Development of a Portable Lightweight Hood-Type "Distancing-Free Mask" that eliminates COVID19 lockdown

Desmond Tan

School of Mechanical and Aerospace Engineering

Nanyang Technological University

Assoc Prof Shu Dong Wei

School of Mechanical and Aerospace Engineering

Nanyang Technological University

Abstract - This project aims to produce a hood-type mask to replace traditional face masks to prevent the spread of pathogens. Face masks can cause skin issues and cannot effectively prevent the virus from entering it. Face masks can also lead to plastic fibre inhalation. For this project, two successful prototypes have been developed and tested. The prototypes were made with the following factors in mind: cost, airtightness, filtration effectiveness, and portability. The first prototype uses a red plastic bag as a frame, with a plastic screen for vision. It has pockets made from filters that can contain portable fans to act as air pumps. The hood contains a helmet attached with Velcro to keep the hood stationary on the user's head. By removing the helmet and fan, the hood can be folded for easier transportation. The plastic frame can be cheaply replaced, making it a disposable and replaceable product. Prototype 2 is made from the frame of an IKEA brand lamp. It is spherical with a double helix wire frame. It has two containers containing fans to act as air pumps. The container has a cap with holes in it to allow air to enter through the filters in it. The cap can be unscrewed to open the container to replace the filters.

Keywords – Personal Protective Equipment; airtight; portability

1 INTRODUCTION

Considering the recent Covid-19 pandemic, it is important to prevent the spread of such diseases. This project aims to produce a hood-type/helmet-type mask to replace traditional face masks to prevent the spread of pathogens. The report will refer to the prototypes as hoods to avoid confusion with the conventional face mask. Face masks can cause skin issues and cannot effectively prevent the virus from entering it [1]. Face masks can also lead to plastic fibre inhalation [2]. This project will focus on portability of said hoods to facilitate easy packing of the hoods for air travel. The full list of criteria required of the prototypes is listed in the Design Objectives section. For this report it is assumed that airtightness of the hoods is attained when the air pressure in the hood is slightly higher than that outside the hood.

The report will flow as follows: section 2 is a literature review of the most relevant designs and how some features can be made better or can be used in a new design. Section 3 goes over the development of two different hood prototypes and section 4 summarises the project and suggests directions for the future development of such Personal Protective Equipment (PPE).

2 LITERATURE REVIEW

2.1 NEWEST HOODS TO PROTECT AGAINST AIRBORNE PATHOGENS

This section will look at some of the latest models of hoods that have been developed to protect against airborne pathogens. The complications and successes of the models will be discussed, and these will then be looked at when developing a brand-new design for such a hood.

2.1.1 Gunma University "Distancing-Free Mask"

The Gunma University prototype is worn like a helmet and uses pumps to enable airflow through HEPA H13 filters. The prototype uses a CO2 sensor and a pressure sensor which controls the power of the pump, potentially extending battery life. The prototype is shown in Fig.1 below. Its size is approximately 38cm (width) × Approx.26cm（Depth）× Approx.29cm（Height). The selling price was estimated to be US$20 [3].

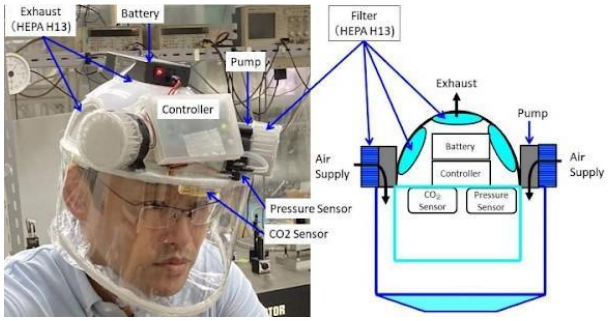


Figure 1 Gunma University prototype

A downside of this model is that it is not that portable when it is not in use. It is not foldable and so will stay the same size as being slightly larger than a human head. The use of sensors to control the air pumps add complexity to the prototype which can potentially increase its production cost and can also increase the actual weight of the model which should be kept as low as possible for the user's comfort. The neck seal which is made from a shower cap would also need to fit the size of the user. It is stretchable but cannot be tightened or loosened to fit different neck sizes comfortably.

2.1.2 BioVYZR

BioVYZR is a hood that uses custom replaceable filters that is claimed to have particulate filtration efficiency of 95%. Air enters from the back filter and exits through the top filter. The product is supported on the shoulders unlike the Gunma University prototype which is supported on the user's head. The BioVYZR is also bulkier than the Gunma university prototype as it not only covers the head but the upper back as well. The size of the BioVYZR is 28" x 20" x 14". The BioVYZR can be flattened but not folded (due to the PVC screen) which can make it more portable than the Gunma University prototype. The BioVYZR also has gloves to allow the user to touch his face if needed without making direct contact. The BioVYZR also has adjustable straps at the bottom which allows for adjustment for users of slightly different sizes. The BioVYZR can be seen in Fig.2 on the right.



Figure 2 BioVYZR

The main downside to this model would be the price which is given as US$379 which is much higher than conventional face masks and the Gunma University prototype. The lack of foldability also limits the portability of the product. The weight of the product with its power bank is given as 2.25kg which is much heavier than the Gunma University prototype [4].

2.1.3 Review Summary

After reviewing the current designs of filtration hoods being developed, some potential shortcomings were identified. The problems that are considered for this project to design new prototypes are listed below.

1. Protective hoods are not foldable, limiting the portability of the product.
2. The hoods can be expensive.
3. The hoods could potentially be lighter.

3 DESIGN & DEVELOPMENT

3.1 DESIGN OBJECTIVES

For this project, we looked at several factors as listed below that we wanted to achieve, and these would then act as points of evaluation for the success of the design.

1. Having a filtered air input
2. Having a positive pressure difference between the inside and outside of the hood so air can only exit through the exhaust. This is used to check the airtightness of the prototype.
3. Clear visibility for the user when in use.
4. Portability
5. Affordability

To test for airtightness, an Arduino Grove BME 280 barometer sensor was used. The hoods were used for 10 minutes before a pressure reading was taken inside and outside the mask. The sensor was placed towards the side, away from the opening and away from the user's nose and mouth.
To test the CO2 levels in the mask, an Arduino MQ-135 gas sensor was used. Readings were taken every ten minutes for thirty minutes. The sensor was placed away from the opening and towards the front but not directly under the nose or mouth. Readings below 1000ppm are considered safe as increasing co2 levels above 1000ppm affects respiration [5].

3.2 PROTOTYPE 1

Size:
approximately 45cm length x 45cm height x 27cm width (side length)
Screen size: 30cm length x 20cm height
Weight: 425g

Folded size:
25.5cm x 24.5cm x 7cm
Helmet size: 29.4 cm radius, 10cm height

Prototype 1 (nicknamed "Amogus 1") emphasises affordability and is a disposable hood made from cheap materials. This is like how disposable surgical masks are cheaper than reusable ones but should only be used once. Prototype 1 is made with a red plastic bag as the frame and clear plastic as a viewing window. An elastic polyester band is used to create a neck seal to limit air leakage while keeping the hood comfortable for the user. The fans act as air pumps and are slotted into back pouches made from non-woven fabric filters. The hood contains a helmet attached with Velcro to keep the hood stationary on the user's head. The fans and helmet can be removed to allow the hood to be folded up for easy storage and for the hood to be cheaply replaced after use.

Fig. 3 and Fig. 4 below are of the hood's front and back view respectively. Fig. 5 shows the hood folded with the helmet and fans removed for easier packing.



Figure 3 Prototype 1 front view



Figure 4 Prototype 1 back view



Figure 5 Prototype 1 folded for packing

3.2.1 Prototype 1 Fabrication Process

Cut a rectangular hole for the visor, if it is too big it could affect how well the hood's integrity but too small and it would be hard to look out of.

After making the hole the right size, paste a piece of clear plastic over the hole and duct tape it from the outside.

Keep the neck entrance airtight by using the elastic band. The length can be adjusted with sewing or by using staples. To keep it attached, have the band wrapping around the outside of the hood. Fold the plastic up and duct tape the plastic. By only taping up the plastic, the band can still be stretched to allow the user's head to enter it. Make sure to stretch out the band before taping the plastic, this will give the band enough room to be stretched after the plastic is stuck together.

For fan pockets, cut a hole slightly bigger than the fan.

Attach a non-woven filter to act as the pocket. The top of the filter is not attached to the hood so it can act as a mouth to the pocket.

Attach fan grills on the inside of the hood to prevent the fan from falling inwards into the hood.

Use Velcro to attach the helmet strap inside the hood, check the positioning of the helmet strap before attaching it.

3.2.2 Prototype 1 Testing

From the results below, the hood can maintain a fresh intake of air while still being airtight by maintaining higher air pressure in the mask.

Atmospheric pressure: 100547 Pa
Pressure in hood: 100559 Pa

Table 1 CO2 readings for prototype 1

Time (min)	CO2 level (ppm)
0 (atmospheric)	415
10	445
20	446
30	450

From empirical testing of the hood, it can be used comfortably for long periods of time with the air pump turned on. If the air pumps were to lose power, the user can still breathe safely but the hood becomes stuffy, and the viewing screen starts to fog up. This hood only uses a single layer

filter as air suction becomes too low when using 2 layers. The viewing screen of the hood also gets crumpled with prolonged use and folding which then obscures the user's vision but since the hood is meant to be disposable this is not that significant. Side windows were added to the hood for better vision but there was no discernible improvement in vision as the front window was already large enough. As adding such features would create more vulnerabilities, they should not have been added.

3.3 PROTOTYPE 2

Size: 46cm radius sphere
Weight: 500g

Folded size:
46cm radius, 13 cm height
Helmet size: 29.4 cm radius, 10cm height

Prototype 2 (nicknamed "Amogus 2") is a reusable hood as opposed to Prototype 1 which is disposable. This prototype is more durable but more expensive. Prototype 2 is made from a spherical IKEA brand Regolit lamp which acts as a frame [6]. It has a spherical double helix wire frame inside that allows it to be stretched and flattened and is held together by its paper skin, akin to a semi-monocoque structure. The air pump is located inside a sealable container. The container cap secures the filter onto the hood and has holes to let air in. It can be removed to replace the filter. This feature also allows users to switch in different kinds of filters if needed.

The front view of prototype 2 is shown in Fig. 6 and the back view is shown in Fig. 7. The filter holes are not the same due to machining issues, but this does not affect the findings in this paper. Fig. 8 shows the hood being prepared for packing by having its helmet removed so it can be flattened.



Figure 6 Prototype 2 front view



Figure 7 Prototype 2 back view

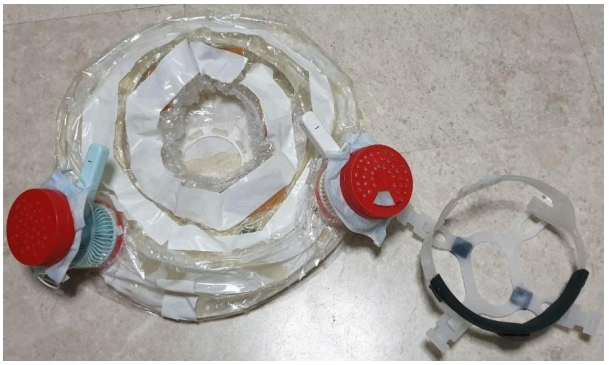


Figure 8 Prototype 2 dismantled and flattened for packing

3.3.1 Prototype 2 Fabrication Process

Cut a hole in the lamp to act as the viewing window. Cutting too much paper can cause it to lose its structural integrity.

Cover the entire lamp with clear plastic.

Add extra plastic at the bottom and use an elastic band to make the neck opening in the same way as the prototype 1.

Cut a hole in a plastic cover that will be attached to the fan. This hole will allow air to enter the hood.

Cut a similar sized hole in the lamp below the midpoint and attach the plastic cover over it.

Attach the fan to the plastic cover with the fan facing inwards so it blows air into the hood.

Cut the bottom of a container to allow the container to fit over the fan. A rectangular slit was added to accommodate the fan handle as shown in the photos.

Make holes in the container's cover.

Attach the container to the hood over the fan.

Simply unscrew the container cap, place a filter over the opening and screw back the cap.

Use Velcro to attach the helmet strap into the hood.

3.3.2 Prototype 2 Testing

From the results below, the hood can maintain a fresh intake of air while still being airtight by maintaining higher air pressure in the mask.

Atmospheric pressure: 100982 Pa
Air pressure in hood: 100987 Pa

Table 2 CO2 readings over 30 minutes of prototype 2 use

Time (min)	CO2 level (ppm)
0 (atmospheric)	390
10	430
20	434
30	435

From empirical testing prototype 2 functions well and comfortably with air pumps on. In the event air pumps lose power, the hood becomes stuffy and gets very uncomfortable and should then be removed from the user's head. The viewing screen also fogs up with the air pumps off. The viewing screen can get crumpled with prolonged use but by pulling the wire frame vertically, the tension generated can keep the screen clear for viewing.

4 CONCLUSION & FUTURE CONSIDERATIONS

4.1 CONCLUSION

For this project, two different hood prototypes were assessed before starting on the design process. The Gunma University prototype is not foldable and is not that easy to package and carry around in hand. The use of sensors potentially increases complexity, costs and weight. The neck seal which is made from a shower cap may be uncomfortable for users. The BioVYZR can be flattened which helps its portability, but it is not foldable. The BioVYZR has replaceable filters and an adjustable strap to secure itself on the user. The BioVYZR is more expensive and heavier than other alternatives in the market. The project aims to design new hoods with filtration, airtightness, visibility, portability and affordability in mind.
The first prototype developed is a disposable single use design which has pockets made from filters. Fans can be placed in the pockets to act as the air pumps. The hood itself is foldable and can be compactly packed after the helmet and fans are removed. Acceptable CO2 levels are maintained throughout its use, and it is airtight.
The second prototype developed uses a "razor and blades" model where the hood itself is not replaceable, but its filters are. The hood has a semi-monocoque structure with spherical double helix wire frame which allows it to be flattened for easier packing. The paper skin which is exposed on the inside helps to trap saliva from escaping it. Acceptable CO2 levels are maintained throughout its use, and it is airtight.

4.2 Future considerations

The hoods can be improved with a stronger air pump which would then allow for higher filtration of the air while allowing for comfortable use. A stronger air pump can be noisier and heavier which is then unsuitable for use. More studies can be done on virus particles escaping from the mask. Although it is airtight, if it were to be removed in public for reasons like eating, the virus particles may then escape. Having an absorbent layer lining the inside of the hood may prevent this. (Prototype 2 has this while prototype 1 does not.) The prototypes currently use the neck seal as the exhaust which is unfiltered, and this should be addressed in future designs. Pockets of prototype 1 can be changed to only open from the inside to reduce air leakage. Prototype 1 side windows were added with no discernible benefit as the main

screen was already large enough and it made the hood more vulnerable to tears and air leakage. More research can also be done on appropriate disinfection methods for the hoods. The shape of the window on prototype 1 is rectangular with sharp corners. This can cause stress concentrations on the corners which increases the chance of tearing so a more rounded optimised shape would be preferable [7]. The hoods can also include a holder for a power bank to extend the battery life of the fans. Sound from the air pumps affect the user's ability to hear his surroundings so developing silent yet powerful air pumps would improve the hood.

ACKNOWLEDGEMENT

I would like to acknowledge the funding support from Nanyang Technological University – URECA Undergraduate Research Programme for this research project.

I would like to thank project supervisor Professor Shu Dong Wei for encouraging me to improve myself and to not be afraid of failure when it comes to learning new things.

I would also like to thank Doctor Fujii Yusaku for giving his advice and providing information from his own project to help this one.

REFERENCES

[1] D.Ser, "Talking Point 2020/2021: Ep14: Which mask is best for me?" CNA, 2020. Available: https://www.channelnewsasia.com/news/video-on-demand/talking-point-fy2021/which-mask-is-best-for-me-12957394

[2] J.Han & S.He, "Need for assessing the inhalation of micro(nano)plastic debris shed from masks, respirators, and home-made face coverings during the COVID-19 pandemic," in Environmental Pollution, Vol. 268, part B, 2020. Available: https://dx.doi.org/10.1016%2Fj.envpol.2020.115728

[3] F. Yusaku, H. Seiji, T. Akihiro, "Lightweight integrated type "distancing-free mask," Gunma University, 2020. Available: http://www.e-jikei.org/site/PR_DistanceFreeMask_AllinOne-type_A4_E.pdf

[4] VYZR Technologies, "BioVYZR: Personal Air-Purifying Shield," 2021; Available: https://www.vyzrtech.com/products/biovyzr

[5] H. Ozawa, K. Azuma, N. Kagi, U. Yanagi, "Effects of low-level inhalation exposure to carbon dioxide in indoor environments: A short review on human health and psychomotor performance," in Environment International, Vol. 121, part 1, pp. 51-56, December 2018. Available: https://doi.org/10.1016/j.envint.2018.08.059

[6] IKEA, "Regolit," n.d. Available: https://www.ikea.com/sg/en/p/regolit-pendant-lamp-shade-white-handmade-00172789/

[7] B. Dong Ho, K. Myoung Han, S. Myung Won, "Optimum shape of the bus window pillar member based on B-spline," in KSME International Journal, Vol. 14, No. 11, pp 1179-1186, 2000. Available: https://www.koreascience.or.kr/article/JAKO200011920733031.pdf