Tuesday, 7th July 2020

Press Release

Development of a Helmet Mask for General Citizen

- Proposal of new social infrastructure that eliminates lockdown -

Gunma University Graduate School of Science and Engineering
NPO e-JIKEI Network Promotion Institute

Latest file (PDF file) is available here:
http://www.e-jikei.org/site/Press_Perfect_Mask.htm

【Time and Place】

Time: 13:00～14:00, Tuesday, 7th July 2020
Place: Meeting Room, Building No.3,
School of Science and Technology, Gunma University
1-5-1 Tenjin-cho, Kiryu 376-8515, Japan

【Overview】

We have invented a lightweight full-face helmet-type mask that completely shields the invasion of viruses from the outside (and almost completely shields the discharge of viruses). We have developed a prototype mask based on this patent (**Japanese Patent Application 2020-113097**). This mask is a full-face mask that simultaneously achieves the four items of **(1) complete screening of viruses, (2) lightweight body, (3) easy breathing, and (4) inexpensive manufacturing costs**, at a high level **by precise control of pressure and flow rate inside the helmet**. **The wearer of this mask, just like the antibody carrier**, cannot be infected itself with the virus, nor infect others with the virus. If every general citizen keeps the mask on hand and wears it when going out when the risk of spreading virus infection arises, the convergence of the infection can be ensured. **If most people own this mask, lockdown, restraint on going out, restraint on business, etc. are completely unnecessary.** In the press release, we will explain "Outline of this mask", "Social infrastructure that eliminates the lockdown used for this mask", and demonstrate the function of the prototype of the mask.

【Features of the Developed "Mask"】

Figure 1 shows a schematic diagram of the helmet part. Figure 2 shows the mechanism of air supply and exhaust of purified air in this mask consisting of a helmet part and a backpack part. The features of the present invention are the following three points.

[1] **By controlling the inside of the helmet to a slight positive pressure**, it is possible to **completely block the entry of outside air** from the seal part of the neck. In addition, the helmet dome can be made of a lightweight transparent resin material by keeping the internal pressure high to some extent. Invasion of virus can be blocked 100%. The virus emission depends on the air tightness of the neck seal, but it can be suppressed at a high level.

[2] **A constant flow of air** is taken in and out to keep a fresh air flow in the helmet. This allows fresh air to be breathed without adding extra load to the lungs.

[3] A **high-performance filter** with extremely large flow resistance can be inserted by forced air supply and exhaust by a pump, pressure buffer, and electromagnetic control valve housed in a backpack. It is also possible to equip the air supply side and the exhaust side with virus killing devices (UV irradiator, plasma cluster generator, etc.).

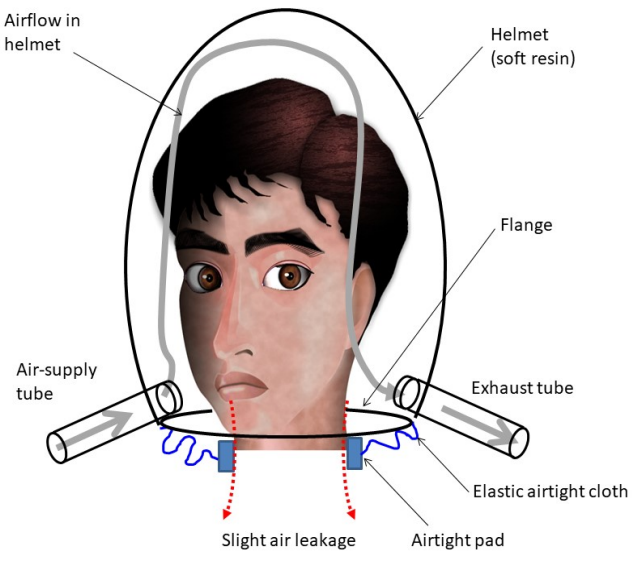

Figure 1. Airtight helmet part

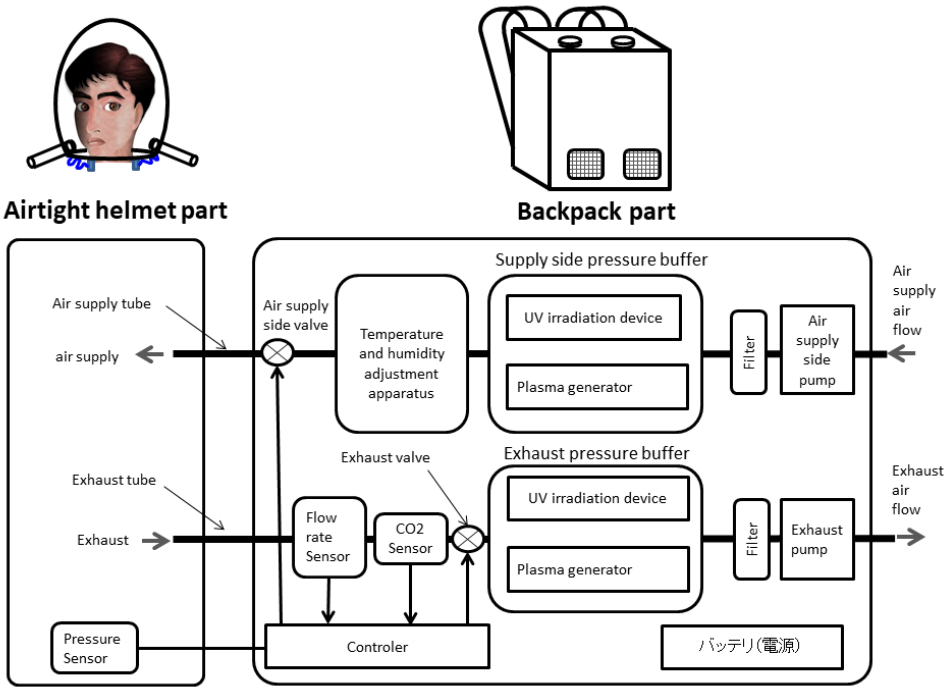

Figure 2. Mechanism of air supply and exhaust of purified air

【Variations of the Invention】

The following are variations of the "mask" based on the present invention.

[4] A **temperature/humidity adjusting device** and an **air composition adjusting device** (increasing oxygen concentration, decreasing carbon dioxide concentration, etc.) can be freely installed on the air supply side.

[5] Various products can be created by **replacing the airtight helmet part with an arbitrary airtight space**. As an example, a stroller with an airtight structure (Fig. 3), a bed with an airtight structure, clothes with an airtight structure, etc. can be used.

[6] We propose a **system that allows the airtight helmet part to be connected to an external intake/exhaust service port** (Fig. 4). Each seat of vehicles (cars, buses, trains, airplanes, etc.) and facilities (offices, conference rooms, theaters, cinemas, etc.) is provided with a service air supply/exhaust port connected to the air supply/exhaust tube of the mask. In addition, clean air with controlled temperature and humidity and composition (composition) is supplied to provide a more comfortable, cleaner and quieter mask environment.

[7] By incorporating a virtual reality display, a smartphone function, a noise canceling function, etc., the helmet part can be made a **user-friendly information terminal**.

[8] Like a glove box, **gloves and various feed-throughs** can be built in so that the weater can squeeze his/her face or blow his/her nose.

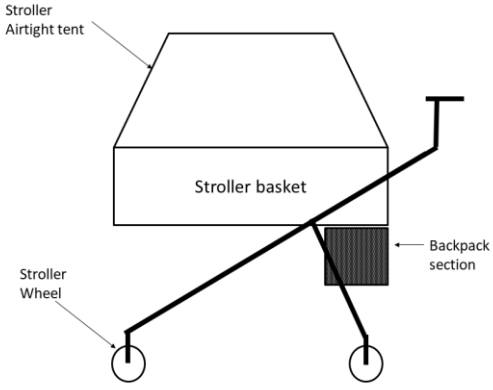

Figure 3. Stroller type

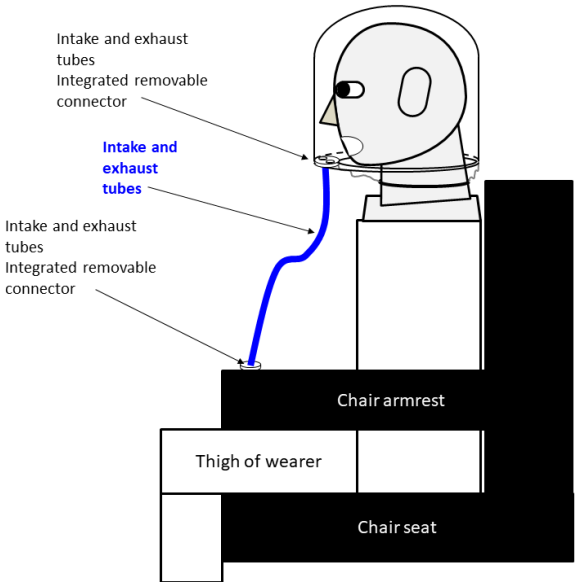

Figure 4. Service air supply and exhaust from seats

【Aim of Invention/Development】

The new coronavirus is expected to continue mutations and remain on the earth. The greatest threat is that the virus is more virulent and more infectious due to mutation than the current virus threat, and it is not known when such more virulent and more infectious virus will emerge. **Society in the future will always be required to be prepared for the emergence of vicious viruses due to such mutations.** In the future society, it is expected that the social aspect will be changed on the premise of keeping a social distance. Telework, online classes, etc. will become popular as standard, but there are still demands for physical movement of people, such as commuting, going to school, face-to-face meetings and conversations at companies and government offices, experiments and practical training at schools and universities. It is expected that it will definitely remain.

Currently, Japan and other parts of the world are experiencing intermittent lockdown as a countermeasure against new coronavirus (SARS CoV 2) infection. There are **4 possible scenarios to get out of the locked-down intermittent state**. ("Lockdown" here is defined as "a state in which the government requests or orders some kind of going-out regulation, business regulation, or behavior regulation as a countermeasure against infection." Japan is now under a weak lockdown.)

[A] Most of the people have become infected and have acquired immunity, and acquired collective immunity.
Collective immunity is acquired when most of the people have become infected and have been cured and acquired immunity. Here, the important point is that the "mask wearer" cannot be infected by the virus nor infect the virus to others, so from the viewpoint of collective immunity, it is equivalent to the "immunity acquirer".

[B] A "prophylaxis (vaccine)" has been developed, and vaccination will obtain collective immunity.
If a "prophylaxis (vaccine)" is developed, as with influenza, the majority of non-infected persons will be vaccinated to obtain collective immunity.

[C] An "effective therapeutic agent" is developed.
Once "effective remedies" have been developed, made available, and are able to heal infected individuals easily, there is no need to fear the spread of infection.

[D] A "simple and reliable test method" is developed.
Obviously, if there is a "simple and reliable test method/tester" just like a thermometer or a blood pressure monitor, it is enough to promptly detect the infected person, isolate and treat it. Others (=confirmed to be non-infected people) do not need to keep staying at home at all. Since there is no "easy and reliable test method" available now, the whole society will be placed in the darkness where no one knows who is infected, and everyone can only respond uniformly.

If any of the above-mentioned scenarios [B] preventive method (vaccine), [C] therapeutic agent, and [D] simple and reliable test method are developed, the problem will be solved. However, neither of them has the prospect of immediate development. (It is expected that it will take at least one year at the shortest.) Therefore, **[A] Collective immunity acquisition will be the only realistic solution**. In a society (group) where there is no antibody possession, **"ratio of wearers of this mask" is equivalent to "group immunity rate"**.

The collective immunity rate Pc required to obtain the collective immunity can be expressed by the following equation using the basic reproduction number R0.
$Pc = 1 - 1/R0$
Example: When R0=2, the infection ratio Pc=1-1/2=0.5 (50%) required for collective immunity acquisition. If R0=1.2, Pc=1-1/1.2=0.17 (17%) is enough. The above formula is based on the assumption that the behavior of individual movement and contact does not change even if the collective immunity increases due to the spread of infection.

The basic reproduction number R0 can be expressed by the following equation.
$R0=\beta \times k \times D$
β: Probability of infection per contact
k: The average number of times one person contacts another person (=uninfected person) in the group per unit time
D: Average infection period

The basic reproduction number R0 is defined as the average number of people who are infected by an infectious disease and are directly infected during the infection period when they join a group (society) in which no one is immune. From the definition, in the "state where there are almost no infected people", if R0=1 for the group (society), it is a steady state, if R0<1, it converges, and if R0>1, it expands. R0 depends not only on the nature of the virus, but also on the nature of the population (racial constitution, condition, public health condition, individual health condition, etc.). It is thought that R0 can be reduced against all viruses by improving public health.

That is, the following is valid.
Reduction of β: Immunity increased, mask worn, hand washing encouraged.
Reduction of k: Working from home, introducing home-based learning, avoiding 3 secrets, and ensuring social distance.
By creating a social state in which β and k are reduced, R0 is reduced and Pc is reduced.
It can be said that the lockdown state is a state in which β and k are extremely reduced.

The effective number of reproductions Rt is defined as the average number of people who are directly infected during the infection period, when one infected person infected with an infectious disease joins the group at the stage when the infection has spread to society to some extent (= the stage when the collective immunity rate has reached a certain level). For example, in the case of a population with a collective immunity rate of 20%, the above k will be substantially 80% (because 20% of the people who come into contact will have immunity), and Rt=0.8R0.

Like the basic reproduction number (R0), the effective reproduction number (Rt) can be conveniently expressed as the following equation.
$Rt = \beta \times k \times D$
β: Probability of infection per contact with uninfected persons
k: Number of times one infected person contacts uninfected people in the group per day
D: Days of infection

The following will be effective in converging infection (achieving Rt<1).
Reduction of β: Wearing a mask, encouraging hand washing, improving immunity, etc.
Reduction of k: introduction of work-at-home/at-home learning, securing of social distance, increase of immune carriers (improvement of collective immunity), etc.

If all the people wear "masks that can completely shield viruses" when going out, a society where the number of basic reproductions (R0) and the number of effective reproductions (Rt) are zero for all viruses can be realized. No lockdown or self-control is required.

At the stage when the risk of spread of the virus is predicted, a sufficient number of people will wear "masks that can completely shield the virus", and the basic reproduction number (R0) in the society concerned, and The effective number of reproductions (Rt) is reduced to a sufficiently small value less than 1, and infection can be stopped.

An uninfected person wearing a "mask that can completely shield the virus" he does not infect the virus or infect others with the virus, as does a cured immune carrier. In other words, if the proportion of uninfected persons who wear a "mask that can completely shield the virus" increases, k will be reduced by that proportion. The "infected person wearing the mask according to the present invention" does not release the virus to the outside, or the virus does not enter the "uninfected person wearing the mask according to the present invention". It can be interpreted that the above β (probability of infection per contact with an uninfected person) decreases as the proportion of "wearers" increases.

The "wearer of the mask according to the present invention" has an "infinite social distance" to the people around it. (It takes an infinite social distance regardless of the physical distance.) A nation (society), in which **all the people have one "mask according to the present invention" and wear it** when they go out, is **extremely resistant to viruses**.

We expect the social aspects of the corona era to be as follows.
[1] **All people have one "mask"** (= "mask" according to the present invention).

[2] If there is a risk of spreading the virus, the government will declare an emergency and oblige the people to wear “mask” when going out.
→ If a person wears "mask", he/she can go out freely without any restrictions.
→For example, if **80% of people wear “mask”** when going out, it is equivalent to achieving **80% of the collective immunity**.
[3] When it is confirmed that the virus infection has been resolved, the government lifts the declaration of emergency and ceases to be obligated to wear a "mask" when going out.

Nowadays, many people are drinking **"potable water" instead of "tap water"**. Especially in urban areas, "air" contains various pollutants such as PM2.5. Therefore, in the near future, people will want to breathe **"purified/filtered air" instead of "natural air"**. In the near future, many people will wear "mask" (= "mask" according to the present invention) when going out, regardless of the spread of virus infection and whether or not there is a request from the government to wear it.

People wear "shoes" when they go out. Similarly, in the near future, people will wear "mask" when going out. Then, it is expected that people will own various types of "masks" in the same way as they own various types of "shoes".

We believe that the "mask" based on the present invention and its peripheral systems (provision of service air supply/exhaust ports in vehicles and facilities, home airlock systems, etc.) will become an indispensable social foundation in the corona era.

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【Appendix-1: Control/Electronic Circuits】

Figure 1 shows a block diagram of the basic configuration of the control system related to the helmet type mask which completely shields viruses. The flow rate and pressure in the helmet are measured by a flow sensor and a pressure sensor. Feedback control is performed by two fans for air supply and exhaust. As a result, the pressure and flow rate inside the helmet are controlled at high response and with high accuracy.

The rotation speed of the exhaust side fan is controlled so that the output of the flow sensor installed in front of the exhaust side pressure buffer quickly follows the reference value. Similarly, the rotation speed of the air supply side fan is controlled so that the pressure in the helmet measured by the pressure sensor follows the reference value.

Here, the flow rate is controlled as a sufficiently large value (40 L/min), considering that human respiration is about 10 L/min. Its responsiveness is fast enough within 1 s. In addition, the pressure inside the helmet is set to a value slightly higher than the external atmospheric pressure (fine positive pressure: +20 Pa, about 0.02% of 1 atmospheric pressure) to completely prevent the entry of outside air. The pressure response is also within 1 s, which is a sufficiently quick response. Due to the forced intake and exhaust of the two fans, a mask filter and a thick filter can be used on the inside (helmet side) without preventing the flow.

In addition, a CO2 sensor is installed and monitored in the helmet, and the carbon dioxide concentration of the situation inside the helmet is constantly monitored. When it exceeds a certain value (set to 2000ppm, the maximum value of dirty air), the flow rate is increased and an alarm is set to sound.

The demo model has two fans installed for clarity, but this function can also be realized with one fan and one valve. In addition, the sensor measurement, fan, and control unit are all driven by a single battery (12V lithium-ion type).

Also, for the sake of ease of recognition in the demonstration, a large-sized fan that produces sound is used, so a backpack of this size is used. However, considering the miniaturization, it can be made into a volleyball size, a large lunch box size, or a helmet-built-in type, and it is fully portable.

As a verification of each feedback control effect, for example, when the tube on the exhaust side is pinched and the flow rate is reduced, the rotation speed of the exhaust side fan increases in order to increase the flow rate. If the cover under the helmet is pushed back and the internal pressure is increased, the internal pressure tries to decrease to the set value, and the rotation speed of the air supply side fan decreases. Furthermore, if you repeat quick breathing in the helmet and increase the carbon dioxide concentration, the CO2 sensor will sound an alarm.

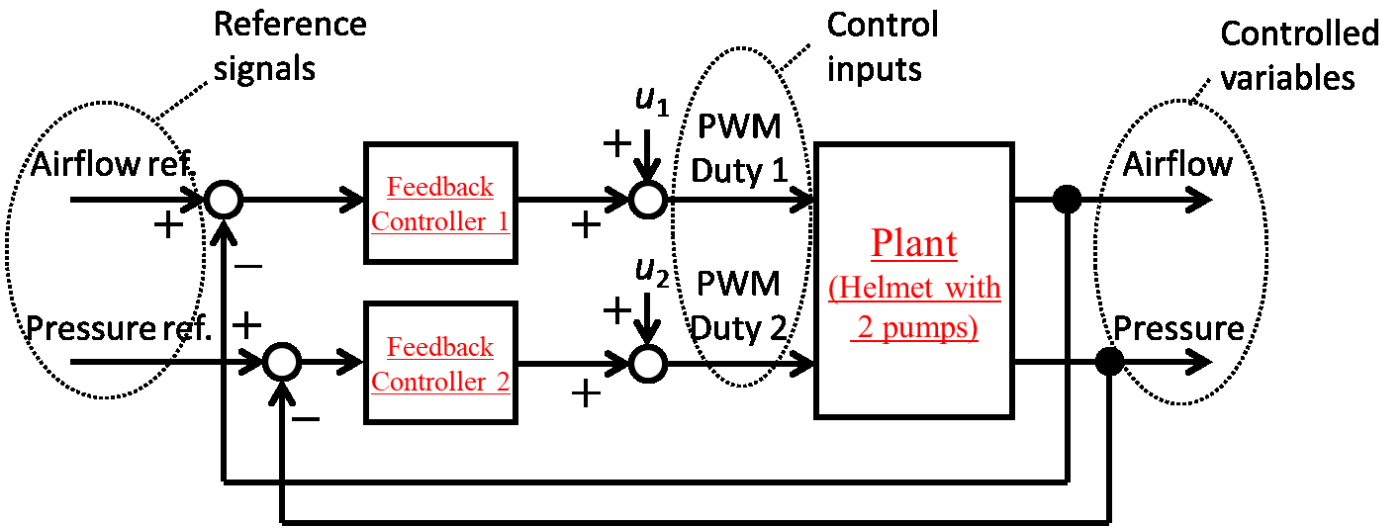


Fig. 1 Block diagram of helmet type mask with intake and exhaust control function.

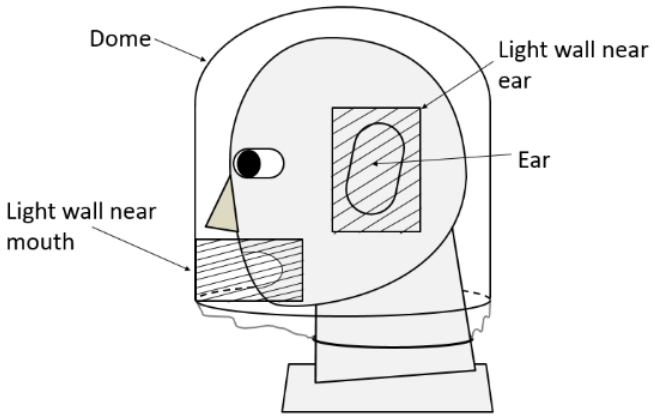
【Appendix-2: Acoustic/Mechanical Structure】

【Problem 1】

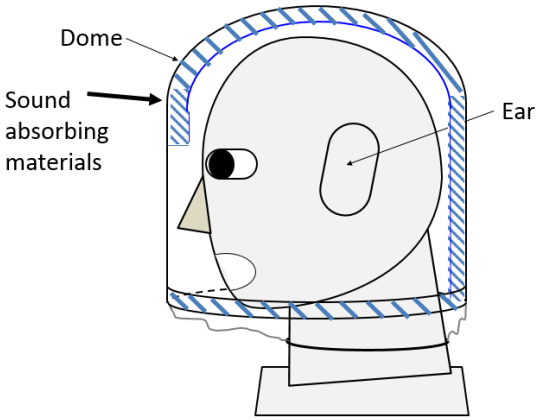
The material for the walls in the helmet must be impermeable for air. And the walls require material strength not to be destroyed under static pressure (i.e. intake pressure).However, if we adopt too thick walls or too heavy materials for the helmet because of the strength, the sound insulation property of the walls become too high (i.e. sound transmission through the wall reduces.). This leads to too much sound reflection in the helmet. And then, the people in the helmet feel hard to hear outer conversations and sounds. Further, the voices and sounds from the people in helmet are hard to propagate to people in the outer space. Moreover, the people in the helmet feel uncomfortable because of too much echo of the voices and sounds in the helmet.

【Solution for Problem 1】

Sound insulation performance of an impermeable uniform wall is under mass law. Due to this law, sound in higher frequency range is easily cut off when the wall is heavier. Therefore, to obtain natural and comfortable acoustic environment, we adopt the lighter wall around the mouth and ears. This causes that static pressure (intake pressure) cannot go out the walls, but fluctuated dynamic pressure (sound waves) can propagate through the walls via vibration of the walls. We can solve the problem 1. We can hear easily sounds in the outer space, and the people in the helmet can propagate his voices or sounds to the people in the outer space. Further the undesirable echo can be depressed.



Light walls near ears and mouth



Layout of sound absorbing materials

【Problem 2】 The people in the helmet feels uncomfortable because of too much echo of the voices and sounds in the helmet. Further, noise from the air supply unit is amplified due to resonances in the space of the helmet.

【Solution for Problem 2】

To decrease the amplitude of the undesirable noise and echo, we lay out sound absorbing materials in the space of the helmet. These sound absorbing materials have many microscale or nanoscale pores. The acoustic energy is dissipated due to viscous resistance when the sound waves propagate through the small pores. However, we do not set the sound absorbing materials around the eyes, ears, nose and mouth of the people in the helmet not to disturb the visual sense, auditory sense, sense of smell, breathing and voice generation.

We can also adopt the sound absorbing materials in the intake/exhaust tubes and the duct in the back packs.

The sound absorbing materials also have a role of shock absorber to protect the head and face of the people in the helmet. Moreover, the sound absorbing materials can adjust and fit between the shape of this head and that of the helmet. This increases comfortable feeling of wearing the helmet and decrease tiredness.

【Another Solution for Problem 2】

We can set noise canceling devices in the helmet and/or near the sound sources beside the air supply unit in the backpack. The actuators like speakers and/or piezoelectric bodies are fabricated near the ears of the people in the helmet and/or near the sound source. The sensors like microphones are also set around the ears and the sound sources. Against the sound waves from the sensors, we add sound waves with phase inversion by controllers from speakers. This cancels the noise from the air supply unit and /or the environmental noise outside of the helmet.

【Appendix-3: Information and Communication, AR】

Because our helmet mask should be worn long time in a day, it is important to perform various tasks with wearing the mask. In particular, the integration of information and communication technologies such as smartphones and XR (a general term of VR, AR and MR) technologies such as augmented reality will be important to extend the comfort and convenience of masks.

As the integration of information and communication technology, it is important to incorporate the functions of smartphones, which are widely used today. At first, by integrating a microphone and speakers into a mask, it becomes possible to hands-free call and voice control. Particularly with AI assistants, the functions such as changing music, controlling lights, reading out news, email and SNS services, are enabled. Secondly, if a head-mounted display is integrated with the mask, we can watch a movie or play a game. Since the image is only visible to the wearer and the sound leakage can be prevented by the mask, the privacy protection is perfect. Because the needs for viewing outside is depending on the purpose of the image, it is recommended to select transmission or blocking of the outside light by means of a physical shutter or a liquid crystal shutter.

Figure A3-1 shows an example of a helmet-type mask with an XR screen. In this mask, a concave half-mirror is installed in front of the helmet, and projectors project a virtual screen in front of the wearer. The liquid crystal shutter on the back side of the half-mirror controls the transmission or blocking of the outside light. In addition, two cameras are used to determine the current position and rotation of the mask for generating XR images. This system allows us to experience a virtual reality world created on a computer (VR), an augmented reality world (AR) synthesized CG and captured outside image, MR (mixed reality world in which CG images are superimposed on the real world. As input devices, in addition to the voice input and additional controller held in the hand, wearer can also use cameras and their own hands for hand tracking controlling.

As the usage of the XR-enabled mask, in addition to the experience of games and attractions, there are other possibilities, such as a navigation system that superimposes the real world and CG on the road, and a work assist that displays work procedures near the levers and buttons that are actually operated.

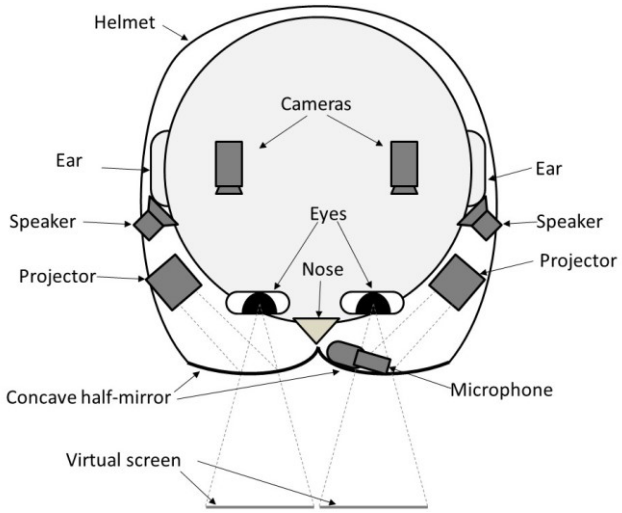


Fig. A3-1. Sample of VR screen integration

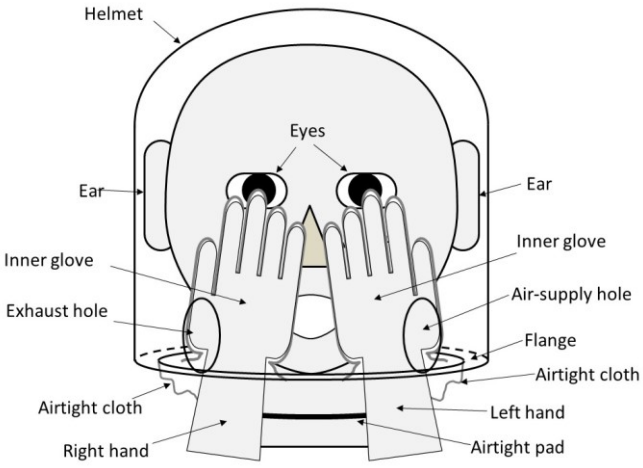


Fig. A3-2. Sample of inner glove.

【Additional comfort amenities】

[Inner glove]

One of the problems with wearing the helmet-type mask is that wearer may want to touch their face to relieve sweat and itching. As a solution, it is proposed that a thin glove is built into the airtight cloth part at the lower part of the mask as shown in Fig. A3-2. By inserting wearer 's hands into the glove from under the helmet and bringing their hands in front of their face, they can touch their face and wipe sweat off. By using thin and flexible material for the glove, the glove can be folded up and stored in the airtight cloth when not in use.

[Inner pocket]

Wearing a mask for long time requires food intake and medicine taking. Wearing or removing a mask to eat or take medication increases the risk of infection. A function which enables to eat and take medicines while wearing a mask is required. As a solution to this problem, we proposed a system to create a pocket inside the mask for storing small items, food and medicine. The flexibility of the airtight cloth enables to take out the item in the pocket. The inner globe described above is also useful.