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Tesis

Half face mask with regulation thermal stability system for continuous air flow: Stabimask

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Half face mask with regulation thermal stability system for continuous air flow: Stabimask

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ABSTRACT

This article presents the design and prototyping of an electronic mask as personal protective equipment for the virus pandemic known as COVID − 19. Needs were identified such as: tightness and comfort. Requirements for use for long periods of time; this was considered for the design, also it has an adjustable ventilation system. The mask was simulated and validated with Solidworks Flow Simulation software, in addition a PID control model was implemented, thereby, it was shown that enough flow is generated to vary the temperature in a range of 20 to 37.2 ° C inside the mask. The design considers an outlet duct and an inlet duct with filters that prevent the entry of polluting particles, providing adequate protection. The prototype was made by 3D printing, And the thermal stability was achieved with the implementation of the temperature regulation system. The results obtained were validated, and they allow to future research to provide greater efficiency to masks.

CCS CONCEPTS

• : **Human-centered computing**; • **Interaction design**; • **Interaction design process and methods**; • **Interface design prototyping**;

KEYWORDS

3D printing, Electronic mask, Thermal stability, Regulation system

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1 INTRODUCTION

At the end of 2019 in China, the pandemic of the virus known as the SARS-CoV-2 coronavirus began, which was notified to the World Health Organization (WHO) on January 3, 2020 after 27 cases and zero deaths [1], in August 2021, there were more than 200 million cases in the world [2]. the transmission of the disease occurs through the drops that a person expels, these can reach a distance of 1 to 8 m depending on the force with which they are ejected, the temperature and environmental conditions [3], For this reason, the WHO determined different prevention measures such as the use of masks, social distancing and implementation of biosafety protocols and the mandatory quarantine, these measures helped to contain the increase in contagions [1]. if 80% of the population wears masks and social distancing is maintained the time until the extinction of the pandemic would be reduced, and the number of people affected would decrease [4]. Nevertheless, with the reactivation of some sectors of the economy in Latin America, countries such as: Peru, where the cases of contagion were increasing [5], generando que la situación sanitaria fuera preocupante por la falta de equipos de protección personal (EPP) y la falta de distanciamiento social [6, 7].

The main PPE are masks, according to the WHO, 89 million masks are needed per month [8], reason why they are different types. They are separated by categories such as respirators or filtering masks, KN95 being the most recommended, that creates a physical barrier against particles or microorganisms forming hermetic seals in contact with the skin and covering the oronasal structure avoiding the passage of 95% of particles approximately [9]. Also, there are fabric masks that provide less protection than KN95, but provide security during short and long-term activities [10]. Finally, you have the medical or surgical mask, that can protect people by being 1 to 2m from the person due to its 3 to 4 layers, the final layer being responsible for the absorption of moisture generated by the person's temperature [10]. However, the masks described are disposable, but due to their scarcity, Different methods are used for disinfection and to ensure the integrity of the filter. Being decontamination by vaporized hydrogen peroxide, ultraviolet germicidal irradiation and incubation with humid heat, the most efficient [11] but this generates the loss of properties of the material, in addition to being used for long periods of time.

Although each mask has different positive characteristics, negative ones prevail, such as: The lack of durability, the temperature that is generated due to the tightness, among others. Therefore, different types of masks were designed, such as: those that can be reusable, that avoid the humidity generated, since it causes physiological responses such as the appearance of acne due to the pressure of carbon dioxide [4]. Taking into account the basic characteristics of the recommended mask, due to the scarcity, the manufacture of masks using 3D printers was evaluated. Making use of additive manufacturing (AM) technology that changes the way of manufacturing, since it allows customizing according to what the user needs, obtaining complex designs and geometries, in addition to achieving mass production that reduces costs [12]. The first 3D printed mask approved by the FDA (Food and Drug Administration) is the Stopgap face mask, that was manufactured due to the lack of equipment, The mask fits securely around the nose and mouth, holding it to the ears, and has a removable filter to make your change [13]. The Stopgap doesn't solve the problem of the temperature generated by the user inside the mask. In Hong Kong the AC MASK was developed, which is a mask that uses an air conditioning system, which uses two fans, connected to a heat exchanger to then dissipate the air inside the mask [14], this system isn't automated, and can't be regulated, and since the user doesn't maintain a constant breath, and the breath varies according to the activity performed.

This is how we present in this article a design capable of satisfying the needs of current masks, and that allow the daily activities of medical personnel, public workers, engineers, etc. A ventilation system is used to regulate the temperature inside by means of a sensor. The sensor will identify the variation in temperature, caused by carrying out any type of activity, if the temperature inside increases this will activate the ventilation system. Since the main function is to regulate the temperature, the design is called Stabimask.

2 MATERIALS AND METHODS

The method used to develop the design of the face shield with thermal regulator is an adaptation of the German standard VDI2221, which consists of establishing a list of requirements in the process, to obtain an efficient product [15]. Also, the simulation and prototype were carried out to validate the result.

2.1 Current mask analysis

An analysis was carried out on the consequences caused by existing masks, and it was determined that it can be improved in each design process, to obtain a mask that meets the requirements of the users.

To determine the design specifications, the consequences of wearing PPE for long periods of time were taken into account, problems produced in the skin such as: rashes and irritability in the user, the pressure that it exerts on the face to maintain airtightness and that causes headaches [16, 17].

2.1.1 Problems produced in the skin. The lesions produced on the skin by wearing the masks for long periods of time, such as: allergic dermatitis, worsening cases of rosacea, cases of eczema, among other problems, caused by the contact of the mask with the skin, which produces friction [16], Another cause is the hyperhydration of the PPE, produced by sweating inside and the occlusion effect of the masks [18].

2.1.2 Headaches. The effects by the use of masks for long periods of time cause headaches, the HAPPE study (headaches associated with personal protective equipment) has defined, together with studies carried out later, as clinical characteristics of headache related to the use of PPE, lateralization, intensity, duration and other symptoms such as nausea and vomiting; Symptoms caused by mechanical factors due to the tightness of the masks, affecting oxygen levels, in addition to the retention of carbon dioxide (CO2) [19, 20].

2.1.3 Carbon dioxide retention. In the process of respiration, excess CO2 is exhaled from the body to maintain the balance between the acidic and basic reaction of the cells, due to the use of the mask for prolonged periods, CO2 is concentrated producing possible cases of respiratory acidosis, which could lead to sleep disorders, memory loss, personality loss and excessive dizziness during the day [21]. Se ha determinado que la producción de CO2 con la mascarilla varia en un intervalo de 2150 y 2875 ppm de acuerdo a la actividad realizada, la concentración sin el uso de mascarilla varia de entre 500 a 900 ppm [22].

2.2 Descripción de Stabimask

The design of the mask structure was made in Solidworks software, considering an anatomical structure, it has an inlet duct and another outlet duct (figure 2).

The inlet duct is located in the direction of the nose and mouth, and the outlet duct is located at the bottom of the mask as shown in the figure 2, both ducts made up of removable filters, which prevent the user from becoming infected or contagious, avoiding the recirculation of the expelled CO2.

The inlet duct has a ventilation system, that will allow a greater entrance of oxygen for the regulation of the temperature to the interior, at the same time avoiding the accumulation of humidity. As previously mentioned, the temperature varies inside depending on the activity carried out. The ventilation system consists of a removable cover for the filter, the fan and the power source, as shown in the figure 1

2.2.1 Ventilation system. The adjustable ventilation system has a temperature sensor that provides information to compensate for the lack of air and oxygen, avoiding the discomfort of wearing the mask for long periods of time.

According to the simulation carried out, the path of the air generated by the fan goes directly to the user's nostrils, and then be expelled through the outlet duct as shown in the figure 3

The speed with which the air flow enters is inversely proportional to the temperature, because it will be regulated according to the temperature provided by the sensor.

2.2.2 Temperature regulation system. To be able to reach a suitable temperature inside the mask, it was implemented a continuous regulation system (figure 4).

The system includes a PID controller (Proportional-Integral-Derivative), for temperature regulation, this type of control is used

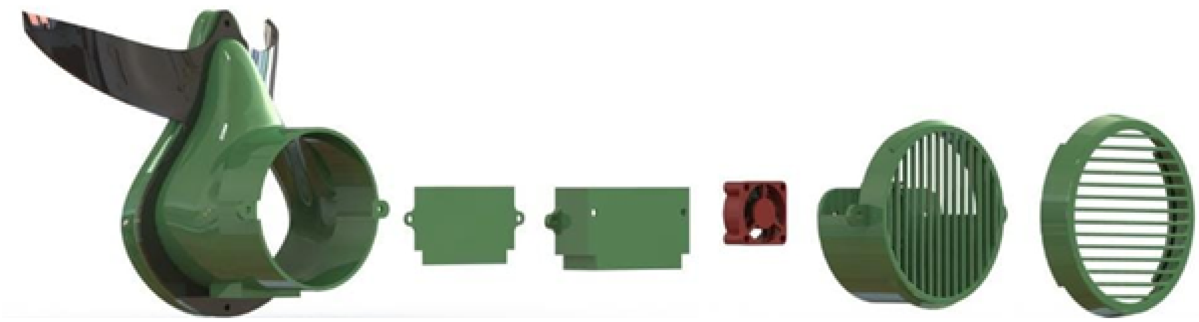

Figure 1: Stabimask Exploded View.

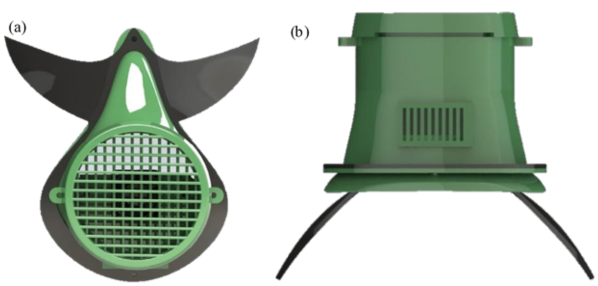

Figure 2: Mask Ducts. (a) Inlet duct, (b) outlet duct.

Figure 3: Path of air entering the interior of Stabimask.

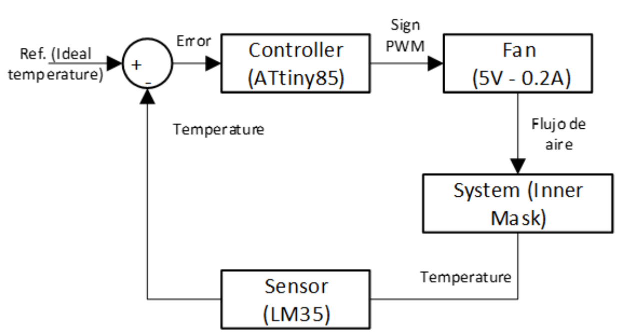

Figure 4: Diagrama de control - lazo cerrado

because the plant model can't be extracted by an analytical design method. To perform a response test, values of the fan speed and the temperature in the mask were taken, getting a response relationship (figure 5).

The figure 5 allows to determine a base speed for the fan, value to be used as the "bias" or constant parameter, starting from this value, the PID controller will correct the temperature variations inside the mask. It starts with a speed of 304.23 rad / s for a temperature ratio of 35.5 ° C. Starting from this value, the PID controller will regulate the fan speed so that the temperature remains at 35.5 ° C.

The PID control model, in its discrete form, is expressed according to equation 1.

$$U = K_p \cdot e_k + K_i \cdot \sum_{k=0}^{n} e_k \cdot \Delta t + K_d \cdot \frac{\Delta e}{\Delta t} + bias \qquad (1)$$

The discrete model of the PID controller was programmed into a controller, that will receive information from the sensor and drive the fan.

3 RESULTS AND DISCUSSION

Based on the simulations carried out in the Solidworks software, the variation of the temperature inside the Stabimask was obtained (figure 6).

As can be seen in figure 6, by increasing the temperature inside the mask, and this in a range of 20 ° C to 36.5 ° C, the controller will activate the ventilation system, that will regulate the speed according to the ideal temperature 35.5 ° C. Finally stabilizing the temperature inside the mask.

In order to validate the results of the simulations carried out, a prototype was manufactured with 3D printing, based on TPU and PLA (deposition printing materials), that molds from the beginning of the nose to surround the chin.

The finished and prototyped design can be seen in figure 7. Consider protecting the main areas of contagion such as the eyes, nose and mouth. It has a frame to place an eye protector, It also has a switch that will turn on the thermal regulation system.

It is considered that in future designs the intake duct can be reduced to improve the aesthetics of the design.

Inside the Stabimask is the electronic installation, which will fulfill the purpose of achieving the thermal regulation inside (figure 8).

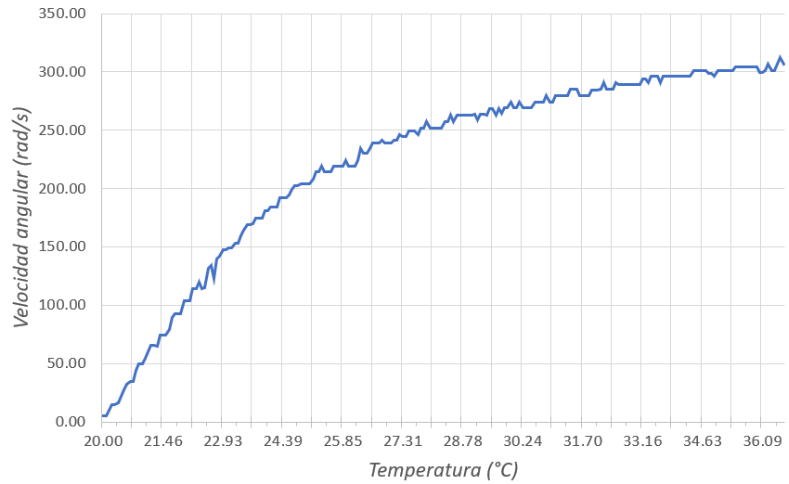

Figure 5: Datos Temperatura vs. Velocidad.

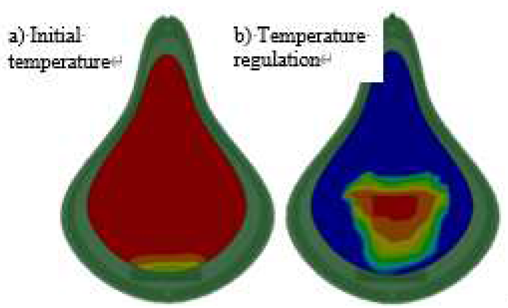

Figure 6: Phases of temperature change inside Stabimask [a) Maximum initial temperature at 37.2° C b) Temperature in regulation phase at 35.5° C]

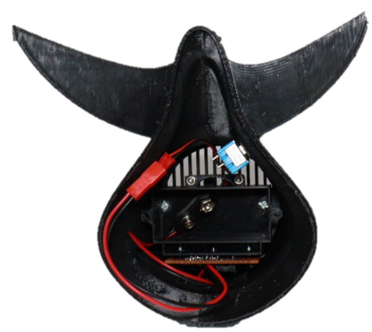

Figure 8: Interior de prototipo de Ther-stabimask impresa en 3D

Figure 7: Stabimask prototype printed in 3D.

4 CONCLUSIONS

It was concluded in the test with the prototype made with 3D printing, that the temperature manages to maintain a stability around 35.5 ° C. Fulfilling the objective of achieving thermal stability in the mask.

The prototype considers an anatomical structure that can accommodate the user's face, generating the required tightness to avoid possible infections in this case the research focuses on the thermal stability inside the mask, but to get better comfort, studies can be performed on the weight and size of the Stabimask, These two variables are key to achieving an ideal product in subsequent versions.

The Stabimask considers easy assembly and disassembly for proper cleaning of parts, also, the temperature regulation system has basic electronic components that can be easily acquired.

For better applicability in future works, it is necessary to characterize the reference point of the ideal temperature, according to: age, gender, working conditions, etc. In order to identify the ideal reference value for the mentioned groups.

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