WOST2018

COST & FUNCTION OPTIMIZATION

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Agenda

1. Dilemma of the Product Development
2. Innovation Hypothesis
3. Linear Force Solenoid for Automated Transmissions
4. Requirements to Set Up a Cost and Function Optimization
5. Workflow
6. Topology Variation – Details and First Evaluation
7. Tolerance Variation – Details and First Evaluation
8. Conclusion
Cost & Function Optimization

Dilemma of the Product Development

Influence on Cost & Function

Realization of Product

high

low
Cost and Function Optimization

Innovation Hypothesis

State of the Art – Functional Optimization

Workflow

- Input (Parameter, targets)
- Method (Optimization,...)
- Solver (Edyson,...)
- Plausibility check
- Post processing (OptiSLang, Excel)

Evolutionary Algorithm

An evolutionary development process creates a pareto front of the best designs

Variation of design parameters with evolutionary algorithm

Result: Optimized technical behavior based on simulation

Enhance function optimization with cost optimization to develop in shorter time competitive products.
Cost and Function Optimization
Linear Force Solenoid (LFS) for Automated Transmissions

Product Description
- LFS for transmissions with direct shift control

Customer Benefits
- High accuracy, low hysteresis
- Curve of magnetic force adaptable
- Variability of the connectors

Specification
- Current range: 1.2 A
- Range of resistance: 1.5 – 6.3 Ω
- Diameter: 28.4 and 32.5 mm
- Length: 33 and 40 mm
- Stroke range: 2.2 – 3.5 mm
- Force Level: up to 25 N
Cost and Function Optimization

Requirements to Set Up a Cost and Function Optimization

<table>
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<th>Cost</th>
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<td>Scrap @ Bosch</td>
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- Topologies
- Tolerances
- Materials and Technologies
- Parameter Values
- KPI calculation

MAT: direct material costs
*) MAE: machinery and equipment

Scrap
Raw material costs (price & volume of raw material)
Material reimbursement (price & volume of the material cut)

Value add @ supplier
Manufacturing steps
Cycle time
Machine costs
Labour costs
Set-up time
E.g. plant administration costs, manufacturing overheads,...

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Cost and Function Optimization

Workflow

Optimization Module

Parameter Optimization
\[ p_{1,1} = 9.0 \ldots 10.0 \]
\[ p_{1,m} = 2.5 \ldots 2.6 \]

Material / Technology Optimization
\[ m_{1,1} = \text{DC04 / Stamping} \]
\[ m_{1,p} = \text{SFeP130 / Sintering} \]

Change Material and Process Data

Automatic Meshing

Tolerance Optimization
\[ \text{tol}_{1,1} = \text{H7} \]
\[ \text{tol}_{1,o} = \text{F9} \]

Analysis Module

Function Analysis

Cost Analysis

Cycle Time Calculation

Robustness Analysis (Scrap)

Start Design

New

State of the art

Target Design

Q: Convergence / Number of Iteration

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Realized workflow of the cost and function optimization includes:

- Sensitivity analysis (4000 designs)
- Metamodel of optimal prognosis
- Evolutionary algorithm
- Integrated robust design analysis
- Duration of simulation ~38 h
- 99 variables
- 3 objectives and 9 constraints
Cost and Function Optimization
Topology Variation - Workflow

Description of components

OptiSLang creates design variants based on predefined topologies

Automatic geometry update

Automatic mesh update

Automatic start of simulation

Points
\[ p_{1.1} = (x_{1.1}, y_{1.1}) \]
\[ p_{1.2} = (x_{1.2}, y_{1.2}) \]
...

Lines
\[ l_{1.1} = (p_{1.1}, p_{1.2}) \]
...

Areas
\[ a_1 = (l_{1.1}, l_{1.2}, ...) \]

Topology 1
- part 1.1
- part 1.2
- part 1.3

Topology 2
- part 1.4
Cost and Function Optimization
Topology Variation – First Evaluation

Form Deviation over MAT

- Topo_1
- Topo_2

Target

Characteristic Curve

- Magnetic Force in N
- Stroke in mm

Targets

Form Deviation in N

MAT in relative values
Cost and Function Optimization
Tolerance Optimization – Details

**MAT – Calculation**

1. Create new designs with different dimensions and tolerance classes
2. Automatic manufacturing steps selection based on given dimension and tolerance class
   - IT 6: Turning
   - IT 9: Turning
   - IT 6: Grinding
   - IT 9: Grinding
   - MAT 1
   - MAT 2

**Robustness Analysis**

3. Automatic adjustment of individual dimension range based on given tolerance class
4. Run robust design analysis for each design

**Component Cost**

5. Calculate new component costs based on scrap cost and MAT cost

![Graph showing frequency distribution and robustness analysis](image)
Cost and Function Optimization
Tolerance Optimization – First Evaluation

Form Deviation over MAT+Scrap

Characteristic Curves

Influences on Costs of different Tolerances up to 12 %
Cost and Function Optimization

Conclusion

- Procedure indicates optimal designs regarding function and cost
  - Which fulfil requirements
  - Save money
- Relationships between function, design features and costs are transparent
- Useful in concept phase to compare different designs
- Individual adaptable
  - Manufacturing processes
  - Products (proportional magnet, e-machine,...)
THANK YOU