STUDY OF AIR FLOW RATE THROUGH MULTIPLE MEBRANES OF MASK

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ABSTRACT

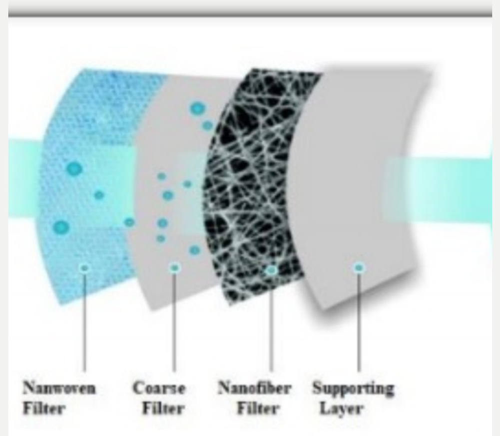
We study the penetration of particles as small as SARS-COV-2 and find out the required size of the pore in a filter to stop the penetration of a virus through it completely but in multiple membranes. In the second part of the study, we reach the final formula through a derivation starting from darcy's law and brinkman equation. After doing the theoretical calculations, we reach 90 L/min air flow rate which is required for effortless breathing through a mask, using this final formula. We verify it by simulating the whole scenario in Comsol multiphysics. We have used polycarbonate as the material for the filter in the simulation.

Also, the static structure of the mask is worked on the simulation platform SOLIDWORKS.

INTRODUCTION

Masks have become the necessity of our lives in today's situations. In our previous study, we derived results of a polycarbonate membrane mask with lesser pore size and apt airflow rate through theoretical calculations verified by simulation results. Further, in this study, multiple membranes are used for better filtration of air.

There are many particles that are of very smaller sizes and can cause serious harm to many people, especially patients of asthma, children and senior citizens.Hence, the study focuses on making multiple membranes in mask with decreasing pore sizes can prevent a lot of other particles other than covid which can lead to inhalation of better filtered air.

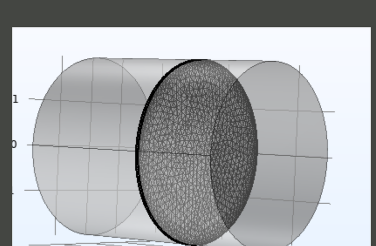


SINGLE MEMBRANE

- Single membrane was used for filtration
- Single Pore Size was used throughout.

Drawbacks -

1. Particles with smaller size can penetrate
2. Less Protection

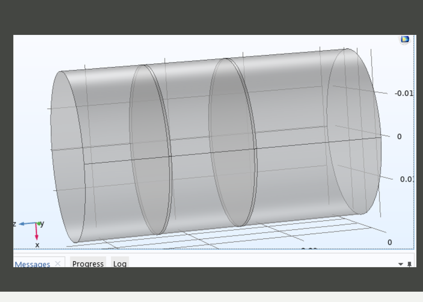


MULTIPLE MEMBRANE

- Multiple membranes are used for filtration
- Multiple pore sizes are used in different membranes

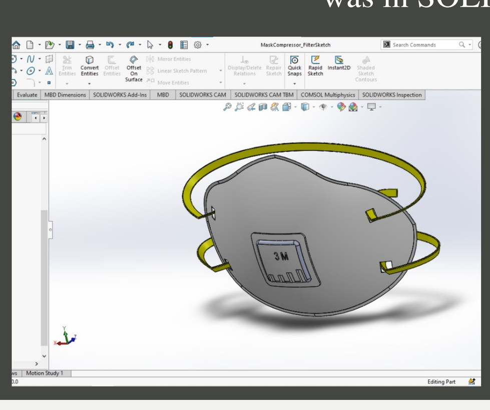
Benefits -

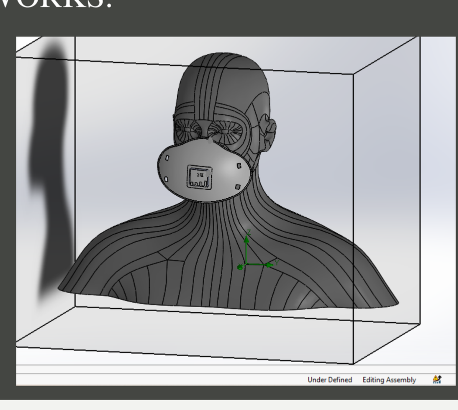
1. Smaller Particles can not penetrate due to decreasing pore size
2. Better airflow rate
3. Higher Protection
4 Better air velocity
5. Useful in various sectors like patient, doctors, mining areas etc



MASK STRUCTURE

The following is the static structure of mask that was in SOLIDWORKS.





THEORETICAL CALCULATIONS

- To get the air flow rate through all the three membranes above 75L/min, Q was kept constant in every membrane, so that the pressure on lungs of human beings while breathing is minimal.
- The area of the mask was such assuming its diameter 20mm, and the thickness of mask was also kept constant as 6 micrometres.Now atmospheric pressure is 101325 Pa, and it is compressed to 600 Pa by air compressor, after which again pressure drops by 250 Pa through the 3 membranes. Now the variables are number of pores and porosity of mask which we vary in the formula below to get the required air flow rate.

$$Q = \frac{m\, a\, A\, \Delta P\, dp^2}{4\, h\, \eta\, (A - m\, a)}$$

SIMULATION DETAILS

Software used : Comsol Multiphysics

Physics Interface : In comsol multiphysics, under the Porous Media and Subsurface Flow Interfaces, the Brinkman Equations Interface was used.

Inlet : The atmosphere side of the mask.

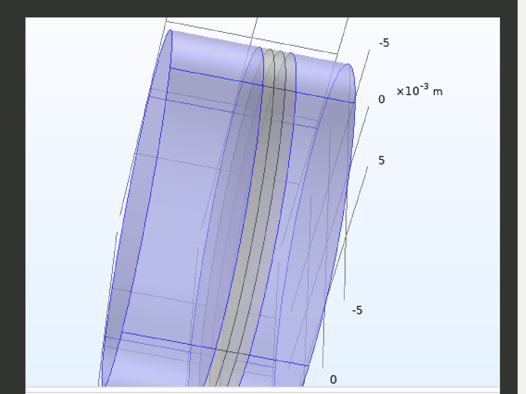
Outlet : The face side of the mask.

Pressure at the Inlet : 600 Pa

Drop Required : 250 Pa

Geometry : The cylinder represents the surroundings and atmosphere and the three membranes are made in between.

Materials Used : Air for the surroundings and polycarbonate for the mebranes.

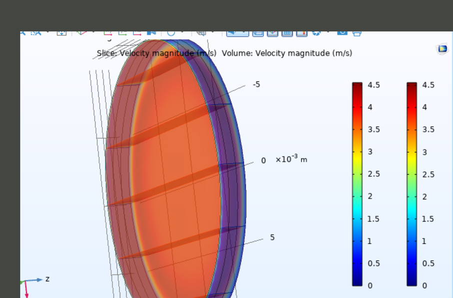


RELATION B/W THEORY AND SIMULATION

- Through theoretical results, number of pores required were 63 billion, 99 billion and 177 billion for diameter size 0.05 * 10^6 , 0.04 * 10^6 and 0.03 * 10^6 and hence porosity of three membranes were kept 0.9976, 0.9991, 0.9999 resp.
- So for each membrane in our geometry in the simulation we take these three respective porosities for the three polycarbonate filter membranes.

RESULTS AND DISCUSSIONS

Figure 1: Depicts the airflow through the three membranes and show the velocity change through the membranes.



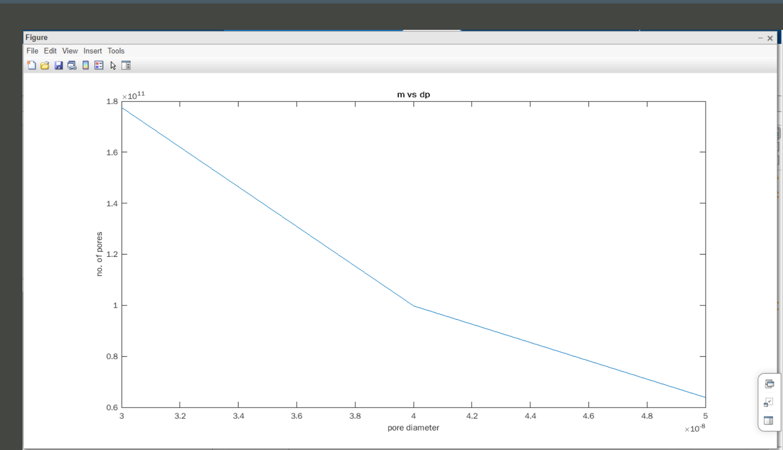


Figure 2: m vs dp Graph

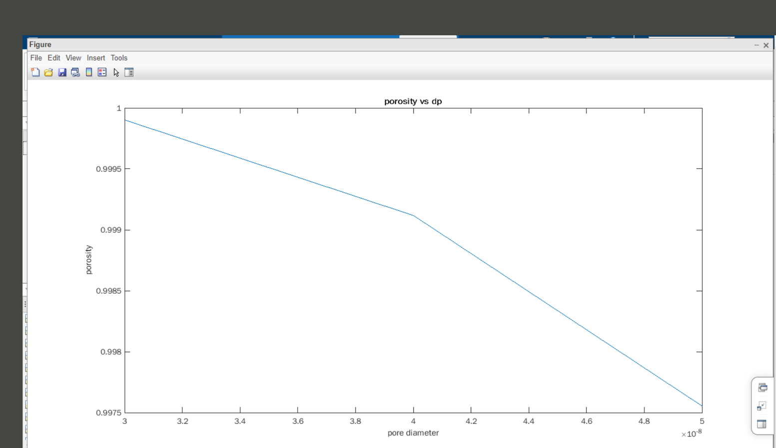


Figure 3: porosity vs dp Graph

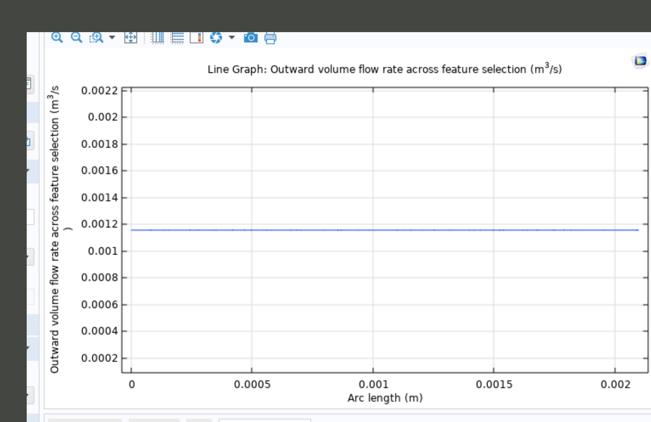


Figure 4: The airflow rate graph which confirms that the airflow rate is constant throughout the membranes.

Therefore this graphs shows that the result is correct because we are getting required constant air flow rate throughout.

CORRECTION CONSTANT

- The permeability of the material has been introduced in the formula after which the results of simulaton and theoretical caluclations matched and flow rate of the multiple membranes were constant.
- Permeability was added to decrease the proportion of numerator and obtain better flow rates, pressure and velocity outputs.

After the introduction of the parameter, the final formula is as follows-

$$Q = \frac{m\, a\, (0.1)\, A\, \Delta P\, dp^2}{4\, h\, \eta\, (A - m\, a)}$$

CONCLUSION

We conclude that we have successfully completed a research that has given an efficient type of membrane to use, we have increased the efficiency of the masks by increasing number of membranes and as the pore size and thickness used is comparatively low which will render the coronavirus to pass the masks which increases the prevention. The research has verified the results both theoretically and practically and has given great breathable results.

References : 1. https://pubs.acs.org/doi/10.1021/acsnano.0c03976 , 2 .https://www.comsol.com/paper/download/367781/kumar_paper.pdf , 3. https://journals.asm.org/doi/10.1128/mSphere.00637-20