Complex Glazing Summary

Christian Kohler, Mike Rubin, Jacob Jonsson
Dariush Arasteh, Robin Mitchell

Windows & Daylighting Research Group
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Software Tools Overview

Design / Simulation Tools
- DOE-2
- EnergyPlus
- Radiance

Optics
- Window Glass

THERM
- Window Frame

IGDB
- Specular Glass Data Source

CGDB
- Complex Glazing Data Base

WINDOW
- Whole Window

COMFEN
- Whole Building Commercial

RESFEN
- Whole Building Residential

Environmental Energy Technologies Division
WINDOW6

CGDB
(Complex Glazing Data Base)

WINDOW
(Whole Window)
Specular vs Complex Glazings

- WINDOW4 and WINDOW5 have focused on specular glazings. These are products that are non-diffusing, such as clear or coated glass.
- WINDOW6 can handle ‘complex glazing devices’
Component Characterization

Optical

- Visible & Solar
- Far Infrared

Thermal

- Conduction
- Convection
## Complex Shading Device Types

<table>
<thead>
<tr>
<th>Diffuse</th>
<th>Woven shades</th>
<th>Plexiglass/Acrylic</th>
<th>Non-woven Planar Shades</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Patterned glass</td>
<td>• Complex weaves</td>
<td>• Honeycombs</td>
<td>• Roller shades</td>
</tr>
<tr>
<td>• Translucent interlayers</td>
<td>• Bi-color threads</td>
<td>• Prismatic panels</td>
<td>• Solid Vinyl shades</td>
</tr>
<tr>
<td>• <strong>Fritted glass</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slat shading</th>
<th>Drapes</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• <strong>Diffuse</strong></td>
<td>• Woven material with pleated,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Specular</td>
<td>non-planar shapes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Transparent</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Square weave products</th>
<th>Honeycomb Shade</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• <strong>Bug screens</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Simple, uniform weave</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Other products               |                               |                               |                             |
Optical Measurements and Models

- Integrating Sphere Measurement
- Angular Scan Measurement
- Radiosity Model
- Ray Tracing
Optical – Radiosity Model

• Calculation method based on defined geometry, diffuse component materials only
• Large effort to develop model, quick calculations
• Venetian blind slat example:
Optical – Direct Scan

- Scanning all scattering directions mechanically
- Data stored in CGDB without model (except compression)
Optical– Integrating Sphere

- Total hemispherical data
- Limited BTDF data
- Might be enough for isotropic samples
Optical– Ray Trace

- Material properties obtained with experimental methods.
- CAD model using measured material properties.
- Data stored explicitly without any model.

Virtual Goniospectroradiometer in Ray Trace software

Ray Traced Geometric / Optical model
Product Location

Exterior  Integral  Interior
Thermal Models

• ISO 15099
• Convective Scalar
• Waterloo (Integral venetian blind)
• Waterloo (Interior shade)
Thermal – ISO 15099

- Chapter 7, Shading Devices
- Glazing cavity is divided into 3 sections
- Minimal effect of openness of shade and gaps at top and bottom of shade

\[ T_{b,i} \quad T_{f,i+1} \]

\[ q_{cv,b,i} \quad q_{cv,f,i+1} \]

\[ 2h_{cv,i} \quad 2h_{cv,i} \]
Thermal – Convective Scalar

• Only applies to convection
• Radiation is calculated based on real geometry

Convective Scalar = 0

Convective Scalar = 1

Actual system
Thermal – Waterloo Integral

- Specific to Venetian Blinds
- Convection only
- Radiation is calculated based on real geometry
Thermal – Waterloo Interior

- Based on CFD correlations
- Developed for ASHRAE
- Convection only
- Radiation is calculated based on real geometry
Thermal – CFD

- Detailed calculation to verify model parameters or develop new models
- Calculation intensive
Material, Layer, System
## Diffuse Products

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Optical Characterization &amp; Calculation Method</th>
<th>Thermal Calculation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse</td>
<td>Material Characterization</td>
<td>Same as WINDOW 5</td>
</tr>
<tr>
<td></td>
<td>• Patterned glass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Translucent interlayers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fritted glass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Layer Characterization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Angle scan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Angle Scan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Integrating sphere (possibly)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• W6 Frit model (Implemented)</td>
<td></td>
</tr>
</tbody>
</table>
## Plexiglass / Acrylic Products

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Optical Characterization &amp; Calculation Method</th>
<th>Thermal Calculation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plexiglass/Acrylic</td>
<td>Material Characterization:</td>
<td>Issues</td>
</tr>
<tr>
<td></td>
<td>• Standard nonscattering test for base material</td>
<td>• Need better thermal conductivity (Keff) of layers</td>
</tr>
<tr>
<td></td>
<td>• W6 Radiosity Model (To be developed)</td>
<td>• Treat as a solid layer</td>
</tr>
<tr>
<td></td>
<td>• Raytrace</td>
<td></td>
</tr>
</tbody>
</table>

- **Issues**
  - Need better thermal conductivity (Keff) of layers
  - Treat as a solid layer

- **Material Characterization:**
  - Standard nonscattering test for base material
  - W6 Radiosity Model (To be developed)
  - Raytrace
## Slat Products

### Optical Characterization & Calculation Method

- **Material Characterization**
  - Measure slat material
- **Layer Characterization**
  - W6 Radiosity model (Implemented)
  - Raytrace needed for specular slats

### Thermal Calculation Method

- **Interior shading systems:**
  - ISO 15099 (Implemented)
  - Convective Scalar – LBL (Implemented)
  - Waterloo/Nusselt (not yet implemented)
- **Integral (between glass) shading systems:**
  - ISO 15099 (Implemented)
  - Convective Scalar – LBL (Implemented)
  - Waterloo (Implemented)
- **Exterior shading systems:**
  - ISO 15099 (Implemented)
  - Convective Scalar – LBL (Implemented)

### Issues

- Sensitivity studies to compare the results between models

### Device Type

<table>
<thead>
<tr>
<th>Slat shading (such as venetian blind)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Diffuse</td>
</tr>
<tr>
<td>• Specular</td>
</tr>
<tr>
<td>• Transparent</td>
</tr>
</tbody>
</table>
# Square Weave Products

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Optical Characterization &amp; Calculation Method</th>
<th>Thermal Calculation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square weave products</td>
<td>Material Characterization • Measure thread material</td>
<td>Interior systems:</td>
</tr>
<tr>
<td></td>
<td>Layer Characterization • W6 Radiosity model (Ross McCluney) (Implemented)</td>
<td>• ISO 15099 (Implemented)</td>
</tr>
<tr>
<td>Bug screens</td>
<td></td>
<td>• Convective Scalar – LBL (Implemented)</td>
</tr>
<tr>
<td>Simple, uniform woven</td>
<td></td>
<td>• Waterloo/Nusselt (not yet implemented)</td>
</tr>
<tr>
<td>material</td>
<td></td>
<td>Integral (between glass) systems:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ISO 15099 (Implemented)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Convective Scalar – LBL (Implemented)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Waterloo (??) (Implemented)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exterior systems:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ISO 15099 (Implemented)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Convective Scalar – LBL (Implemented)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Issues</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Thermal performance depends on gaps between shades and window frame (top, bottom, left and right)</td>
</tr>
</tbody>
</table>
## Woven, Non-uniform Products

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Optical Characterization &amp; Calculation Method</th>
<th>Thermal Calculation Method</th>
</tr>
</thead>
</table>
| Woven shades         | Material Characterization  
• Angle scan  
• Integrating sphere (maybe)  
Layer Characterization  
• Angle scan  
• Integrating sphere (maybe)  
• Generalized W6 Radiosity bug screen model to accept any geometry (To be developed)  
• Ray trace (to determine accuracy of using the simple bug screen model for complex, non-uniform weave patterns) | Interior systems:  
• ISO 15099 (Implemented)  
• Convective Scalar – LBL (Implemented)  
• Waterloo/Nusselt (not yet implemented)  
Integral (between glass) systems:  
• ISO 15099 (Implemented)  
• Convective Scalar – LBL (Implemented)  
• Waterloo (??) (Implemented)  
Exterior systems:  
• ISO 15099 (Implemented)  
• Convective Scalar – LBL (Implemented)  
Issues  
• Thermal performance depends on gaps between shades and window frame (top, bottom, left and right) |
| • Complex weaves (not square, not uniform)  
• Bi-color threads  
• Roller shades | Material Characterization  
• Angle scan  
• Integrating sphere (maybe)  
Layer Characterization  
• Angle scan  
• Integrating sphere (maybe)  
• Generalized W6 Radiosity bug screen model to accept any geometry (To be developed)  
• Ray trace (to determine accuracy of using the simple bug screen model for complex, non-uniform weave patterns) |
# Non-Woven Planar Products

## Material Characterization

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Optical Characterization &amp; Calculation Method</th>
<th>Thermal Calculation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-woven Planar shades</td>
<td>Material Characterization</td>
<td>Issues:</td>
</tr>
<tr>
<td>• Solid vinyl shade</td>
<td>• Angle scan of material</td>
<td>• Is material IR transparent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Thermal performance depends on gaps between shades and window frame (top, bottom, left and right)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Convective scalar may be most appropriate</td>
</tr>
</tbody>
</table>
## Drapes

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Optical Characterization &amp; Calculation Method</th>
<th>Thermal Calculation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drapes</td>
<td>Material Characterization</td>
<td>Issues:</td>
</tr>
<tr>
<td></td>
<td>• Angle scan</td>
<td>• Minimal insulation from</td>
</tr>
<tr>
<td></td>
<td>• Angle scan</td>
<td>material</td>
</tr>
<tr>
<td></td>
<td>• W6 Radiosity model</td>
<td>• Thermal performance</td>
</tr>
<tr>
<td></td>
<td>(To be developed) – maybe Wright / Waterloo?</td>
<td>depends on gaps between</td>
</tr>
<tr>
<td></td>
<td></td>
<td>shades and window frame</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(top, bottom, left and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>right)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Determine material IR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>transparency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Review existing research</td>
</tr>
</tbody>
</table>
## Honeycomb Products

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Optical Characterization &amp; Calculation Method</th>
<th>Thermal Calculation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeycomb shade:</td>
<td>Material Characterization</td>
<td>Issues:</td>
</tr>
<tr>
<td>• Geometry of honeycomb</td>
<td>• Measure fabric</td>
<td>• Material can be insulating</td>
</tr>
<tr>
<td>depends on how far the</td>
<td>• Layer Characterization</td>
<td>• Thermal performance</td>
</tr>
<tr>
<td>shade is “extended”</td>
<td>• W6 Radiosity model</td>
<td>depends on gaps between</td>
</tr>
<tr>
<td></td>
<td>• (To be implemented)</td>
<td>shades and window frame</td>
</tr>
<tr>
<td></td>
<td>• Ray trace</td>
<td>(top, bottom, left and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>right)</td>
</tr>
</tbody>
</table>

### Issues:
- Material can be insulating
- Thermal performance depends on gaps between shades and window frame (top, bottom, left and right)
- Determine material IR transparency
- Review existing research
### Other Products

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Optical Characterization &amp; Calculation Method</th>
<th>Thermal Calculation Method</th>
</tr>
</thead>
</table>
| Other Products  
- Products that do not fall into previous categories (Koester blind)  
- Complex / arbitrary geometries, etc | Material Characterization  
- N/A  
Layer Characterization  
- Develop BSDF (Ray trace, goniometer, etc) | Issues: |
BSDF for Advanced Systems

• Bi-directional Scattering Distribution Function (BSDF) is a data format that can store information on how a product affects light transmission

• Any product that currently not has a specific model in WINDOW6, can be defined by a BSDF

• Retrolux Koester blind.
  – Complicated geometry
  – Can be Raytraced or Measured and stored into BSDF format
  – WINDOW6 reads BSDF
Creating Layer Data

• **Venetian Blind Model**
  – Specify slat angle, slat width, slat spacing and curvature

• **Woven Shade Model**
  – Specify thread diameter and thread spacing

• **Fritted Glass Model**
  – Specify coverage percentage

• **BSDF-XML Input**
  – Specify XML file

```xml
<XML>
<Layer>…</Layer>
</XML>
```
Complex Glazing Test Facility

- Provide objective, comparative data on emerging façade technologies in order to understand the risks, benefits, and costs of using such systems in commercial buildings
Availability

- Downloadable from our website:

http://windows.lbl.gov/software/window/6