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Individual protection mask with improved filtering properties: 3D printed solution guided by design materials selection

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ABSTRACT

The COVID-19 pandemic has mobilized most countries to investigate multiple virus mitigation interventions, the face protection masks are among the main ones. Filtration and breathability are important factors in the applied materials choice. Design plays a fundamental innovative role in developing new products and materials that meet this emergency demand. 3D printing allows adjustments from an industrial production to answer an increasingly specific demand. This process allows the printing of a poly (lactic acid) (PLA) filter mesh with Tourmaline (TM) for a mask made in a triple layer with cotton fabric. One of the properties of TM is the negative ions emission, which allows capturing particles dispersed in the air. PLA is a bio-based and biodegradable polymer, with the corn as it's most effective source. It makes it a good choice for the project, aiming to be aligned to environmental issues. In addition, the cotton application and the modeling directed to the domestic sewing use make the project accessible to the population, adaptied to digital and personal manufacturing and aligned to the Maker Movement.

Keywords: 3D Printing, COVID-19, Design & Materials.

INTRODUCTION

COVID-19 emerged as a cluster of pneumonia cases in Wuhan, a city in China's Hubei Province. It was, thus, named by the World Health Organization (WHO) in February 2020, meaning corona virus disease 2019 (WHO, 2020). The 21st century was marked by epidemics such as: SARS Cov in 2002 and MERS-CoV in 2012, both caused by the coronavirus; the Ebola epidemics in Africa; and the avian influenza (H5N1) epidemic. They were controlled in more favorable time and space. But, although H1N1 influenza in 2009 caused a devastating death rate (Dawood et al., 2012), COVID-19 will cause more than 2 million deaths (Walker et al., 2020). COVID-19, also caused by a coronavirus identified as SARS-CoV2, is perhaps one of the greatest global health challenges of this century (Werneck & Carvalho, 2020).

Strategic virus mitigation procedures have been taken. Denominated as non-pharmacological interventions (INF), the strategies are designed to reduce the population contact levels and thus reduce viral transmission. When singly applied, the strategies present lower impact on virus transmission, requiring a combination of multiple interventions (Ferguson et al., 2020). Some of them are: social distance for the entire population, preventing agglomerations, closing schools and universities, and the use of facial masks by the population, known as an important virus barrier method (Brazilian Ministry of Health, 2020; Ferguson et al., 2020).

Initially, was detected that the transmission occurred by respiratory droplets released in cough, speech or sneeze (Mcintosh et al., 2020). Later was also considered the transmission by the so-called aerosolized or aerosolized cores, that are capable of remaining suspended in the air for long periods of time (WHO, 2020). Considering that, the Brazilian Ministry of Health (2020) determined the use of cloth masks by the population. According to Technical Standard 04/2020 GMIMS/GGTES/ANVISA, this measure, when combined to other hygiene care, minimizes the spread of droplets while still asymptomatic (ANVISA, 2020).

One of the related concerns about that solution is the filtering effectiveness, which have been stimulating materials researches aiming such property. Materials with air filtration purpose are already applied in interface to textile materials for several sectors such as air conditioning equipment or vacuum cleaners (Mao et al., 2019; Liu *et al.,* 2020).

In contexts where solutions require a broader perspective, a multidisciplinary team formation is necessary. For this moment, when functional, emotional and aesthetic issues are interconnected in the construction of solutions more easily absorbed by the population, the different knowledge areas collaborative work increases the chances of success of the adopted solution. Design has increasingly been recognized as the element responsible for the development of solutions that promote quality of life improvement linking innovation, technology, research, business and users (WDO, 2020).

In a multidisciplinary team, as the case of this project, the designer takes the responsibility of human factors related to the materials selection. The professions heart is to understanding people's needs, turning it into opportunities to co-create solutions. As important as the technical requirements, the usability requirements must be considered, improving the users experience in interface to the product. The weighted materials selection, considering different dimensions of requirements, makes the user receive the sensations and interpretations predetermined in the project (WDO, 2020; Karana *et al.,* 2016).

Users and objects interaction is composed by different levels of experience, being the second defined by Moles (1981) as the mediator between man and the world. One line of reasoning, involves the distinction between practical, aesthetical and symbolic functions of a product, with possibility of each artifact involve different proportions of each function (Löbach, 2001). The same distinction can be applied to materials, with the practical function related to the cognitive dimension, involving the materials characteristics; the aesthetic function is related to the affective dimension, involving the emotions and pleasures promoted by the material; and the symbolic function is related to the conative dimension, involving the decisions and attitudes taken under the material's influence.

For this solution creation were construed connections between materials engineering, understanding materials properties and potentials, and the design, understanding users needs under ergonomic, functional, production and emotional perspective. Based on this comprehension, this article presents, as a main focus, a protective mask prototype development project, which acts against the COVID-19 causer virus spread. The project consists of a fabric mask with three layers. The intermediate one presents filter properties, due its composition of polymeric material containing tourmaline particles as a filtering and antibacterial material. The research is divided into: phase of polymeric materials laboratory

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experiments, which started two years ago; and the prototype development phase, in which users tests will require one year to complete. Currently, the research is in the laboratory testing phase, focused on the polymeric material used for the filtering grid development. The tests seek to prove the air filtration activity effectiveness, both of the textile material and of the tourmaline.

1. LITERATURE REVIEW

1.1. Tourmaline filtering properties

Taking into account the masks use recommendation as protection against COVID-19, one of the concerns is the filtering effectiveness (OPAS, 2020). The demand for Personal Protective Equipment (PPE) encourages researches into materials with air filtration properties.

One of the investigated materials is the Tourmaline (TM), a kind of natural mineral, which can absorb dust and hazardous substances to purify air, due its self-polarization property, releasing negative ions, besides its infrared radiation (Mao et al., 2019, LIU *et al*., 2020). Recent researches in this area, as the Wang et al. (2020) example, reported the addition of graphene to enhance the negative-ion release performance of TM. As stated by them, 0.5% of graphene, in relation to tourmaline mass, can improve the air purification effect of tourmaline by over 11.9%, and this will produce vital environmental and social influence.

On the other hand, Mao et al. (2017) investigated the filtering effect on fine particle of warp-knitted mesh fabrics treated with five different concentrations of TM. According to them, the TM concentration should be enough to generate sufficient electrostatic interaction on the fabrics to absorb fine particles. They concluded that the filter mesh fabrics with 30% concentration of tourmaline (m/v) and the structure of one by two insertion had the optimum filtration efficiency.

Results indicate that up to an ideal level, the increase of tourmaline percentage added to the fabric led to a voltage rise and a consequent greater particle attraction, reaching a filtering efficiency of 64.8%, against 30.2% efficiency without its insertion (Mao *et al.,* 2019). One of the strategies to promote the expansion of the particle retention capacity in a filter is the fibers static loading. To be considered a good filter, it must be able to preserve, for as long as possible, high charge levels (Yu *et al*., 2015).

1.2. Design, digital manufacturing and polymeric materials

Design performances its role of gathering different fields so that the product meets the user's needs. Science, technology and design are different and autonomous fields with their contexts and ways of acting in the world. Design has considerable potential when joined to scientific and technological fields in innovation processes. Bonsiepe (2013) considers that when a design project is related to science it should not be interpreted as a postulate by a scientific design or with the purpose of transforming design into science. When the theme requires it, the design must resort to scientific knowledge. Design isolated performance can fall into the aesthetic formalism (Bonsiepe, 1997), not involving the practical and symbolic functions into the configuration of a product. The configuration can be understood as a process of materializing an idea, within a broader, general concept. Providing the products with aesthetic functions meets the user's multisensory perception, since the senses are globally activated, and one-dimensional perception is rarely possible. On the other hand, products can perform suitable practical functions that satisfy physical needs, fulfill the fundamental conditions for man's survival and maintain his physical health (Lobach, 2001). Symbolic functions serve as a backdrop for products with a greater practical function, requiring an interpretation of certain socio-cultural contexts (Bürdek, 2005).

While the craftsman used to create objects with a main function, subordinating the other functions to this central one, industrial civilization and series production conceded the function of organizing the object structure to the designer. Not only the general function is introduced, but also the visual aspect, the practicality and durability (Moles, 1981). The materials applied to products play an important role in their functions, which become more defined through user's perception when in contact with a multisensory experience (Ashby, Johnson, Marques, 2011). Bürdek (2005) considers that materials, when added to their visual, tactile and auditory expression, form the solid basis of the designer's work. It is very important to balance the object's technical and semantic aspects. This polarity between the material and the symbolic aspects is a characteristic of products or artifacts according to Riccini (2005), as they are instruments and bearers of values and meanings. It is up to the designer this polarity reconciliation, projecting products as a result from the socio-technical process interaction.

Among the various materials used throughout human history and design, plastics were the materials chosen by many designers in the 20th century due to the great versatility of production processes (Fiell & Fiell, 2009). They went through innovations demanded by the First Industrial Revolution, and later by the Second Industrial Revolution, including incorporation into the chemical industries (Koplos & Metcalf, 2010).

Transformations in materials and production processes availability have, throughout history, guided changes in different areas of human life, leading to longevity, quality of life, population concentrations and demographic growth increased (Anderson, 2012). As result of those transformations was also possible to see negative environment impacts, with the increase of solid residues, in most part composed by plastics.

Those factors have promoted changes in people behavior, mainly in relation to consumption. Movements like Consciousness Consume became more intense over the recent years, with people thinking deeply about products origin, the materials applied, how they were produced, and the social, economical and environmental impacts promoted (Akatu, 2020). Another response to mass production was the purpose of people to being part of the products concept or production processes. The Do It Yourself culture became more popular, culminating in the Maker Movement, supported by Digital Manufacturing technology and the Open Design culture, favoring sharing (Anderson, 2012).

Digital fabrication consists of using digital information from a project to produce a physical object by computer-controlled processes. Its technologies are an alternative to serial production, allowing local and customized manufacturing. Its application allows, in some cases, the adjustment of industrial production system to meet an increasingly specific and variable demand (Barros & Silveira, 2015). The equipment is divided in two technology systems: materials addition or subtraction, and is currently understood as rapid prototyping technologies.

One of the most known additive technologies is the Fused Deposition Modeling (FDM) 3D printing, for its affordable price and materials availability (Volpato *et al.,* 2017).

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One of the most used material in FDM 3Dprinting is the poly (lactic acid) (PLA), for its translucency and wide range of available colors, as well as being bio-based and enabling a greater detail finishing (Wijk & Wijk 2015). Besides those factors, for this research, the material was one of the chosen ones because of its biodegradability, reducing the negative impacts of its discard, and its biocompatibility to the human body (Nampoothiri *et al.,* 2010).

PLA presents a considerable lower biodegradability rates when compared to polycaprolactone (PCL), which also offers greater flexibility (Niaounakis, 2015). PCL became commercially available following efforts to identify synthetic polymers that could be degraded by microorganisms. PCL is a hydrophobic, semi-crystalline polymer; its crystallinity tends to decrease with increasing molecular weight (Woodruff & Hutmacher, 2010). Those properties motivated some tests with PCL for this research.

Additives are substances inserted to improve or modify polymers properties (Callister & William, 2012). The present research contemplates the polyethylene glycol (PEG) use as PLA polymeric plasticizer due its good miscibility (LI *et al.*, 2015). Nanocomposites are also incorporated into the fibers by masterbatch method, a mixture of additives dispersed in a chosen polymer compatible medium (Shen *et al.,* 2015). This research involves the TM use as PLA additive to produce a filament used in the protection mask filtering mesh 3D printing.

2. DEVELOPMENT

2.1. Materials

The following materials were used in this research: Natural poly (lactic acid) (PLA) filament; Polyethylene glycol (PEG 6,000) (cod. 812550) ; Micronized white TM ; 650 TN Unicotton Fabric (frame: canvas, plain, mesh; composition: 100% CO; weight: 170.0g / m^2; 4.95oz; width: 1.70m; 67").

2.2. Product project: individual face mask with improved filtration capability

To the mask project, were collected information about standards towards the product, ergonomic information and usability tests with the involved team. Were, then, reunited the main requirements that should be considered in the material and the product development.

This research follows ABNT PR 1002: 2020 standards (AFNOR, 2020) for designing a fabric mask with respiratory filter. The standard recommends the use of fabrics composed by 100% cotton and weight from 90 to 210 g/m^2, or synthetic fabrics with 4 to 10% elastane. The materials choice influences the mask's filtration and breathability.

The acceptable breathability for a surgical mask is less than 49 Pa/cm^2, while for non-surgical masks, an acceptable pressure difference, across the entire mask, is less than 100 Pa/cm^2. The filtering of cloth and mask fabrics varies between 0.7% and 60% (AFNOR, 2020).

According to the WHO (2020), the masks must have three layers: an inner layer of hydrophilic material such as cotton; a hydrophobic intermediate filtering layer of non-woven synthetic material or polypropylene; and an outer layer in hydrophobic material such as polyester, polypropylene (OPAS, 2020).

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In relation to the dimensions, was defined that the masks must meet Brazilian population average morphological measures, tanking as reference the COVID-19 targeted population, following anthropometric data from ISO/TS 16976-2: 2015. The technical specifications with masks modeling followed the technical sheet ET-010 (SENAI, 2020).

Based on the data collected, requirements were defined in three main groups: technical, functional and aesthetic. Besides the filtering capability, the mask must be easy to use, transmit to the user the message of security and of quality, as well as easily adapting to what the user is already used to, not representing a point of concern. The requirements are shown at Table 1.

Table 1. Mask project requirements

Technical Requirements	Functional Requirements	Aesthetical Requirements
Hydrophobic Layer	Adaptation do body curves	Visually neutral, adapting to different users
Filtering Layer	Breathability	Sense of security
Absorbent Layer	Anthropometrically ergonomic	Sense of quality
Adapted fabric composition	Soft touch	
	Foldable, for easily keeping	

2.3. 3D printing filaments production

The commercial PLA filament was granulated with granulator , and later manually mixed with the plasticizer PEG 6.000 in different average molar masses and contents. They passed through an extruder at 178°C of temperature, and 3.0 rpm of extrusion speed. The filament samples generated were: PLA/PEG (1), with 1% of PEG; PLA/PEG (5), with 5% of PEG; PLA/PEG (10), with 10% of PEG. Part of the filaments were pelleted and hot pressed which underwent mechanical tensile tests .

Compared to pure PLA, the sample PLA/PEG (1) did not show significant differences in the tensile strength property. But there was a property decrease while the PEG proportion increased to 5 and 10%. However, the PLA/PEG (10) sample showed a decrease in elongation at break. Li et al. (2015) attributed this to the phase separation between PEG and PLA caused by the exceeded solubility limit of PEG in the PLA. The values of the mechanical tensile properties found in the literature for PLA/PEG 6,000 mixtures (5%) were: 40.5 MPa for tensile strength, 557 MPa for Young's modulus and 8.1%, for elongation at break (Liu et al, 2017). According to the results, the PLA/PEG (5) sample was chosen as the ideal PLA/PEG ratio for having better mechanical properties.

Pure PLA and the three filament samples also underwent tests to evaluate the ideal 3D printing temperature. On a FDM printer the temperature tower test was carried. This test allows the evaluation of the best nozzle and bed temperatures to work with each filament based on the pieces final finish observation. It is also possible to determine the best work temperature for each material, since there are temperature variations along the piece (3D LAB, 2020).

The files were obtained from a 3D models sharing community . Figure 1 brings the printed towers picture, using as material the pure PLA filament and those with different PEG contents, under the temperature ranging from 185 to 220°C with a 5°C variation each 1 cm of printed height.

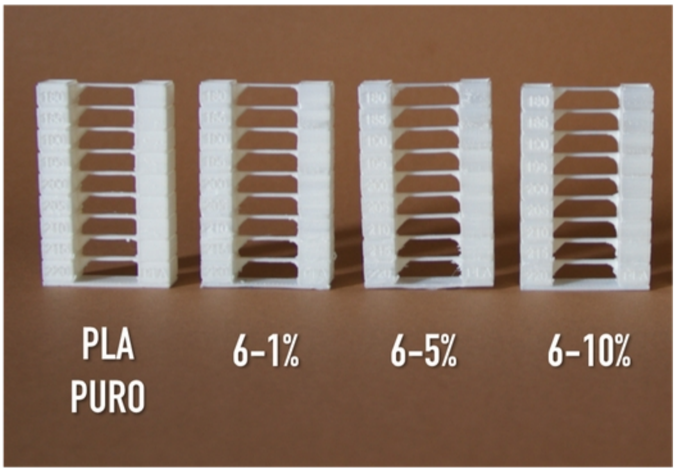

Figure 1. 3D printed temperature towers with four filament samples.

The printed towers were digitalized and the images were analyzed using the Image J. software. The hollow area (h area) was measured (Figure 2a) and also the X distance, related to the maximum bridge width extremities (Figure 2b).

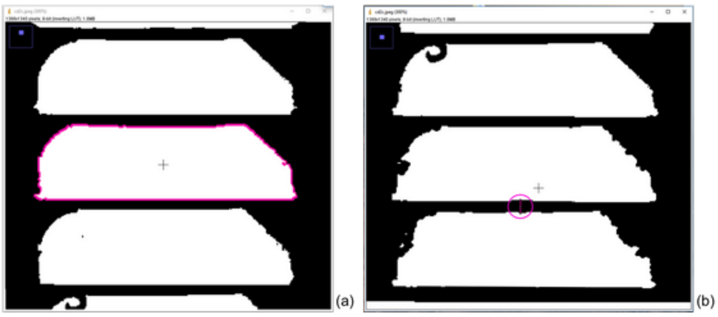

Figure 2. area measurement: (a) hollow area; (b) distance X.

The smaller the h area, more polymer residues from the printing can be seen into the hollow area, meaning that the better work temperature is the one with results pointing to the largest h area. The results showed that 185°C was the worst printing temperature for three of the samples because it presented the smaller h area. On the other hand, the distance X measures the bridge's warping. The shorter the distance X, the less it warped and the better the printing temperature is. The temperature of 220°C had the shortest distance X for three of the samples, and thus, was the one chosen for mesh printing.

After choosing the PEG content and the ideal temperature for 3D printing, the TM powder was added to the PLA/PEG (5) sample. To produce the TM loaded filament, the micronized TM was firstly mixed with PEG using a 1: 1 (w/w) ratio. The mixture was melted and oven-dried at 40°C for 24 h. Then it was grounded and sieved trough a Mesh 100 to obtain the powder masterbatch (MB). Filaments were thereafter produced following the procedure previously described for PLA/PEG.

2.4. Filter mesh 3D printing

Geometric models were printed as a test for the filter mesh prototype. Geometric patterns were developed in Solidworks 2013, and available models were used. The printing parameters were: 220°C nozzle temperature, 0.2 mm layer thickness, and 70°C bed temperature.

The geometric models were generated by the concept of Representative Volume Element (RVE), using the smallest possible repetitive volumetric element (Lomov et al., 2001). Geometric shapes with connection spaces offer greater mesh flexibility allowing better adaptation to the user's face. Different geometric patterns were printed (Figure 3 a) and show the structure flexibility (Figure 3 b).

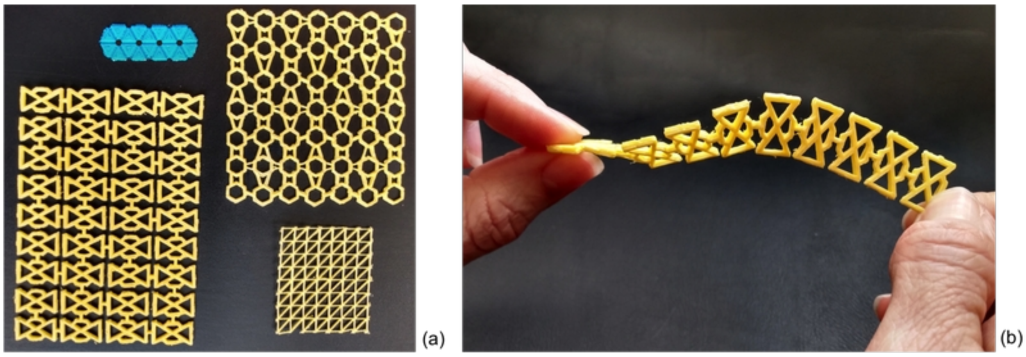

Figure 3. 3D printing: (a) geometric patterns (b) structure flexibility.

Considering the PLA mesh low flexibility, added to lower comparative biodegradability rates, impressions were also made with PCL. PCL is widely used in medical applications due to its biocompatible property, besides of being approved by U.S. Food and Drug Administration (FDA) (Vijayavenkataraman et al., 2019). The polymer presents mechanical properties compatible to diverse applications, being the most highlighted ones it's low melting temperature, non-toxic nature, flexibility and softness (Fox et al., 2020). Furthermore, it can be easily processed by any polymer fabrication technology (Arbade et al., 2020).

Some prototypes of filtering meshes were printed with PCL filament containing tourmaline, showing dimensional stability (Figure 4 (a) and (c), and resistance to folding avoiding breaks of the mesh (Figure 4 (b)).

Figure 4. filter printed in PLA / PCL: (a): dimensional stability (b) flexibility (c) dimensional stability.

2.5.Final project development: selected strategies

After the results obtained during the mesh filtering production by 3D printing, was possible to decide what strategies of manufacturing, applied materials and distribution would be available and adapted to the mask project. Towards the materials selection in product projects, Ashby (2012) says the good project works, but the excellent project brings pleasure. Table 2 brings the relation between market needs and current standards; the solutions that the project should consider to meet the needs; and the strategies adopted from the practical point of view for its solution.

Table 2: Project strategies related to market needs and product requirements

Market needs	Project requirement	Adopted solution
Adapt to the WHO recommendation	Hydrophobic Layer	It was preferred a environmentally responsible solution besides the fabric affordance
	Filtering Layer	Insertion of a separated filter
	Absorbent Layer	100% cotton fabric
Good filtering property	Trapping particles dispersed in the air	Use of tourmaline as an additive in the filter, because of the self-polarization and release of negative ions
	Physical barrier promoted by the fabric weight	The three layer mask improves the filtration
Good breathability	Materials that balance the distance between fibers and the particles retention	The cotton presented equilibrated properties between breathability and filtering. The fact of being natural fibers favors the filtering
Affordable to users over the world	Locally producible	3D printed filtering solution – open source file to print
		Affordable modeling to domestically production
		Accessible materials: tourmaline, cotton fabric, PLA and PCL
	Low cost solution	National materials and Accessible productive process as domestic sewing machine and FDM 3D printing
Lower environmental negative impact	Separate part substitution	Removable filter
	Low discard impact	Bio-based and biodegradable materials as PCL, PLA an cotton fabric
	Use of wasted materials	Cotton fabric from reused clothes pieces, tourmaline as waste of jewelry sector, and PCL and PLA as waste of 3D printing process
Ergonomically anthropometric adapted	Alignment to ISO/TS 16976-2: 2015 statement	The mask modeling was based on the statement, being anthropometric aligned to the population's faces measures
	Easily adaptable to face curves	PCL shows grater flexibility to geometrically adapt
		Adopted geometry to the filter mesh favors the flexibility
		Natural fibers present in cotton fabric makes it more soft and foldable
	Comfort in contact with the skin	Cotton fabric and PCL soft touch
		PCL and PLA biocompatibility
Visually neutral	Form	Modeling in rectangular form
	Color	Cotton fabric presents a great available colors range, adapting to different users
Easily adapt to what users are already familiarized	Mask models which people have already seen in other contexts, such as medical, dental, cosmetics, and others	Common modeling mask
Biosecurity	Side margin sealing	Adapted to the ET-010 SENAI statement
Sterilization	Virus inactivation high temperatures	Cotton fabric allows contact with high temperatures
	Easily washing	Cotton fabric allows chemical products contact in the washing process
	Allow separate parts washing	Easy filter extraction and replacement from the mask
Easily transport	Allow the mask fold with no damages	PCL and cotton fabric are foldable materials

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Taking into account the adopted solutions, the mask was produced on a domestically sewing machine. Figure 5 shows an illustration of the final product (mask) with three layers, being: an inner and outer layer in the same fabric (100% cotton); an intermediate layer in the form of a PLA/PEG (TM) filtering mesh. The inner layer has an 6.0 cm (approximate) opening on the back, as shown in figure 5. The opening function is to allow the filtering mesh insertion.

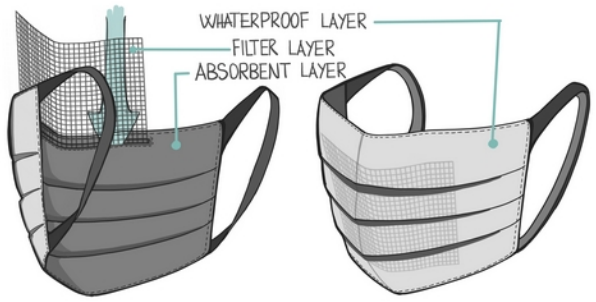

Figure 5. Mask illustration with filter (a): back (b) front

The fabric mask prototype applies to the user's routine activities, not indicated for hospital or dental use. It was based on the technical specification ET-010 (SENAI, 2020), used for making in industrial or semi-industrial machinery. The measures of the finished mask are: 20.0 cm wide and 12.0 cm high. The mask body has three central folds of 1.0 cm each. A side seam holds the elastic of 5.0 mm wide and 20.0 cm long on each side of the mask. Figure 6 shows the mask technical drawing, with the reference measurements for the production.

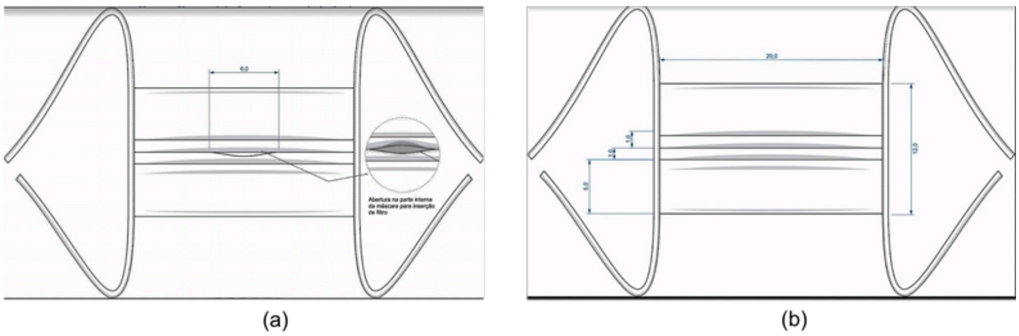

Figure 6. Mask's blueprint (a): front (b) back (SENAI, 2020)

WHO recommendations (2020) that masks should have three layers were also followed, with an intermediate as a filter. The materials choice is based on the criteria of filtration efficiency (FE) or filtration, breathability, number and combination of used materials, format, coating and maintenance according to OPAS (2020) guidelines.

The project was made using Illustrator software and the fabric was cut using ECNC laser cutting equipment for better edge sealing and better finishing.

The mesh filtering capacity will be evaluated in future works, while the textile materials has already passed through tests that evaluated the particles capture. Corona virus particles are

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spheres with approximately 0.125 microns (125 nm) diameters, with 0.06 microns smallest particles and 0.14 microns largest (Zhu, 2020).

The tests evaluated the effectiveness of mask materials in capturing 1.0 micron and 0.3 micron particles. They offered reasonable estimates of each material effectiveness in capturing 0.1 micron particles – the corona virus size when it is not in droplets form (Robertson, 2020).

The inner and outer layers fabrics choice was based on research data about breathability and filtering of homemade masks materials (Robertson, 2020). The materials with the greatest filtering power were those with the least breathability. The 100% cotton T-shirt achieved breathability close to the N95 mask and filtration of only 3.4% of the 0.3 micron particles. But when they used a double layer of the shirt, the filtration increased to 15%. This shows that the weight and thickness of the material are important factors for facial masks and justifies this research choice for of 100% cotton fabrics with 170.0g / m^2 and 4.95oz for both the inner and outer mask layer.

The cotton fabric choice is due to the study in which is proofed that natural fibers generally filter better than synthetic fibers. In addition, synthetic fibers tend to be smooth and uniform, while natural fibers are rougher and more irregular. The natural fibers irregularity is likely to make them better at capturing small particles (Robertson, 2020).

3. CONCLUSIONS

In front of an emergency situation, such as the one faced in recent times with COVID-19, several areas are committed to proposing quick solutions to issues related to individual protection and contamination risk reducing. Design, however, due to its nature linked to the human behavior understanding and needs, has a greater capacity to develop solutions that go beyond. The proposals connected to the design activity take into account, in addition to the practical functional aspects, the emotional dimension and the environmental, social, cultural and economic impacts.

In the proposal developed in this research, design worked in all of the project stages, bringing its systemic look. The project went through the survey of needs, the understanding of the current topic statements, in contextual research, reaching a grouping of requirements that led the material and the product development. The proposed product exemplifies the potential of the designer's performance in a multidisciplinary team, as an element responsible for the connection between materials technical information, their production processes, and the subjective aspects of human behavior and needs. The fact that the demand is still very current, makes still necessary the proposal validation, being submitted to steps for further development and possible adjustments to its solutions.

The research has been successful during its development, the mask showed few limitations in terms of use, as it follows ergonomics and materials adequacy standards. The research boundaries may consist of investigating the mask effectiveness as a protection against the coronavirus. That will require a study in interface with volunteer users, preferably those professionals with greater exposure to the coronavirus. As the sampling, another limitation may also be the specialized laboratories request, in order to analyze the masks, demanding partnerships and support from other institutions and universities.

The project has large application in Brazil, once it is the world's largest tourmaline producer. The state of Minas Gerais, where the research has been conducted, stands out as the state of greatest production in the country due the region of Eastern Pegmatitic Province of Minas Gerais. However, the research applies to other countries that are also tourmaline producers, such as in Africa: Nigeria, Mozambique, Zambia, Madagascar, Namibia, Tanzania and Kenya; in Asia: Afghanistan and Sri Lanka; in North America: USA (Pala and Mesa Grande, both in California) (CORNEJO, BARTORELI, 2009).

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