Statistical Optimization and Structural Analysis: Design of handmade custom Snowboards

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Introduction
Materials & Structure, Geometry & Shape

1. Calibration of test feedback
   Elaboration of questionnaires
   Overview of first results

2. Correlation of test results with board parameters
   Direct Sensitivity Study and ranking of significant parameters
   Application: optimization of custom handmade snowboards

3. Optimization under Structural analysis
   Ranking of significant parameters according to certain target outputs
   Board parameters – Analysis results – Test results

Conclusions
Materials & Structure

Wood

Composite reinforcements

Layup

Edges

Thickness profile

Sidewalls

Input parameters:
- Wood species combinations
- Thickness profile
- Reinforcement & Matrix types
- Layup (orientation, thickness, stacking sequence)
- Material properties (E Modulus {E}, G Modulus {G}), Poisson ratios)
- Tensile, Compressive, Flexural Strength {σ_e}, {σ_r}
- Density, Toughness, Stability

UD Roving

±45° fabric

UD Lin fiber

BASACITE
Geometry & Shape

**Dimensions**

**Sidecut shape**

**Camber profile**

**Inserts positions**

**Input parameters:**
- $L$, $L_m$, $L_{contact}$
- $L_{nose}$, $L_{tail}$, $L_{camber}$
- $W_{nose}$, $W_{waist}$, $W_{tail}$
- Stance
- Setback
- $H_{nose}$, $H_{tail}$, $H_{camber}$
- Curvatures: sidecut, camber, rockers
Portfolio
Calibration of test feedback

→ 25 output parameters including:
- Board behaviour (discipline related)
- Board aspect (graphics, weight)
- Terrain conditions (weather, snow quality)

→ 35 feedback results gathered over Winter 15/16
Calibration of test feedback

**Board Overall**

**First Impression**: 35 responses

- Too soft: 0 (0%)
- Too stiff: 1 (2.9%)
- Very grippy: 6 (17.1%)
- Very slippery: 18 (51.4%)
- I’m loving it: 10 (28.6%)
- I’m gonna die: 0 (0%)

**Overall Fun**: 35 responses

- A lot of fun!: 12 (34.3%)
- Too soft: 0 (0%)
- Too stiff: 11 (31.4%)
- Very slippery: 11 (31.4%)
- Very grippy: 10 (28.6%)
- Boring: 1 (2.9%)

**Edge Hold**: 35 responses

- Very slippery: 0 (0%)
- Very grippy: 14 (40%)
- Too soft: 6 (17.1%)
- Too stiff: 13 (37.1%)

**Mid / Torsional flex**: 31 responses

- Too软: 1 (3.2%)
- Too stiff: 10 (32.3%)
- Very grippy: 15 (48.4%)
- Very slippery: 4 (12.9%)
- Boring: 1 (3.2%)
Calibration of test feedback

Freeride

Turning Radius : (35 réponses)

<table>
<thead>
<tr>
<th>Turning Radius</th>
<th>Number of Responses</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 (0 %)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1 (2,9 %)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>31 (88,6 %)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3 (8,6 %)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0 (0 %)</td>
<td></td>
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</tbody>
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Easily

Float easily
Correlation of test results

Direct Sensitivity Study:
- Compute Correlation Coefficients between two sets of {Inputs} and {Outputs}
  → determine which parameters are significant to which outputs

- Quantify parameter influence (slope of fitted numerical model)
  → compare effects of different parameters

⚠ input parameters must be standardized to their practical variation range
Correlation of test results

"Overall stiffness" = f(Dx)

Box Plot(Dx, Global Stiffness)

Feedback parameter « Global Stiffness »

« Too soft »

« Too stiff »

Average Bending Stiffness Dx [N.mm]
Sensitivity Study: computation of average bending Stiffnesses for different layups

<table>
<thead>
<tr>
<th>Stacking sequence (symmetric)</th>
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<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Fiberglass</td>
</tr>
<tr>
<td>Fiberglass</td>
</tr>
<tr>
<td>Wood core</td>
</tr>
<tr>
<td>Fiberglass</td>
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<tr>
<td>Fiberglass</td>
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</tbody>
</table>

Input parameters: 3 (t_{core}, t_{0}, t_{45})
Variation interval: ±15%
Number of samples: 2197 (all combinations)

\[
D_x = f(t_c) \quad \text{CC} = 0.980 \quad \text{Slope} = 2.6 \times 10^5
\]

\[
\begin{align*}
\varepsilon_x & = A_{11} A_{12} A_{16} \quad B_{11} B_{12} B_{16} \\
\varepsilon_y & = A_{12} A_{22} A_{26} \quad B_{12} B_{22} B_{26} \\
\gamma_{xy} & = A_{16} A_{26} A_{66} \quad B_{16} B_{26} B_{66}
\end{align*}
\]

\[
\begin{bmatrix}
\varepsilon_x \varepsilon_y \gamma_{xy}
\end{bmatrix} =
\begin{bmatrix}
A_{11} & A_{12} & A_{16} \\
A_{12} & A_{22} & A_{26} \\
A_{16} & A_{26} & A_{66}
\end{bmatrix}
\begin{bmatrix}
B_{11} & B_{12} & B_{16} \\
B_{12} & B_{22} & B_{26} \\
B_{16} & B_{26} & B_{66}
\end{bmatrix}
\]

\[
M_x = \frac{1}{D_{11}} \cdot K_x
\]

Theory of thin laminates, [ABD] matrix

Average bending stiffness

\[
D_x [N.mm]
\]

\[
D_x = f(t_0) \quad \text{CC} = 0.130 \quad \text{Slope} = 9.2 \times 10^5
\]

\[
\begin{align*}
D_x & = f(t_0) \\
\text{CC} & = 0.130 \quad \text{Slope} = 9.2 \times 10^5
\end{align*}
\]
- Define optimization target parameter (*Mass, Material Cost, Time...*)
- Assess variation of single parameters around the deterministic sample
- Sort the parameters by influence ranking

**Optimization of structural thickness according to output**

*Mass [kg]*

- Variation of CORE thickness only
- Variation of UD PLY thickness only
- Variation of 45° PLY thickness only

**Structural Analysis Optimization**
Conclusions

Design of a custom snowboard:

1) Define the board specifications: for whom? for which activity?
2) Pick up the best fit among all existing shapes, based on rider profile and feedback results
3) Run sensitivity study with the chosen existing board as "mean value"
4) Optimization of geometrical and structural parameters using the study results:
   - sort significant input parameter by influence level (descending)
   - define priorities and « best compromise »

Further steps:

- Expand number of samples and feedback results
- Structural analysis via FE modelization: consideration of field inputs and selected load cases
- Qualification of material data
- Consideration of physical inputs correlation
- Fitting of nonlinear numerical models
Thanks!

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