Modelling the reflective properties of coated blinds comprising an innovative CFS in Radiance

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The speakers

Luca Papaiz

Lars Oliver Grobe

Giuseppe De Michele
- inventor of ScreenLine integrated blind

- world largest producer (8 production facilities worldwide)

- world oldest producer (more than 25 years)
ScreenLine integrated blinds

- Warm edge spacer bars
- Middle glass
- External glass
- Gas or air
- Sun shading system
- Internal glass
- Control device
How to improve energetic performance

Improve spectral reflectance
An interference filter deposited through a process of Physical Vapour Deposition (PVD) makes the slat more reflecting and with low emission to long wave infrared.

Reflection spectra:
- Coated V95 Slat
- Raw Aluminum
- Painted Slat
The reflection of the coated slat is calibrated to compensate the low reflection (hence high transmission) of the solar control selective glazing. The two solutions spectra are complementary.
Having a high reflection slat has its pros and cons

- Very low g-value
- Very good light shelf

But if blinds are not controlled precisely

- Blinds too closed
- Higher solar gain and possible glare
How to improve light/energetic performance

Improve slat reflectance “geometry”
New concept of retro-reflection slats

Retro-reflective microstructure on standard shaped slats

- Low g-value even with open slats (visual contact)
- Glare reduction
The forming of the research group

Patent and Product Engineering phase for retro-reflective micro-structure on slats

Support for product modeling and coating optimization during engineering phase

Support from HSLU: coating modeling and goniophotometric measurement for Luzern’s “High Resolution Complex Glazing Library” project.
Research context at HSLU:
The High Resolution Complex Glazing Library (BIMSOL)

- Project started at Lucerne University of Applied Sciences and Arts right now
- Two year duration, supported by the Swiss Federal Office of Energy SFOE
- Public availability of high-resolution models to experts on time
- Provide derived models to Complex Glazing Database CGDB
- Industry partners
  - Siteco Beleuchtungstechnik GmbH, Hella Storen AG, Pellini SpA, ...
- Research partners
  - Lawrence Berkeley National Lab, EURAC Institute for Renewable Energy
- Partners from consultancy, planning, software development
  - Transsolar Energietechnik GmbH, HZDS AG, Reflexion AG, Preluce AG, Relux AG, Bartenbach, ...
BIMSOL: Contributors

Industry partners
Provide samples (target: 30)
Funding measurements

Swiss Federal Office of Energy
Funding of measurement infrastructure
Model development

Consultants, Planners, ...
Testing
Demonstration

BIMSOL (HSLU)
Radiance
Relux
...

CGDB (LBL)
EnergyPlus
Window
...

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE
Swiss Federal Office of Energy SFOE

Hochschule Luzern
Technik & Architektur
Two innovative coatings for CFS: The samples

Sample A: Highly reflective coating on metal substrate.

Sample B: Retro-reflective coating on metal substrate.
Measurement: Instrumentation

Scanning gonio-photometer at Lucerne University of Applied Sciences and Arts.
Measurement: Sample A / highly reflective coating

DSF incident elevation $\theta_i=40^\circ$

DSF incident elevation $\theta_i=70^\circ$
Modelling: Compiling data-driven BSDF model from measured DSF

- Generate interpolants (front reflection)
  
  \texttt{pabopto2bsdf -n 8 -p *.dat > rff.sir}

  DSF for 56 incident directions

  \texttt{bsdf2ttree -g 7 -t 98 rff.sir > highrefl_g7t98.xml}

  data reduction by 98%

  data-driven model

- Compile adaptive resolution tensor tree from interpolants:
Modelling: Tensor tree model from measurement

DSF incident elevation $\theta_i = 40^\circ$

DSF incident elevation $\theta_i = 70^\circ$
Measurement: Sample B / retro-reflective coating

DSF incident elevation $\theta_i=40^\circ$  

DSF incident elevation $\theta_i=70^\circ$
Modelling: Sample B / Computation of retro-reflection BSDF

- Prepare model of surface structure

- Call genBSDF

```
genBSDF -n 20 -t4 6 -c 16384 +b +f -r 'ab 5' \
eg-geom millimeter sampleB.rad > retrorefl_t45c16384.xml
```
Modelling: Tensor tree model computed with genBSDF

DSF incident elevation $\theta_i=40^\circ$

DSF incident elevation $\theta_i=70^\circ$
Modelling: Comparing measurements with models

*Measurement*

*Model*

**DSF Sample A, $\theta_i=40^\circ$**

**DSF Sample B, $\theta_i=40^\circ$**
Simulation-based assessment of the blinds with Radiance

- Comparison: standard vs innovative system
- mkillum approach
- Glare and daylight availability
Shading system and configurations

- ScreenLine SL27 Pellinindustrie

Standard configuration
- high reflective

Configuration 1
- retro-reflective
- high reflective

Configuration 2
- high reflective
- retro-reflective
Test room

Reflections
Wall 0.6
Ceiling 0.8
Floor 0.2

View position -vp 0 4 1.6 -vd 0 -1 0 -vu 0 0 1
Sensor points 0 n0.5 0.85 0 0 1 (16 points)
Combination over the façade

- Improve glare protection
- Daylight redirecting effect
Sky condition

# sky description
!gensky -ang 15 0
skyfunc glow sky_glow
  0 0
  4 1 1 1 0
sky_glow source sky
  0 0
  4 0 0 1 180
skyfunc glow ground_glow
  0 0
  4 1 1 1 0
ground_glow source ground
  0 0
  4 0 0 -1 180
BSDF lamella surface material - coating.mat

```plaintext
# BSDF material

void BSDF blindsMat.Spec
6 0 ../HCCGL001-Pellini_g7t99.xml 0 1 0 .
0
0

void BSDF blindsMat.Retro
6 0 ../HCCGL002-Pellini_t4_6.xml 0 1 0 .
0
0
```

measured

calculated
sceneCase2.rad

# scene file Case2

# configuration 1 for the bottom window
!genblinds blindsMat.Retro blindsObj.LowerFront .016 3 2 166 -31.5 +r .040 | xform -rz -90 -r -1.5 0 0
!genblinds blindsMat.Spec blindsObj.LowerBack .016 3 2 166 -31.5 +r .040 | xform -l -rz -90 -t -1.5 0 -.0005

# configuration 2 for the top window
!genblinds blindsMat.Spec blindsObj.UpperFront .016 3 1 83 -31.5 +r 0.040 | xform -rz -90 -r -1.5 0 2
!genblinds blindsMat.Retro blindsObj.UpperBack .016 3 1 83 -31.5 +r 0.040 | xform -l -rz -90 -t -1.5 0 1.9995

+...
Sky condition
Material+Geometry
# illum input file - scenelllum.rad

```
@mkillum d=64 s=24
void glass glassMat
0
0
3 .7 .7 .7

glassMat polygon windowObj.Bottom
0
0
12
  1.5  0  2
  1.5  0  0
-1.5  0  0
-1.5  0  2

glassMat polygon windowObj.Top
0
0
12
  1.5  0  2.994
  1.5  0  2
-1.5  0  2
-1.5  0  2.994
```

file with surfaces to be converted into illuminance sources
rad input file - sceneCase2.rif -> image-based simulation

# rad input file
OCTREE= oct/sceneCase2.oct
ZONE= I -1.5 1.5 0 8.3 0 3
RESOLUTION= 1024
QUALITY= M
PENUMBRAS= TRUE
VARIABILITY= H
INDIRECT= 2
REPORT= 10

PICTURE= hdr/sceneCase2
RAWFILE= unf/sceneCase2.unf
AMBFILE= amb/sceneCase2.amb
scene= rad/SceneCase2.rad
materials= rad/coating.mat
illum= rad/Scenellum.rad
view= inside -vf vf/inside.vf
mkillum= -ad 512 -lw .0015 -aa .15
render= -ad 768 -aa .15 -lw .0008

...going to the terminal

$ rad sceneCase2.rif

oconv rad/coating.mat rad/testScene.rad > oct/sceneCase1.oct
oconv -i oct/sceneCase1.oct rad/testScenellum.rad \ 
> oct/sceneCase10.oct
mkillum oct/sceneCase10.oct "<" rad/testScenellum.rad > ilMjcjRf

oconv -f -i oct/sceneCase1.oct ilMjcjRf > oct/sceneCase11.oct

rpict -t 600 -vf vf/inside.vf -dp 512 -ar 55 -ms 0.12 -ds .2 -dj .9
-dt .1 -dc .5 -dr 1 -ss 1 -st .1 -ab 2 -af amb/sceneCase2.amb -aa .1
-ad 1536 -as 392 -av 0.01 0.01 0.01 -lr 8 -lw 1e-4 -x 64 -y 64 -ps 1
oct/sceneCase2.oct
Prospective view

Case 1

Case 2

Results
DGP calculation Case1

Results

$ pcomb -o sceneCase1_fe.hdr | evalglare -vth -vp 0 4 1.6 -vd 0 -1 0 -vu 0 0 1 -vh 180 -vv 180 -c sceneCase1_fe_check.hdr
dgp,ugi,ugr,vcp,cgi,Lveil: 0.567620 28.619001 34.613251 0.000000 40.963387 2974.534668
DGP calculation Case2

$pcomb -o sceneCase2_fe.hdr | evalglare -vth
-vp 0 4 1.6 -vd 0 -1 0 -vu 0 0 1 -vh 180 -vv 180
-c sceneCase2_fe_check.hdr

dgp,dgi,ugr,vcp/cgi,Lveil: 0.254569
20.078901 23.994635 4.022694 26.819836
399.066040
### DGP comparison

#### Daylight glare comfort classes

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<thead>
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<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>best class</td>
<td>good class</td>
<td>reasonable class</td>
</tr>
<tr>
<td></td>
<td>95% of office-time glare weaker than</td>
<td>95% of office-time glare weaker than</td>
<td>95% of office-time glare weaker than</td>
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<tr>
<td></td>
<td>‘imperceptible’</td>
<td>‘perceptible’</td>
<td>‘disturbing’</td>
</tr>
<tr>
<td>DGP limit</td>
<td>$\leq 0.35$</td>
<td>$\leq 0.40$</td>
<td>$\leq 0.45$</td>
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<tr>
<td>Average DGP limit</td>
<td>0.38</td>
<td>0.42</td>
<td>0.53</td>
</tr>
<tr>
<td>within 5% band</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Wienold 2009, DYNAMIC DAYLIGHT GLARE EVALUATION.

**Case 1**
- **Ev = 5903 lux**
- **DGP = 0.56**
- **Category C**

**Case 2**
- **Ev = 1070 lux**
- **DGP = 0.25**
- **Category A**
grid based simulation - rtrace

<table>
<thead>
<tr>
<th># sensors.pts</th>
<th># x y z vx vy vz</th>
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<tbody>
<tr>
<td>0 0.5 0.85 0 0 1</td>
<td></td>
</tr>
<tr>
<td>0 1 0.85 0 0 1</td>
<td></td>
</tr>
<tr>
<td>0 1.5 0.85 0 0 1</td>
<td></td>
</tr>
<tr>
<td>0 2 0.85 0 0 1</td>
<td></td>
</tr>
<tr>
<td>0 2.5 0.85 0 0 1</td>
<td></td>
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<td>0 4 0.85 0 0 1</td>
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<tr>
<td>0 4.5 0.85 0 0 1</td>
<td></td>
</tr>
<tr>
<td>0 5 0.85 0 0 1</td>
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<td>0 6.5 0.85 0 0 1</td>
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</tr>
<tr>
<td>0 7 0.85 0 0 1</td>
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<td>0 7.5 0.85 0 0 1</td>
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</tr>
<tr>
<td>0 8 0.85 0 0 1</td>
<td></td>
</tr>
</tbody>
</table>

take the octree file from the imaged-based simulation -> oct/sceneCase12.oct

$ cat illum/sensors.pts | rtrace -l+ -ab 5 \ oct/sceneCase12.oct | rcalc \ -e '$1=47.4*1+120*2+11.6*3$' > illum/sceneCase1.ill
Daylight availability

Results
Daylight availability

Results

Comfort range
300-3000 lux

Illuminance [lux] $\log_{10}$

Distance from the window [m]
Conclusion

- Glare reduction
- Better regulation of the daylight inside the space

Outlook

- Improving daylight redirecting
- Optimization of the system