Weight Optimization of a Helicopter Component using HEEDS and Simcenter 3D

Date:

December 4, 2020

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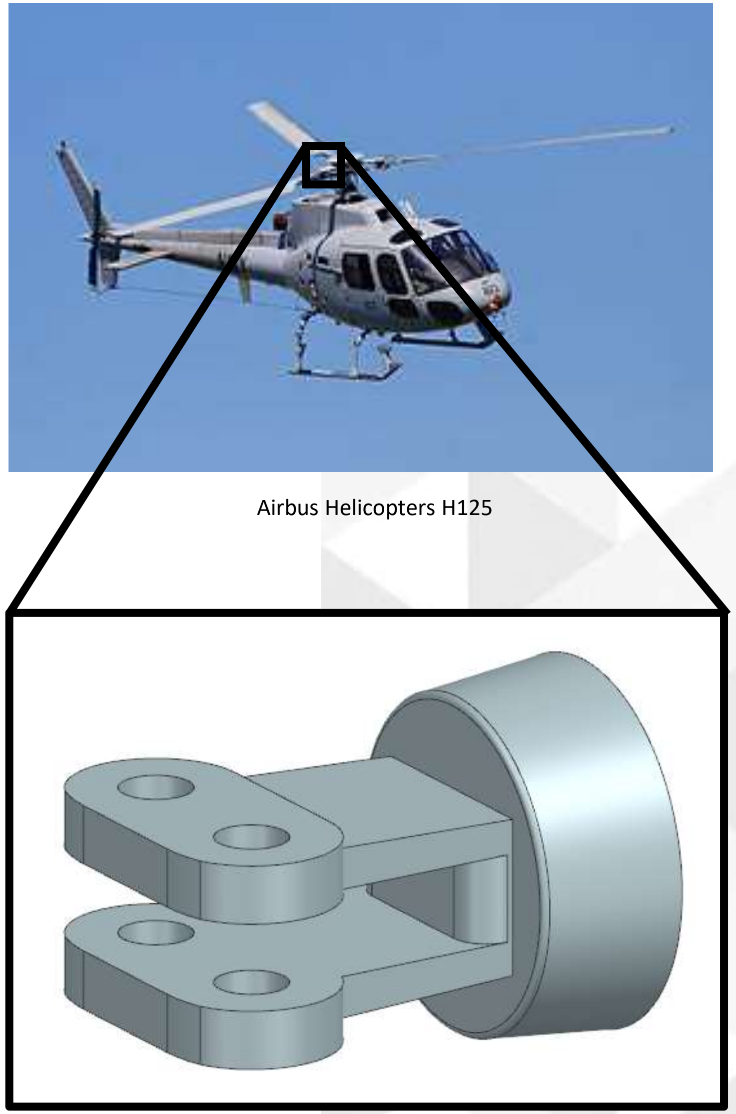
Lighter is Better

- Aerospace vehicles place a premium on low weight
- Consequences of failure can be catastrophic, so margins of safety must be met
- Increasing these margins usually means additional material and greater component weight
- Helicopters are particularly complex and require many mechanical components
- Manual redesign of each component is costly and requires a great many man-hours
- Automated, multi-disciplinary optimization can be used to reduce weight while maintaining safety margins and limiting engineering time

Airbus Helicopters H125

Case Study: Helicopter Blade Grip

- The blade grip is required to hold the helicopter blades to the rotor hub
- Blade rotation, lift, drag, and pitch adjustments produce high-frequency high-amplitude cyclic loads on the blade grip
- Blade grip failure would be catastrophic but weight savings of this and other components are desired
- With HEEDS and Simcenter 3D, safe weight reduction of the blade grip can be obtained by intelligently selecting and evaluating hundreds of design variants in an automated workflow



Airbus Helicopters H125

Notional Blade Grip

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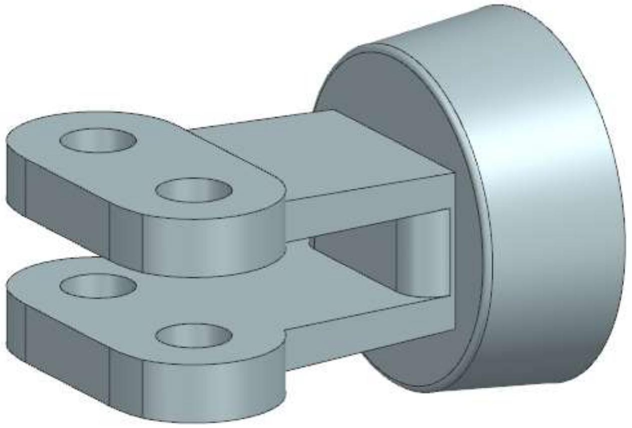
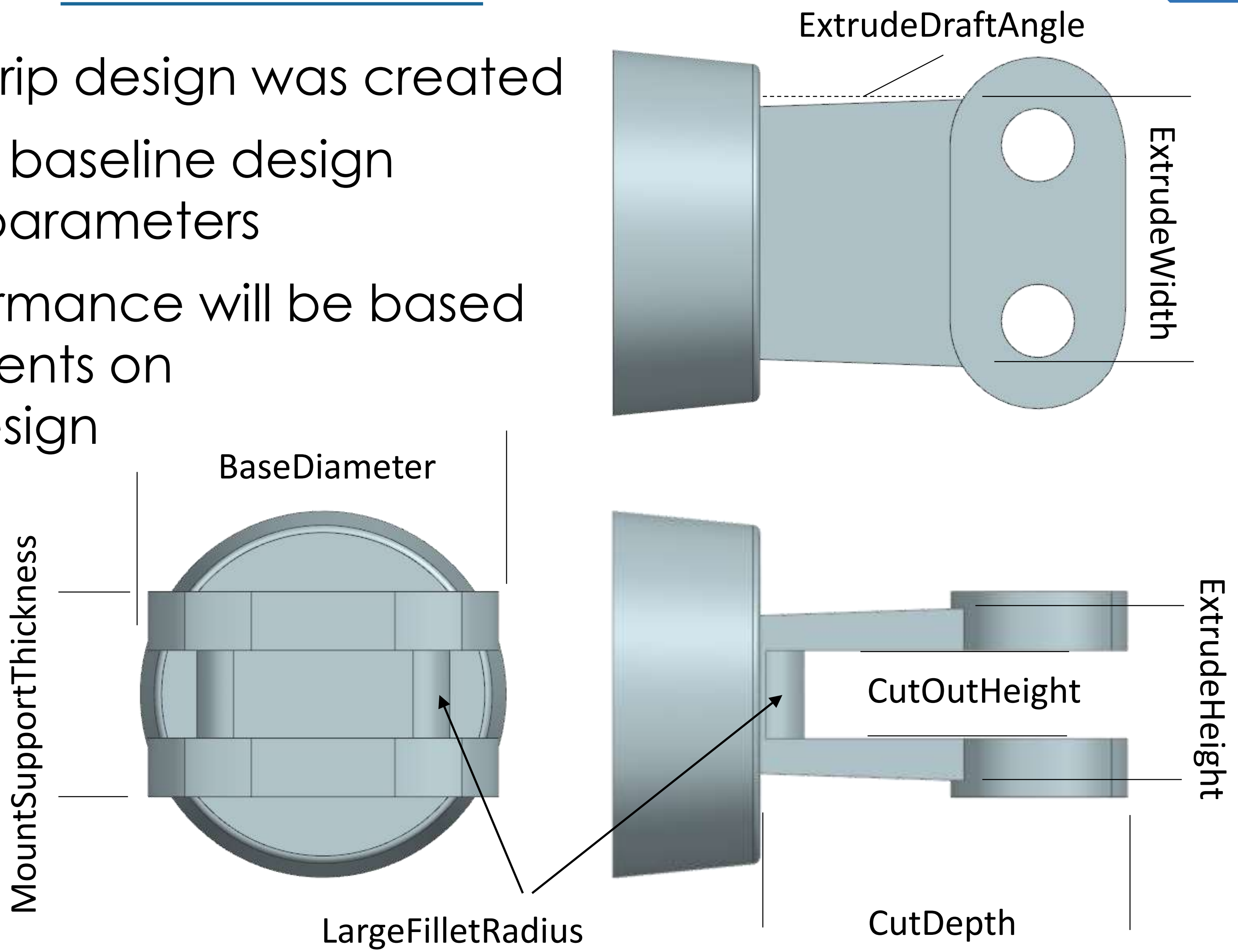
Baseline Blade Grip Design

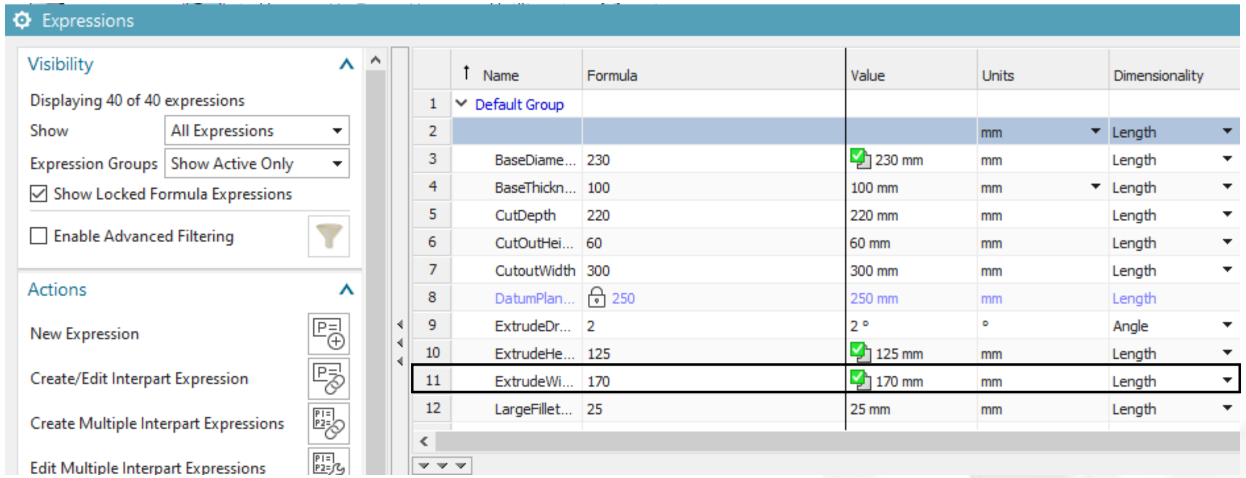
- A baseline blade grip design was created
- Variations from the baseline design dictated by eight parameters
- Optimization performance will be based on mass improvements on 35.3 kg baseline design

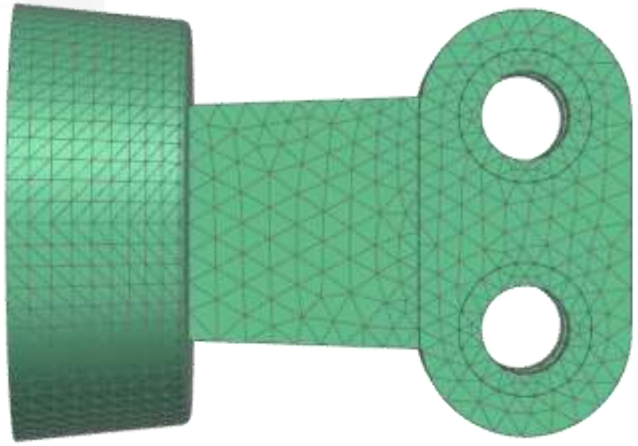




Simcenter 3D Seamlessly Remeshes FEM After Each Geometry Change

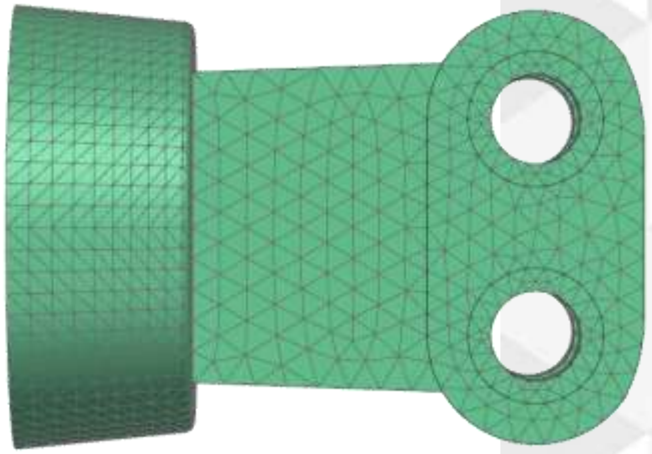
- Design parameters exposed to HEEDS through the use of CAD Expressions
- Simcenter 3D modifies the the geometry and meshes the FEM





ExtrudeWidth
150 mm → 190 mm

Auto-remesh after geometry modification



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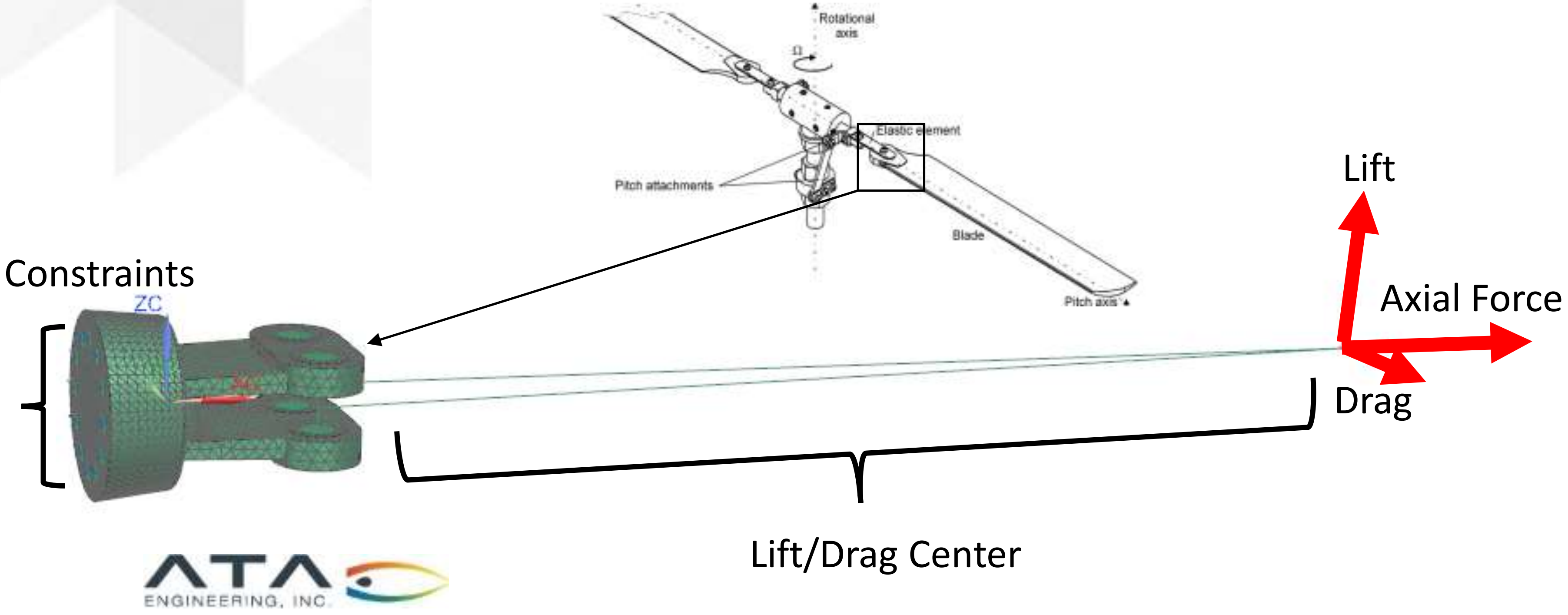
Blade Grip Loads

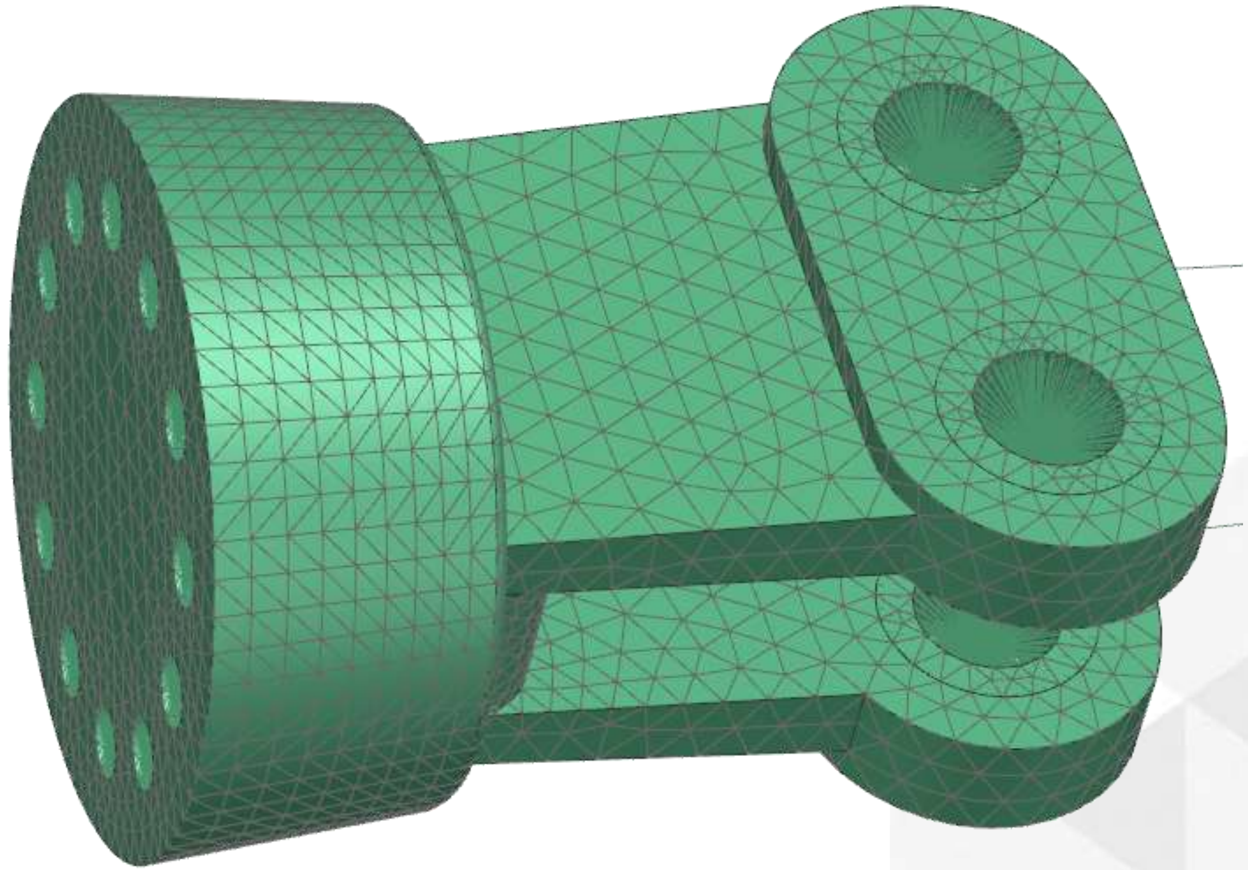
- Lift and drag applied to blade lift/drag center
  - Blade represented by rigid RBE2 element
- Bolts attaching blade and grip represented by CBAR elements
  - Connected to grip with RBE3 elements
- Constraints between grip and rotor hub represented by RBE2 elements



Blade Grip Loads	
Helicopter Gross Mass (kg)	1292
Blade Mass (kg)	22
Number Blades	3
Thrust to Weight Ratio	1.2
Lift/Blade (N)	5068
RPM	800
Blade Radius (m)	3.84
Blade Drag (N)	634
Lift/Drag Center (m)	1.92
Blade Axial Force (N)	592913

Computational Model

- Simcenter 3D Simulation Setup
  - NX 1899
  - Solution 101: Linear Static
  - Solved Serially
- Material: Ti Alloy
  - Young’s Modulus: 120 GPa
  - Poisson's Ratio: 0.29
  - Fatigue Limit: 880 Mpa
  - Density: 4.6 g/cm^3
- Mesh
  - 482 Tet Elements
  - 13 RBE2 Elements
  - 4 RBE3 Elements
  - 2 CBAR Elements



A modest-sized model was used for this demonstration case but the same approach can be scaled up to model realistic problems with finer meshes

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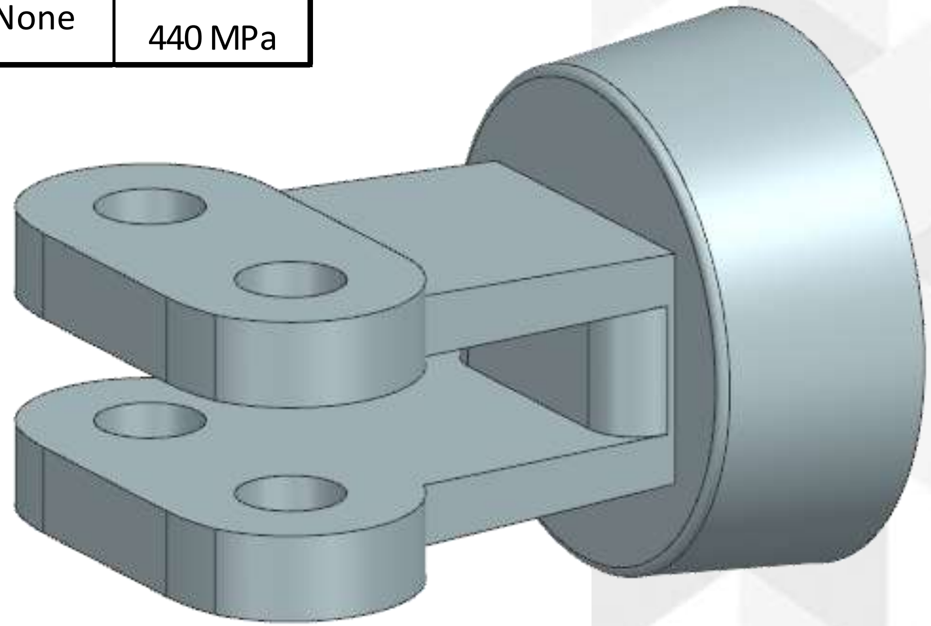
HEEDS Optimization

- HEEDS SHERPA design space exploration intelligently searches parameter ranges to determine minimum mass design
- Constrained to positive margins with a FOS of 2 on the fatigue limit

Parameter	Range		Resolution
	Minimum	Maximum	
BaseDiameter (mm)	210	250	101
CutDepth (mm)	150	230	101
CutOutHeight (mm)	50	70	5
ExtrudeDraftAngle (deg)	0	5	6
ExtrudeHeight (mm)	100	150	11
ExtrudeWidth (mm)	150	190	9
LargeFilletRadius (mm)	5	25	3
MountSupportThickness (mm)	60	80	5

Response		
Variable	Objective	Constraint
Mass	Minimize	None
Von Mises Stress (MPa)	None	less than 440 MPa



- Exhaustive search of this design space: 454 million simulations
- SHERPA finds significantly improved design after 200 evaluations

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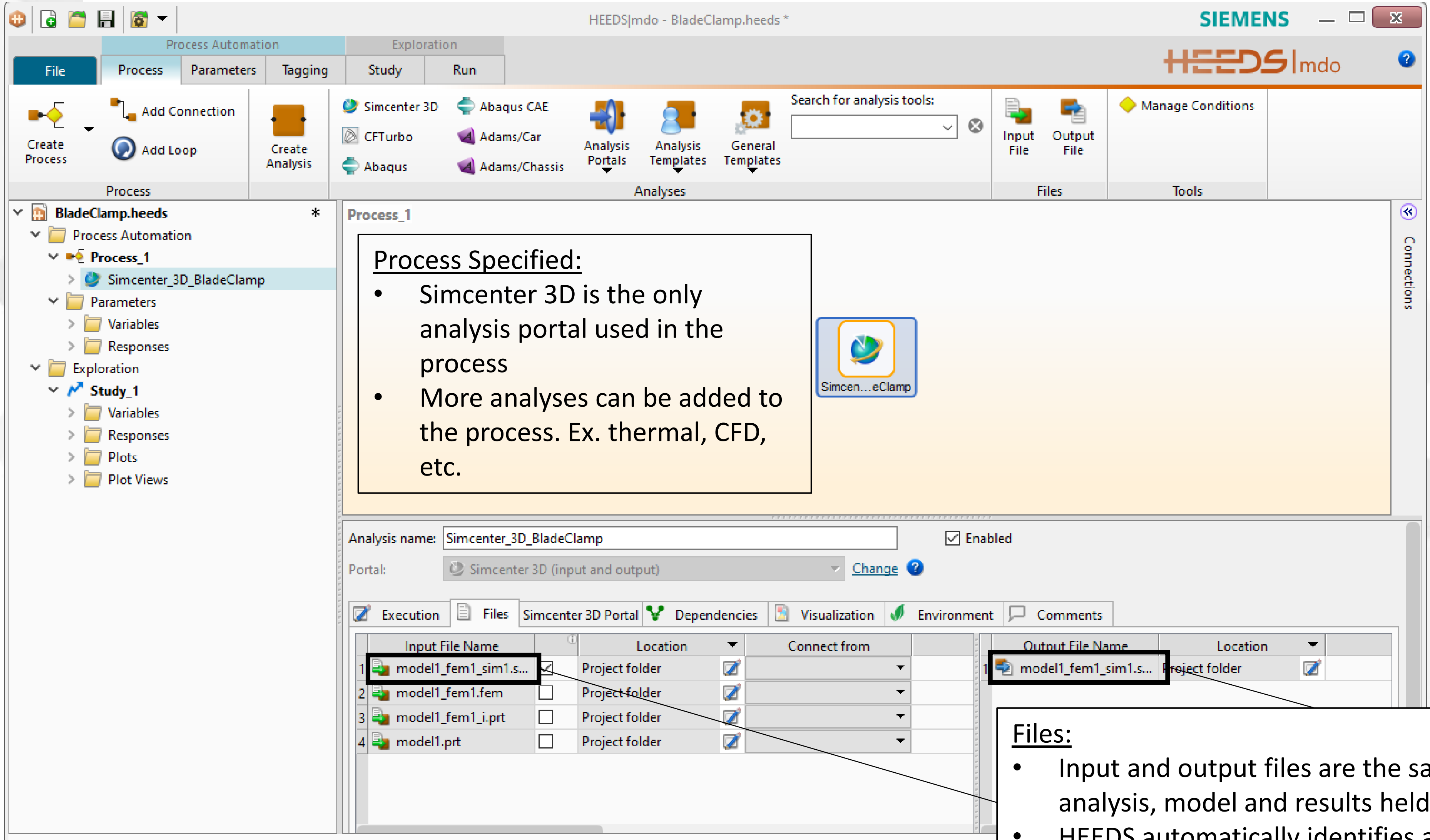
HEEDS Setup is Easy with the Simcenter 3D Analysis Portal



Process Specified:

- Simcenter 3D is the only analysis portal used in the process
- More analyses can be added to the process. Ex. thermal, CFD, etc.

Files:

- Input and output files are the same in this analysis, model and results held in .sim file
- HEEDS automatically identifies accompanying .fem and .prt files

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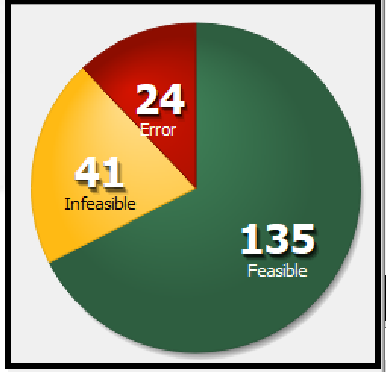
HEEDS Keeps You Updated on Progress

Keeps track of feasible, infeasible (ex. negative margin), and skips simulations with errors

Optimization problem definition

Study_1



Status: Completed
Type: Parameter Optimization
Method: SHERPA
Version: 2020.1.1.11291
Started: Dec 2, 2020 @ 17:15
Elapsed: 3 hr 52 min 15 sec

Study Details
Completed 200 designs

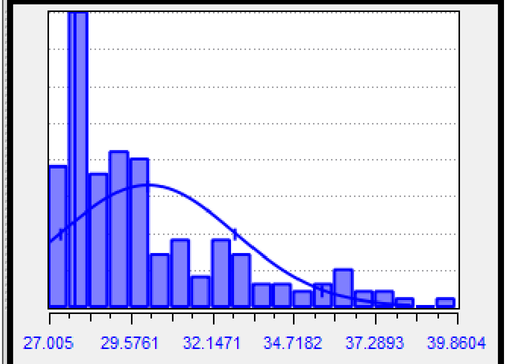
Objective: Minimize Mass

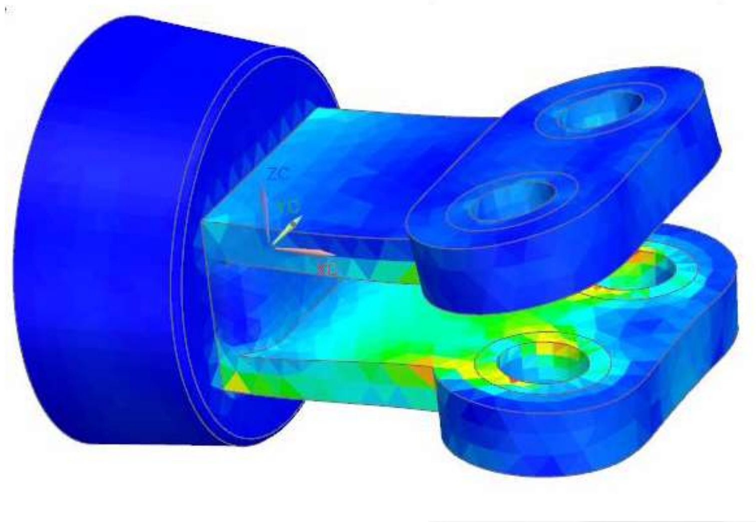
Subject to: MaxStress ≤ 440,000

By modifying: (8 variables)
210 ≤ BaseDiameter ≤ 250
150 ≤ CutDepth ≤ 230
50 ≤ CutOutHeight ≤ 70
0 ≤ ExtrudeDraftAngle ≤ 5
100 ≤ ExtrudeHeight ≤ 150
150 ≤ ExtrudeWidth ≤ 190
5 ≤ LargeFilletRadius ≤ 25
60 ≤ MountSupportThickness ≤ 80

Name	Min	Max
Mass	27.005	39.8604
MaxStress	225,865	1.20096e+06
BaseDiameter	210	246.8
CutDepth	150	230
CutOutHeight	50	70
ExtrudeDraftAngle	0	5
ExtrudeHeight	100	150
ExtrudeWidth	150	190
LargeFilletRadius	5	25
MountSupportThickness	60	80

Mass





Range of parameters and responses vs. baseline

Histogram showing distribution of designs evaluated

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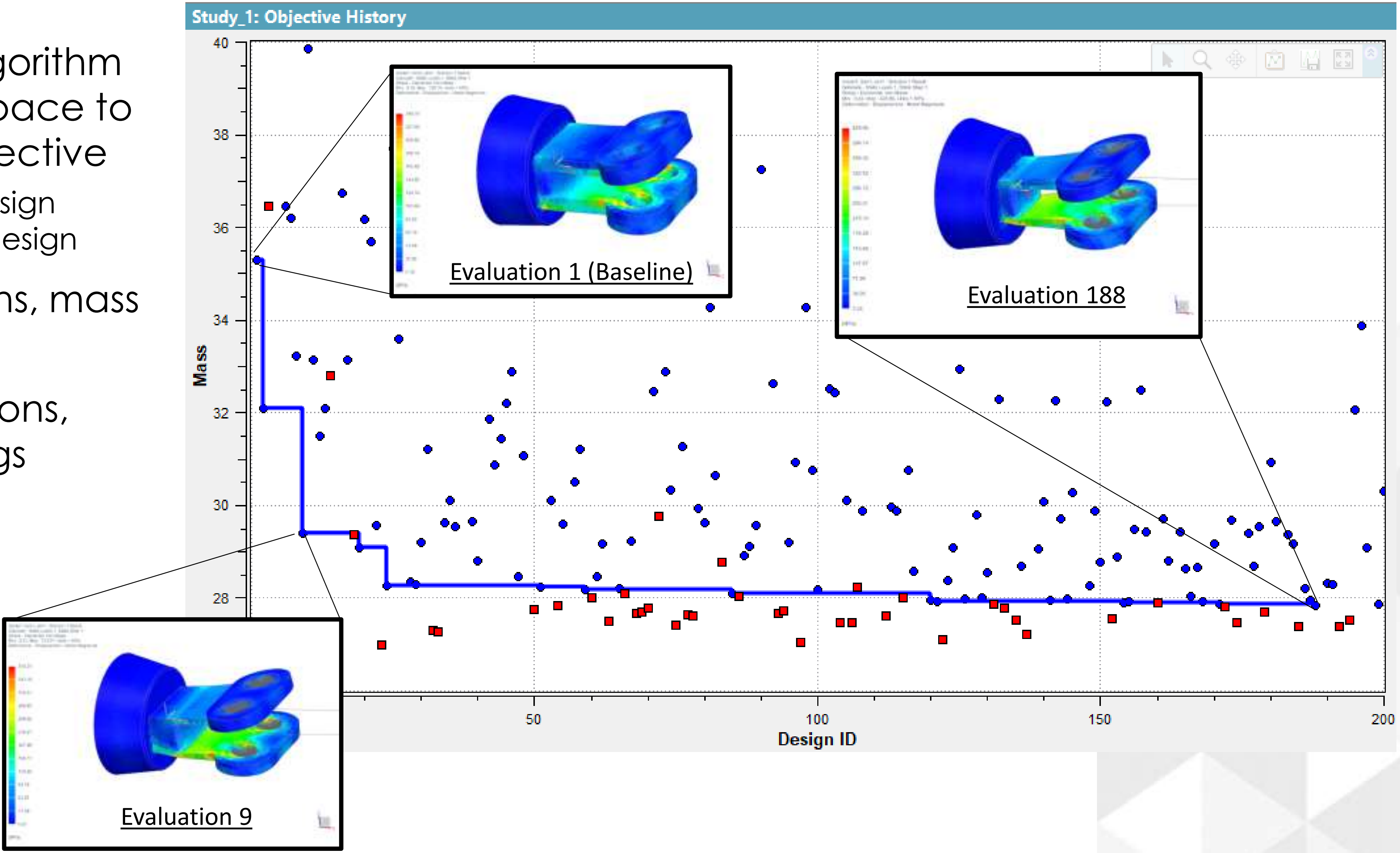
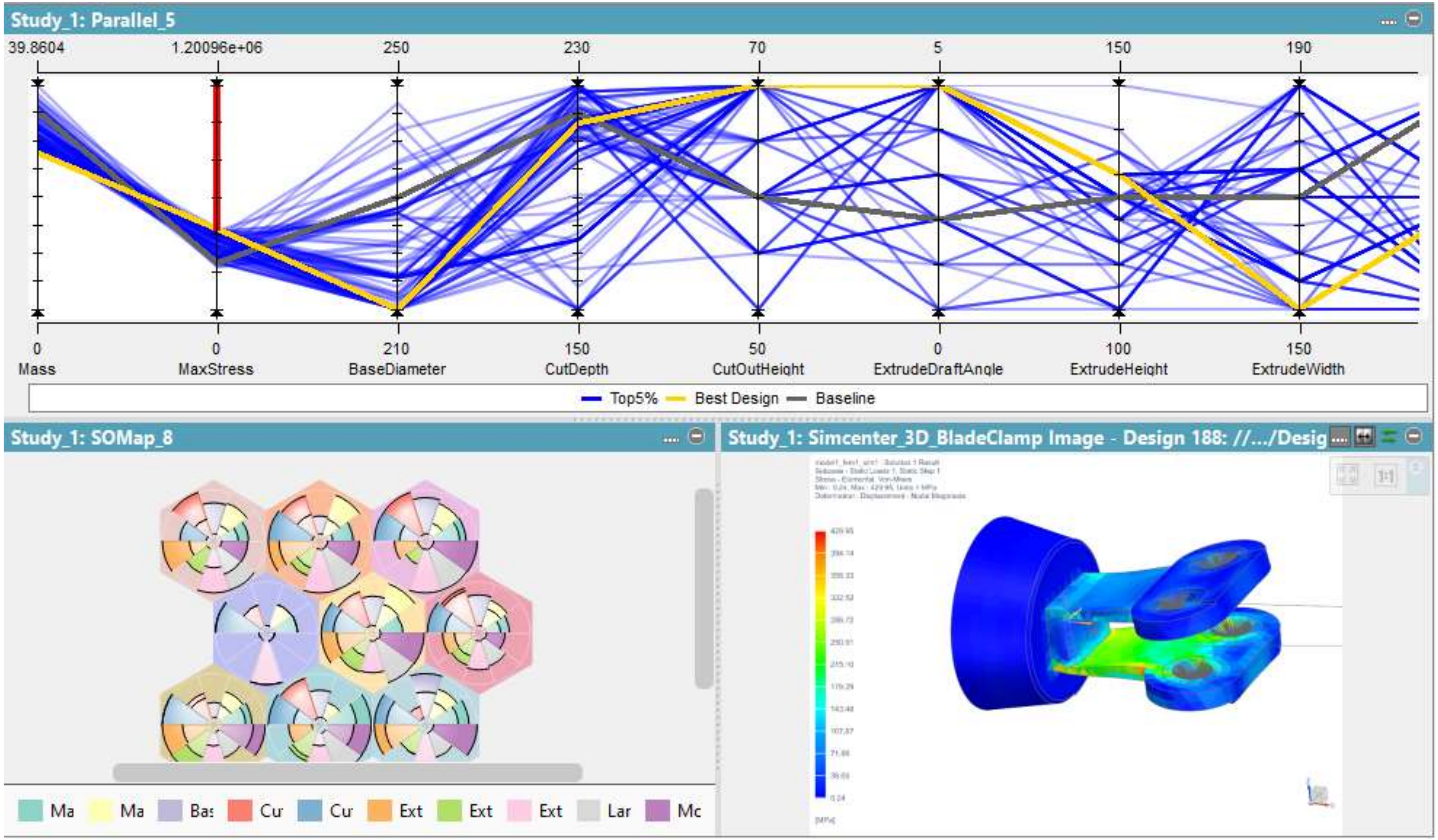
HEEDS Design Optimization

- HEEDS SHERPA algorithm explores design space to drive towards objective
  - Blue – feasible design
    Red – infeasible design
- In first 9 evaluations, mass dropped **16.7%**
- After 188 evaluations, **21.1%** mass savings



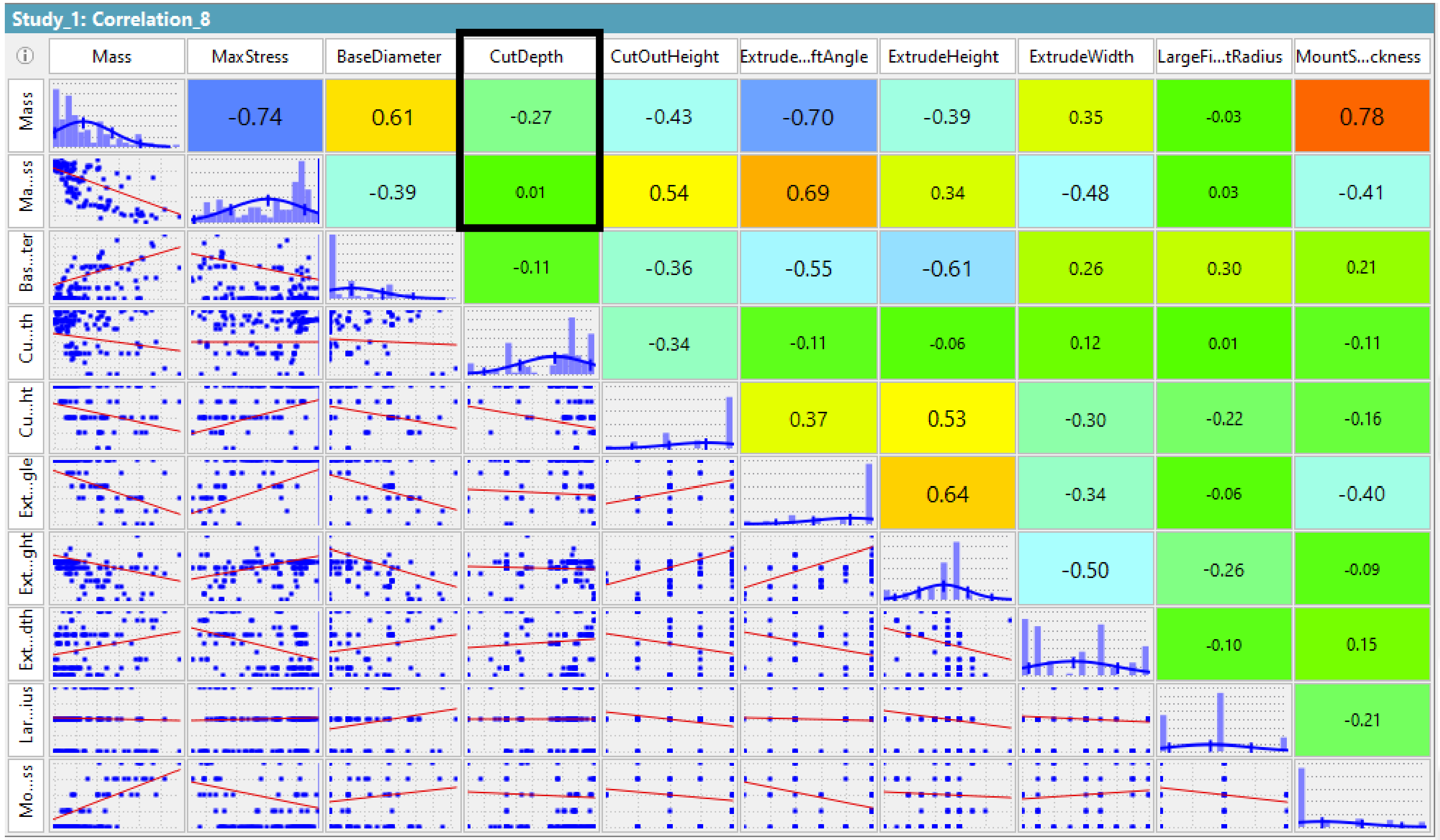
HEEDS Post Processing Tools

Powerful post processing capabilities help identify trends and show common features of the highest performing designs



Design Parameter Correlations

- ➢Correlation table quickly shows relationships between parameters and responses
- ➢Example: CutDepth – Correlation with mass, little correlation with stress
  - ✓Knob to reduce mass without affecting stress!



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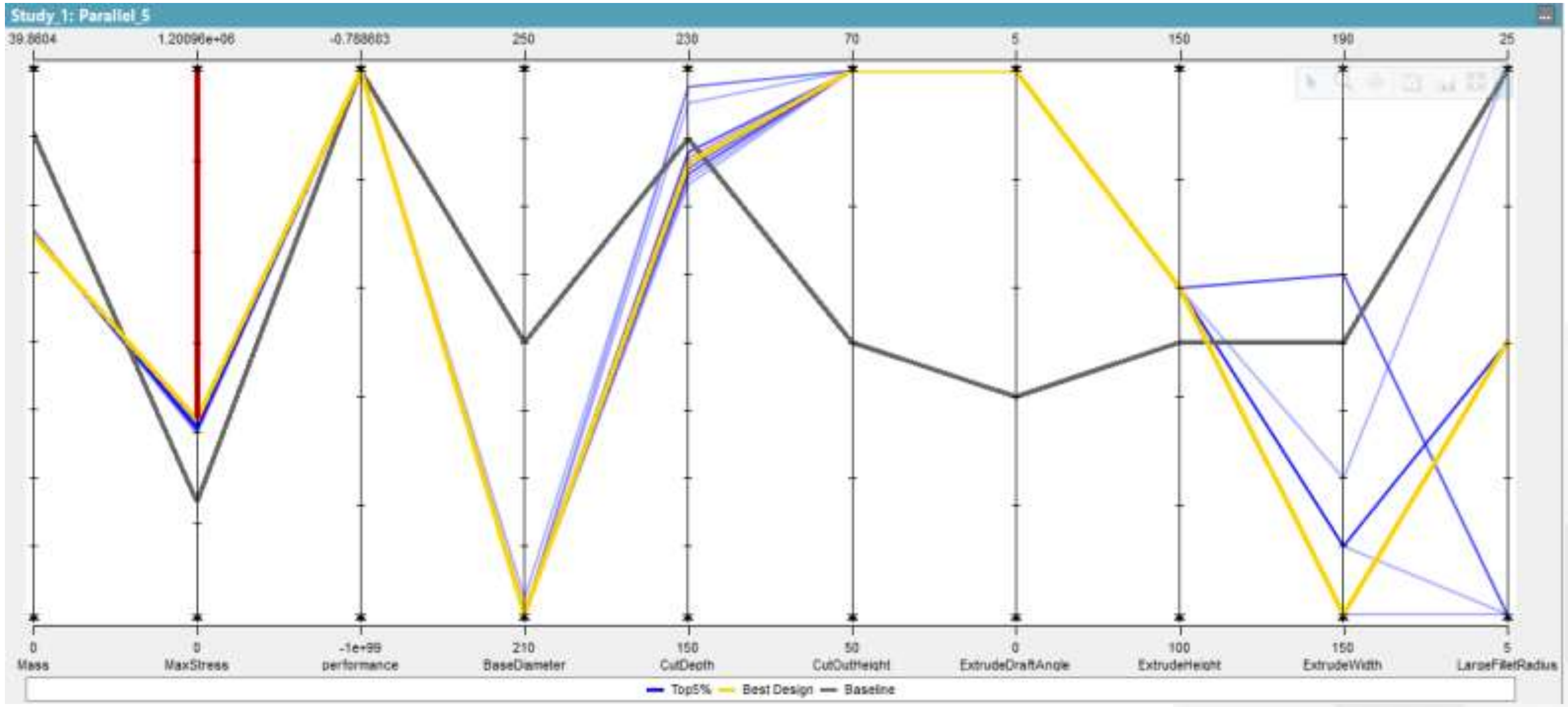
Investigating Alternate Designs

- Design Set created to look at top 5%
- Top 5% plotted in parallel plot to look at common features among top performers



- Yellow – Best Design
  Black – Baseline
- Similarities among top 5%:
  - BaseDiameter
  - CutDepth
  - CutOutHeight
  - ExtrudeDraftAngle
  - ExtrudeHeight
  - MountSupportThickness
- Large variation in ExtrudeWidth and LargeFilletRadius indicates low sensitivity to this parameter
- Helps identify design variants that better satisfy manufacturing constraints

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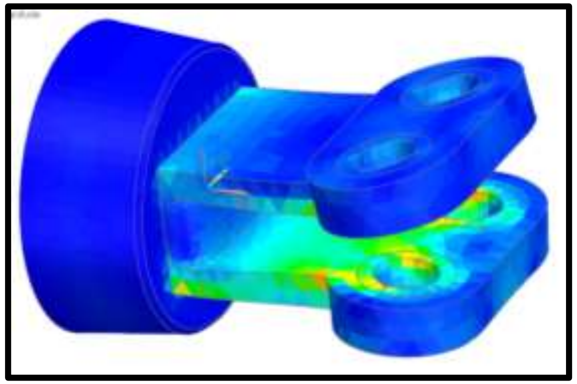
Scalability

- This small demonstration case took under 4 hours in serial on a desktop computer to improve the design 21.1% over 200 evaluations in with minimal analyst setup
  - Automated workflow managed by HEEDS after baseline completed, no analyst intervention
- If manually investigated, 200 evaluations would likely take a fast analyst 50 hours to modify part, remesh, run simulation, and document results
  - This would likely take longer for the space to be searched intelligently, which is really what HEEDS is doing.

Summary

- Need: Design a weight-optimized helicopter component.
- Method: Employed HEEDS Design Space Exploration software with Simcenter 3D to find a better design automatically.
- Results: The virtually hands-off method produced a design with a 21.1% reduction of component weight while achieving positive margins with a factor of safety of 2 on the material fatigue limit.
- Conclusion: HEEDS and Simcenter 3D produced an improved helicopter component design on a desktop computer with minimal effort from the analyst.



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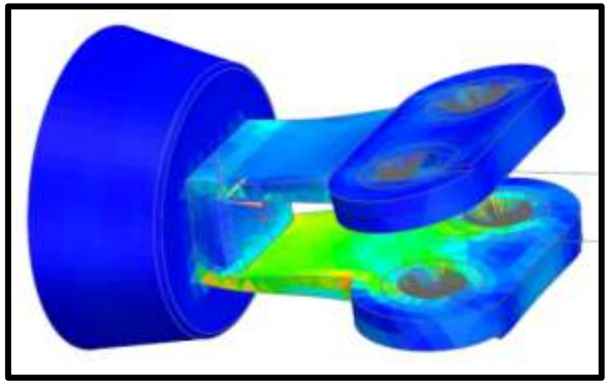

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