Robust Design of an Actuator Assembly for high-precision Positioning under static Aspect
Actuator Assembly in SolidWorks®

Actuator Head for high-precision Positioning

Driving Force

X-Position

Y-Position
Design Parameters and Uncertainties

- Young Modulus
- Poisson Ratio
- Joint Stiffness
- Driving Force

- Plunger Length
- Link 1 Length
- Link 2 Length
- Piston Length
- Casing Length
- Bracket Length 1
- Bracket Length 2
- Bracket Length 3
- Bracket High 1
- Bracket High 2
- Bracket High 3
Design Space and Specifications

Design Constraints

- All Geometry Tolerances = 0.1 mm
- Actuator Head Positioning:
  - 75 mm ≤ X-Position ≤ 79 mm
  - 30 mm ≤ Y-Position ≤ 34 mm

Design parameter with variable nominal and fixed tolerance (0.1 mm)

For each parameter:
- Design range = 4 mm
- Design center = nominal value

Design uncertainties with fixed nominal and fixed tolerance
Nominal Design: Nominal FEM-Simulation in SolidWorks ®

Nominal Deformation under Static Load

Idealistic Position  = Geometry Position
(X-Position= 0.07712 m;  Y-Position=0.03111 m)

Realistic Position  = Geometry Position + Static Deformation
(X-Position = 0.07735 m;  Y-Position = 0.03246 m)

Nominal model parameters without tolerances for nominal simulation

<table>
<thead>
<tr>
<th>Name</th>
<th>Nominal</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plunger Length</td>
<td>0.058890916</td>
<td>m</td>
</tr>
<tr>
<td>Bracket High 1</td>
<td>0.03048</td>
<td>m</td>
</tr>
<tr>
<td>Bracket High 2</td>
<td>0.0196819364</td>
<td>m</td>
</tr>
<tr>
<td>Link 2 Length</td>
<td>0.01476502</td>
<td>m</td>
</tr>
<tr>
<td>Piston Length</td>
<td>0.1016</td>
<td>m</td>
</tr>
<tr>
<td>Link 1 Length</td>
<td>0.00635</td>
<td>m</td>
</tr>
<tr>
<td>Casing Length</td>
<td>0.05939536</td>
<td>m</td>
</tr>
<tr>
<td>Bracket Length 1</td>
<td>0.171704</td>
<td>m</td>
</tr>
<tr>
<td>Bracket High 3</td>
<td>0.0427736</td>
<td>m</td>
</tr>
<tr>
<td>Bracket Length 2</td>
<td>0.00518904</td>
<td>m</td>
</tr>
<tr>
<td>E-Modulus Alloy Steel</td>
<td>2.1e+011</td>
<td>N/m²</td>
</tr>
<tr>
<td>Poisson Alloy Steel</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>E-Modulus Cast Steel</td>
<td>1.9e+011</td>
<td>N/m²</td>
</tr>
<tr>
<td>Poisson Cast Steel</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>Pin Stiffness</td>
<td>1000000</td>
<td>lb/in</td>
</tr>
<tr>
<td>Pin 12 Stiffness</td>
<td>500</td>
<td>lb/in</td>
</tr>
<tr>
<td>Force</td>
<td>15</td>
<td>lbf</td>
</tr>
</tbody>
</table>
OptiY starts a loop of several calculations (DOE) automatically using the direct integration node Solidworks:

- Generate distributed values for stochastic parameters in OptiY
- Put the parameter values from OptiY to SolidWorks
- Update the parameters, rebuild the assembly, check geometry constraints and interferences in SolidWorks
- Start static FEM-simulation for the new assembly in SolidWorks and update sensor data from simulation
- Read the sensor data from SolidWorks and put them to the output parameters of OptiY
Stochastic Distribution of Model Parameters
Geometry Tolerance Analysis without Uncertainties

Probability Density Function of Idealistic X-Position

Probability Density Function of Idealistic Y-Position

Tolerance Sensitivities of X-Position

Tolerance Sensitivities of Y-Position

Total Failure Probability = 0%
0.03 m ≤ Y-Position ≤ 0.034 m
Probabilistic Simulation for Nominal Design with Uncertainties

Total Failure Probability = 24.44%
0.03 m ≤ Y-Position ≤ 0.034 m
Robust Design Optimization

Robust Design Goal to Minimize the Failure Probability using Taguchi Quality Loss Function. Center point = 0.033 m for Y-position because of its unsymmetrical distribution (0.03 m ≤ Y-Position ≤ 0.034 m)

Optimization Results:
Optimal nominal values of the design parameters with the same tolerances
Probabilistic Simulation for Robust Design

Total Failure Probability = 0.04%
0.03 m ≤ Y-Position ≤ 0.034 m
Same-Scale PDF Comparison between Designs

Nominal Design
only by Geometry Tolerances
without Uncertainties
Failure Probability = 0%

Nominal Design
with Uncertainties
Failure Probability = 25.44%

Robust Design
with Uncertainties
Failure Probability = 0.04%

X-Position: [0.0765 – 0.0775] m
Y-Position: [0.030 – 0.036] m
Conclusion

Nominal design using classical nominal simulation cannot warranty the reliability and quality of the products, because the nominal parameters are only one fix value.

Robust design is a power-full tool for design of reliable and quality product in the early design stage without any cost. It considers the uncertainty parameters as stochastic distributions.

In the case of the actuator assembly, the failure probability has been reduced from **25,44% to 0,04%** for the manufacturing process.

**OptiY®** is the leading software platform for robust design of all engineering fields using different commercial CAD/CAE-software or in-house codes.