International Core Journal of Engineering Volume 6 Issue 12, 2020
ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0025

The Effects of Whether Wearing the Mask in the Spreading Process of COVID-19

Junyi Lin[1], Sharui Zhang[2], Zhangliang Li[3]

[1]Fuzhou Gezhi High School, Fuzhou, Fujian 350001, China;

[2]Chengdu Shude High School, Chengdu, 610066, China;

[3]School of mechanical and electrical engineering, Wuhan University of Technology, Wuhan, Hubei 430070, China.

Abstract

During the pandemic of COVID-19, wearing a mask, and keeping social distance become significant topics among the public, which are somewhat controversial. In this project, it discusses the fluid field changing when coughing, which will produce a large quantity of saliva. The project conducts series of experiments to prove the importance of wearing a mask when being in a crowd. The result of the project shows that wearing a mask can reduce the probability that saliva particles enter the breathing zone by 44.7%, which can largely reduce the affection rate of the virus.

Keywords

COVID-19, Face Mask, Pandemic.

1. Introduction

1.1 Background Introduction

As the pandemic of COVID-19 globally, the masks become the most needed medical equipment, while some individuals did not believe that wearing a mask is beneficial in prevent spreading of the virus in the early stage. Currently, the outbreak of COVID-19 has already caused approximately 224,301 people lost their lives and 3,181,642 confirmed cases because of its transmissibility. The data is collected on May 2, 2020. The latest data can be obtained by visiting the official website of World Health Organization (WHO), by clicking the link: (https://www.who.int/emergencies/diseases/novel-coronavirus-2019). In this case, a method to decrease the transmit opportunities become looming.

1.2 Questions and Hypothesizes

In the beginning stages, most of publics did not have conscious to wear surgical mask, and even some Americans were told to wear cloth masks[1]. However, whether wearing a mask will have different preventing effect, and cause various fluid fields around the coughers, which will cause the transmit of virus.

In this case, authors assumed that whether people wearing masks will be the variables that determine the fluid field around a cougher, which determine the travelling distance of saliva particles and the particles conditions when people inhaling, which will probably make other get infect.

1.3 Feasible Methods

During the COVID-19 pandemic period, it will be unsafe to do the experiment with team. To follow the social-distancing call, authors decided to use simulation software, ANSYS, injecting the particles into the model, to simulate the coughing process, obtaining the scientific data and analysis the result.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0025

2. Experimental Section

2.1 Particle Configuration

By using the "Fluid Flow (Fluent)" tool in the ANSYS, creating the particle injection, authors can use the path of the particle to simulate the fluid field of saliva that released by coughing.

According to the research done before, authors consider configuring the particles' diameter accordingly as the Table 1.[2]

Table 1. Units: μm

Min. Diameter	Max. Diameter	Mean Diameter
50	100	60

Additionally, the particles all have following properties when they are released as Table2 listed. The initial velocity of injection is determined as 1.007 m/s.[3]

Table 2. The properties of injection in coughing experiment.

X-velocity (m/s)	Y-velocity (m/s)	Total Flow Rate(kg/s)	Spread Parameter	Number of Diameters
1.007	0	1	3.5	100

For the inhale experiment, the particles have different configuration with the data listed in Table 3.[4]

Table 3. The properties of injection in Inhale experiment.

X-velocity (m/s)	Y-velocity (m/s)	Total Flow Rate(kg/s)	Spread Parameter	Number of Diameters
0	0	0.747	3.5	3

2.2 Model Setup

The experiment is targeting to simulate the exhale and inhale procedure. Authors determined the height between the floor to the injection point as 1.6m, which is easily to calculate and close to the average human height.

For inhale procedure, especially, there is another “mouth” on the opposite site of the inlet point as a pressure outlet. The horizontal distance between two people is determined as 2.3m.

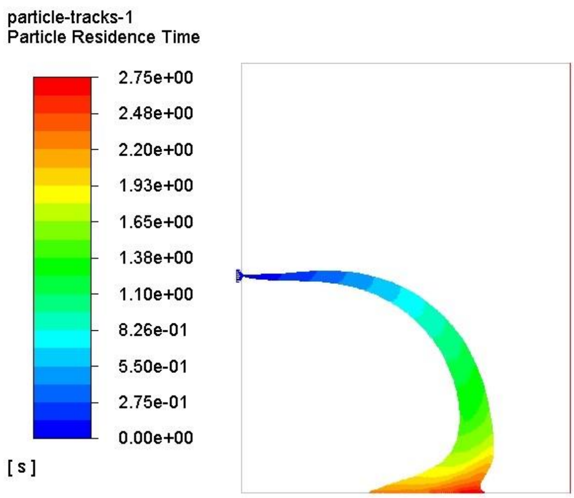

Fig 1. The fluid field of coughing without a mask

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0025

3. Experiment Section

3.1 Exhale Experiment

According to the experiment data, the distance between the exhale point to the original point is 0.3792m. Therefore, the data about the X-position need to be calculated.

3.2 Particle Track Without Wearing A Mask

Since the person is coughing without wearing a mask, the particle will be injected without any obstacle, as Figure 1 shown.

To determine the travelling distance of the particles, authors made the particles' data which the Y-position is less than or equal to -1.4m as the valid data. By filter the data, there are 13,111 records valid in 154,659 records, which has the properties listed in the Table 4.

Table 4. The properties of particles released without mask.

Min. X-position	Mean X-position	Max. X-position
0.516682	1.005880227	1.31855

By rewriting the data, authors determined the horizontal distance between the particles landing points and the injection point as Table 5.

Table 5. The travel distance of the saliva particles.

Min. X-position	Mean X-position	Max. X-position
0.895882	1.385080227	1.69775

3.3 Velocity Contour of Coughing with A Mask

For the model with a mask which will prevent the saliva from flying into the air, authors decided to add an obstacle in front of the injection point, having a 1cm gap between the mask and the injection point. To simplify the calculation, authors assumed the mask is impenetrable. The velocity contour condition is shown as Figure 2.

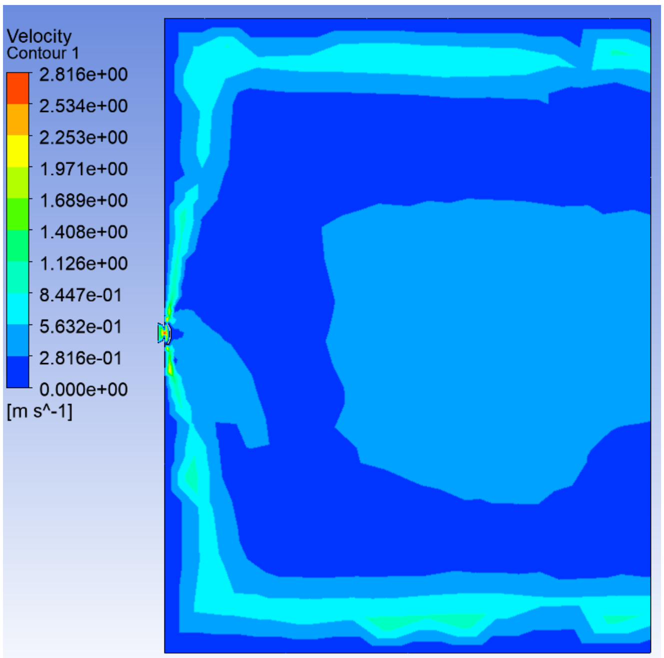

Fig 2. The velocity contour condition when coughing with a mask

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0025

3.4 Inhale Experiment

When people inhale, they cause an air flow of 1.8055556 meters per hour, and a pressure of -200Pa is formed in the mouth[5]. According to the experiment data, the distance between the exhale point to the original point is 0.3792m. Therefore, the data about the X-velocity, Y-velocity and the proportion of particles entering breathing zone need to be calculated.

3.5 Particles Tracks Without Wearing A Mask

When the person is inhaling without wearing a mask, the particle will be injected into person's mouth without any obstacle, as Figure 3 and Figure 4 shown.

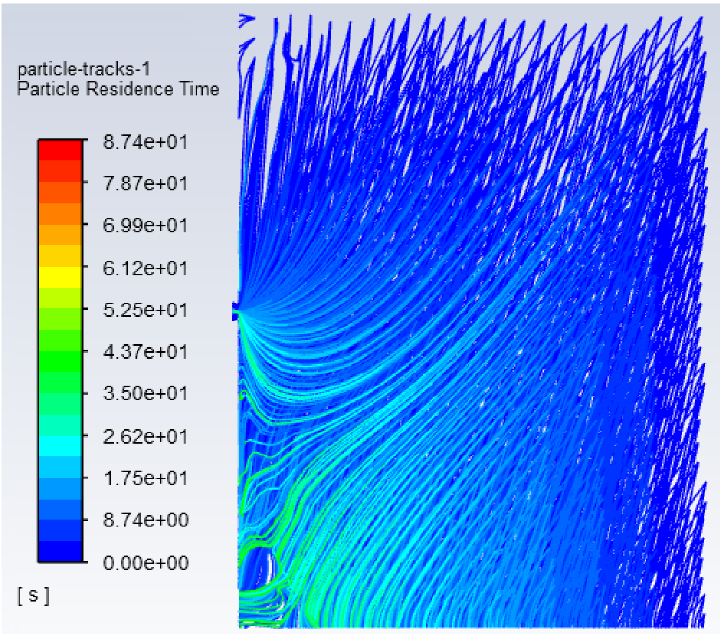

Fig 3. The fluid field when a person inhaling without a mask

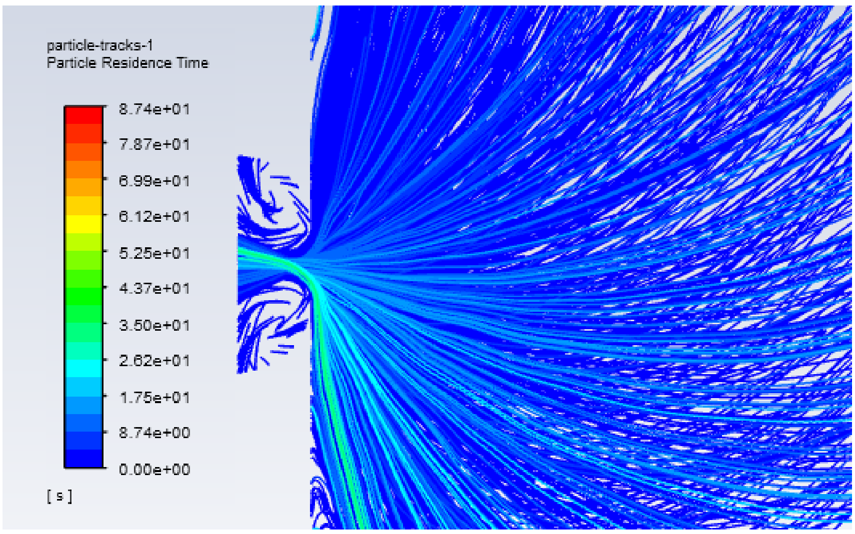

Fig 4. The fluid field of inhale without a mask. (Zoomed in the mouth part)

In order to determine the X-velocity, Y-velocity and the proportion of particles entering breathing zone (with a diameter of 0.2286m), authors made the particles' data with the x-position is between -0.1506m and -0.3792m as the valid data. By filter the data, there are 977,205 records valid in 118,421 records, which has the properties listed in the Table 6 and Table 7.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0025

Table 6. The X-velocity of particles released in breathing zone without wearing a mask

Min. X-velocity	Mean X-velocity	Max. X-velocity	Max. Absolute value of X-velocity
-4.96688	-0.0801	1.18092	4.96688

Table 7. The Y-velocity of particles released in breathing zone without wearing a mask

Min. Y-velocity	Mean Y-velocity	Max. Y-velocity	Max. Absolute value of Y-velocity
-9.29283	-0.0451	5.10287	9.29283

Accordingly, by analysis the position of the particles, authors determined the probability that the particles enter the breathing zone is 12.11%.

3.6 Particles Tracks with A Mask

When the person is inhaling with wearing a mask, the particle will be injected into person's mouth indirectly, as Figure 5 and Figure 6 shown.

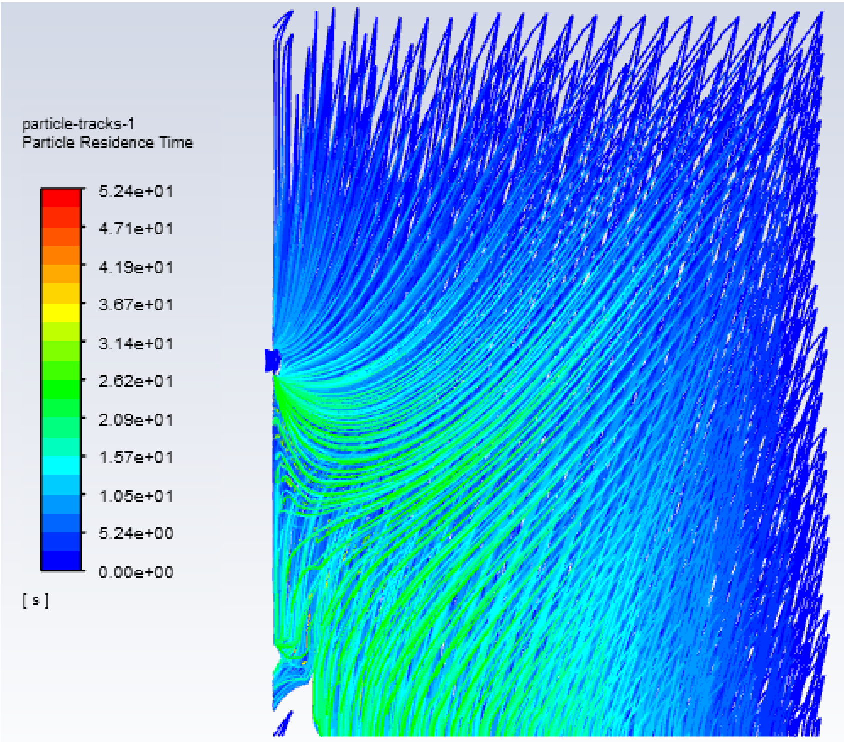

Fig 5. The fluid field of inhale with a mask

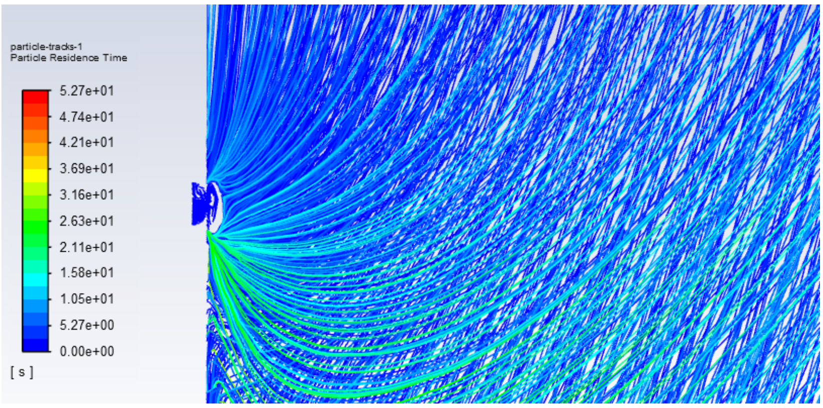

Fig 6. The fluid field of inhale with a mask (Zoomed in to the part of the mouth)

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0025

In order to determine the X-velocity, Y-velocity and the proportion of particles entering breathing zone (with a diameter of 0.2286m), authors made the particles' data with the x-position is between -0.1506m and -0.3792m as the valid data. By filter the data, there are 977,205 records valid in 66,279 records, which has the properties listed in the Table 8 and Table 9. Consequently, authors determined the position of the particles by analysis the position data of the particles and calculated out the probability that the particles enter the breathing zone is 6.78%.

In conclusion, it can be obtained by comparing two experiments. When a person inhales without wearing a mask, a large amount of saliva particles enters the mouth and the air flow around the mouth is fast. But when a person wears a mask to inhale, only a few saliva particles will enter the mouth (the number is one-half of the number without a mask), and the speed of air flow around the mouth will be greatly reduced.

Table 6. The X-velocity of particles released in breathing zone without wearing a mask

Min. X-velocity	Mean X-velocity	Max. X-velocity	Max. Absolute value of X-velocity
-0.279995	-0.0634	0.0231833	0.279995

Table 7. The Y-velocity of particles released in breathing zone without wearing a mask

Min. Y-velocity	Mean Y-velocity	Max. Y-velocity	Max. Absolute value of Y-velocity
-0.293649	-0.0240	0.504446	0.504446

4. Convergence Test

4.1 Mesh of Default Size

At the beginning, the residual of steady-state calculation, as shown in Figure 7, has a residual curve for each physical quantity. The residual curves of velocity in X direction and velocity in Y direction are lower than the set standard of 0.001. Authors determined that the calculation is convergent.

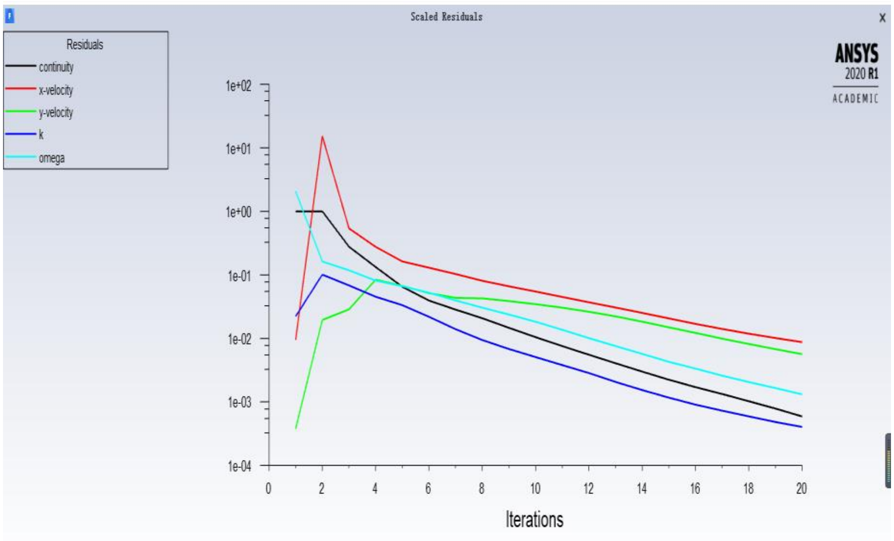

Fig 7. Residual curve of steady state calculation

4.2 Reduce Mesh Size

Then authors tried to change the mesh size. Our team used the refinement function in insert. When setting the refinement value to 1, the original mesh is divided into four parts, and the calculation results are shown in Figure 8. It is obvious that the calculation results are convergent.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202012_6(12).0025

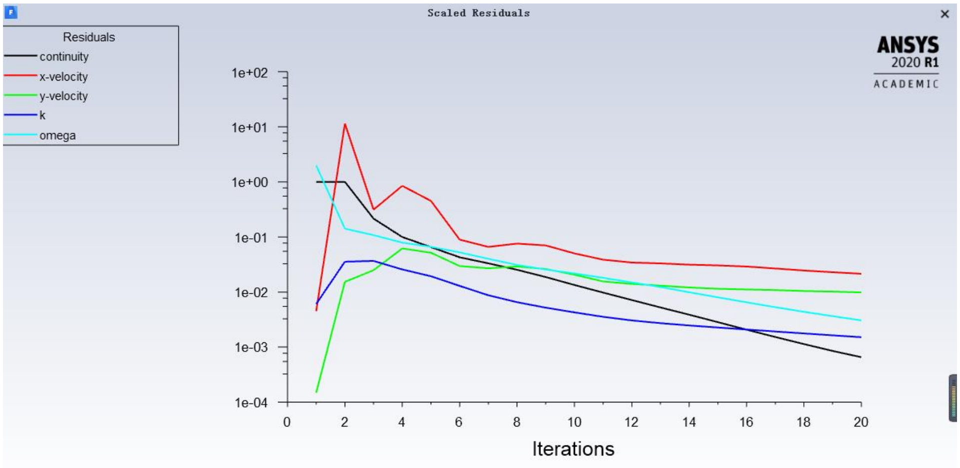

Fig 8. Residual curve when refinement is 1

4.3 Further Reduce Mesh

In order to make the experimental results more universal, authors believed that the value of refinement is set to 2, the first mesh is divided into 9 parts, and the calculation results are still convergent as shown in Figure 9.

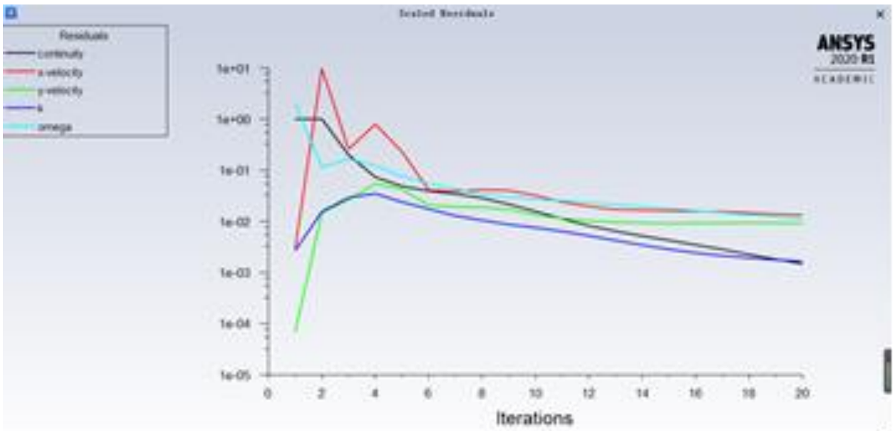

Fig 9. Residual curve when refinement is 2

5. Result and Discussion

5.1 Coughing Process

In the experiment, the path of the particles will follow the graph as the polynomial and drop toward the ground. Most of the particles will land on the distance of 1.385m away from the injection point, which is the standing point of the cougher. People standing in this range of distance will be easily affected, which is the normal distance between two chatting people.

By wearing a mask, the particles travel distance will decrease phenomenally, which will decrease the probability that make others being affected significantly. Consequently, it shows that it is an essential way to control the virus by wearing a mask.

5.2 Error Analysis

1. In the actual world, whatever the material of the mask is, it will not be impenetrable, which will allow more particles being emitted to the atmosphere. Authors assume that once the penetrability of the mask become continuously decreasing, the phenomenon will tend to that of coughing without wearing a mask.

ISSN: 2414-1895
DOI: 10.6919/ICJE.202012_6(12).0025

2. In the actual world, the particle will not drop directly to the ground. Due to the mass of the particles, in some cases, the particles will remain in the atmosphere and being inhaled by others. Consequently, the particles may travel much longer than the distance that listed above.

3. In the experiment, there still have a boundary on the mesh, which may still have some effect to the air flow in the container. If the condition allowed, doing an actual experiment may obtain a more accurate result.

References

[1] Tanne, J. H. (2020). Americans are told to wear cloth masks. British Medical Journal, 369.

[2] Xiaojian Xie, Y. L. (2009). Exhaled droplets due to talking and coughing. Interface, S703-S714.

[3] Bourouiba, L., Dehandschoewercker, E., & Bush, J. W. (2014). Violent expiratory event: on coughing and sneezing. Journal of Fluid Mechanics, 537-563.

[4] Ruoshi Xu, B. C. (2020). Saliva: potential diagnostic value and transmission of 2019-nCoV. International Journal of Oral Science, 12:11.

[5] Rakhimov, A. (2019, September 22). Normal Respiratory Frequency, Volume, Chart, Retrieved from Normal Breathing: https://www.normalbreathing.org/respiratory-rate-volume-chart/