tells us that the output distribution for the environment such as the air entering the hull is uniform, Figure 5(a) show simulation start, Figure 5(b) show final simulation, which is convenient and points towards the efficiency of the prototype.

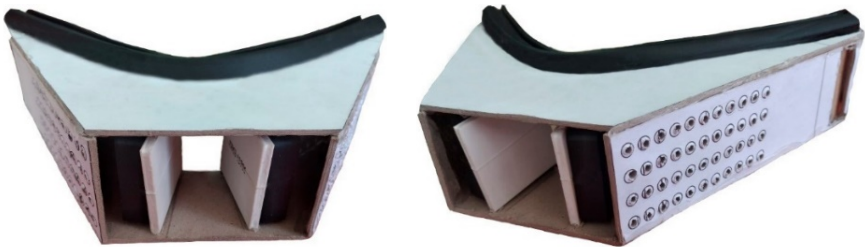
In Figure 6 the electrical connections to the 12-volt regulating source for the correct operation of the Peltier cells and heat sinks can be observed, finally, Figure 7 shows how the air flow test with a thermo-anemometer is performed to define important parameters such as the actual air flow simulation for subsequent laboratory tests, of which there are flow values according to the speed travelled on the motorcycle, these values can be seen in Table 1.

The actual air flow velocity values needed to simulate in the laboratory were obtained, this will allow the project to be completed to the extent that the prototype can be realized on a larger scale in which tests are carried out on motorcyclists and in this way to evaluate factors such as the satisfaction and the impact generated in the community to which this project is directed, taking into account their innovation, low price and ergonomics.



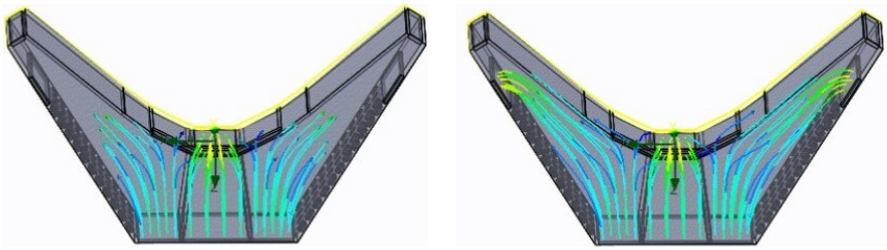
(a) (b)

**Figure 3.** Final design of the prototype integrated motorcycle helmet cooling system; (a) front view; (b) side view.



(a) (b)

**Figure 4.** Laboratory test prototype; (a) front view; (b) side view.



(a) (b)

**Figure 5.** Airflow simulation in SolidWorks software; (a) simulation start; (b) final simulation.

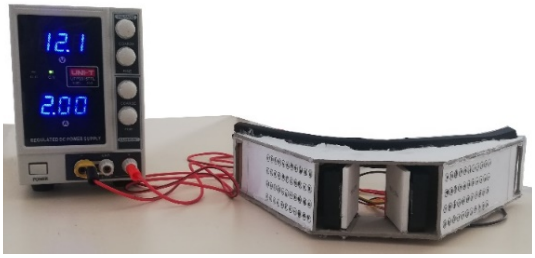



**Figure 6.** Electrical connections to the 12-volt control source prototype air conditioning test for motorcycle helmet.




**Figure 7.** Air flow test with a thermo-anemometer.

**Table 1.** Velocities collected with the thermo anemometer.

| Speed of the motorcycle (Km/h) | Speed anemometer (m/s) |
|---|---|
| 20 | 5.55 |
| 40 | 11.11 |
| 60 | 16.66 |
| 80 | 22.22 |

## 4. Conclusions

The prototype test of an integrated motorcycle helmet cooling system was produced, applying the physical principles corresponding to heat transfer and temperature variations in the air flows entering the helmet, allowing this device to feel thermal comfort when driving; this initiates the conduct of small-scale laboratory tests to establish and configure the system variables to be able to build the robust prototype that will be tested on a larger scale on motorcyclists where the efficiency and effectiveness of the system is verified integrated climate control for motorcycle helmet.

The manufactured system is portable and can be upgraded to 95% of the closed helmets that comply with the legal regulations in force at national level; it is also ergonomic and economical which makes it accessible to any stratum of the motorcycle population because of its low price, this eradicates in the implementation of Peltier cells as cooling technology in the air conditioning system.

Wind speed values were recorded to simulate in the laboratory, which will make it possible to carry out the initial small-scale tests and thus open the way to future modifications needed to achieve the final prototype that can be acquired by motorcyclists.

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