Journal of Technology and Social Science (JTSS)

Very-Low-Cost Powered Air-Purifying Respirator (PAPR) "Distancing-Free Mask Industry (DFM-I) Prototype No.1" and Proposal for a Lockdown-Free Industry

Edwin Carcasona[1,a], Ronald M. Galindo[2,b], Akihiro Takita[3,c], Ethelda Magalang[4,d], Tabetha S. Galindo[5,e], Seiji Hashimoto[3,f], Takao Yamaguchi[3,g], Edgar U. Tibay[1,h], Dongwei Shu[6,i], Haruo Kobayashi[3,j], Kenji Amagai[3,k], Naoya Ohta[3,l], Noriaki Yoshiura[7,m], Anna Kuwana[3,n], Ayako Yano[3,o], and Yusaku Fujii[3,p,*]

[1]Faculty of Engineering, University of San Carlos, Cebu, Philippines
[2]Faculty of Engineering, Cebu Technological University, Cebu, Philippines
[3]School of Science and Technology, Gunma University, Kiryu, Japan
[4]Cebu Doctor's College of Medicine, Cebu, Philippines
[5]Obstetrics and Gynecology Department, Visayas Community Medical Center, Cebu, Philippines
[6]Nanyang Technological University, Singapore, Singapore
[7]Department of Information and Computer Sciences, Saitama University, Saitama, Japan

*Corresponding author

[a]< edcarc123055@yahoo.com>, [b]<ronald.galindo@ctu.edu.ph>, [c]<takita@gunma-u.ac.jp>, [d]<etheldacarmelamd@gmail.com>, [e]<tebetha7762@yahoo.com>, [f]<hashimotos@gunma-u.ac.jp>, [g]<yamagme3@gunma-u.ac.jp>, [h]<edgar.tibay@ctu.edu.ph>, [i]< mdshu@ntu.edu.sg>, [j]<koba@gunma-u.ac.jp>, [k]<amagai@gunma-u.ac.jp>, [l]<ohta@gunma-u.ac.jp>, [m]<yoshiura@fmx.ics.saitama-u.ac.jp>, [n]<kuwana.anna@gunma-u.ac.jp>, [o]<yano@gunma-u.ac.jp>, [p]<fujii@gunma-u.ac.jp>,

Keywords: COVID-19, Distancing-Free Mask (DFM), herd immunity, droplet infection, aerosol infection.

Abstract. A very-low-cost Powered Air-Purifying Respirator (PAPR) "Distancing-Free Mask Industry (DFM-I) Prototype No.1", which is suitable for use by the factory workers, is developed. This development is done in Cebu, Philippines under an international research collaboration project between Philippines, Singapore, and Japan researchers, in which the vaccine-independent and lockdown-free society/nation by means of spread of low-cost PAPR, is proposed and pursued. The present status and future prospect of DFM-I project in the whole DFM project are discussed.

1. Introduction

The measures against COVID-19, securing social distancing and obliging to wear masks have been implemented all over the world for more than 2 years. However, the spread of the infection cannot be eradicated, and reinfections are occurring repeatedly. And lockdown, which causes enormous damage to the society, has been carried out every time of the spread of infection. As a complete solution, the acquisition of herd immunity by vaccination is sought after all over the world. However, there is not a good prospect of promptly developing, producing, and spreading an effective vaccine when a newly mutated variation of SARS-CoV-2, against which the existing vaccines are not sufficiently valid, appears. [1,2]

Among the COVID-19 infection routes, contact infection and oral infection are relatively easy to prevent by enforcing hand washing and food hygiene management. It is thought that droplet infection and airborne infection are the main infection routes that are difficult to prevent. [3,4]

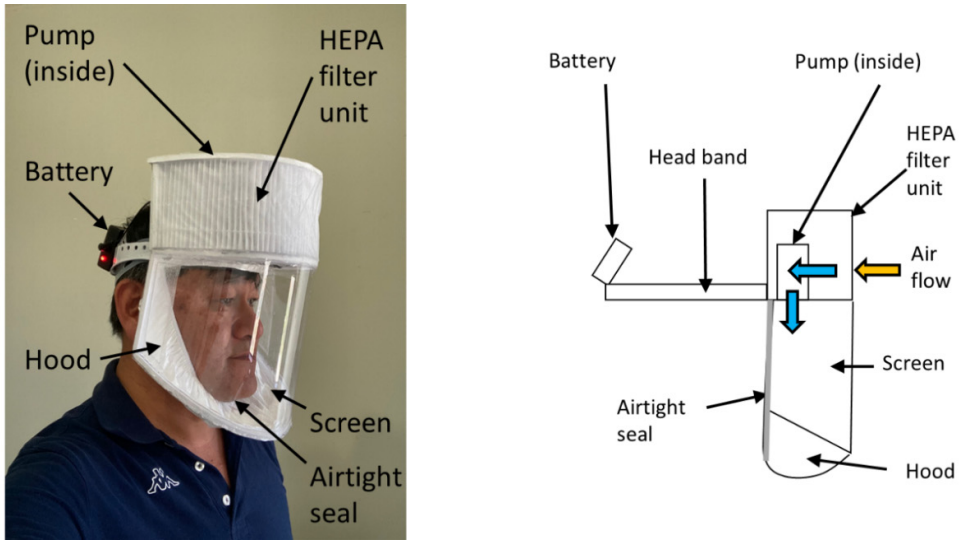
A face mask can capture a large amount of droplets with a large particle size at the time of discharge. However, aerosols, which are small particles, easily leak to the outside through the gap between the mask and the wearer's face, and it makes countermeasures difficult. [5]

Since droplets with a large particle size fall at a high speed due to gravity, it is thought that most of them can be prevented by securing social distancing. However, aerosols are easy to diffuse widely in the air, and it is difficult to remove the released aerosols from the air. [6]

There is a non-woven fabric filter as a device that shields aerosols. Face masks used by the general public tend to have gaps between them and the face, and most of the breathing air goes in and out through the gaps.

As for wearable-type high-performance Powered Air-Purifying Respirator (PAPR), medical PAPRs and industrial PAPRs are commercially available. However, they are designed to be used by special people in special environments and are expensive and uncomfortable. Therefore, in order to show that an inexpensive and comfortable high-performance PAPR can be realized, we have developed the prototypes of the "Distancing-Free Mask" [7] and the "Distancing-Free Booth" [8].

In this paper, a very-low-cost Powered Air-Purifying Respirator (PAPR) "Distancing-Free Mask Industry (DFM-I) Prototype No.1", which is suitable for use by the factory workers, is developed. This development is done in Cebu, Philippines under an international research collaboration project between Philippines, Singapore, and Japan researchers, in which the vaccine-independent and lockdown-free society/nation by means of spread of low-cost PAPR, is proposed and pursued [9]. The present status and future prospect of DFM-I and the project are discussed.



(a) Photo of DFM-Industry (b) Drawing of DFM-Industry

Fig. 1. Photo and drawing of Distancing-Free Mask Industry (DFM-I) Prototype No.1

2. Distancing-Free Mask Industry (DFM-I) Prototype No.1

Fig.1 shows the photo and drawing of Distancing-Free Mask Industry (DFM-I) Prototype No.1. The features of the DFM-I No.1 are as follows.

[1] A helmet-type mask with an airtight structure by a chin strap, which is based on a light work helmet and is composed of non-woven fabric and vinyl chloride sheet.

[2] Ears are exposed, so that communication with surrounding persons is easy. Easy to put on and take off by means of front entry with the chin strap.

[3] The outside air purified by a pump and a non-woven fabric filter (99.97% shielding of fine particles up to 0.3 μm) is supplied to the inside of the helmet.

[4] The internal pressure is kept to a positive value by the pump. Therefore, the intrusion of outside air through a small gap that may be formed in the chin strap seal is prevented. It is estimated that the air supply shielding rate $S_{r,in}$ is 99.97%.
[5] The air inside is exhausted through a non-woven fabric filter due to the pressure difference between the inside and outside.
[6] Leakage of internal air from the neck seal is estimated to be up to 5%.
[7] The supply air flow rate is large enough at approximately 400 L/min.
[9] The total weight is about 540g, including the battery for approximately 8 hours operation.
[10] The total cost of parts for the prototype is approximately $ 40. In the case of mass production, the price will be approximately 30 dollars or less.

Table 1. Features of DFM-F, DFM-I, and DFM-P

Model name	Aim	Target	Aerosol shielding performance	Low-cost	Active pressure control	Control via smartphone	Network Monitoring System
DFM-F (DFM-Frontline)	Protecting hospital doctors/staffs from COVID-19	Hospital Doctors /staffs	excellent	fair	excellent	excellent	good
DFM-I (DFM-Industry)	Creating a vaccine-independent, Lockdown-free industry	Factory/hotel/ restaurant/shop workers	excellent	excellent	not-applicable	not-applicable	not-applicable
DFM-P (DFM-Public)	Creating a vaccine-independent, Lockdown-free Nation	General public	excellent	good	good	good	excellent

3. Discussions

We will develop the following 3 models in this project, whose features are shown in Table 1.

[1] Distancing-Free Mask Frontline / DFM-F

DFM-F is a high-end model suitable for use in hospitals by the doctors/staffs.

[2] Distancing-Free Mask Industry / DFM-I

DFM-I is a very-low-cost model suitable for use in factories, hotels, and shops by their employees. By means of mass-producing and distributing DFM-I to every employee in the company, the company can continue the business even if the lockdown is announced. DFM-I is developed for saving the economy in the nation by this economy but high-performance PAPR.

[3] Distancing-Free Mask Public / DFM-P

DFM-P is a low-cost model suitable for use in daily life by the general public. DFM-P will be developed based on the achievements of DFM-F and DFM-I. DFM-P is the most important model, which will be operated in "Wearing Rate Monitoring Network System". By means of mass-producing and distributing DFM-P to everyone throughout the nation, the government can give the public the choices "stay home" or "go out with it" when the lockdown is necessary. DFM-P is developed for creating a vaccine-independent and lockdown-free nation.

4. Concluding Remarks

We propose the following procedure fighting against COVID-19 for the industry in the nation.

[1] The government set an experimental industrial area, in which the factories can continue the operation even in the other areas in the nation are locked down, under the conditions that all the workers are securely ware DFM-Industry.
[2] Many owners of companies are expected to prepare DFM-Industry for the possible lockdown.
[3] The government can evaluate the effectiveness of DFM-Industry in the experimental area at the time of lockdown.

Acknowledgements

This research is funded by Promotion of Joint International Research, KAKENHI (Grants-in-Aid for Scientific Research for FY2021, Issue No. 21KK0080). The authors thank Prof. Rosana Ferolin at USC for her suggestions to develop a very-low-cost PAPR for industry in Cebu city.

References

[1] Christie Aschwanden, "Five reasons why COVID herd immunity is probably impossible", ***Nature***, Vol.591, pp.520-522, 2021. https://doi.org/10.1038/d41586-021-00728-2

[2] Ewen Callaway and Heidi Ledford, "How to redesign COVID vaccines so they protect against variants", ***Nature***, Vol.590, pp.15-16, 2021. https://doi.org/10.1038/d41586-021-00241-6

[3] Kimberly A. Prather, Linsey C. Marr, Robert T. Schooley, Melissa A. McDiarmid, Mary E. Wilson and Donald K. Milton, "Airborne transmission of SARS-CoV-2", ***Science***, Vol. 370, Issue 6514, pp. 303-304, 2020. http://doi.org/10.1126/science.abf0521

[4] Dyani Lewis, "COVID-19 rarely spreads through surfaces. So why are we still deep cleaning?", ***Nature***, Vol.590, pp.26-28, 2021. https://doi.org/10.1038/d41586-021-00251-4

[5] Siddhartha Verma, Manhar Dhanak and John Frankenfield,"Visualizing the effectiveness of face masks in obstructing respiratory jets", ***Physics of Fluids***, Vol.32, 061708, 2020. https://doi.org/10.1063/5.0016018

[6] Michael Klompas, Meghan A. Baker and Chanu Rhee, "Airborne Transmission of SARS-CoV-2. Theoretical Considerations and Available Evidence", ***JAMA***, Vol.324, No.5, pp.441-442, 2020. https://jamanetwork.com/journals/jama/fullarticle/2768396

[7] Yusaku Fujii and Akihiro Takita, "Personal respiratory air purification device (helmet-type): Distancing-Free Mask (Prototype No.5)", ***Journal of Mechanical and Electrical Intelligent System***, Vol.4, No.2, pp.1-5, 2021. http://jmeis.e-jikei.org/ARCHIVES/v04n02/JMEIS_v04n02a001.pdf

[8] Yusaku Fujii and Akihiro Takita, "Booth-type of Personal Respiratory Air Purification Device: Distancing-Free Booth (Prototype No.1)", ***Journal of Mechanical and Electrical Intelligent System***, Vol.4, No.2, pp.6-12, 2021. http://jmeis.e-jikei.org/ARCHIVES/v04n02/JMEIS_v04n02a002.pdf

[9] Ronald M. Galindo, Akihiro Takita, Edwin Carcasona, Ethelda Magalang, Tabetha S. Galindo, Seiji Hashimoto, Takao Yamaguchi, Edgar U. Tibay, Dongwei Shu, Haruo Kobayashi, Kenji Amagai, Naoya Ohta, Noriaki Yoshiura, Anna Kuwana, Ayako Yano, and Yusaku Fujii, " Low-Cost Powered Air-Purifying Respirator (PAPR) "Distancing-Free Mask Frontline (DFM-F) Prototype No.1" for the Operational Tests in Hospitals in Cebu City, Philippines", ***Journal of Mechanical and Electrical Intelligent System***, Vol.5, No.2, pp.1-6, 2022. http://jmeis.e-jikei.org/ARCHIVES/v05n02/JMEIS_v05n02a001.pdf