Model for Multidimensional Heat, Air and Moisture (HAM) Conditions in Building Envelope Components

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Contents

• Introduction
• Problem Definition
• Methodology
• Results
• Conclusions
Predicting and avoiding building performance problems in design stage
Improving building performance

Analyzing and predicting HAM conditions in building components

Modelling and Simulation HAM Transport in and around Building Components
Problem Definition

HAM Component Models

Uniform indoor environment

Fixed surface transfer coefficients
\[ \alpha_c = \text{constant} \]
\[ \beta_c = \text{constant} \]

Reality

Non-uniform indoor environment

- Space: corners, airflow.

Variable surface transfer coefficients
\[ \alpha_c = \alpha_c(t, u, T, RH, \ldots) \]
\[ \beta_c = \beta_c(t, u, T, RH, \ldots) \]

Research Question
Influence of non-uniform surface transfer coefficients on Heat, Air and Moisture conditions in building component?
Methodology

1. Literature study
   • State-of-the-Art

2. Case study
   • Parameter analysis.
   • Airflow modelling
     – Forced convection
     – Mixed convection
     – Natural convection

How to consider this influence of non-uniform transfer coefficients?
1. Literature study
   • State-of-the-Art

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How to consider this influence of non-uniform transfer coefficients?
HAM Component model ↔ Airflow model
Influence of non-uniform surface transfer coefficients on HAM conditions in the building?
State-of-the-Art

HAM Component model

Outdoor climate → Indoor climate

Airflow model

\[ \text{mass and heat balance for a space zone (a) mass balance (b) heat balance} \]
HAM Component model \(\leftrightarrow\) Airflow model

### Multi-zone (zonal) models
- **Average** temperature and concentration in a room.
- **No information about local quantities.**

### Sub-zonal models
- **Information about local** conditions in the room.
- **Simplified airflow modeling**
- **Transient**
- **Relatively short computation time**

### CFD
- **Very detailed information about local** conditions in the room.
- **Solving of Navier-Stokes equations**
- **Steady-state**
- **Long computation time**

Mass and heat balance for a space zone (a) mass balance (b) heat balance
**HAM Component model** ↔ **Airflow model**

<table>
<thead>
<tr>
<th>Multi-zone (zonal) models</th>
<th>Sub-zonal models</th>
<th>CFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Average temperature and concentration in a room.</td>
<td>• Surface transfer coefficients</td>
<td>• Solving of Navier-Stokes equations</td>
</tr>
<tr>
<td>• No information about local quantities.</td>
<td></td>
<td>• Steady-state</td>
</tr>
</tbody>
</table>

**Focus:**
- Temperature and Relative Humidity near the building component
- Surface transfer coefficients

Mass and heat balance for a space zone (a) mass balance (b) heat balance
Methodology

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How to consider this influence of non-uniform surface transfer coefficients?
Airflow Modelling

Case: Natural convection - Modeling

Standard subzones:
\[ j_{\text{air}} = C_d \rho \Delta P^n \]

Thermal boundary layer model:
**Laminar**
\[ \delta(y) = 0.048(H - y)^{1/4} \Delta T^{1/4} \]
\[ j_{\text{air}}(y) = 0.0024(H - y)^{3/4} \Delta T^{1/4} L \]

**Turbulent**
\[ \delta(y) = 0.11(H - y)^{7/10} \Delta T^{-3/10} \]
\[ j_{\text{air}}(y) = 0.0021(H - y)^{6/5} \Delta T^{2/5} L \]
Case: Natural convection - Modeling

Local convective surface heat transfer coefficient ($\alpha_c = h_{Tx}$)

Comparison between:
- Beausoleil-Morrison: average $h_T$ obtained from Beausoleil-Morrisson (state-of-the-art)
- Zonal Wall Model 1: flat plate analogy
- CFD

Local convective surface moisture transfer coefficient ($\beta = h_{Mrx}$)

Chilton-Colburn analogy
Results

Case: Natural convection - Results

Local convective surface heat transfer coefficient \( (\alpha_c = h_{T,x}) \)

Comparison between:
- Beausoleil: average \( h_T \) obtained from Beausoleil-Morrisson (state-of-the-art)
- Zonal Wall Model 1: flat plate analogy
- CFD

![Graphs showing comparison between Beausoleil, Zonal Wall Model 1, Zonal Wall Model 2, and CFD for West and East walls.](image-url)
Results

Case: Natural convection - Results

Local convective surface moisture transfer coefficient ($\beta_c = h_{M,x}$)

Comparison between:
- Beausoleil: average $h_T$ obtained from Beausoleil-Morrisson (state-of-the-art)
- Zonal Wall Model 1: flat plate analogy
- CFD
## Conclusions

**Case: Natural convection - Conclusions**

<table>
<thead>
<tr>
<th>Sub-zonal airflow model</th>
<th>Surface transfer coefficient model</th>
<th>Maximum relative deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Indoor environmental conditions</td>
</tr>
<tr>
<td>Thermal boundary layer</td>
<td>Beausoleil-Morrisson</td>
<td>20 – 30%</td>
</tr>
<tr>
<td>Thermal boundary layer</td>
<td>Wall model 1: Flat plate analogy</td>
<td>20 – 30%</td>
</tr>
<tr>
<td>Thermal boundary layer</td>
<td>Wall model 2: Turner et al. (1980)</td>
<td>10 - 15%</td>
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</tbody>
</table>

**Main limitation:**
A reference (experiments, CFD) is always required in order to tune the sub-zonal airflow model and select the appropriate surface transfer coefficient model.
\[ f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x) \]