A Low Resistance Mask with Fan

Mingjun Gao

1. Overview

Masks became the most commonly used health protection devices for people during the pandemic, but wearing them for a long time often leads to difficulty breathing. The device designed in this project uses a fan to reduce the difference in air pressure between the inside and outside of the mask to improve the smoothness of inhalation, significantly improving the suction resistance of the mask while not affecting its original exhalation resistance. The device is small in size and can be carried around, powered by a power bank. All materials can be obtained from the market, and the cost is low, making it more suitable for ordinary people.

To solve the long-term comfort of mask matching, it is necessary to develop and analyze the structure of the mask. Masks are usually composed of multiple layers of filtering materials, and air can only enter after being filtered

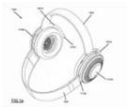
layer by layer, which is hindered by the filtering layer. The better the filtering performance of a mask, the more excellent the breathing resistance.

Masks purchased from pharmacies usually indicate respiratory resistance, measured using professional instruments. To accurately determine the mask's resistance in this project, the AS510 handheld micro pressure gauge was used to measure the pressure difference inside and outside the mask (specific measurement methods can be found in the appendix). For example, the KN95 mask has a pressure difference of +40 Pa between the inside and outside when exhaling and -40 Pa between the inside and outside of the mask when inhaling. The professional KN99 mask was not tested in this project, and according to online data, the breathing pressure difference can reach 100-200Pa.

Simply put, the better the protective performance of the mask, the more difficult it is to breathe through it. The direct way to relieve suffocation after wearing a mask is to reduce respiratory resistance and the pressure difference inside and outside the mask.

In many masks with good filtering performance (such as the KN95 mask), an exhaust valve is added to the front of the mask. When exhaling, the air is directly discharged through the valve without passing through the mask filter layer, which has almost no resistance and reduces the feeling of suffocation. However, due to its unique design, the exhaust valve will still close during inhalation, so the resistance to inhalation has not completely decreased. This inspired me to design my mask, hoping to create an assistive breathing device to solve the inhalation problem.

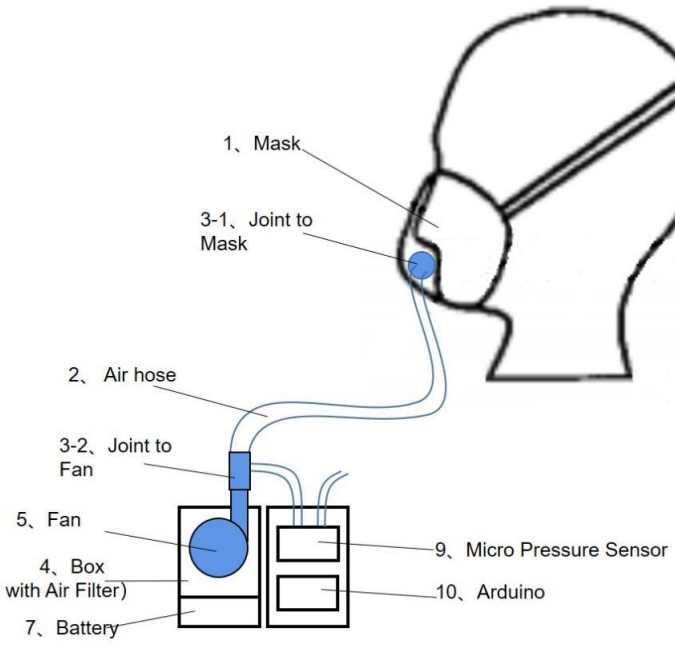
Furthermore, common instruments that do this job are either too expensive or too inaccessible:

Category	Image	Usage	Price (Chinese-Yuan)
Medical ventilator		rescue critically ill patients	10000 ~ 100000
Household oxygen		oxygen supply, health care	1000
Household ventilator		reduces snoring	1000~5000
Dyson mask		filtering virus	not yet on the market until 2021

Thus, I needed to make my design affordable as well.

2. Structure

The device designed in this project consists of three parts: a mask, an airtight box with a fan, and a microcontroller with a sensor. Refer to the appendix for a detailed list of accessories and costs.

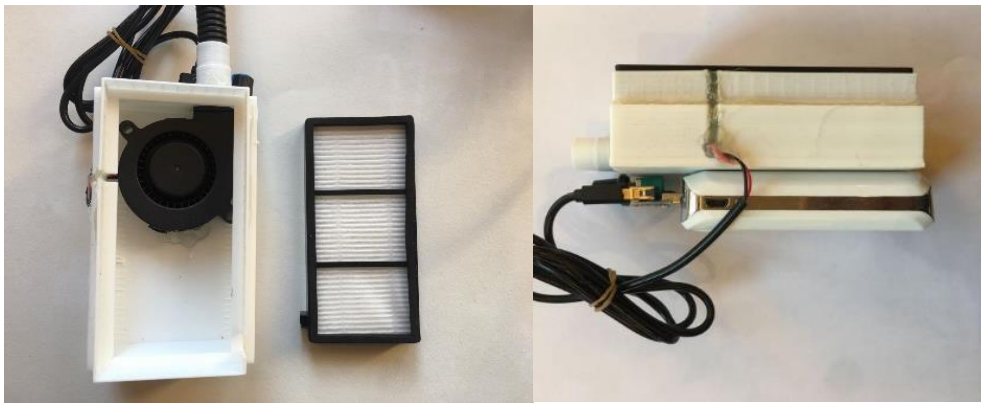


3. How did I make it

3.1 Making Process

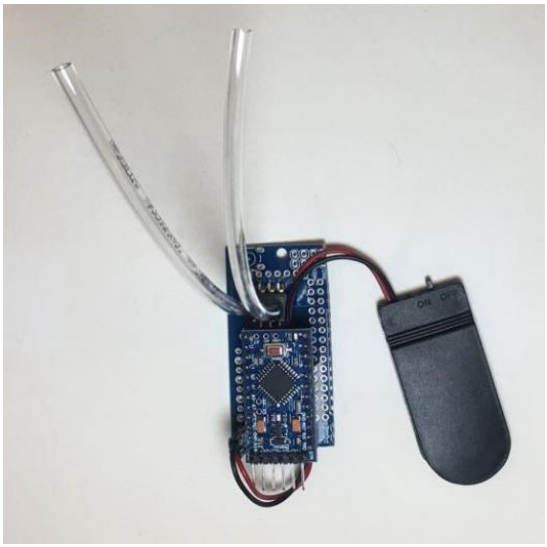
Step 1: Purchased a mask with an exhaust valve (1) from the pharmacy, remove the exhaust valve, and install the 3D printed air supply pipe connector (3-1).

Step 2: Install the turbine fan (5) into the 3D-printed airtight box (4) and cover it with a filter (6). Connect the fan's power cord to the battery (7), and connect the fan's exhaust port to the air supply pipe connector (3-2).



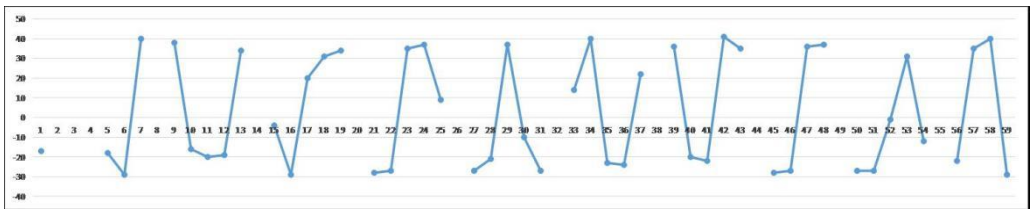
Step 3: Connect the mask (1) and the airtight box (4) with a fan and filter using the air supply pipe (2). Turn on the power, and the fan starts supplying air and pressurizing the mask.

Step 4: Keeping the fan on constantly makes the device very power-consuming, so it is necessary to detect when it is inhaling and when it is exhaling to control the switch automatically. The solution is to add a micropressure difference sensor (9) to sense the slight pressure difference generated during breathing and then use a microcontroller (10) to read the pressure difference. If it is a negative pressure value, it is judged as inhalation; if it is a positive pressure value, it is considered as exhalation. Then, the relay (11) is used to control the fan switch.



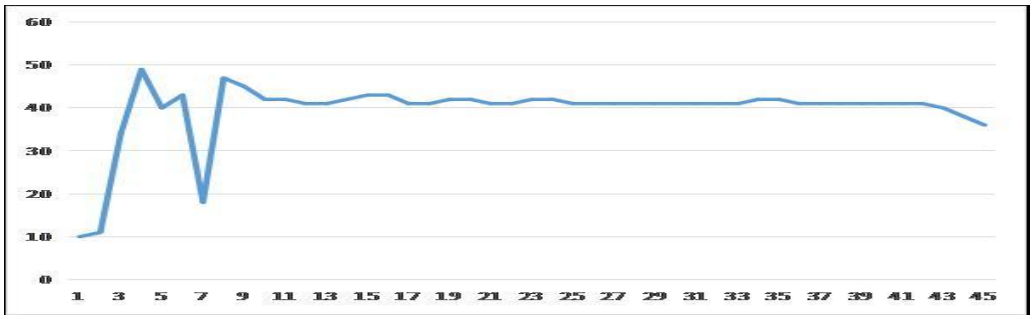
3.2 Testing

Test case 1: Without turning on the fan, AS510 tests the pressure difference between the inside and outside of the mask during breathing.



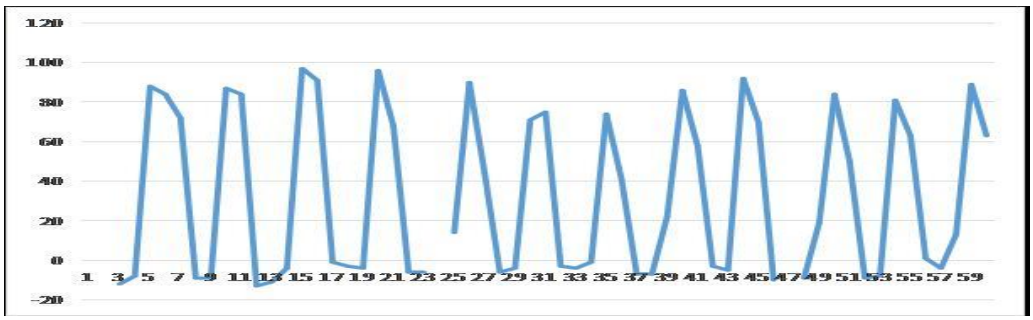
The maximum expiratory pressure is about 40 Pa, and the minimum inspiratory pressure is about -30 Pa.

Test case 2: Turn on the fan, hold your breath, and test the pressure difference inside and outside the AS510 mask.



After the fan stabilizes, the pressure difference between the mask's inside and outside remains at 40Pa.

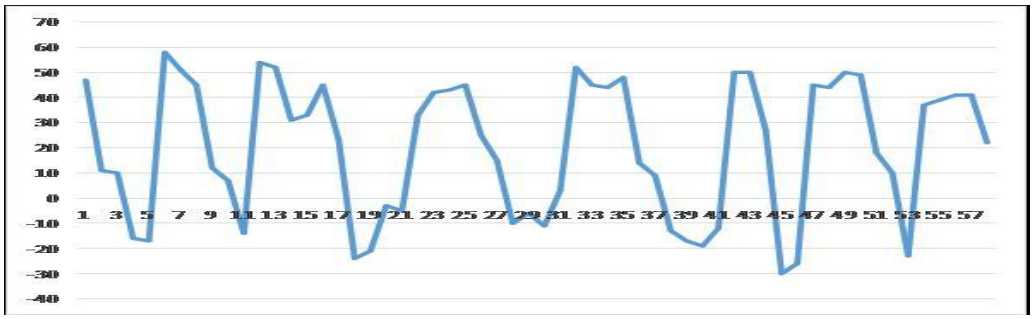
Test case 3: Turn on the fan, and AS510 tests the pressure difference between the inside and outside of the mask during breathing.



The maximum expiratory pressure difference is about 90Pa, and the minimum inspiratory pressure difference is about -10Pa.

It can be seen that the absolute value of the suction pressure difference in Test case 1 has been reduced by 20Pa, which significantly improves the suction resistance. However, the total value of the exhalation pressure difference increased by 50Pa, and the exhalation resistance increased.

Test case 4: The Arduino microcontroller automatically switches the fan on and off during breathing, and AS510 tests the pressure difference between the inside and outside of the mask during breathing.



After controlling the fan, when exhaling, the fan was turned off. Compared to Test Case 3 (with the fan on), the maximum pressure difference decreased from 90Pa to about 50Pa, and the exhalation resistance decreased, which was equivalent to Test Case 1 (without the fan);

When inhaling, the fan was turned on, and compared to Test case 3 (with the fan on), the maximum absolute pressure difference increased from 10Pa to 20Pa. The breathing resistance increased but was still better than in Test Case 1 (without the fan). This indicates that the microcontroller control of the fan has not kept up with the rhythm of inhalation.

4. Reflection

The mask is of moderate size, making it possible to carry it around easily. Using common materials in the market, with a total cost of less than 100 Chinese Yuan. The battery uses an ordinary 5V power bank, which is easy to obtain. So this mask is suitable for ordinary people to use.

Several difficulties I encountered throughout the process:

1. Can the fan reach inside the mask? I initially tried fans with diameters of 12mm and 18mm, which were attached to the inside of the mask. However, I found no significant change in the air pressure difference after turning on the fan. There may be two possible reasons for this: 1) The fan size is small, and the power is too low; 2) The fan cannot fit the inner layer of the mask and cannot suck in external air. This attempt rejected the direction of the built-in fan and identified a fundamental principle: "Fan power should be high, and air tightness is also important," guiding subsequent design.

2. How to trigger the fan automatically? The initial idea was to use a physical spring switch, but the force generated by breathing was too small to trigger the switch. I disassembled the AS510 micro pressure measuring instrument I bought and found that it uses a micro differential pressure sensor internally. I searched online and found a similar sensor, which is very cheap. This solves the problem of fan switch triggering by measuring the pressure difference between the inside and outside of the mask.

There are still many shortcomings in this mask. The major issue is that the automatic control judgment conditions are rather in-adjustable. In addition, the size of the fan box is a bit too large. It is best to find a smaller and high-

power fan that can be directly installed on the outside of the mask, eliminating the need for air supply pipes and making it more convenient.

5. Additional Information

5.1 BOM

No.	Name	Qty	Image	Price(Yuan)	Description
1	**KN95**	1			buy from drugstores
2	**Air hose**	1		3.6	Taobao, 2 meters
3	**Joint**	2		-	3D print
4	**Box**	1		-	3D print, 112mm*66mm*35mm
5	**Fan**	1		14.7	Taobao, 5V
6	**Air Filter**	1		10	JD online store
7	**Battery**	1			Portable Power, 5V
8	**USB Speed control**	1		7	Taobao,
9	**Micro pressur e sensor**	1		48	Taobao,
10	**Arduino**	1		12.5	Taobao, Arduino Pro Mini
11	**Relay**	1		0.93	Taobao, HKE HRS1H-S-DC5V
12	**CR2032 case**	1		0.98	Taobao
13	**PCB板**	1		7	Taobao

5.2 Measurement of Pressure Difference of Mask

The AS510 handheld micro pressure gauge (priced around 150 yuan on Taobao) has a measurement range of 0-100hPa and an accuracy of ± 0.03hPa.

Measurement method:

1. Turn on the power of AS510 and reset it to zero
2. Insert a trachea of AS510 into the mask, close to the mouth and nose
3. Place the other trachea outside the mask
4. The display screen of AS510 shows the pressure difference between the inside and outside of the mask