Eco Friendly Breathing Zone Ventilation with Textile Ducts

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Abstract
In order to minimize the energy costs and at the same time create a healthy indoor environment in public buildings such as offices and schools, the idea of an eco-friendly breathing zone ventilation using textile ducts was developed. The main goal is to lower the total air volume by delivering fresh air directly into the breathing zone of the room occupants. By reducing the air volume it is possible to save money as it is not necessary to ventilate the entire room, but only to ensure a good air quality in the breathing zone. This new idea was accomplished while using tailored textile ducts with a specifically invented hole pattern so that an even airflow could be obtained with a guidance beam cut directly into the fabric. At the Technical University of Denmark (DTU) this new system was tested in their laboratories using manikins that produce pollutants to obtain a real life situation. By applying this new way of thinking it was established that it is possible to reduce the air volume by up to 25-30% compared with conventional ventilation systems. Further, it was discovered that both the cleanliness of the delivered air and the system’s ability to remove contaminated air from the breathing zone was better than that of conventional ventilation systems even when this new breathing zone ventilation system was operating at a lower air volume than conventional systems.

1. Objective
Is it possible to create a high learning environment with lower cost? The main goal is to lower the total air volume by delivering the fresh air directly into the breathing zone for the users of the room.

2. Idea [1]
Many public schools in Denmark either do not have a ventilation system or they do not provide a satisfying level of indoor air quality for the children and teachers. Recent studies in Denmark show that over 60% of public schools have a CO₂ level above the maximum recommended level of 1,000 ppm. The most common excuse for not optimizing the ventilation systems in public schools in Denmark is that it is a very expensive area to finance within the budget of the local community even though it is a very well-known fact that a good working environment can have significantly
improved effects for the users of the building. For school children their learning capacity may increase by up to 18% with a good indoor climate [2], [3].

The main idea was to come up with a solution to minimize the total airflow in a room (e.g. a classroom) in order to reduce the total energy consumption hereby leading to less greenhouse emissions and possibly also reduce financial costs, both purchase price and running costs.

The main focus was to obtain an optimal breathing zone for the occupants of the room by examining the possibility of reducing the total airflow, without reducing the air quality in the breathing zone hereby keeping a good working environment.


At the Technical University of Denmark (DTU) the first objective was to examine the placement of the textile duct as shown in Fig. 1. What would be the best distance, x, in order to minimize the risk of draft and optimize the ventilation rate in the breathing zone area? For this many different layouts using different customized permeabilities and specially placed hole patterns were applied [5].

![Fig. 1 Optimum placement of textile duct](image1)

Furthermore, the minimum airflow for the breathing zone needed to be established in order to obtain a good and satisfying environment for the occupants. In order to investigate the quality of the air in the breathing zone, three methods were used: Smoke, laser visualization and tracer gasses.

Fig. 2 represents the pollution sources and their placements as it was tested at DTU for the tracer gasses experiments.

![Fig. 2 Overview of the used pollution sources and their placements](image2)

During the tracer gas experiment the influence of supply airflow rate, position of occupants, height of installation and inlet temperature of the breathing zone area were investigated. Fig. 3 shows the impact when changing the airflow rate of the best textile solution.

50 l/s proved to be sufficient enough to efficiently remove the contamination from the table, groin and feet of the manikins. The contamination removal effectiveness acceptance level is 1.0 which is also the reference set-up for Mixing Ventilation and Displacement Ventilation [6]. The personalized exposure tells how efficient the system is in providing a high air quality in the relevant zone. However, at 40 l/s only the personalized exposure is not satisfying enough, but this may easily be optimized by making a different textile duct permeability and hole pattern. The contamination level for 40 l/s is around the 1.0 level this is shown at Fig. 3.

Fig. 3 Tracer gas comparison of different airflow rates using Textile Ventilation

5.  Results From DTU – Performance Comparison [4]

To obtain the optimum comparison of Textile, Mixing and Displacement Ventilation the reference between these three was set at 60 l/s.

In Fig. 4 Textile Ventilation has a far better ability to remove contamination from the breathing zone compared with Mixing and Displacement Ventilation.
Fig. 4 Comparison of three types of ventilation systems. MV – Mixing Ventilation, DV – Displacement Ventilation and TV – Textile Ventilation – 60 l/s.

In Fig. 4 it is possible to see that using a customized textile duct for this experiment has a much better cleanliness of the air in the breathing zone when compared directly with Mixing and Displacement Ventilation. As expected the Mixing Ventilation principle performed very close to 1.0.

Fig. 5 shows that if five people were sitting underneath the textile duct it would remain above the 1.0 reference point for Mixing Ventilation.

Fig. 5 Tracer gas comparison with more people underneath the textile duct – 60 l/s.
6. Sumary

Fig. 6, Fig. 7 and Fig. 8 show three diagrams that have been made in order to compare all the mentioned ventilation principles, and here it clearly shows that the solutions with Textile Ventilation are far better than the traditional Displacement and Mixing Ventilation systems. However, it is very important that the textile ducts are made with the correct permeability and amount, size and direction of the laser-cut holes in order to achieve this advantage. It can also be seen that even with more people or less air the textile solution is the best choice in order to get not only an optimal and good, clean air quality in the breathing zone, but also to remove the contaminated air.

![Comparison of different ventilation systems (Table)](image1)

Fig. 6 Comparison of the different types of ventilation looking at the table. Here both the 50 l/s, 60 l/s with three and five people have an outstanding performance on the capability to deliver fresh clean air into the breathing zone. The 40 l/s performs almost just as good as the Mixing Ventilation system at 60 l/s when focusing on the contamination removal effectiveness.

![Comparison of different ventilation systems (Groins)](image2)
Fig. 7 Comparison of the different types of ventilation looking at the groin area. Here both the 60 l/s with three and five people have an outstanding performance on the capability to deliver fresh clean air into the breathing zone. Here even the 40 l/s performs better than the Mixing Ventilation system at 60 l/s when focusing on the contamination removal effectiveness.

7. Solution

Fig. 8 Comparison of the different types of ventilation looking at the feet. Here both the 50 l/s, 60 l/s with three and five people have an outstanding performance on the capability to deliver fresh clean air into the breathing zone. The 40 l/s does not perform well in this reading, but it could easily be optimized with a different textile duct layout. Here even the 40 l/s performs better than the Mixing Ventilation system at 60 l/s when focusing on the contamination removal effectiveness.

Fig. 9 shows a picture from the test environment at DTU in Copenhagen. The three manikins are seated and the blue textile duct is placed at the ceiling of the test chamber.
The final solution was a laminar flow with a built-in guidance beam. This was rendered possible due to the flexible solution of Textile Ventilation that can be tailored to match different permeabilities and with specially designed laser-cut hole patterns for any purpose and demand. This means that a breathing zone ventilation system combined with a textile based ventilation system can work at different airflow rates, room heights, amount of occupants and ΔT.

A comparison of three different types of ventilation was made: Mixing, Displacement and Textile.

Fig. 10 shows the principle of Mixing and Displacement Ventilation set-up at DTU in Copenhagen. These three different ventilation methods were compared in order to examine the possibilities of this new personalized breathing zone ventilation principle using textile ducts for the delivery of air.

Fig. 10 Illustration of mixing and displacement ventilation principles

Fig. 11 shows how the air (smoke) is leaving the tailored duct with the special laser-cut holes made directly in the fabric, providing a hybrid textile solution. This illustrates the laminar flow working together with the guidance beams that directs the fresh air directly into the breathing zone.

Fig. 11 Smoke simulation from the lab at KE Fibertec
This new eco friendly ventilation system has the potential to deliver air quality near the students’ breathing zone that is close to the inlet air quality. Meaning less influents from the building and the people inside than with traditional ventilation systems. The best solution is a tailor made textile duct for distributing the air.

8. **Real Life School Case [8]**

Imagine a school with several classrooms all using this new breathing zone ventilation principle.

- What would the energy savings be over 10 years?
- What would the purchase price be compared with a traditional solution?
- What would the running costs be compared with a traditional solution over 10 years?
- How much better would the students be in cognitive performance?
- Is it possible to improve indoor climate at less costs?

Fig. 12 shows a comparison of a traditional Ventilation System and this new Personalized Ventilation System. Together with Vent2Learn a cost comparison has been made. In this comparison the airflow has been reduced based on the study carried out at DTU resulting in a reduction in airflow of 50%, 30% and 20%. The case is built up around “Hældagerskolen” in Vejle which is a traditional Danish school. In this study 13 classrooms with app. 295 students are used as reference [9]. MagiCAD was applied to design and calculate the systems.

<table>
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<tr>
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<th>Traditional Ventilation</th>
<th>Textile Duct Ventilation 80%</th>
<th>Textile Duct Ventilation 70%</th>
<th>Textile Duct Ventilation 50%</th>
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<td><strong>Cost comparison</strong></td>
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<td>6.442</td>
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<tr>
<td>Running Cost [DKK]</td>
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Fig. 12 Cost comparison of a traditional and a textile duct ventilation system during the first year

Based on the figures from Fig. 12 it can be calculated that over a period of 10 years with a reduction of 30% of the airflow the money saved including construction costs and running costs is around 160,000 DKK, and this is without reducing the air quality for the students. In fact this new eco friendly breathing zone ventilation system using textile ducts for handling the air distribution would have shown an increased effect for the children, as
the tests carried out at DTU shows the contamination removal effect and personalized exposure effect with a reduced airflow would lead to at least an equal air quality or in some cases better.

At Danish Teknologisk Institut Vent2Learn carried out a test at level 50% of the traditional airflow in order to examine the proportion of CO$_2$ that will be close to the manikins. The result was 1000 ppm CO$_2$ at 50% air volume whereas Mixing Ventilation would require 100% airflow to reach the 1,000 ppm CO$_2$ level. So it is possible to apply less airflow to reach better air quality.

Having obtained better air quality in the breathing zone with less airflow, has the learning environment for the students also improved then? At Harvard University they found that a lower CO$_2$ level results in much better cognitive performance. [10]

9. Conclusion

During this investigation it was established that the best flow was a laminar flow with a guidance beam. This was created by means of a tailored textile duct with a customized permeability and laser-cut hole pattern. Even with the guidance beam draft would not become a problem as this system is running with a reduced airflow compared with a traditional system.

This new concept of breathing zone ventilation using textile ducts to supply air into the breathing zone has established a reduction of the total airflow by up to 25-30% meaning that the whole air handling system, energy consumption etc. will be significantly reduced compared with traditional ventilation. A comparison was made at a traditional school in Denmark with 13 classrooms. Over a period of 10 years the cost savings were estimated at 160,000 DKK.

The study was also compared with the effectiveness against both Mixing and Displacement Ventilation and also here it was proven that this new ventilation principle was better in keeping contaminations away from the breathing zone for the occupants and delivering clean fresh air directly into the breathing zone area where it is most needed. This is even possible using less airflow than the traditional Mixing and Displacement Ventilation principles.

This new method will ensure a much more cost-friendly solution for many types of buildings looking for a cheaper and also better way to optimize the indoor environment both for new buildings and for retro-fitting.
Acknowledgement

Lillian for being able to think outside the box and bring her ideas to life. Lillian is the main concept creator. KE Fibertec appreciates the contribution and support of Rasmus Wiebe Johansen for his thorough and in-depth work at DTU while investigating this new ventilation principle.

References

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