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Self-Designed 3-D Printed Mask to Tackle COVID-19

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Abstract- In the current scenario of the pandemic of Covid-19, the mask is becoming an essential part of the human body. For this, we have designed a 3D mask on professional designing software called Solid Works, which will be 3D printed using polylactic acid (PLA) material, which is very light in weight, durable and cheap material. We have designed it in 3 different sizes–small, medium, and large according to the face type; everyone can select the best suitable size for themselves. A gap is significantly provided at the very front of the mask in which one inhale valve and two exhale valves will be attached to the mask so that no one will feel suffocated while wearing this mask and the respiration process can take place smoothly. Then CFD (Computational Fluid Dynamic) analysis of the flow of air passing through the designed mask is done using the simulation software ANSYS to check the ease in breathing while wearing this mask. After 3D printing, this mask on the Stratasys Fortus 400mc 3-D Printing System at Dayalbagh Educational Institute, Agra, India. The inner lining will be done by the silicon fiber padding, which will provide the soft and firm grip of the mask on the face as well as increase the protection against the virus. Then straps will be attached in the provided hooks in the design of the mask. The design of the mask can also be edited according to the face type of the person before 3D printing it to provide a high level of comfort to the wearer.

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I. Introduction

Corona virus is taking hold across the globe; we see countries implementing social distancing measures, travel restrictions, and policies like work from home. Even the more developed countries are also seeing their healthcare systems overloaded by COVID-19.

According to the World Health Organization (WHO), people can transmit the virus to others while showing no signs or symptoms of COVID-19. A mathematical model from a 2020 study supports this, suggesting that 40–80% of transmission stems from those showing no symptoms [1].

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Types of face mask people are currently using:

- Surgical mask
- Cloth face coverings
- Respirators, such as FFP2, N95, or the equivalent

We are making a 3-D printed mask for better protection with advanced technological valves to make sure the proper breathing process.

3-D printing is an additive manufacturing process by which three-dimensional solid objects are made by industries using a digital file containing the 3-D design details [2]. The creation of 3-D printed objects takes place in an additive manner, i.e., by lying down of material in successive layers. Each layer is a cross-section of the 3-D printed object. 3-D printing is used by people to build complex shapes using less material as compared to traditional manufacturing.

Nowadays, 3-D printing is becoming popular in aviation industries. 3-D printing is used for printing different parts of aircraft engines. Earlier individual components were constructed and had to be welded together by welding, but now, by use of many parts, 3-D printing is consolidated to a single component which is lighter in weight, uses lesser material, and, most importantly, it is about four-five times stronger. 3-D printing reduces the cost of labor as well as material and improves quality and thus, overall benefits the aviation industries [3]. GE Aviation is a company that has already started using 3-D printers for better efficiency, economical products that are lighter and stronger, and build using automated machinery with higher accuracy [4].

3-D printing starts with designing a 3-D model, i.e., Computer-aided design (CAD) model, a 3-D model, can be created or can be downloaded using the online 3-D repositories. Therefore 3-D scanners, apps, coding, or 3-D modeling software may be used to create designs.

PLA (poly lactic acid) is a green material and an alternative to petrochemical commodity plastics. Its mechanical characteristics are its superior tensile and flexural strength. PLA (poly lactic acid) is very light, with a density of 1.210 - 1.420 g-cm-3. PLA can be used in areas of high temperature without wear and tear as it has a high melting point of 423 to 433 K[5]. It is insoluble in water, making it useful during rains and humid weather conditions.

II. Literature Review

In previous research papers, there were various findings of masks, their usages, their comfort, their reusability, and the material appropriate for filtering out the germs. The researches show that 80% of the germ transmission can be lessened the masks are worn properly by the people The comment is stated in some of the findings of Professor M.Fasher, D.Dwyer, and N.Ovdin along with few other prominent medical scientists[6]. In findings with different experiments by Van der Sande in 2008 / Netherlands, it was found that masks made from any material can reduce the viral transmission of diseases [7]. In 2013 a research by Davies in the United Kingdom proved that the surgical mask was three times more effective from the homemade masks in blocking any type of virus transmission. It also stated that homemade masks should be the last option to use. In 2011 in a meta-analysis by Jefferson, it was affirmed that N95 was more effective for any kind of respiratory viruses [8].

A research paper in 2013 by K.P. Chellamani, D. Veerasubramanian, and R.S. Vignesh Balaji showed the efficiency of the masks on the basis of the filtration, pressure difference, splash difference, etc. [9]. The Annals of Occupational Hygiene, Volume 48, Issue 8, November 2004, developed the prototype for half-mask face pieces from 3-d printing technology and the respiratory filters [10]. The previous researches show the use of different masks and their effectiveness in preventing the germs. In2020 a demonstration by Amayu Wakoya Gena, DAAD scholarship holder at the chair of Bauphysik at the Bauhaus-Universität Weimar he showed how differently the air spreads by using of the mask and by not using it, this shows wearing a mask is a necessity for stopping the spread of respiratory viruses [11].

III. Working of a Mask

There's no end to airborne diseases where working of a mask must be efficient. It is a type of a protective layer worn particularly over the nose and the mouth (the main entry points of the germs). Hence the making of the mask and its working is designed in a way such that it stops the 99% germs from entering in our body. It has three main components:

1. A filter that filters the germs/filter material that covers the whole nose and mouth.
2. The exhale valve for the warm air of the mouth to go out.
3. A string/band that keeps the mask intact of the mouth and nose.

The efficacy of the mask depends on the three components used appropriately to give the best results. Surgical masks made of the cloth prevent the larger respiratory droplets from entering [12]and hence, are made from single-layer cloth. While designing of mask, the thickness and permeability of the mask depend on the material's ability to absorb the particles; hence according to these parameters, the designing of the mask is done [12].

N95s are usually curved or duck-billed and, form a tight seal over the mouth and nose when fitted in correct manner. They can be uncomfortable to wear for longer durations of time. When surgical masks are worn outside the operation room, it works as a mask to stop the virus, and this mask is usually soft, pleated layers secured to the face with strings or ear loops, and pulled under the chin. So, they are more comfortable than N95s. Both N95s and surgical masks have an inner mesh that contains tiny plastic fibers that work as a filter. Also, both masks are disposable by design, usually discarded whenever they become too dirty, wet, or damaged [13].

The key role of the mask is to reduce the distance of the aerosol droplets while breathing, speaking, coughing and cold. That is why it is of utmost importance that we cover our face with our hand's side elbow while sneezing etc. and that is why masks are prime to wear to reduce the dispersal of the germs [14].

IV. Methodology

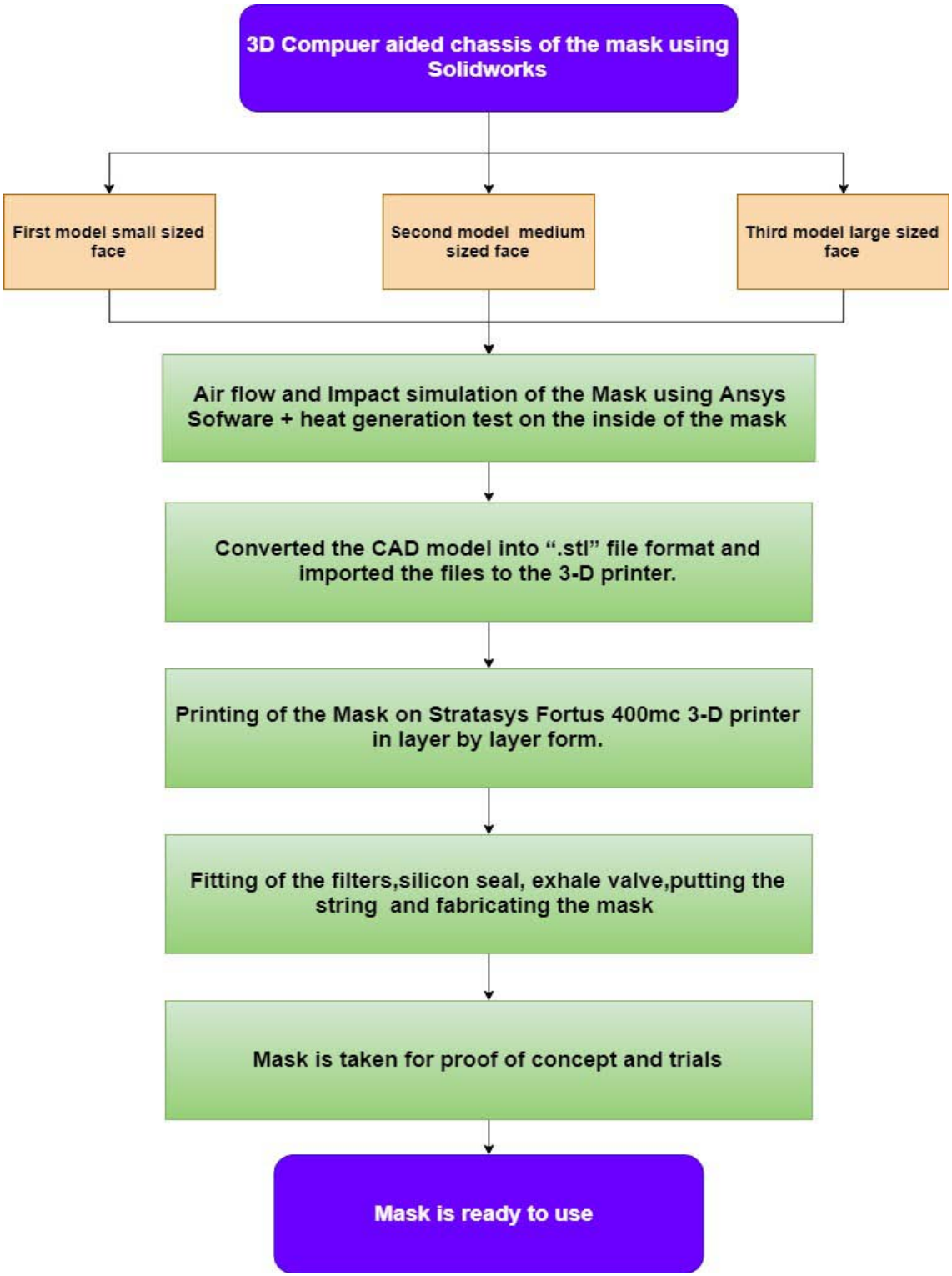
This design will be 3D printed after converting this solid-works file into. stl file format. PLA (Polylactic Acid) material will be used to 3D print the mask. PLA is a thermoplastic derived from renewable resources, so it is quite cheap as compared to the other 3D printing materials that are used for masks. PLA provides better strength with less weight, which makes it important for forming durable products. PLA is semi-transparent, so it yields a glossier surface which seems attractive. Some basic properties of PLA are referred from Table 01[15], which also gives the strength to the mask made of PLA material.

Table 1: [15]

Properties	Value
Tensile Strength	37 MPa
Density	1.3 g/cm^3
Percentage Elongation	6%
Flexural Modulus	4 GPa
Biodegradable	Yes, under the correct conditions
Melting Point Temperature [6]	423 – 433 K

The main criteria for designing this mask in 3-D designing software were to make it flexible for an upgrade according to the face type of the person. If any desired change in the design of a particular portion will be needed, then the whole mask design will not be disturbed. Changes can be made at that particular part, and this upgrade will automatically transfer from the source file to the main assembly, which will also save the time.

The overall process for manufacturing this mask can be summarized in Flowchart 01:



Flowchart 1

V. Design of a Mask

We designed the mask in professional 3-D designing software namely, Solid Works, which will be 3-D printed on Stratasys Fortus 400mc 3-D Printing System in the 3-D printing lab, Dayalbagh Educational Institute, Agra, India. The screenshots of 3-D design are given in Figure 01, Figure02, Figure 03, and Figure 04 with front view, side view, and top view. In the design of this mask, one rectangular slot is provided for an exhale valve or filter, and two elliptical hole slots are provided in the chassis of the mask to fix the inhale valves which prevents suffocation while wearing a mask.

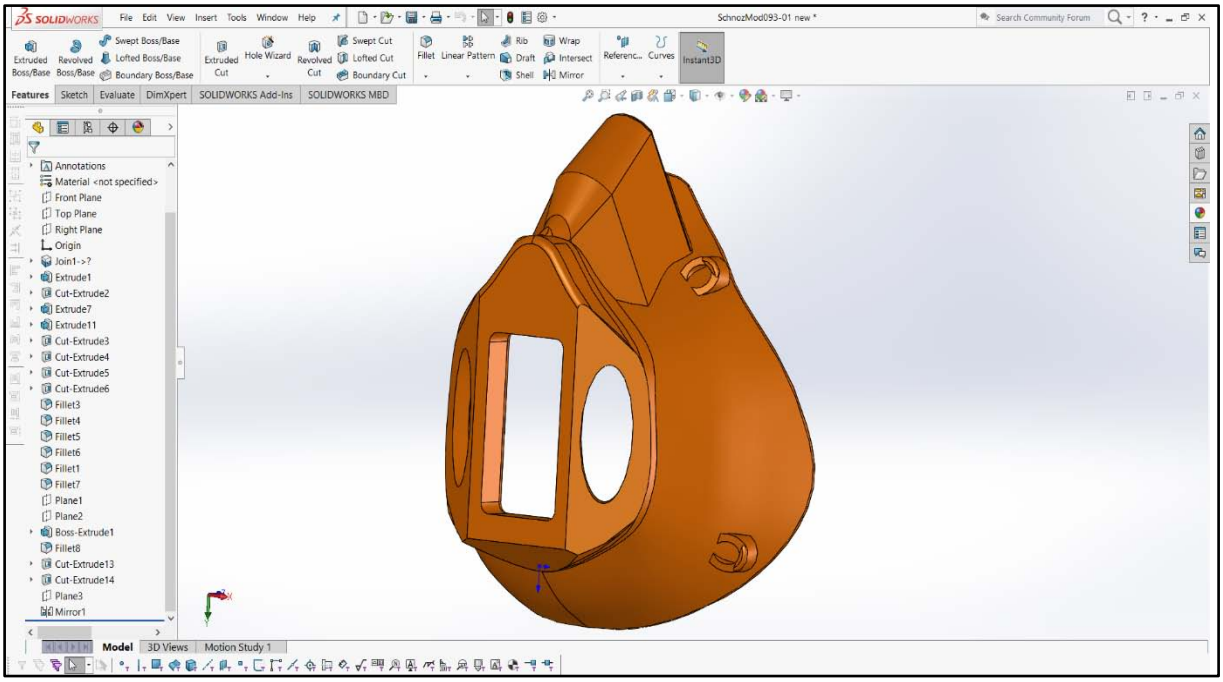


Figure 01: Screenshot of Solid Works 3-D Design of a Mask

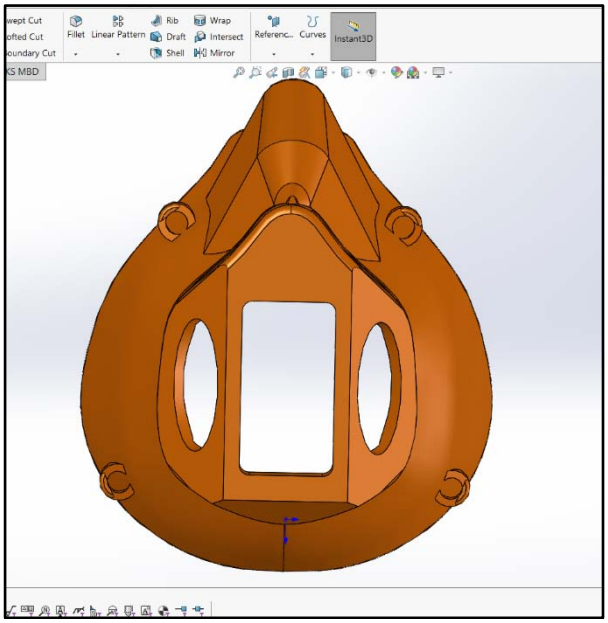


Figure 02: Front View

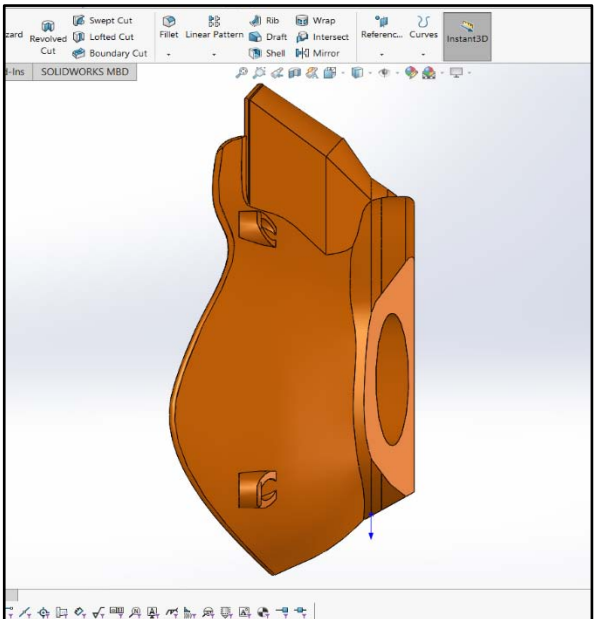


Figure 03: Side View

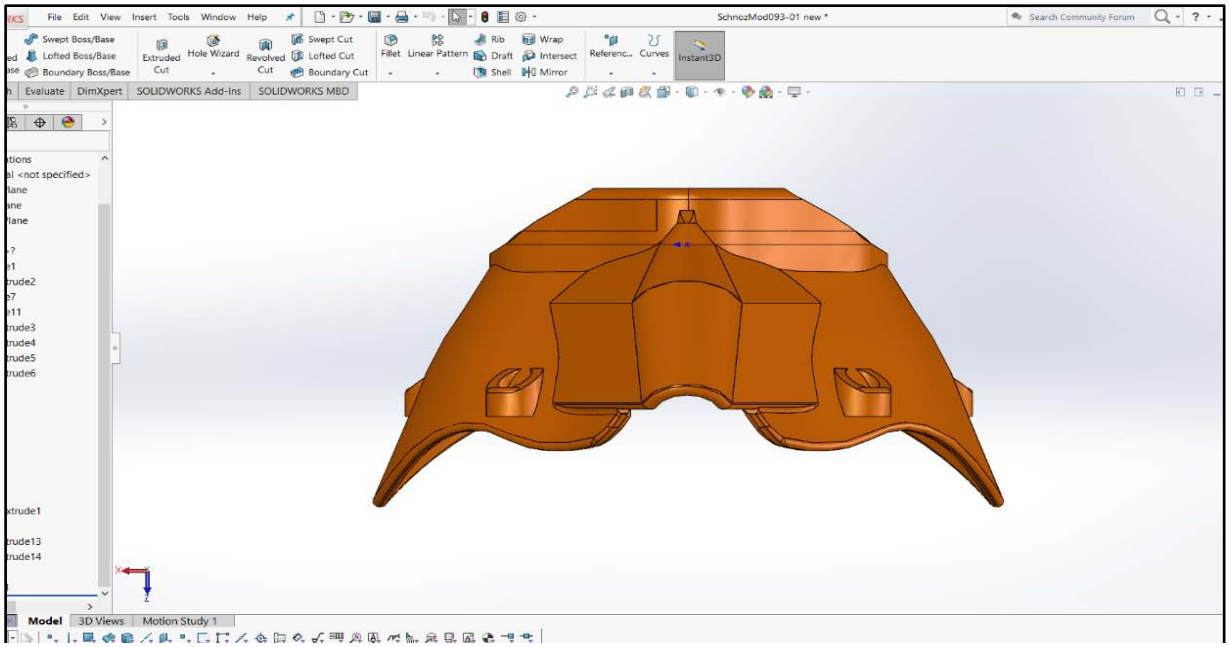
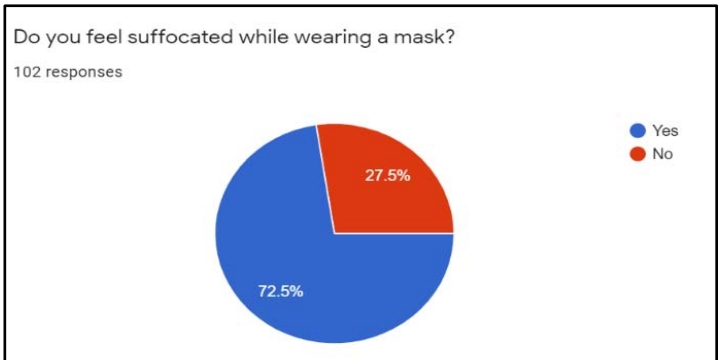


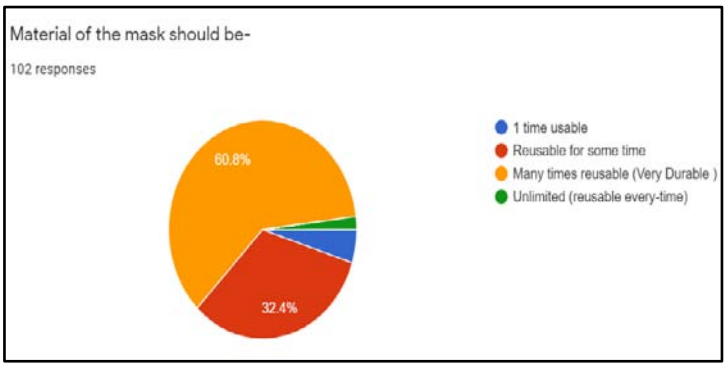
Figure 04: Top View

VI. Statistics and Graphs



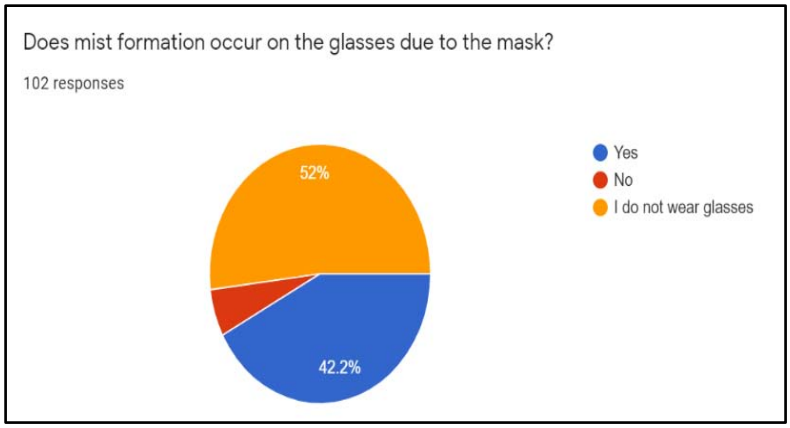
Nearly 73% of people fell suffocation while wearing mask because there is no or a small filter is provided for air transfer. Our mask will contain 3 valves; 2 for inhale, and 1 for exhale, so that no chances of suffocation will be there, and therefore people can wear it all the time.

Graph 1



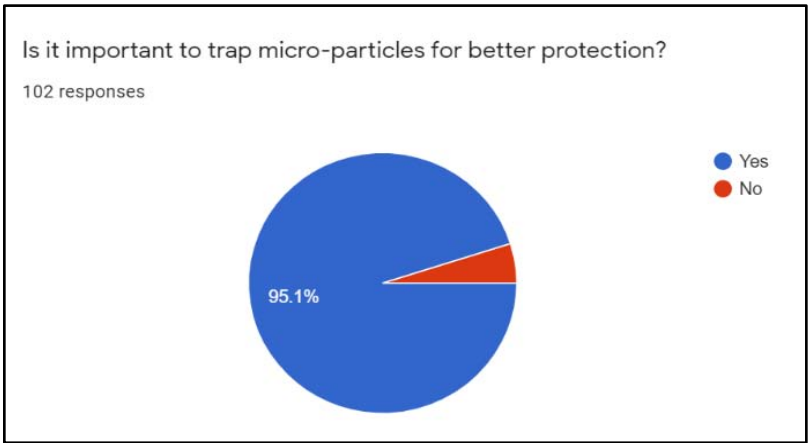
About 61% of the people want the material to be very durable, so we will use PLA (Polylactic Acid) material for the 3D printing of the mask. PLA is very durable, and possess a good resistance to wear and tear.

Graph 2



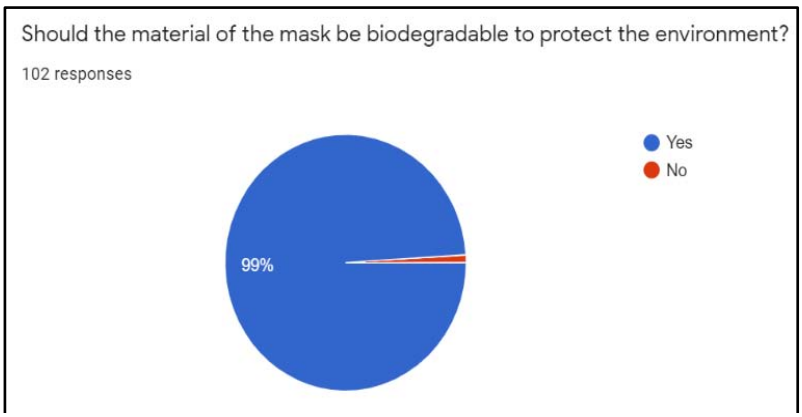
People who wear glasses feel the problem of mist formation on the mask because the distance between the mask and nose is quite less. Our mask will have sufficient distance so that no such problem will occur.

Graph 3



The material that we will use for the valves will be able to entrap the micro particles of Covid- 19, so the mask will allow full protection from the covid-19 infection.

Graph 4



Almost all of the people choose that the material for the mask should be biodegradable. The material PLA that we are using is also biodegradable, so it does not harm environment in any way.

Graph 5

VII. Simulation Analysis

The CFD (Computational fluid dynamics) pressure analysis is done by us on the surface of the mask using the simulation software, namely ANSYS, which shows the durability of the material while wearing it. The screenshots shows the overall process with the results in Figure 05, Figure 06, and Figure 07.

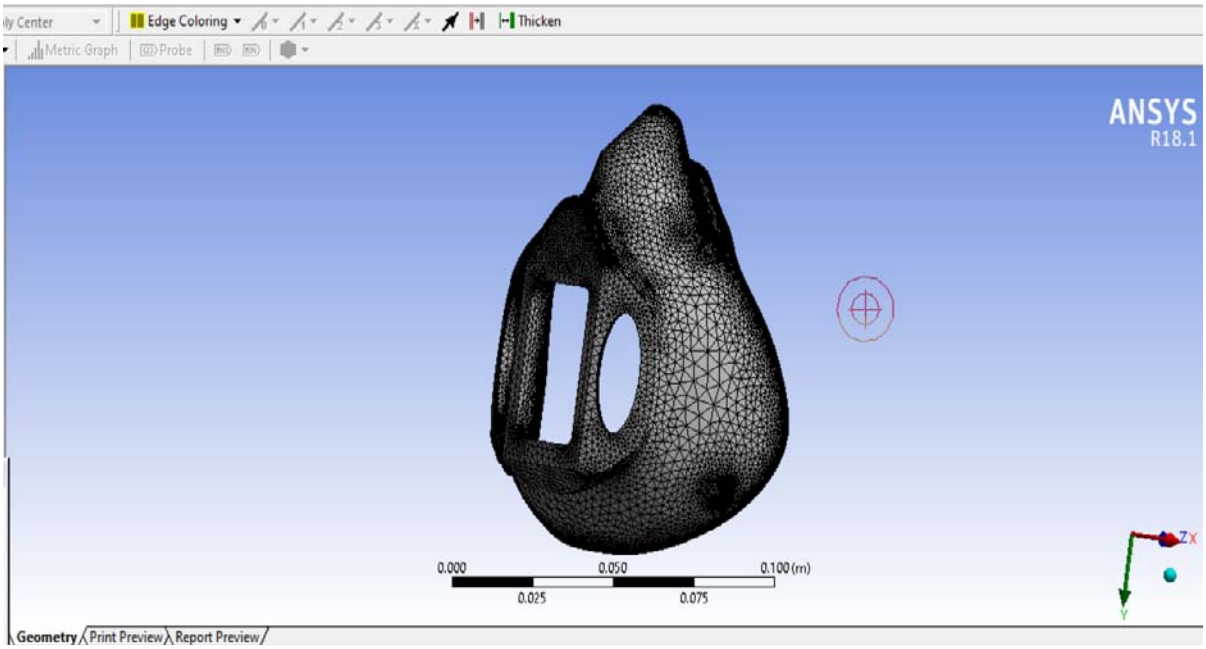


Figure 5: Meshing

The meshing of the mask is shown in Figure 05 and it is done by divding the mask in very minute elements, and at the edges of the mask, the size of the meshing is very small to get the accurate and desired results. Figure 06 represents the graph of iterations while running the calculation. And finally, result of CFD pressure analysis is shown with the color codes in Figure 07. As we can see, the red part is occurring at a smallest portion of the mask, and most of the part is either green or blue, so we can state that it can sustain high pressure, and this designed mask holds high durability.

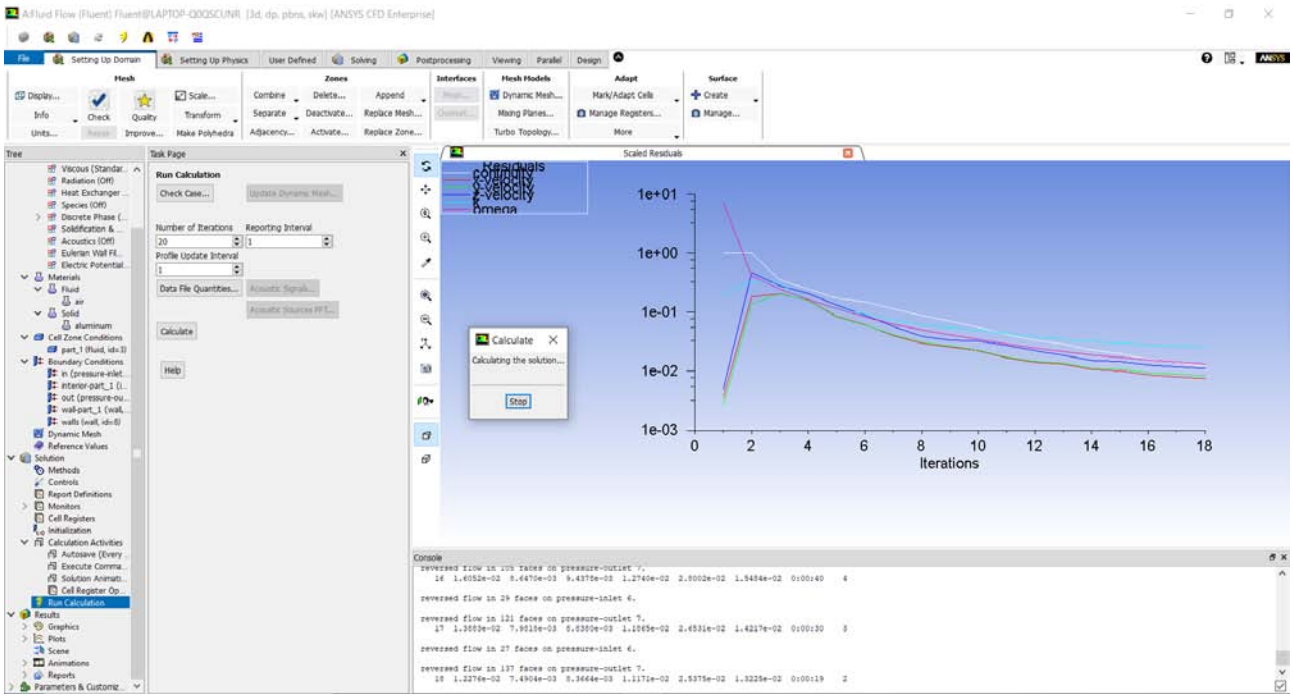


Figure 6: Iteration Graph

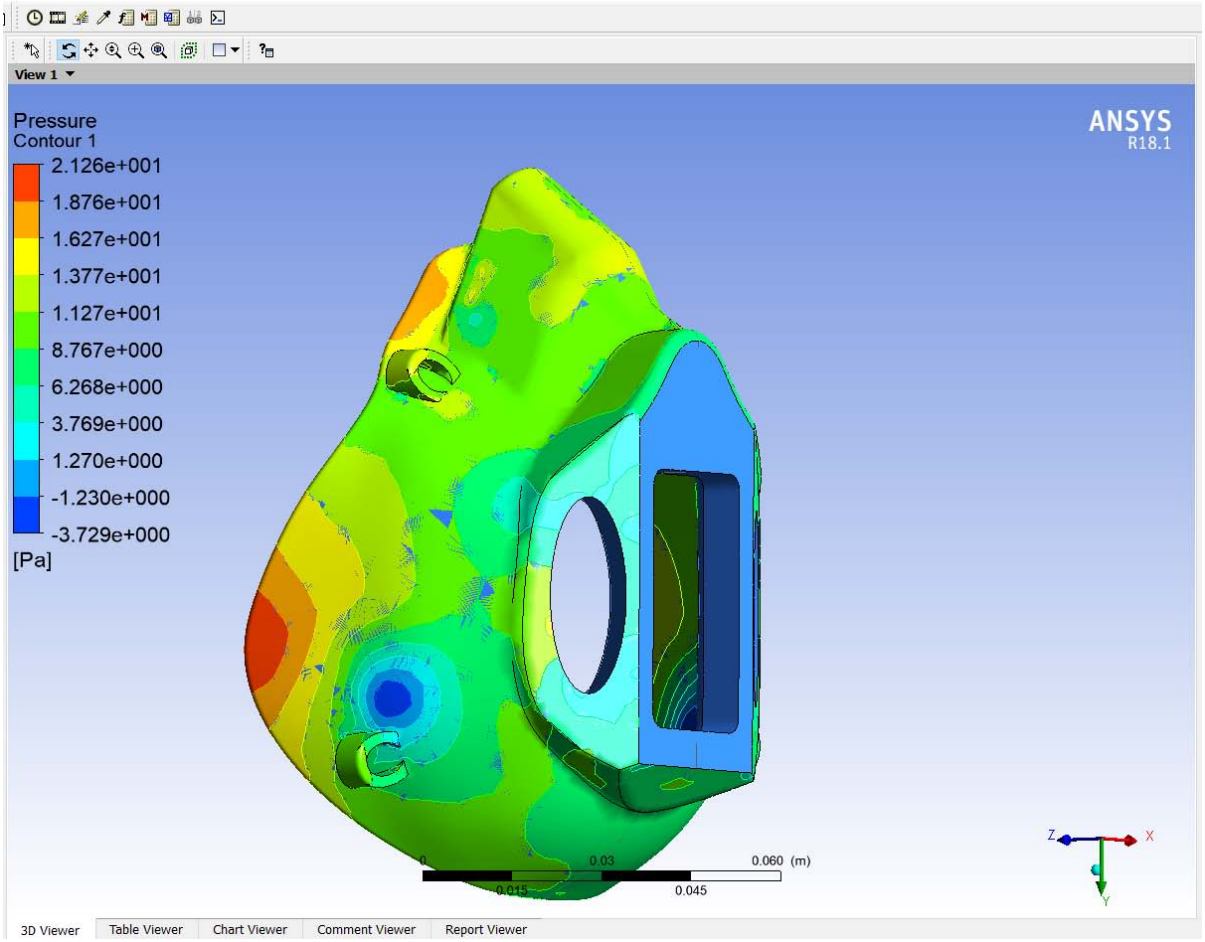


Figure 7: Pressure Simulation

VIII. Conclusion

With the Covid-19 pandemic at our doorsteps, face masks have become an integral part of our daily life. The masks which are currently available in the market lacks some basic human comfort and safety aspects such as lack of proper air circulation, mist formation in case of eye-glasses, unsatisfactory entrapment of micro-particles, limited reusability, etc. The prime perspective of our paper is to design a face mask that eliminates all these factors, and provides proper air circulation, no mist formation on eye-glasses, and the mask is made up of durable material having considerable reusability cycle.

The main result of the paper was that the 3-d printed mask is more durable than the regular 3d mask or surgical mask. The mask has better comfort and does not produce mist over the glass due to the exhale valve attached to it. The pie charts from the sample size of more than 100 people of every age show that people need a biodegradable mask that can be used for a sufficient amount of time, so 3-d printed mask is made from a biodegradable material which is durable as well. The mask is also light in weight and has valves which can be used by people having claustrophobia, the material of the mask has high specific capacity, therefore, it does get heat up quickly; hence the mask overcomes crucial differences of the N95 mask as well as surgical masks.

Our achievement is the design of a 3D printed face mask, which provides all the aforesaid qualities. The mask is made of durable PLA (poly lactic acid) material, which is also biodegradable. This mask will provide all the human comfort and safety measures to the wearer. This mask can also be customized according to the facial anatomy of the wearer as it can be customized digitally on SolidWorks and can be 3D printed easily.

Another advantage of 3d printed mask is that it can have auxiliary attachments (shield) fit into the 3d chassis of the mask, which makes it flexible according to the use and necessity.

With the help of our supervisors in the Dayalbagh Educational Institute, India, we have got all the technical knowledge and resources to complete this project successfully. This paper describes the complete design of an indigenous mask.

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