An alternative approach to automotive door seal design using HyperStudy

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Sales: 2.5 Md$
Employees: 20,000
Locations: 55+
Sealing design: current approach

Today, seal design and closing effort forces are determined using a nominal seal shape at extreme BIW tolerances.
What is the problem?

When designing a weather-strip seal:
- Match the OEM’s requirements
- Find the design of the seal which will better fulfill these requirements.

» Shape optimization

When manufacturing the weather-strip seal:
- Reduce the impact of small extrusion tolerance variation
- Verify that a given design is less sensible to these variations

» Sensibility study

- Find the design of the product which will both satisfy the requirements and be less sensitive to small deformations

» Robust design optimization
Objectives

What:
- Design process  Parametric design approach

How:
- Identify the numerical tools
- Define a procedure
- Study the effect of size and shape variations in seal design
The numerical tools

**HyperStudy**: optimization  
(*Altair Engineering*)

**HyperMesh**: Morphing function  
(*Altair Engineering*)

**Marc & Mentat**:  
FE solver & pre-processor  
(*MSC Software*)
Communication not obvious between the numerical tools
Data exchange not easy

Python routines (in house developments):
- 2 initialization procedures
- 2 analysis procedures
- 5 scripts

Initialisation
- Parameterization of the product
- Choice of results to extract
- Creation of the model file
- First calculation

Steps of analysis
- Definition of parameters value
- Writing of the calculation input file
- Calculation
- Extraction of results
A simple typical design

Ideal (nominal design)  Reality (geometric scatter)

Requirements
Parameterization of geometric scatter

Parameters

- Height
- Thicknesses
- Radiuses

Process

1. Creation of geometry
2. Definition of elements to project and support
3. Morphing
4. Displacement OK?
   - YES: validate, save shape
   - NO: adjust domains and handles
Initialization of study – export of parameters

- Accessible from *optimization* panel of HyperMesh
- Associates to each deformation a variable (initial value and definition interval)
- Export two files:
  - *shp*: contains the definition of all deformations as a list of $\Delta x$, $\Delta y$, $\Delta z$ associated to the nodes coordinates.
  - *marc.node.tpl*: definition of parameters and list of nodes coordinates in *Marc* format; the nodes affected by a deformation are indicated by a tag and point to the matching line in the *shp* file.

```plaintext
1 {parameter(epaisseur_3,"epaisseur_3", 0.00000000e+000, 0.00000000e+000, 1.00000000e+000)}
15 {coeff1 = read("model_0_7.shp",0,0,1)}
30 {I1 = I1 + epaisseur_3 * coeff1}
```
Initialization of study – creation of model file

- Procedure accessible in HyperStudy
- Ask the user for the location of the Marc input file on which the morphing were based, and for the location of the .marc.node.tpl file
- Delete the list of nodes coordinates in the input file and replace it by an inclusion of the .marc.node.tpl file

```plaintext
coordinates

3 1.636 0 1

(include "W:\calcul\Bastiares\Maxime_Lecoinc\Etude_19\model_0_7.marc.node.tpl")
define node set fx-y_nodes
22 63
define node set fx-x_nodes
22 63
define element set gde-levre
398 to 735
mooney
```

- The file created will be used as model (template) to HyperStudy
Procedure accessible from HyperStudy

Analyses of the Marc input file used for the study
  - Lists all the contacts and loadcases

Opens a Python/Tk window where the user chooses the couples Contacts / Load cases to be studied
The model can now be imported in HyperStudy; the parameters will be recognized automatically.

A first calculation (nominal run) must be performed in order to define the responses (numerical values) to study.
Initialization of study – Definition of response

- During initialization: choice of couples contacts/loadcases to study
- During a calculation: writing of a text file containing the forces applied to a contact during the associated loadcase, for each increment and both X- and Y- axis
- After the nominal run, choice of particular values by a tool in HyperStudy
Type of DOE
Number of runs
Set of possible values for each parameter
Set of combinations for all parameters
DOE: results

- Extraction of results
- Main and secondary effects
- Distribution of responses
Choice of the optimization algorithm: ARSM for a shape optimization
Choice of the objectives: get as close as possible to the requirements
## Optimization: results

### Convergence in 23 iterations

<table>
<thead>
<tr>
<th></th>
<th>Optimized design</th>
<th>Requirements</th>
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</thead>
<tbody>
<tr>
<td>Force mini</td>
<td>5.52</td>
<td>5.5</td>
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<tr>
<td>Force nominal</td>
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<tr>
<td>Force maxi</td>
<td>11.60</td>
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### Table: Optimization results

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Objective 1</th>
<th>Objective 2</th>
<th>Objective 3</th>
<th>hauteur</th>
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</tbody>
</table>

**Objective 1**: Force mini

**Objective 2**: Force nominal

**Objective 3**: Force maxi
Optimization: optimized section

Comparison Initial CAD section / optimized section

Geometric differences:

Height: +1mm

Thickness_ext: +0.86mm

Thickness_int: +0.15mm

Radius_ext: +0.96mm

Radius_int: +0.97mm
Stochastic study

- Check for robusteness of the optimized design
- Choice of type of study
- Distribution of input variables
Stochastic study: results

- Probability bar chart
- Statistic indicator

Robustness indicator:
- Solution is robust

<table>
<thead>
<tr>
<th>Nominal force</th>
<th>Red: distribution of force values</th>
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<tbody>
<tr>
<td>Green: probability of a force being equal to a specific value</td>
<td></td>
</tr>
<tr>
<td>Blue: probability of a force being lesser than a specific value</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>mini</th>
<th>nom</th>
<th>maxi</th>
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<tbody>
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<table>
<thead>
<tr>
<th>Response</th>
<th>Bound Type</th>
<th>Bound Value</th>
<th>Reliability</th>
<th>Probability of Failure</th>
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</tbody>
</table>
Conclusions

- New design approach
- Effect of extrusion tolerance on the design response investigated
- Optimal response predicted using numerical model
- Design of optimal solution is robust
- The approach used is valid for shape definition that meets specified design requirements.
- Can be extended to define manufacturing tolerances of the design
Merci
Thank you