Diffus ventilation fra ventilationsloft

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Leder

Dette nummer af VentiNet sætter først og fremmest fokus på årets afgangsprojekter. Vi har haft en tradition for, at VentiNets medlemmer møder de studerende hvert forår til en præsentation af projekterne. Da tilmeldingen har været begrænset i de seneste år, har vi valgt, at vi i fremtiden afholder vort årsmøde i forbindelse med et årligt åbent hus arrangement på Aalborg Universitet. Næste årsmøde vil blive afholdt i august 2008.

Peter V. Nielsen

Nyt koncept for personlig ventilation, der kan minimere luftbåren smittespredning

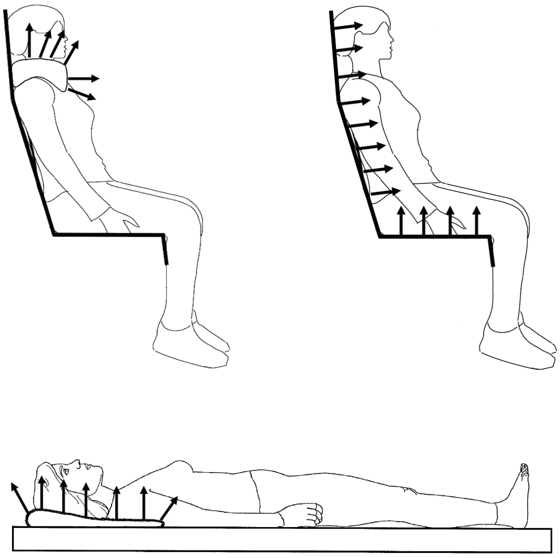
Peter V. Nielsen

Verdensomspændende epidemier som SARS, tuberkulose og den årlige influenza samt frygten for en ny pandemi som fugleinfluenza og brugen af miltbrand i forbindelse med terrortruslen har medført en stigende interesse for luftfordelingssystemer, der kan minimere luftbåren smittespredning. Dette er især aktuelt for miljøer som for eksempel et passagerfly, hvor mange mennesker bringes sammen med stor fare for en smittespredning, der kan dække et stort geografisk område, og for hospitalsstuer hvor der vil være en stor sandsynlighed for en smittekilde.

I det følgende omtales et nyt koncept for personlig ventilation, der netop er blevet afprøvet. Det har vist sig velegnet til beskyttelse af luftbåren smittespredning, og det kan måske også virke reducerende på en smittekildes størrelse (lokal udsugning).

Foruden en minimering af smittespredning rummer konceptet også de traditionelle fordele ved personlig ventilation, nemlig en individuel tilpasning af komfort samt et relativt lavt forbrug af frisk luft i forhold til traditionelle systemer.

Ideen bag den personlige ventilation er at udnytte de flader, som man er i naturlig kontakt med på for eksempel et hospital eller under transport i et fly. Overflader som fx en madras, en hovedpude, et tæppe, et sæde, en nakkestøtte udnyttes til en lokal (personlig) tilførsel af ren luft. Figur 1 viser nogle eksempler. Armaturerne, der anvendes til de forsøg, der er beskrevet her, er produceret af firmaet KE Fibertec AS i Vojens.



Figur 1. Personlig ventilation med diffusor i henholdsvis en nakkestøtte, et sæde samt i en pude.

Figur 2 viser forsøg med en termisk mannequin og en pude. På det øverste billede er der netop tilført røg til PV puden, og man kan se, hvordan den diffunderer igennem oversiden af puden med en hastighed på 5 cm/s. Det nederste billede viser situationen nogle få sekunder senere. Røgen markerer i dette tilfælde den rene luft fra den personlige ventilation.

Den personlige ventilation har i dette tilfælde en virkningsgrad på 80 % til 95 % ved en luftforsyning på 10 l/s, og det giver en meget kraftig reduktion af risikoen for smittepåvirkning (Virkningsgraden 0 % svarer til, at der kun indåndes luft fra omgivelserne, og virkningsgraden 100 % svarer til, at der kun indåndes den rene luft fra PV systemet).

Figur 2. Strømning af luft fra en ventilationspude som for eksempel kan anvendes i et hospitalsmiljø.

Figur 3 viser forsøg med anvendelse af en PV nakkestøtte i et flysæde. Ved denne installation er det muligt at opnå en virkningsgrad på 80 % ved en lufttilførsel på 10 l/s, og virkningsgraden kan komme op på 95 % ved et specielt design af nakkestøtten.

Der er også udført en række forsøg med en stol, hvor hele overfladen er en diffusor, samt en variant hvor der er to langsgående spalter på siden af stolen, som danner lufttilførslen. Ved den sidstnævnte løsning er der opnået en virkningsgrad på 80 %.

Figur 3. Flystol med en nakkestøtte der forsynes med luft fra et PV system. Røgen markerer den rene luft, der tilføres til mannequinens åndingszone.

Det omtalte forskningsarbejde er udført på Aalborg Universitet i efteråret 2006 af N. M. Bartholomæussen, E. Jakubowska, H. Jiang, O. T. Jonsson, K. Krawiecka, A. Mierzejewski, S. J. Thomas, K. Trampczynska og M. Polak. Arbejdet er fortsat i forårssemesteret 2007 på University of Hong Kong af H. Jiang og M. Polak.

Litteratur

P. V. Nielsen, C. E. Hyldgård, A. Melikov, H. Andersen and M. Soennichsen, Personal Exposure between People in a Room Ventilated by Textile Terminals – with and without Personalized Ventilation. Indoor Air 2005, The 10th International Conference on Indoor Air Quality and Climate, Beijing, 2005, China.

Peter V. Nielsen, Niels M. Bartholomaeussen, Ewa Jakubowska, Hao Jiang, Oli T. Jonsson, Karolina Krawiecka, Adam Mierzejewski, Sara J. Thomas, Katarzyna Trampczynska, Marcin Polak and Mads Sønnichsen, Chair with Integrated Personalized Ventilation for Minimizing Cross Infection. Roomvent 2007, 10th International Conference on Air Distribution in Rooms, Helsinki 2007.

Peter V. Nielsen, Hao Jiang and Marcin Polak, Bed with Integrated Personalized Ventilation for Minimizing Cross Infection. Roomvent 2007, 10th International Conference on Air Distribution in Rooms, Helsinki 2007.

‘The Cube’

Olena Kalyanova

‘The Cube’, is the new test facility at the Center for Hybrid ventilation that has already been introduced in one of the previous Ventinet publications. At that point in time the test facility was brand new, shiny white and empty. However, now it is fully equipped and fully functioning test facility with many possibilities.

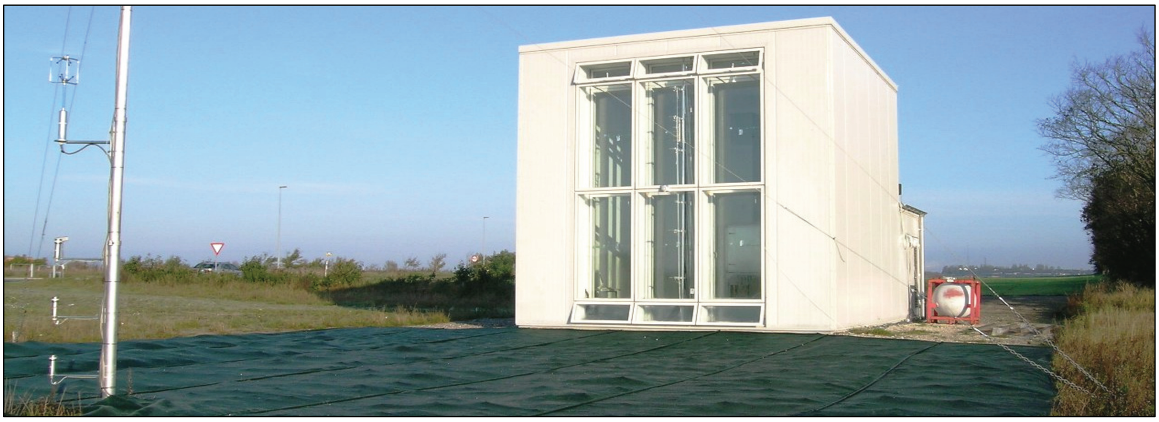


Figure 1. ‘The Cube’

The test facility is designed to be flexible for a choice of the DSF operational modes, natural or mechanical flow conditions, different types of shading devices etc. The superior control of the thermal conditions in the room adjacent to the DSF and the opening control allow to investigate the DSF both as a part of complete ventilation system and as a separate element of building construction. Moreover, the optical properties of the surfaces in ‘The Cube’ are known, as they were tested by EMPA (Switzerland).

A ground carpet of a known reflectance property is placed in front of the test facility to even the ground reflected solar radiation (Figure 1). A vertical wind profile was build specifically for ‘The Cube’ on the basis of a long term measurements of the wind speed and wind directions in 6 heights above the ground. In the near future the measurements of the Cp-values for each opening in the DSF will take place.

During the past year ‘The Cube’ was hosting a wide set of experiments as a part of a PhD study on double-skin façade and as a part of the international project IEA Annex 34/43 “Testing and validation of Building Energy Simulation Tools”. The AAU task in the IEA activity was to prepare a number of benchmark tests for the validation of building simulation software tools for double-skin façade modelling. High criteria have been set to the test facility to ensure high quality of the validation test cases. The criteria included superior air tightness, minimal heat losses and constant indoor environment. ‘The Cube has fulfilled all requirements and a set of data was collected for the empirical validation of building simulation software for the DSF modelling, such as ESPr, BSim, TRNSYS, IDA, VA114 and EnergyPlus. The test cases for the empirical validation of software are available for three DSF operational modes:

- External air curtain (naturally ventilated)
- Transparent insulation
- Preheating mode (mechanically ventilated)

Defined test cases for the empirical validation include all necessary climate data for completing the simulation, a detailed specification of 'The Cube' and a record of the control parameters for a comparison with the simulated ones. The control parameters include air change rate in a naturally ventilated DSF, volume averaged air temperatures and vertical temperature gradients in the DSF, surface temperatures, cooling or heating loads, etc.

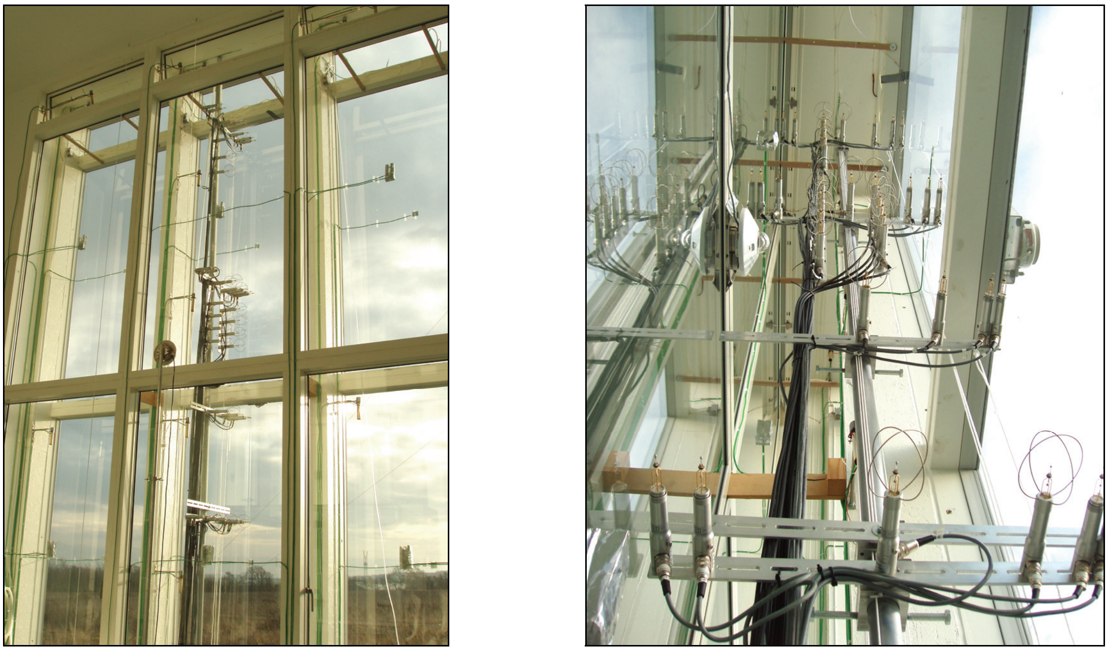


Figure 2. The DSF equipped with the hot-spheres and thermocouples in 'The Cube', view from inside (left). The DSF equipped with the hot-spheres for measurements of the velocity profile, view from the bottom, looking towards the top of the DSF (right).

As a part of IEA Annex 34/43 activity the leading building simulation tools, such as ESPr, BSim, TRNSYS, IDA, VA114 and EnergyPlus, are tested and validated for simulation of buildings with a double-skin façade. Results of validation confirm that several building simulation tools are able to predict the DSF performance as a part of complete ventilation system, but it requires a user with an expert knowledge of the software and experience in the DSF modelling.

Modelling and simulation of the double-skin facades is a well known difficulty for a practicing engineer when the comfort requirements and the energy frame are to be fulfilled. One can sense a certain fear between engineers when architects suggest a DSF-solution. It is explained by existing examples of misfortune in the DSF design and dimensioning, which have resulted in an inferior performance and increased energy spends.

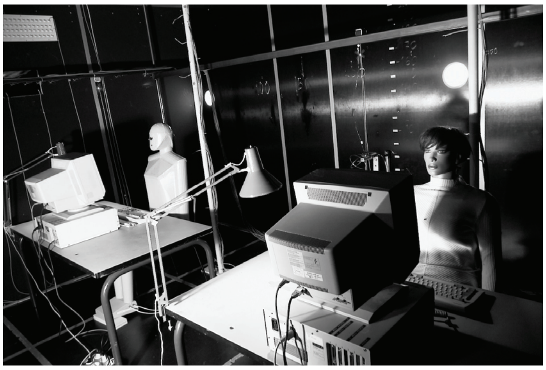
Although, engineering is an exact science where is no space for gambling, engineers face a problem of multiple choice between various building simulation tools without any idea of what is the best tool to use. Validation of the building simulation software for the buildings with double skin façade will provide engineers with a confidence and certainly will improve the quality of the DSF projects. This will give the DSF-technology a chance to generate more positive than negative examples and finally the technology can become more reliable.

Diffus ventilation fra ventilationsloft

Peter V. Nielsen

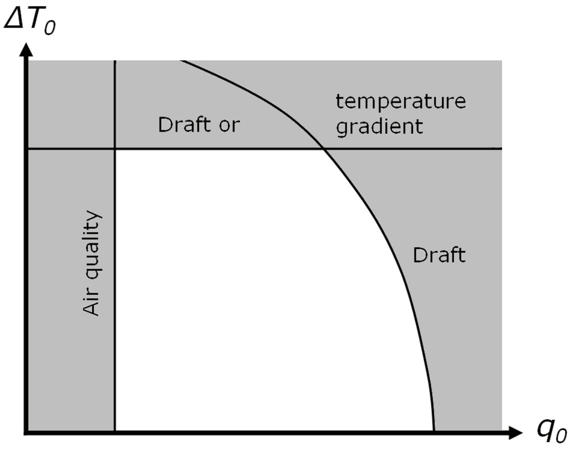
Siden år 2000 har klimagruppen på Aalborg Universitet testet forskellige luftfordelingssystemer og deres evne til at fjerne en høj belastning ved et rimeligt komfortniveau. Desuden har aspekter ved luftbåren smittespredning været belyst ved forsøgene.

Indtil nu har der været udført forsøg med syv forskellige systemer: opblandingsventilation fra et armatur monteret i en endevæg, opblandingsventilation fra et loftmonteret radialt armatur og fra et loftmonteret rotationsarmatur samt fortrængningsventilation fra et vægmonteret armatur. Der har været udført forsøg med vertikal indblæsning fra loftmonterede posearmaturer med og uden åbninger for styrestråler og med en vandkølet konvektor, som gav opblandingseffekt i rummet. Alle forsøg er udført med to forskellige opstillinger i et fuldskalarum. Figur 1 viser den mest anvendte belastning i fuldskalarummet, nemlig et kontor med to personer, to pc'er og to bordlamper. I visse tilfælde blev der kun brugt en belastning på én person.



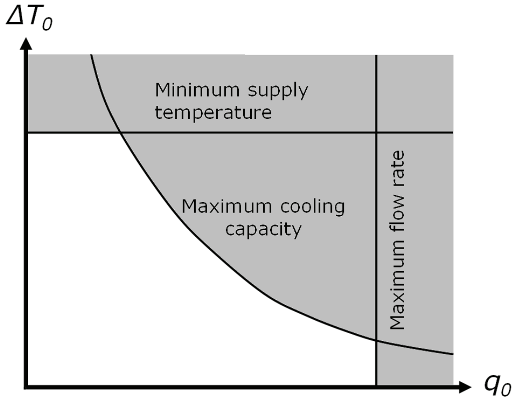
Figur 1. Fuldskalarum indrettet som et kontorlokale med to personer.

Da alle luftfordelingssystemerne er afprøvet i samme rum med samme møblering, er det muligt at foretage en indbyrdes sammenligning af de forskellige systemer, belyse deres forskelle og afgøre deres specielle fordele. Alle systemerne er sammenlignet i en graf, hvor man får et hurtigt overblik over de forskellige karakteristika. Figur 2 viser en sådan graf. Den lodrette akse er temperaturdifferensen imellem udsugning og indblæsning ΔT_o, og den vandrette akse er volumenstrømmen til lokalet q_o.



Figur 2. Designgraf der viser et luftfordelingssystems begrænsninger.

Figuren viser, hvorledes der skal tilføres en vis luftmængde til rummet for at opretholde en god luftkvalitet. Det ses også, at der i mange tilfælde ikke kan tilføres en ubegrænset luftmængde, uden der opstår træk, og det ses ligeledes, at en for stor temperaturdifferens vil skabe træk eller generere en stor lodret temperaturgradient i rummet. Det "frie" areal i grafen viser det område, hvor systemet opretholder et begrænset hastighedsniveau (< 0.15 m/s) og en begrænset temperaturgradient (< 2,5^{o}C/m), og en luftkvalitet der er over 10 l/s pr. person.



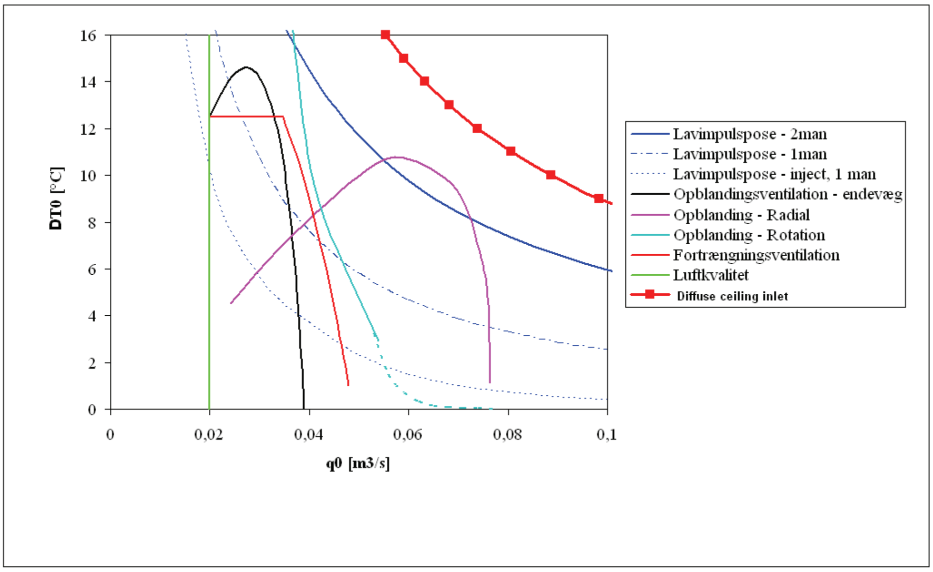
Figur 3. Designgraf der viser ventilationssystemets begrænsninger.

Figur 3 viser, at det også kan være ventilationssystemet, der sætter begrænsningerne, fx en begrænset luftmængde, en begrænset minimumstemperatur eller en begrænset kølekapacitet.

I det følgende vises nogle resultater fra målinger på diffus ventilation fra et ventilationsloft. Luftfordelingen blev skabt ved at sende den tilførte luft igennem lyddæmpende plader over hele loftfladen. Figur 4 viser det rolige indtryk, som et sådant loft giver i forhold til traditionelle armaturer.

Figur 4. Loft med diffus ventilation.

Forsøgene på med diffus ventilation har vist, at systemet kan klare meget høje belastninger uden at skabe træk i opholdszonen, som designgrafen viser, figur 5. Det er karakteristisk, at det ikke så meget er luftfordelingssystemet, der skaber træk, men det mere er den termiske strømning fra varmekilderne i rummet, der giver en luftbevægelse. Den grænse, der er indikeret på figuren, er ikke en grænse for træk men mere en systemgrænse for ventilationssystemets ydeevne.



Figur 5. Designgraf for de forskellige systemer inklusive diffus ventilation igennem en lyddæmpende loftflade.

Forsøgene med diffus ventilation igennem en lyddæmpende loftflade er udført som et afgangsprojekt af Ewa Jakubowska. Detaljerede målinger vil blive publiceret i den kommende tid.

Litteratur om diffus ventilation i stalde

Diffus ventilation er allerede bragt i intensiv anvendelse i landbruget, hvor ventilation af stalde er en vanskelig opgave på grund af de store belastninger og et højt krav til komfort.

L. Jacobsen, P. V. Nielsen and S. Morsing. Prediction of Indoor Airflow Patterns in Livestock Buildings Ventilated through a Diffuse Ceiling. Roomvent 2004, 9th International Conference on Air Distribution in Rooms, Coimbra, 2004.

Røgudbredelse i et atrium ved brand med lav varmeudvikling

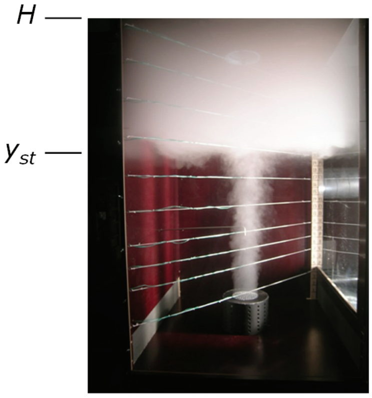
Peter V. Nielsen, Aalborg Universitet

Røgudbredelsen fra en brand i et atrium vil normalt nå op til kippen på grund af den opdriftseffekt der virker på den varme røg. Derfor placerer man udstyr til detektering af en eventuel brand i dette område.

Ofte vil man også have en lodret temperaturgradient i et atrium på grund af solindfald og varmetab. Hvis branden kun har en meget lille varmeudvikling, for eksempel ved en ulmebrand, og røgen er relativt kold, vil den nødvendigvis ikke nå helt op i toppen af atriet. Røgen bliver indlejret i dens opdriftsneutrale højde i den lodrette temperaturgradient. Situationen kan betyde, at branden ikke bliver detekteret.

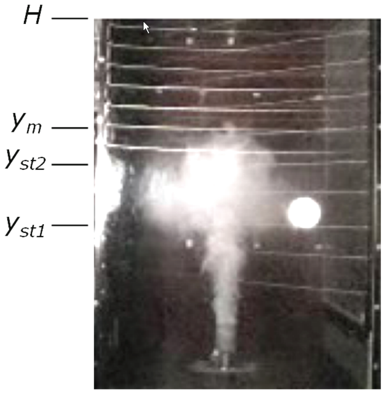
I det følgende omtales en undersøgelse, der fokuserer på at udvikle modeller, der kan bestemme røgbevægelsen i rummet og fastlægge højden til det opdriftsneutrale lag. Undersøgelsen bygger på modelforsøg, CFD simuleringer og analytiske modeller. De udviklede modeller kan også anvendes ved bestemmelse af andre spredningsprocesser som for eksempel spredning af giftige gasser med svage densitetsforskelle.

Figur 1 viser situationen, hvor varmeudviklingen fra branden er så stor, at røgen stiger op til toppen af atriet H. Højden til underkanten af røglaget y_{st} er en funktion af brandens effekt og af en luftstrømning, der tilføres via brandventilationen. Brandventilationen tilfører den friske luft nederst i modellen og fjerner en tilsvarende røgmængde i modellens top.



Figur 1. Røgbevægelse ved brand med høj effekt.

Figur 2 viser en brand med en lav varmeudvikling. Røgventilationen er ikke startet, og røgen stiger op igennem lag med stigende lufttemperatur. I højden y_{st1} til y_{st2} er røgen opdriftsneutral, men den fortsætter til højden y_m på grund af dens bevægelsesmængdestrøm. Derefter falder den tilbage til laget imellem højderne y_{st1} og y_{st2}. Ved den fortsatte brand fyldes rummet under y_{st1} først med røg, hvorefter røgen bevæger sig op i rummet over y_{st2}. Ved start af brandventilationen vil røgen blive fjernet fra atriet.



Figur 2. Røgbevægelse ved brand med en lav varmeudvikling.

I nogle praktiske situationer kan det være vanskeligt at identificere højderne y_{st1} og y_{st2}, fordi der er et strømningsmønster i atriet, som påvirker røgfordelingen. Figur 3 viser en CFD beregning i et atrium med en varm venstre side (fx fra solindfald) og et varmt gulv samt en kold højre side (fx ydervæg) og et koldt glastag. Det ses, hvorledes røgbevægelsen fra en brand med lav varmeudvikling bliver påvirket af den cirkulerende strømning i atriet, og det er ikke muligt at identificere lagdelingen.

Der kan også opstå andre situationer, hvor røgfordelingen påvirkes, så det vil altid være sikrest at supplere beregninger af lagdelingshøjden med CFD simuleringer eller detaljerede modelforsøg.

Figur 3. Røgbevægelse i et atrium med begrænsningsflader med forskellige temperaturer.

De omtalte modelforsøg og CFD beregninger er udført som afgangsprojekt af A. J. Petersen og K. Sommerlund-Larsen i perioden 2005 - 2006.

Litteratur

P. V. Nielsen, Modelforsøg ved dimensionering af brandventilation. VENTInet, Netværkscenteret, Aalborg Universitet, Nr. 17, 2006.

P. V. Nielsen, H. Brohus, H. la Cour-Harbo, M. Lykkegaard, M. Dam and B. V. Jensen. The Design of a Fire Source in Scale-Model Experiments on Smoke Ventilation. Roomvent 2004, 9th International Conference on Air Distribution in Rooms, Coimbra, 2004.

REHVA udgiver en række håndbøger inden for forskellige emner som fx: fortrængningsventilation, ventilationseffektivitet, ventilation og rygning, indeklima og produktivitet i kontorer, lavtemperatur opvarmning og højtemperatur køling samt rengøring og hygiejniske krav til ventilationsanlæg, se www.rehva.com. REHVA har netop udgivet sin 10. bog i rækken, nemlig:

Computational Fluid Dynamics in Ventilation

Peter V. Nielsen, Francis Allard, Hazim B. Awbi, Lars Davidson & Alois Schälin

Computational Fluid Dynamics in Ventilation Design is a new title in the REHVA guidebook series. The guidebook is written for people who need to use and discuss results based on CFD predictions, and it gives insight into the subject for those who are not used to work with CFD. The guidebook is also written for people working with CFD which have to be more aware of how this numerical method is applied in the area of ventilation. The guidebook has, for example, chapters that are very important for CFD quality control in general and for the quality control of ventilation related problems in particular.

A large number of CFD predictions are made nowadays, and it is often difficult to judge the quality level of these predictions. The guidebook introduces rules for good quality prediction work, and it is the purpose of the guidebook to improve the technical level of CFD work in ventilation.

The book contains the following main chapters:

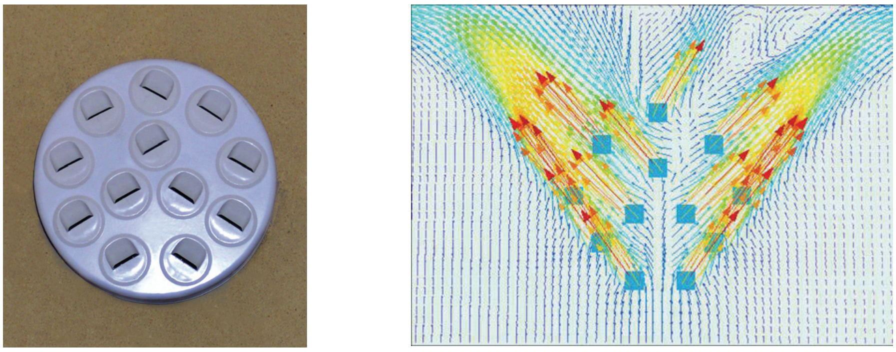
- Mathematical background
- Turbulence models
- Numerical methods
- Boundary conditions
- Quality control
- CFD combined with other prediction models
- Application of CFD codes in building design
- Case studies
- Benchmark tests

The chapters *Mathematical background* and *Turbulence models* give a short introduction to the theory behind the methods used in CFD modelling. The fundamental transport equations are discussed with emphasis on ventilation applications, and descriptions are given for two-dimensional geometry to simplify the concepts. A user of CFD predictions must have some knowledge of fluid mechanics. It is important to understand conditions such as: laminar flow, turbulent flow, steady flow, time dependent flow etc. both in connection with CFD and also with measurements in rooms for validating the predictions. The two chapters give some insight into all of these conditions.

The turbulence model is specially an important aspect of CFD. It is obvious that room air flow will be turbulent because of geometry and practical velocity levels, but it will not always be a fully developed turbulent flow. Some of the widely used models are discussed such as the k-ε model, the SST model, and the Reynolds Stress model. The Large eddy simulation is also shortly mentioned.

The chapter on *Numerical method* illustrates the structure of a CFD programme, and it demonstrates much of the experience a user will have in using a commercial program. Most of this chapter is based on a one-dimensional theory. The use of a one-dimensional analysis made it possible to understand, by hand calculation, many concepts and issues such as: order of accuracy, necessary number of grid points, wiggles in the solution, iterations, divergence, etc. This is demonstrated with a convection-diffusion equation which is solved with the use of different schemes at different velocity levels.

The chapter on *Boundary conditions* is especially important in the ventilation area. Often the flow in a room is determined by small details in the diffuser design. This means that a numerical prediction method should be able to handle small details in dimensions of one or two millimetres, as well as dimensions of several metres. This wide range of the geometry necessitates a large number of cells in the numerical scheme, which increases the prediction cost and computing time to a rather high level. The problem is overcome by applying different simplifications such as *simplified boundary conditions, box method, prescribed velocity method* or *momentum method.* Continuous development of computational capacity and speed will undoubtedly make the direct methods with local grid refinements or multigrid solution possible. This is illustrated in the following with a diffuser consists of 12 small slots which can be adjusted to different flow directions.

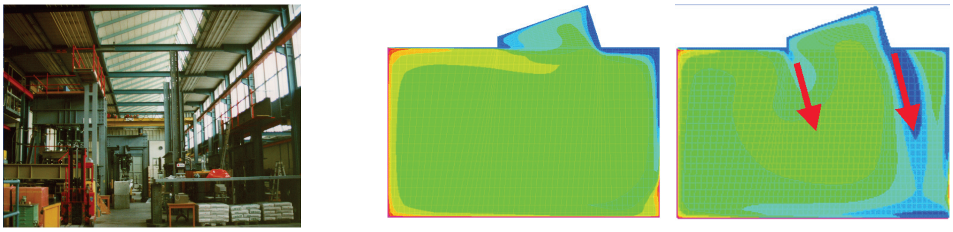


A direct simulation if a diffuser consists of 12 small slots which can be adjusted to different flow directions. Development of computer capacity will make direct simulations of diffusers possible in the future.

The chapter does also discuss other boundary conditions such as surface boundary which is important for heat transfer predictions, free boundary, plane of symmetry, air exit opening and obstacle boundary.

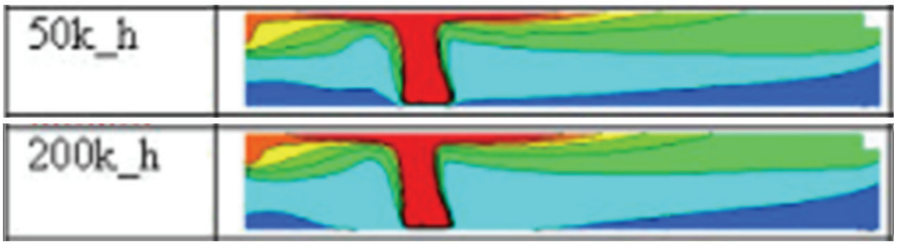
The chapter on *Quality Control* is one of the more important chapters in the guide book. Quality control consists of four major steps: to recognize possible error sources, to check for them in the simulation, to estimate the accuracy of the simulations, and to improve the simulation whenever possible. Two of the many examples given in the guidebook will be shown here.

It is a strong reduction in computing cost to work with two-dimensional flow instead of three-dimensional flow, but is it possible in all situations where the boundary conditions are "two-dimensional"? The figure shows a long hall with a shed roof. There is complain about strong downdraught, but a two-dimensional prediction is not able to show this effect. It is necessary to use a three-dimensional transient approach to predict the downdraught.



Hall with shed roof, two-dimensional prediction and transient three-dimensional prediction.

For each set of problems a grid independence study should be performed. The following figure shows an example of such a study, where the same case (a transient fire simulation) is run for various grids from coarse to fine, and with homogeneous grids and other grids with mixtures of prisms, tetra- and hexahedral cells. The latter performs best. The figure shows the temperature distribution for 50,000 cells and 200,000 cells.

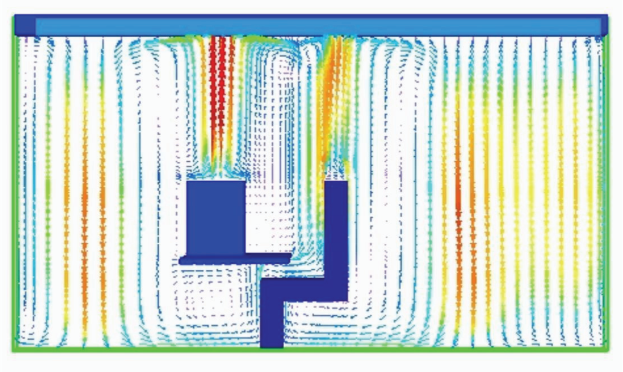


Simulation of a transient fire with 50,000 and 200,000 cells in the solution domain.

The use of a CFD program in connection with other programmes is discussed in the chapter *CFD combined with other prediction models.* Of highest interest and importance to ventilation design are the following: coupling of air flow and multi-zone dynamic thermal simulation, where especially energy storage is an important issue; coupling of air flow, moisture and energy transport through walls; coupling of air flow and multi-zone flow simulation, where the zonal flow simulation also handles the transport of additional components such as contaminants (e.g. smoke, CO_2, odours, moisture); and lastly coupling of the air flow and emission from building materials.

The possibilities for applying CFD for simulating the air flow in a building are discussed in the chapter *Application of CFD codes in building design.* A numbers of areas such as: room air movement, concentration distribution, emission from materials, thermal comfort assessment, ventilation effectiveness prediction and smoke management can be evaluated by a CFD program from the conceptual design to the preliminary design and right through to the final detail design stages.

The chapter, *Case studies*, shows different practical application of predictions made at different stages in the initial design, detail design and commissioning phases. In particular, four different air distribution systems are studied by CFD and compared by measurements. The four systems are mixing ventilation with a wall-mounted diffuser, vertical ventilation, displacement ventilation and mixing ventilation generated by a ceiling mounted radial diffuser. All systems are designed to handle the same load in the same room. The following figure shows the result for vertical ventilation.



Velocity distribution in the centre plane of an office room ventilated by a ceiling mounted textile terminal giving vertical ventilation.

The final chapter is a small chapter discussing different types of benchmark tests. A benchmark test can be used for new beginners in CFD to obtain a fast insight into different problems for the predictions of ventilation and to obtain an initial experience by comparing CFD outputs.