Ansys

APPLICATION BRIEF

Fitting a Respirator Mask for Max Protection

The first step in caring for the growing patient population is ensuring that healthcare workers on the front lines are properly protected. Respiratory viruses, including COVID-19, are especially dangerous for clinical staff because they can be easily transmitted when an afflicted patient coughs or sneezes. Hospital staff and other healthcare workers must wear face shields to protect themselves against potentially deadly airborne particles that can penetrate eye membranes, and respirator masks to protect against particle inhalation.

Products Used:

Ansys LS-DYNA
Ansys Fluent
Ansys CFD

/ Challenges

Respirator masks protect the wearer by filtering particles out of the air before they reach the lungs. And while we understand the important role of materials on mask effectiveness, we pay less attention to fit. Wearing an ill-fitting mask of the highest quality won't adequately protect the wearer. The data show that wearing a well-fitting mask can reduce the risk of contaminating others by up to six times.[1]

To maximize the effectiveness of a mask, wearers can adjust the mask to tighten the seal and minimize discomfort. As an example, the nasal clip on the N95 respirator can be used to customize the fit of the mask to the wearer's facial contour, thereby reducing air leakage around the sides of the mask. To illustrate how fit impacts airflow, Ansys engineers used finite element analysis and fluid dynamics simulation technologies to predict the fraction of air lost through gaps in the mask-face boundary.

/ Solution

To compare the conditions with and without proper adjustment of the nasal clip, engineers employed a high-fidelity headform and N95 respirator model to simulate the contact pressure and airflow between the face and respirator. They began the two-stage process by performing a contact simulation of the face and respirator with Ansys LS-DYNA, to predict the pressure exerted by the mask on the face. Next, they exported the deformed shape of the face and respirator into Ansys Fluent to simulate the airflow around the mask as the wearer breathes.

After the assignment of realistic material properties of the N95 respirator and facial tissues in LS-DYNA, the virtual respirator was placed on the face (Figure 1). To simulate clip adjustment, deformation was applied. The facial contact pressure was then recorded before and after nasal clip adjustment: Areas with zero contact pressure indicate locations of potential leakage (Figure 2). The contact pressure results show that proper nasal clip adjustment can greatly reduce the size and number of the gaps between the respirator mask and the face.

Next, engineers performed computational fluid dynamics (CFD) simulations using Ansys Fluent to demonstrate the differences in airflow and leakage when wearing a loose-fitting versus properly adjusted respirator mask. In the CFD simulations, the respirator was modeled as a porous material and the respiratory flow rate was specified using a realistic inhalation and exhalation boundary condition. The simulations revealed the presence of flow leakage around the edges of the mask and, notably, near the nose region in the model of the loose-fitting respirator (Figure 3). In contrast, the results show very little flow leakage at the edges of the properly fitted respirator.

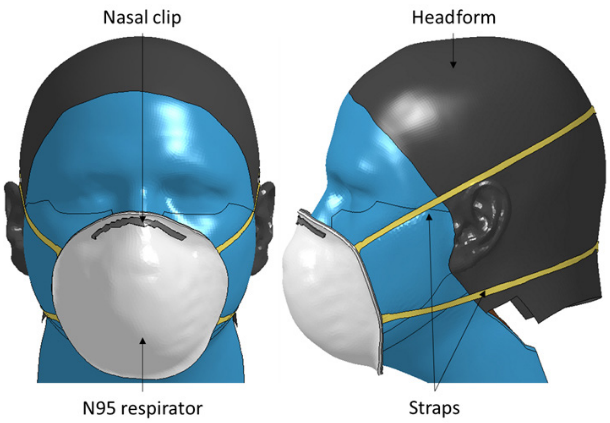

Figure 1: N95 face mask and head model overview

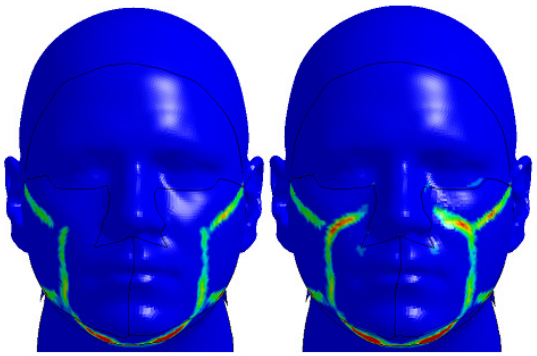

Figure 2: Contact pressure between face and N95 respirator mask before adjustment of the nasal clip (left) and after adjustment (right)

Conclusion

The mechanical simulations demonstrate the ability of the nasal clip to customize the fit of a respirator mask, which significantly improves the degree of contact between the mask and the wearer's face (24.36% increase in contact area). The CFD simulations show how much air can escape along the edges of the mask when there are gaps. Together, the results reveal how critical proper fit is to respirator effectiveness and protecting lives on both sides of the mask.

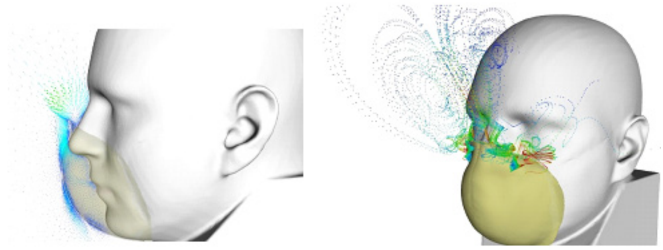

Figure 3: Flow distribution inside of the loose-fitting mask and flow leakage near the nose (left); and streamlines emerging from gaps between face and mask (right).

References

1. High Velocity Nasal Insufflation (HVNI) Therapy Application in Management of COVID-19, Leonard, S., Volakis, L.I., DeBellis, R., Kahlon, A., Mayar, S., Dungan II, G.C., Transmission Assessment Report, VAPOTHERM INC., Science & Innovation.

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Disclaimers

These simulations were designed to replicate physical behaviors under specific circumstances. They should not be considered medical guidance and do not account for environmental variants, such as wind or humidity.