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Computer Aided Simulation with Finite Element Analysis of the Effect of Face Mask Use Against COVID-19 and Other Infections

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Abstract
Viruses are the leading infectious diseases. Viruses spread very fast and has a mortal risk to people with chronic diseases. Different methods are being sought to protect against the virus. In this study, the effect of face mask used against Covid-19 and other infections were investigated using finite element analysis. The effects of droplets formed because of cough or sneezing on the masked and without masked human model were analyzed. The human model without mask has a negative effective on the human face. The risk of infection is higher on the unmasked human model than on the masked human model.

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1.INTRODUCTION

Viruses such as coronavirus disease (COVID-19), Measles, Flu, Rubella, Mumps, Chickenpox and Parvovirus B19 threaten respiratory system of health workers, patients, and all people in the human community. COVID-19 is known as an infectious disease affected by SARS-CoV-2, which is caused severe acute respiratory syndrome. The first case was encountered in December 2019 in Wuhan, China's Hubei province. It has continued to spread ever since and caused an ongoing pandemic. As of March 26, 2021, COVID-19 cases are 480,666,827, deaths are 6,145,158 and recovered are 414,844,261 in the worldwide.

Protective equipment is very effective in protecting against viruses. The use of face masks is crucial. The masks help to protect the social distance with infected people, if you are infected, they prevent you from passing this virus by respiratory system. However, some controversy has arisen about whether to use face masks during the pandemic process. Especially, there are simulation studies using finite element analysis (FEA) or Computational Fluid Dynamics (CFD) in this topic.

Finite element-based computer aided solution methods give very effective results in solving engineering problems. An accurate and reliable finite element model reduces the costs in solving the problem by eliminating experimental studies. While finite element analysis (FEA) is used for solid body mechanics, computational fluid dynamics (CFD) stands out in cases where the dynamic motion of liquids is examined. The defining the correct load and boundary conditions are very important in terms of good results from the methods. Else, we may get unwanted results Gok (2015). Today, FEA is used in engineering problems and simulations of COVID-19 and other infections (Gok et al., 2015; Gok, 2015; 2021; Gok & Inal, 2015; Erdem

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et al., 2017; Gok et al., 2017; 2019; 2021a; Inal et al., 2018; Pirhan et al., 2020; Türkes et al., 2020; Ada et al., 2021).

There are some studies in the literature about the effects of protective masks. Jia et al. (2020) reported the developments in three-dimensional (3D) mask spoofing and anti-spoofing works in last decade. Swennen et al. (2020) have shown the concept and prototype of a custom-made face mask, which can be used anywhere in the world in case of any need, with computer aided design (CAD) data and 3D additive manufacturing method. Alenezi et al. (2021) were designed a novel face mask which is a reusable respirator, and it has small and highly efficient disposable fabric filter. Another paper was highlighted how the combination of current technologies such as 3D scanning, Finite Element simulation, machine learning, and additive manufacturing offers a seamless workflow to generate a sterilizable, reusable and validated custom-fit mask by Degueldre et al. (2020). The custom-made mask design has been used to avoid virus infection by Gok et al. (2021b). Another study is available about human face mask by Gok (2021). Although there are some studies in the literature that argue that face masks are effective against the virus, some groups have also mentioned the negative effects of mask use. The effect of face mask use against Covid- 19 and other infections were investigated using FEA.

2. COMPUTER AIDED SIMULATION

FEA is crucial for the development of optimum designs of mechanics and devices. It is preferable as a important method for verifying experimental and analytical results. In this study, the effect of face mask use against Covid- 19 and other infections were investigated using FEA. Computer-aided simulations were carried out in AnsysWorkbench Explixcit Dynamics.

2.1. 3D Process of Human Face Mask

3D model of a human face was obtained using the Reverse Engineering (RE) method. RE is a widely used method in many areas of engineering to obtain 2D or 3D CAD data of existing objects. It accelerates the design process and enables the prototype of the product to be produced in a shorter time. 3D scanners with one or more cameras are used for this process. The 3D solid model of the classic face mask used for protection from viruses or in hospitals and clinics is modeled in the SolidWorks CAD program, as shown in Figure 1.

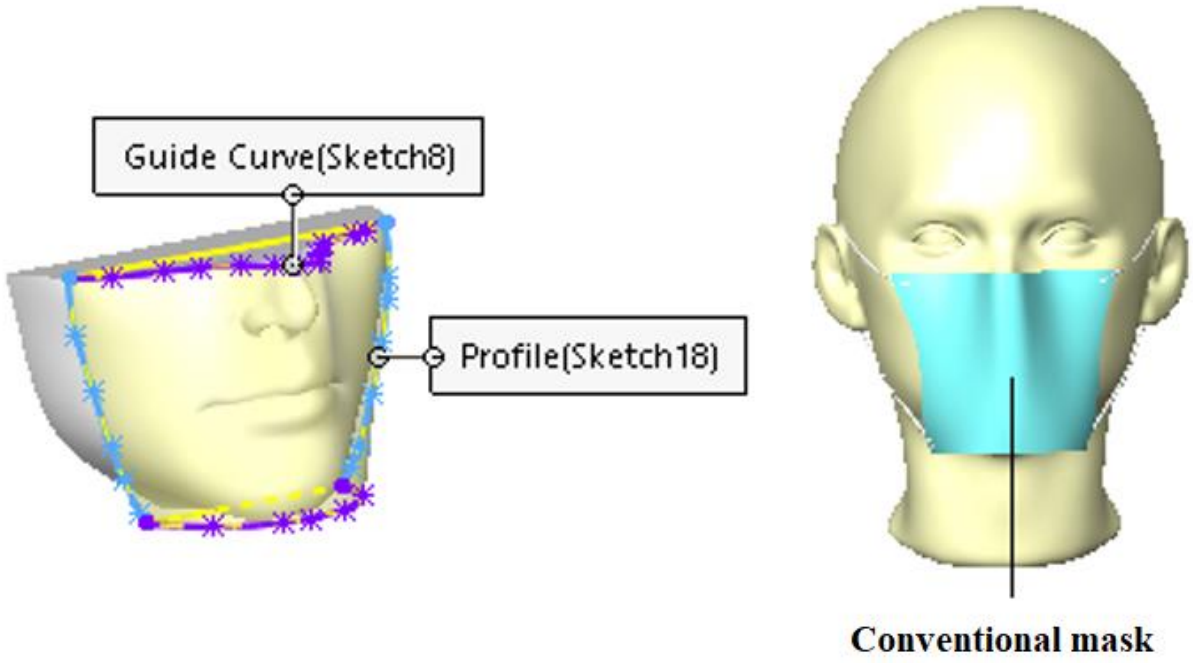

Figure 1. *3D process of human face mask*

2.2. FEA Process

FEA process was given in Figure 2, hex dominant element type, 21698 nodes and 96051 elements. The element size of the human model was chosen as 5 mm and the element size of the other components was spontaneously chosen by the program. The fixed parts were seen in Figure 3. A speed of 160 to 800 km/h of the water droplets (Chhavi et al., 2011). A speed of 69.44 m/s was applied to the water droplet. Table 1 was seen material properties.

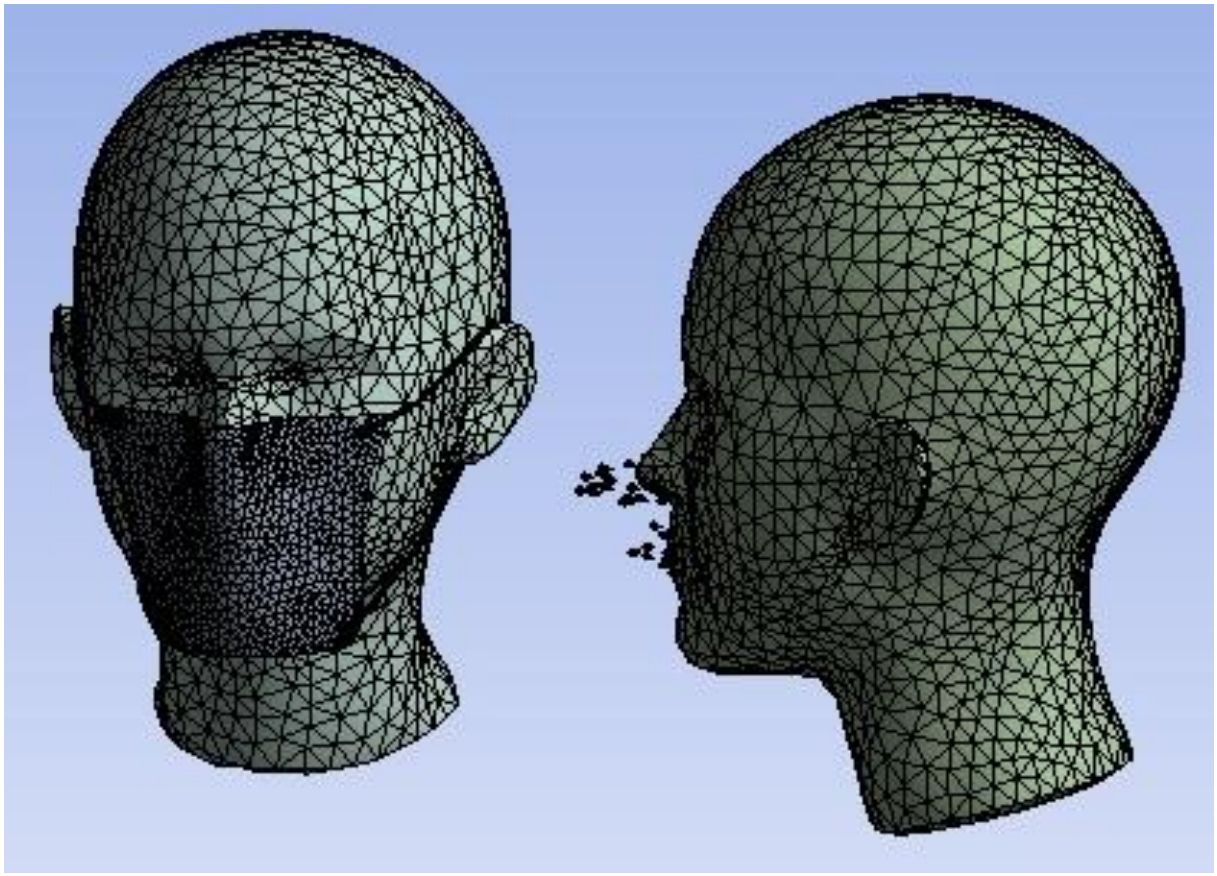

Figure 2. *Mesh process*

Table 1. *Materials properties (Duck, 1990; Endow & Russell, 2015; AnsysWorkbench, 2020)*

Parametreler	Human Skin	Rubber Band	Resin epoxy	Droplet
Density (kg/m^3)	1000	110	1160	998
Shear Modulus (MPa)	4,79	0.58	1400	1e-06
Young's Modulus (MPa)	14.30	1.75	3780	3e-06
Poisson's Ratio	0.49	0.5	0.35	0.5

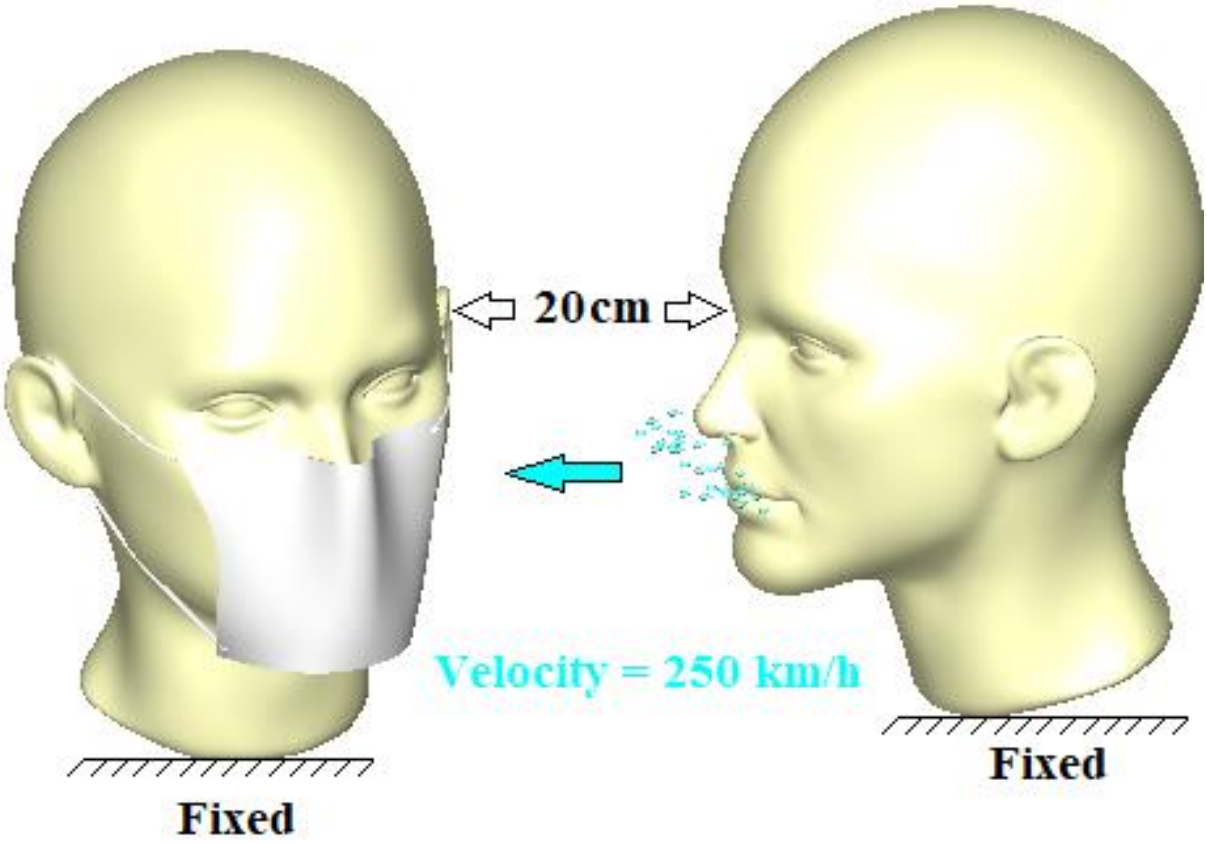

Figure 3. *Loading and boundary conditions*

3. RESULTS AND DISCUSSION

As seen in Figure 4, the droplets ejected by a person coughing from approximately 20 cm (droplet velocity = 69.44 m/s) hit the mask of the person in front of him. Considering that coronavirus-style viruses pass from person to person through droplets, it is noticed how effective the use of masks is. In Figure 5, if someone who does not wear a mask is coughed on the face zone, the droplets contact around the mouth and nose, causing the virus to spread more easily. However, if the person wore a mask as in Figure 4, the probability of being protected from viruses is higher.

Protective equipment is very effective in protecting against viruses. Disposable, standard and hygienic production reveals the importance of protective equipment in protecting against viruses. Experts say that masks prevent the spread of the disease and that everyone should use them in collective environments. Especially those coming from abroad will have a high risk of disease, so these people should use a mask. In addition, it is stated that not every mask is effective against the virus. Experts recommend the use of masks that comply with the specified standards. As seen in Figure 6, the classic face masks cause problems for human skin such as itching, redness and irritation itching, redness and irritation when used for a long time, but these masks have serious protection potential against the viruses Gok (2021).

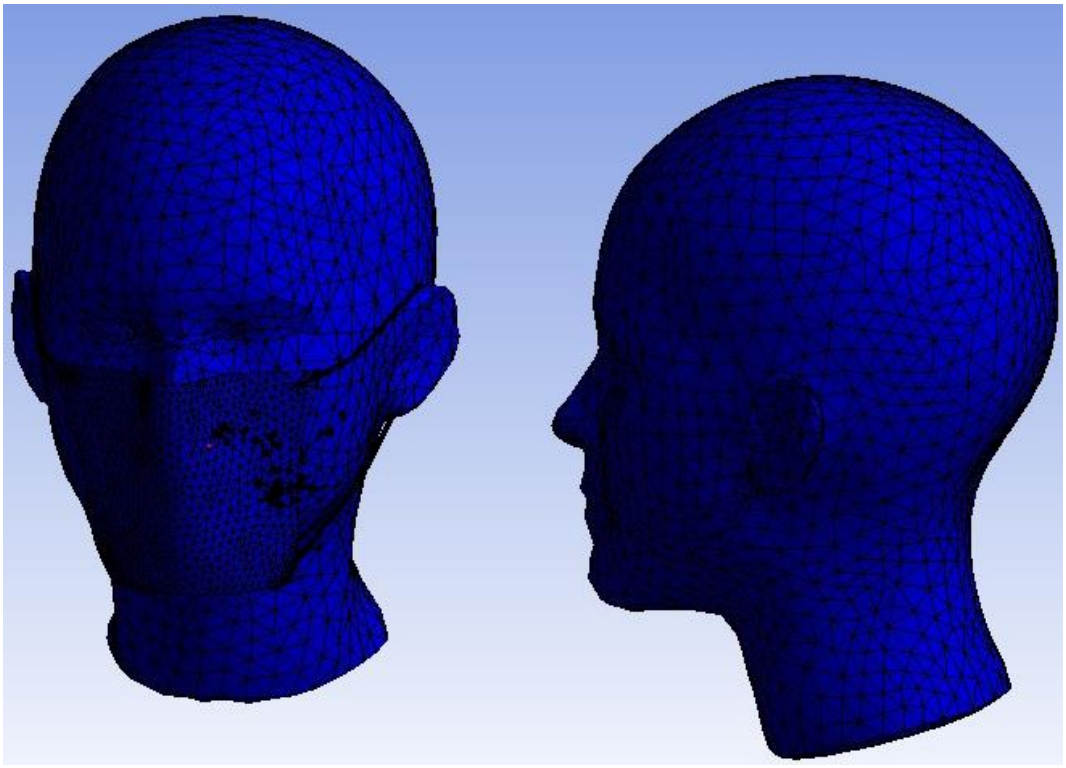

Figure 4. *Droplet effect on the face of a with mask person*

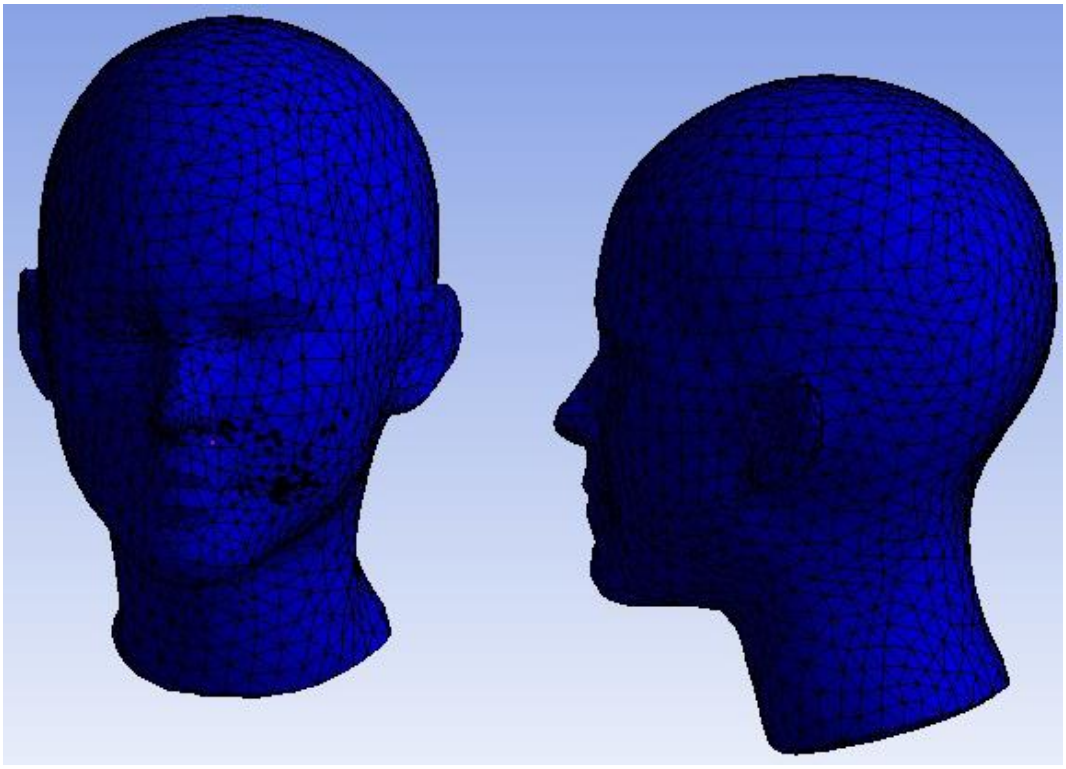

Figure 5. *Droplet effect on the face of a without mask person*

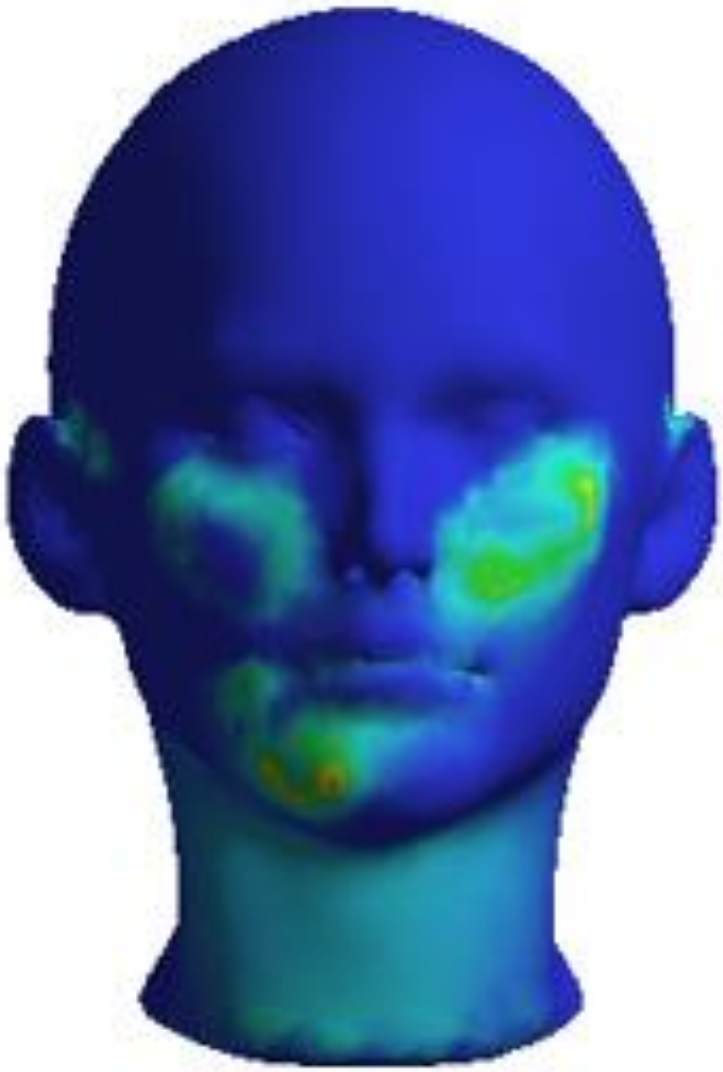

Figure 6. *Stresses occuring from face mask (Gok, 2021)*

4. CONCLUSION

The effect of face mask use against Covid- 19 and other infections were investigated using FEA. The computer simulations were carried out using AnsysWorkbench. Although, the conventional face masks have a harmful effective in terms of itching, redness and irritation on the human face skin, these masks have serious protection potential against the viruses. In the future, authors are planning to research the effects of cough magnitude (droplet velocity) and distance between the persons.

FEA is very important for solve the of engineering problems. It is used as a reliable technique for verifying experimental and analytical results. This method, which has been used effectively in the solution of engineering problems in the field of health in recent years, is especially effective in reducing experimental costs.

CONFLICT OF INTEREST

There is no conflict of interest

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