

# **Ansys Tutorial 6**

## **Support Bracket**

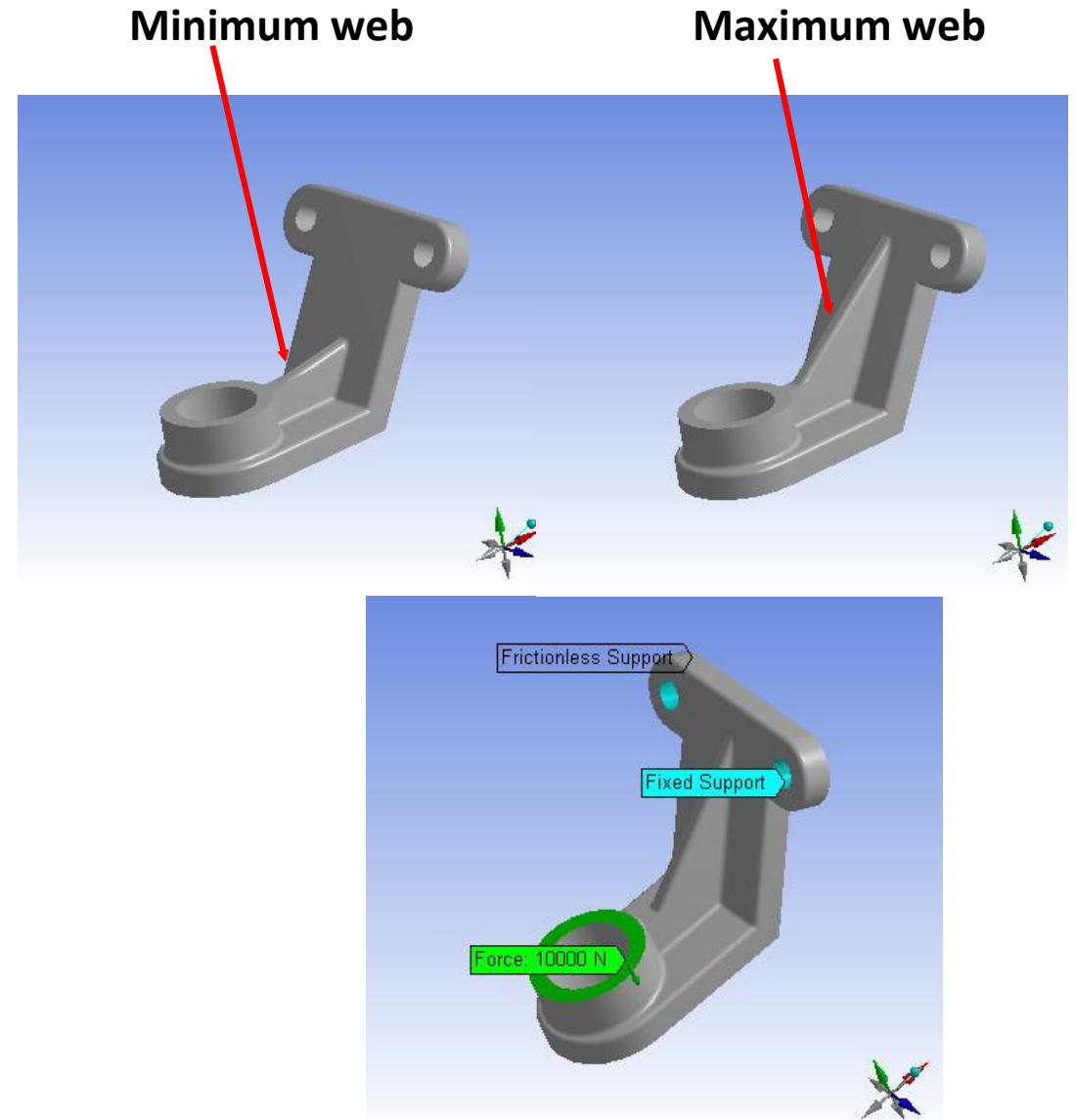
# Overview

- **Goal**

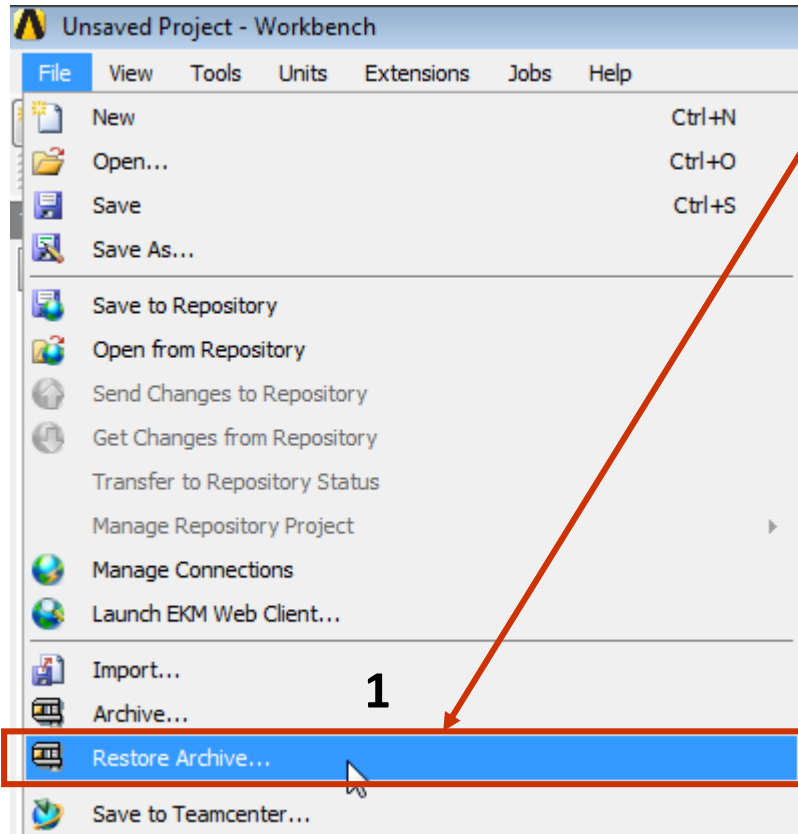
- Investigate the deflection and mass for model shown here as the load and the geometry are varied
- The goal is to minimize mass and deflection with mass as the most important consideration

- **Model Description**

- Constraints and Load are shown on the picture

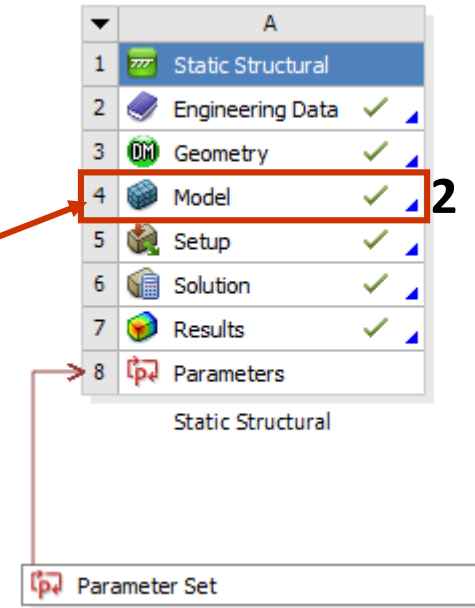


# Project Startup



**1. Restore Archive – file:  
Support Bracket.wbpz**

**2. Double click on model**



# Parameterize Project

3. Parameterize the following parameters by checking the boxes beside them

Details of "Geometry"

- Definition
- Bounding Box
- Properties
  - Volume: 3.3508e+005 mm<sup>3</sup>
  - P Mass**: 2.6304 kg
  - Scale Factor Value: 1.
- Statistics
- Basic Geometry Options
- Advanced Geometry Options

Details of "Force"

- Scope
- Definition
  - Type: Force
  - Define By: Component
  - Coordinate System: Global Coordinate System
  - P Y Component**: -10000 N (ramp)
  - X Component: 0. N (ramp)
  - Z Component: 0. N (ramp)
  - Suppressed: No

Details of "Equivalent Stress"

- Scope
- Definition
- Integration Point Results
- Results
  - Minimum: 1.6146e+008 Pa
  - P Maximum**: 1.978e+008 Pa
- Information

Details of "Total Deformation"

- Scope
- Definition
- Results
  - Minimum: 0. m
  - P Maximum**: 1.574e-004 m
- Information

Details of "Safety Factor"

- Scope
- Definition
- Integration Point Results
- Results
  - P Minimum**: 1.1162
- Information

4. Double click on parameter set

Model, Environment

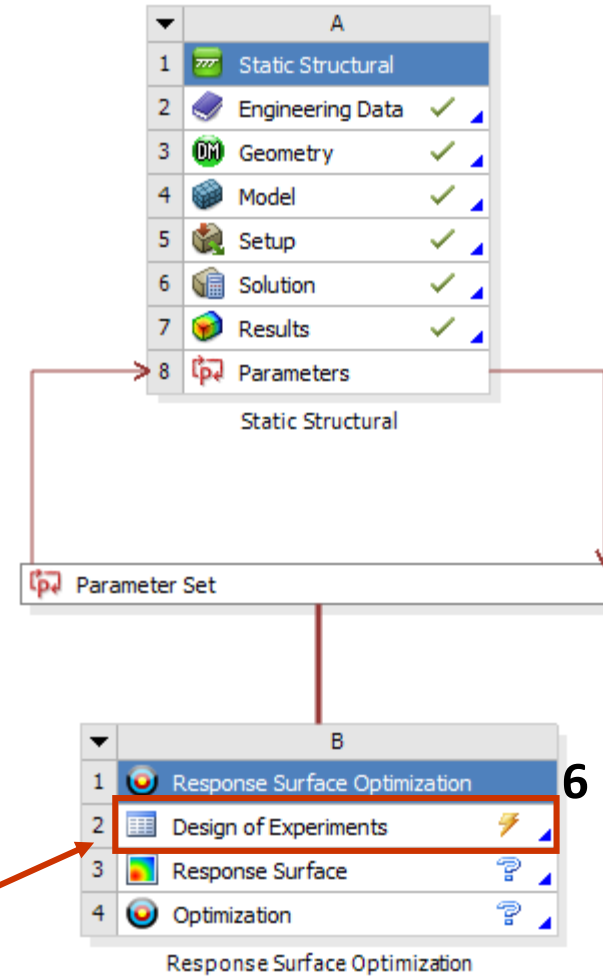
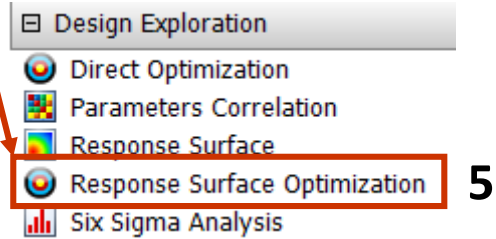
- Parameter Set

The parameters have been created

ID	Parameter Name	Value	Unit
Input Parameters			
Static Structural (A1)			
P1	ds_web	70	
P3	Force Y Component	-10000	N
New input parameter			
	New name	New expression	
Output Parameters			
Static Structural (A1)			
P2	Geometry Mass	2.6304	kg
P4	Equivalent Stress Maximum	2.2398E+08	Pa
P5	Total Deformation Maximum	0.00016951	m
P6	Safety Factor Minimum	1.1162	
New output parameter			
	New expression		
Charts			

# Enter the Response Surface

5. Double click on Response Surface Optimization in the toolbox



6. Right click on Design of Experiments and select Edit

# Conduct a DOE study

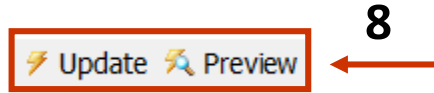
7. Highlight parameters P1 then P3 in the outline of design of experiments, and set up lower and upper bounds as shown in the properties of outline

The image displays two screenshots of a software interface for Design of Experiments (DOE) setup. The left screenshot shows the 'Design of Experiments' outline with 'P1 - ds\_web' highlighted in a red box. Below it, the 'Properties of Outline : P1 - ds\_web' table is shown with 'Lower Bound' set to 60 and 'Upper Bound' set to 80. The right screenshot shows the same outline with 'P3 - Force Y Component' highlighted in a red box. Below it, the 'Properties of Outline A6: P3 - Force Y Component' table is shown with 'Lower Bound' set to -11000 and 'Upper Bound' set to -9000. Red arrows point from the highlighted parameter names in the outline to their respective bound values in the properties table.

Property	Value
Lower Bound	60
Upper Bound	80

Property	Value
Lower Bound	-11000
Upper Bound	-9000

# Conduct a DOE study



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## 8. Preview and Update Design of Experiments

Progress		
	A	B
1	Status	Details
2	Updating the Design of Experiments component in Response Surface Optimization	Updating the Model component in Static Structural for design point 3

## A total of 9 automatic design points are created

Table of Schematic B2: Design of Experiments (Central Composite Design : Auto Defined)							
	A	B	C	D	E	F	G
1	Name	P1 - ds_web	P3 - Force Y Component (N)	P6 - Safety Factor Minimum	P5 - Total Deformation Maximum (m)	P4 - Equivalent Stress Maximum (Pa)	P2 - Geometry Mass (kg)
2	1 DP 0	70	-10000	1.1162	0.00016951	2.2398E+08	2.6304
3	2	60	-10000	1.2329	0.00018051	2.0278E+08	2.6112
4	3	80	-10000	1.0906	0.00016337	2.2924E+08	2.6483
5	4	70	-11000	1.0147	0.00018646	2.4638E+08	2.6304
6	5	70	-9000	1.2402	0.00015256	2.0158E+08	2.6304
7	6	60	-11000	1.1208	0.00019856	2.2305E+08	2.6112
8	7	80	-11000	0.99141	0.00017971	2.5217E+08	2.6483
9	8	60	-9000	1.3699	0.00016246	1.825E+08	2.6112
10	9	80	-9000	1.2117	0.00014704	2.0632E+08	2.6483

# Conduct a DOE study

9. Select DOE

Outline of Schematic B2: Design of Experiments

	A	B
1		Enabled
2	Design of Experiments	
3	Input Parameters	
4	Static Structural (A1)	
5	P1 - ds_web	<input checked="" type="checkbox"/>
6	P3 - Force Y Component	<input checked="" type="checkbox"/>
7	Output Parameters	
8	Static Structural (A1)	
9	P2 - Solid Mass	
10	P4 - Equivalent Stress Maximum	
11	P5 - Total Deformation Maximum	
12	P6 - Safety Factor Minimum	
13	P7 - Geometry Mass	
14	Charts	
15	Parameters Parallel	
16	Design Points vs Parameter	

10. Change design type to Face Centered

Template type: Enhanced

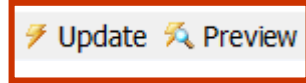
Properties of Schematic B2: Design of Experiments

	A	B
1	Property	Value
2	Design Points	
3	Preserve Design Points After DX Run	<input type="checkbox"/>
4	Failed Design Points Management	
5	Number of Retries	0
6	Design of Experiments	
7	Design of Experiments Type	Central Composi...
8	Design Type	Face-Centered
9	Template Type	Enhanced

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# Conduct a DOE study

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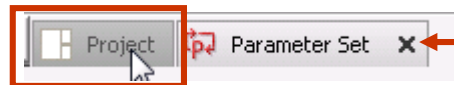
11. Preview and Updated DOE

A total of 17 automatic design points are created

Table of Schematic B2: Design of Experiments (Central Composite Design : Face-Centered : Enhanced)

	A	B	C	D	E	F	G
1	Name	P1 - ds_web	P3 - Force Y Component (N)	P6 - Safety Factor Minimum	P5 - Total Deformation Maximum (m)	P4 - Equivalent Stress Maximum (Pa)	P2 - Geometry Mass (kg)
2	1 DP 0	70	-10000	1.1162	0.00016951	2.2398E+08	2.6304
3	2	60	-10000	1.2329	0.00018051	2.0278E+08	2.6112
4	3	65	-10000	1.1187	0.00017413	2.2347E+08	2.621
5	4	80	-10000	1.0906	0.00016337	2.2924E+08	2.6483
6	5	75	-10000	1.1433	0.00016601	2.1866E+08	2.6395
7	6	70	-11000	1.0147	0.00018646	2.4638E+08	2.6304
8	7	70	-10500	1.063	0.00017798	2.3518E+08	2.6304
9	8	70	-9000	1.2402	0.00015256	2.0158E+08	2.6304
10	9	70	-9500	1.1749	0.00016103	2.1278E+08	2.6304
11	10	60	-11000	1.1208	0.00019856	2.2305E+08	2.6112
12	11	65	-10500	1.0654	0.00018284	2.3465E+08	2.621
13	12	80	-11000	0.99141	0.00017971	2.5217E+08	2.6483
14	13	75	-10500	1.0889	0.00017431	2.2959E+08	2.6395
15	14	60	-9000	1.3699	0.00016246	1.825E+08	2.6112
16	15	65	-9500	1.1776	0.00016543	2.123E+08	2.621
17	16	80	-9000	1.2117	0.00014704	2.0632E+08	2.6483
18	17	75	-9500	1.2035	0.00015771	2.0772E+08	2.6395

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12. Return to Project

# Conduct a Response Surface study

**13. Double click on Response Surface to edit it**

**14. Click on Response surface and in the Properties of Outline change to standard response surface**

**13**

**14**

**14**

Outline of Schematic B3: Response Surface		
	A	B
1		Enabled
2	Response Surface	

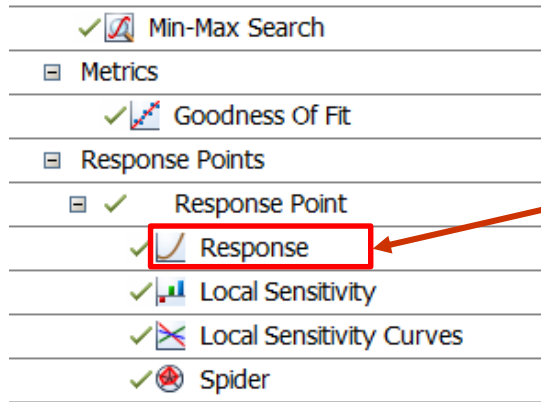
Properties of Outline A2: Response Surface		
	A	B
1	Property	Value
2	Design Points	
3	Preserve Design Points After DX Run	<input type="checkbox"/>
4	Failed Design Points Management	
5	Number of Retries	0
6	Meta Model	
7	Response Surface Type	Standard Respo...
8	Refinement	Genetic Aggregation
9	Refinement	Standard Response Surface - Full 2nd Order Polynomial
10	Verification	Kriging
11	General	Non-Parametric Regression
		Neural Network
		Sparse Grid

**15. Update the Response Surface**

**15**

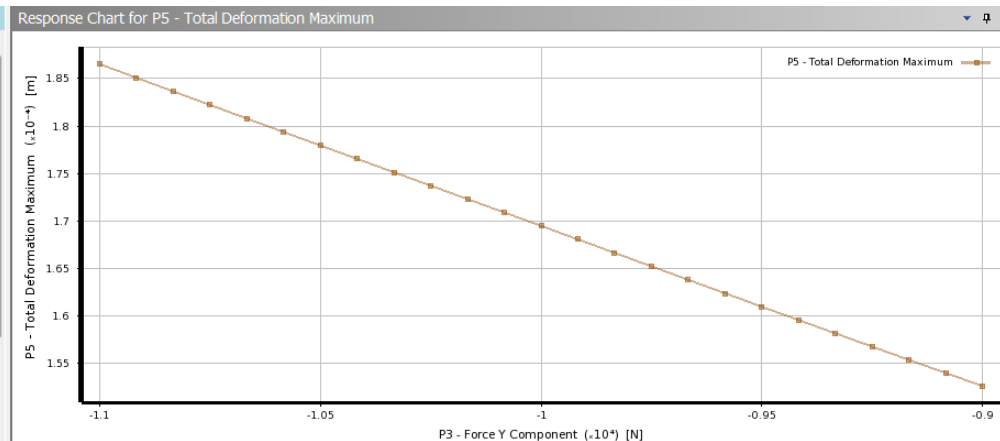
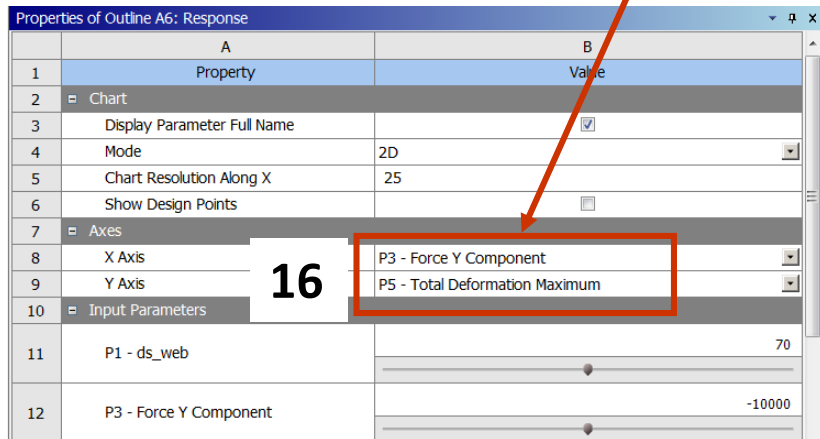
**Update**

# Conduct a Response Surface study



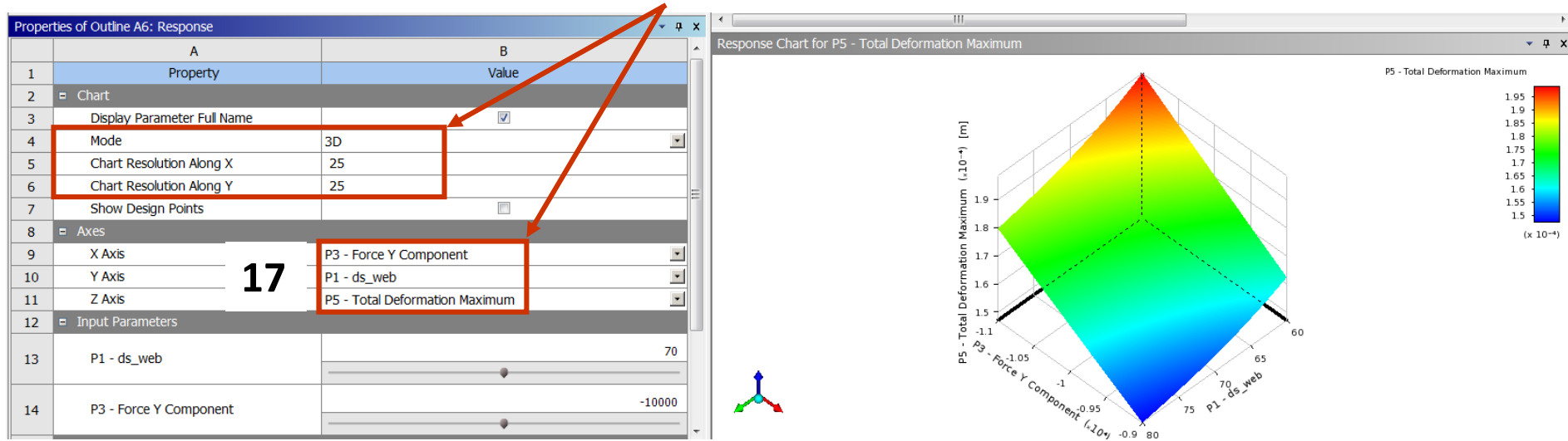
Click Response

16. In the Properties frame, select Force Y Component and Total Deformation Maximum as the x and y axis, respectively

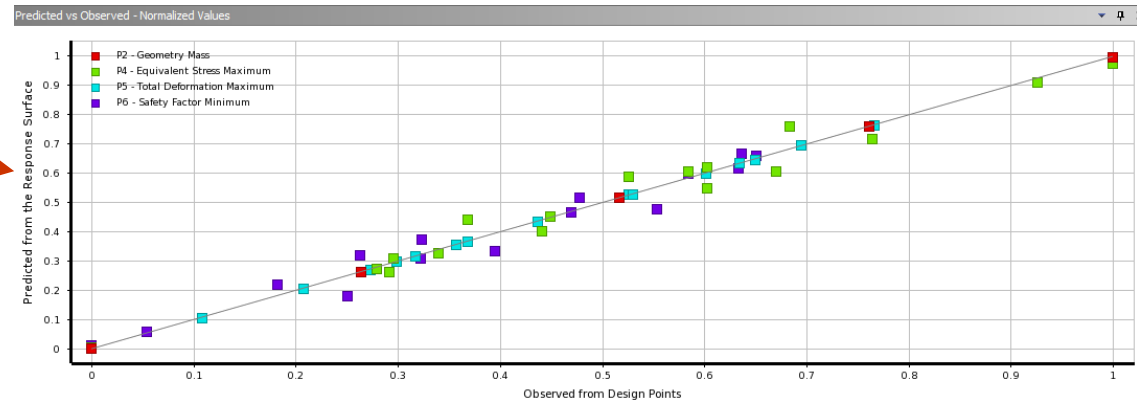
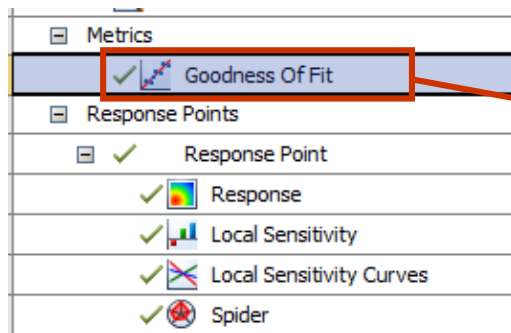


# Conduct a Response Surface study

## 17. Set Mode to 3D



## Check the Goodness of Fit



# Conduct a Response Surface study

The image shows two windows from a software application. The top window, titled 'Outline of Schematic B3: Response Surface', contains a tree view with the following items:

	A	B
1		Enabled
2	Response Surface	
3	Input Parameters	
7	Output Parameters	
13	Min-Max Search	<input checked="" type="checkbox"/>
14	Metrics	
16	Response Points	

The bottom window, titled 'Properties of Outline A2: Response Surface', shows the following properties:

	A	B
1	Property	Value
2	Design Points	
3	Preserve Design Points After DX Run	<input type="checkbox"/>
4	Failed Design Points Management	
5	Number of Retries	0
6	Meta Model	
7	Response Surface Type	Standard ...
8	Refit	Genetic Aggregation
9		Standard Response Surface - Full 2nd Order Polynomial
10	Verify	Kriging
11		Non-Parametric Regression
		Neural Network
		Sparse Grid

18. Click on Response surface and in the Properties of Outline change from standard response surface to Kriging

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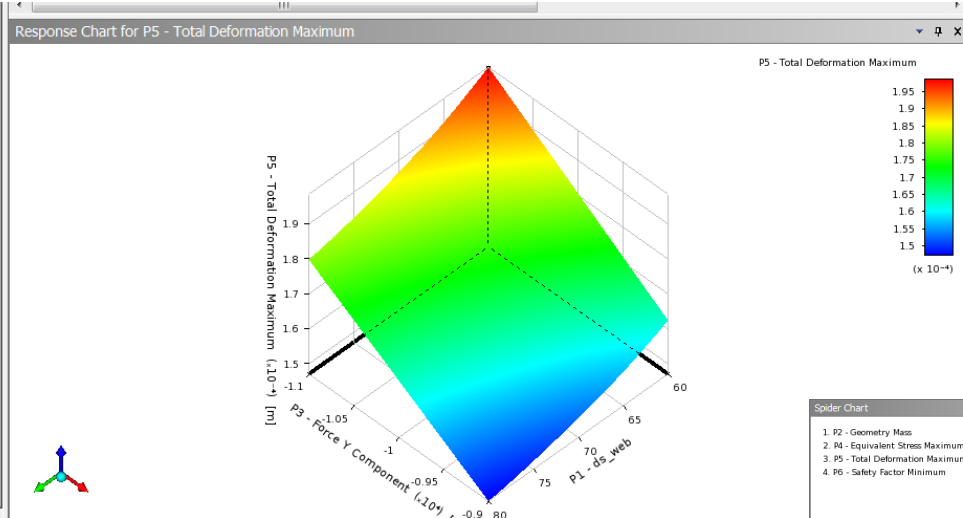
Update Clear Generated Data

19. Update response surface

# Conduct a Response Surface study

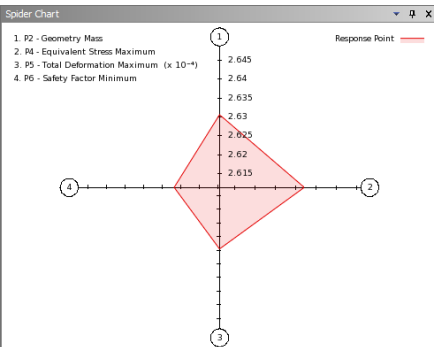
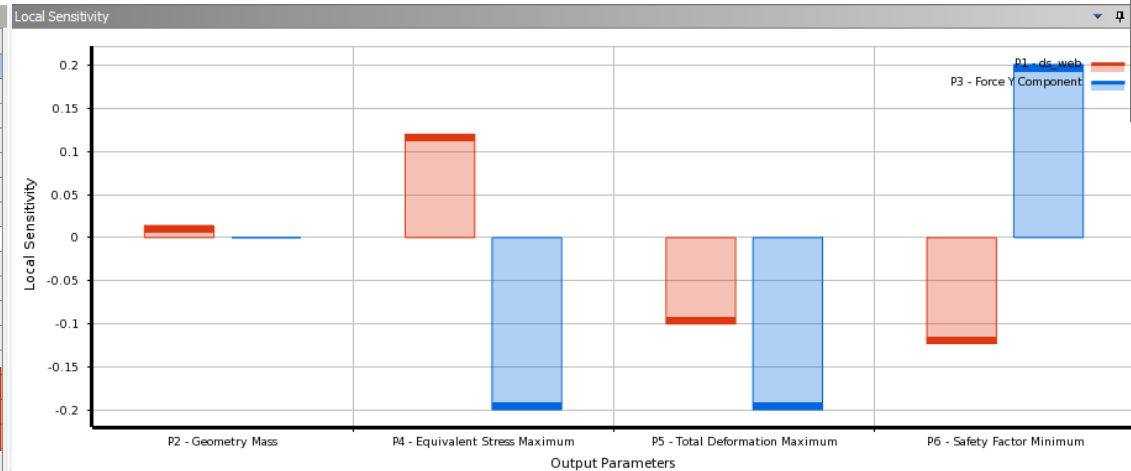
Plot Response surface > 3D (repeat step 17)

Properties of Outline A11: Response	
A	B
1	Property
2	Chart
3	Display Parameter Full Name
4	Mode
5	Chart Resolution Along X
6	Chart Resolution Along Y
7	Show Design Points
8	Axes
9	X Axis
10	Y Axis
11	Z Axis
12	Input Parameters
13	P1 - ds_web
14	P3 - Force Y Component
15	Output Parameters

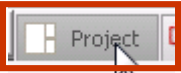


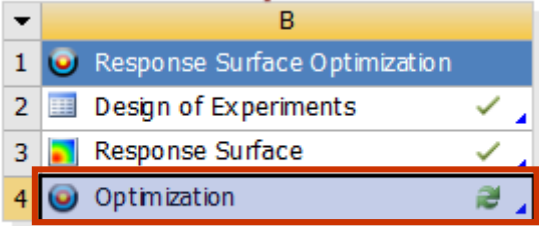
Plot local sensitivities and spider chart

Outline of Schematic B3: Response Surface	
A	B
1	Enabled
2	Response Surface
3	Input Parameters
4	Static Structural (A1)
5	P1 - ds_web
6	P3 - Force Y Component
7	Output Parameters
14	Min-Max Search
15	Metrics
16	Goodness Of Fit
17	Response Points
18	Response Point
19	Response
20	Local Sensitivity
21	Local Sensitivity Curves
22	Spider
*	New Response Point







# Conduct a Response Surface Optimization

**20**  **20. Return to project**

**21**  **21. Double click on optimization**

**22. Click on optimization and set Optimization Method > Screening**

**Number of Samples = 1000**

Outline of Schematic B4: Optimization			
	A	B	C
1		Enabled	Monitoring
2	 Optimization 		
3	Objectives and Constraints		
4	Domain		
5	Static Structural (A1)		
6	 P1 - ds_web	<input checked="" type="checkbox"/>	
7	 P3 - Force Y Component	<input checked="" type="checkbox"/>	
8	Results		

Properties of Schematic B4: Optimization		
	A	B
1	Property	Value
2	Design Points	
3	Preserve Design Points After DX Run	<input type="checkbox"/>
4	Failed Design Points Management	
5	Number of Retries	0
6	Optimization	
7	Optimization Method	Screening <b>22</b>
8	Number of Samples	1000
9	Maximum Number of Candidates	3
10	Verify Candidate Points	<input type="checkbox"/>
11	Optimization Status	
12	Number of Evaluations	0
13	Number of Failures	0
14	Size of Generated Sample Set	0
15	Number of Candidates	0

# Conduct a Response Surface Optimization

## 23. Set the goals as shown in optimization table

*Note: Note that P might have a different suffix in your WB*

Outline of Schematic B4: Optimization

	A
1	
2	Optimization
3	Objectives and Constraints
4	Minimize P2
5	Minimize P5

Table of Schematic B4: Optimization

	A	B	C	D	E	F	G
1	Name	Parameter	Objective		Constraint		
2			Type	Target	Type	Lower Bound	Upper Bound
3	Minimize P2	P2 - Geometry Mass	Minimize		No Constraint		
4	Minimize P5	P5 - Total Deformation Maximum	Minimize		No Constraint		
*		Select a Parameter					

## 24. Update Optimization

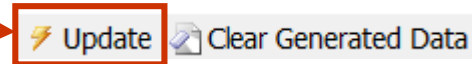


Table of candidate designs based on the goals

Table of Schematic B4: Optimization

	A	B	C	D	E
1	Optimization Study				
2	Minimize P5	Goal, Minimize P5 (Default importance)			
3	Minimize P2	Goal, Minimize P2 (Default importance)			
4	Optimization Method				
5	Screening	The Screening optimization method uses a simple approach based on sampling and sorting. It supports multiple objectives and constraints as well as all types of input parameters. Usually it is used for preliminary design, which may lead you to apply other methods for more refined optimization results.			
6	Configuration	Generate 1000 samples and find 3 candidates.			
7	Status	Converged after 1000 evaluations.			
8	Candidate Points				
9		Candidate Point 1	Candidate Point 1 (verified)	Candidate Point 2	Candidate Point 3
10	P1 - ds_web	60		60.15	60.07
11	P3 - Force Y Component (N)	-9000		-9249	-9499
12	P2 - Geometry Mass (kg)	★ ★ ★ 2.6112	★ ★ ★ 2.6112	★ ★ ★ 2.6115	★ ★ ★ 2.6113
13	P5 - Total Deformation Maximum (m)	★ 0.00016239	★ 0.00016239	★ 0.00016669	— 0.0001713

# Conduct a Response Surface Optimization

25. Select Tradeoff and Samples to get tradeoff and samples chart. Also set Number of Pareto Fronts to 16

Outline of Schematic B4: Optimization

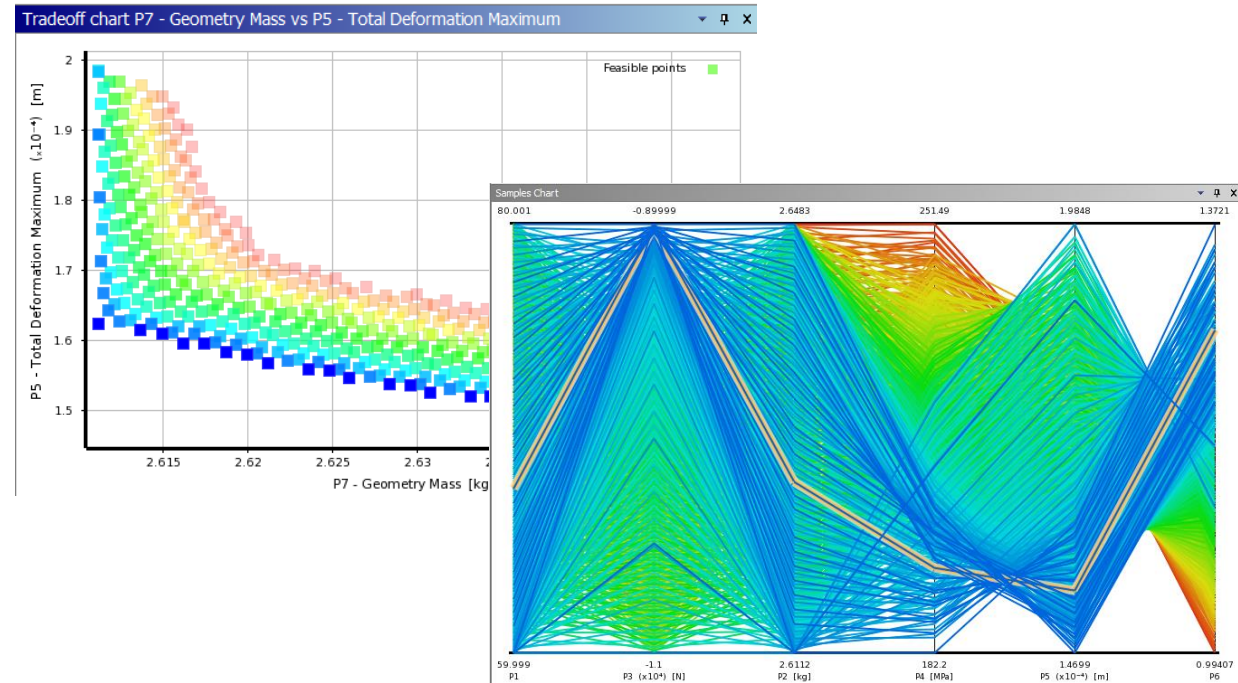
	A	B	C
1		Enabled	Monitoring
2	✓ Optimization		
3	▢ Objectives and Constraints		
4	🎯 Minimize P7		
5	🎯 Minimize P5		
6	▢ Domain		
7	▢ Static Structural (A1)		
8	📌 P1 - ds_web	✓	
9	📌 P3 - Force Y Component	✓	
10	▢ Results		
11	✓ Candidate Points		
12	✓ Tradeoff		
13	✓ Samples		
14	✓ Sensitivities		

Properties of Outline A11: Tradeoff

	A	B
1	Property	Value
2	▢ Chart	
3	Display Parameter Full Name	✓
4	Mode	2D
5	Number of Pareto Fronts to Show	16
6	▢ Axes	
7	X Axis	P7 - Geometry Mass
8	Y Axis	P5 - Total Deformat...

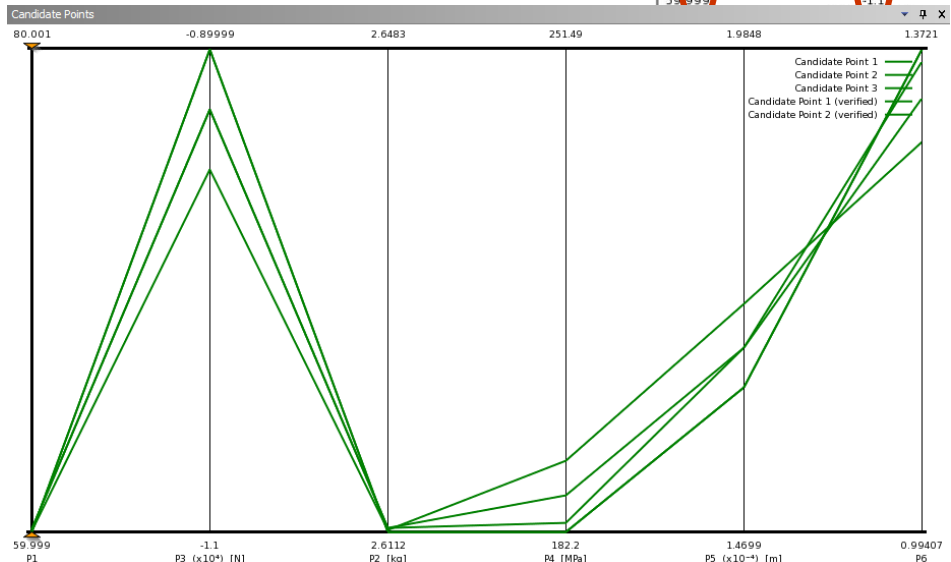
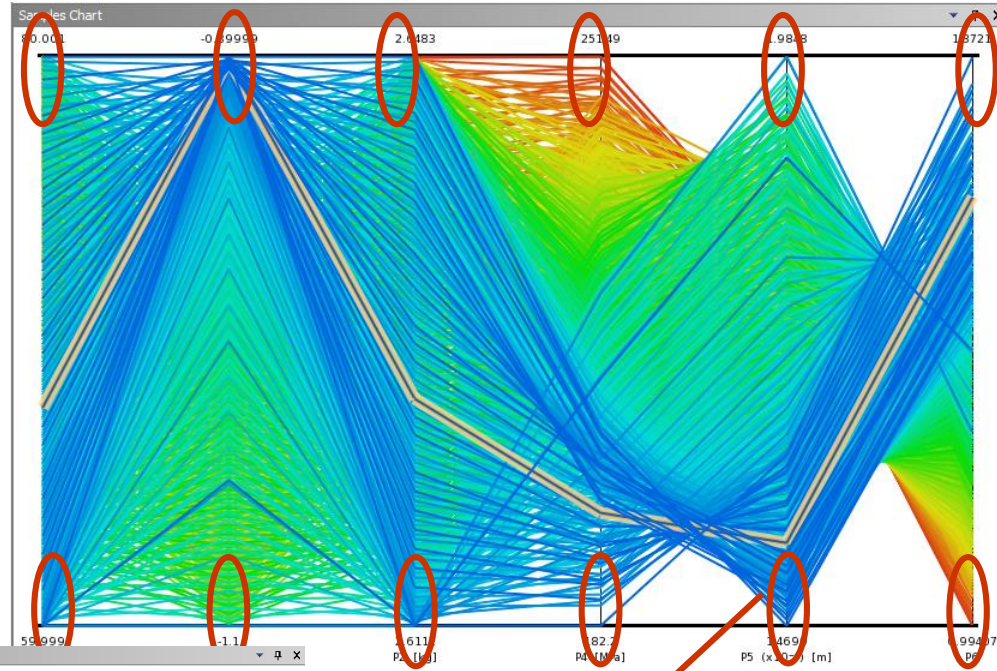
In this case we have optimized goals that are counter to one another (min deformation and min mass)

Reducing the mass means Increasing the deformation and vice versa



# Conduct a Response Surface Optimization

Try holding your mouse over these locations and drag the orange handles that appear up or down



This can help you narrow in on samples with parameters in the ranges you are interested in

# Conduct a Response Surface Optimization

26. Under Optimization, enable the options to “Preserve” and “Retain” the Design Points

Design Points	
Preserve Design Points After DX Run	<input checked="" type="checkbox"/>
Retain Data for Each Preserved Design Point	<input checked="" type="checkbox"/>

Outline of Schematic B4: Optimization			
	A	B	C
1		Enabled	Monitoring
2	✓ Optimization		
3	[-] Objectives and Constraints		
4	🎯 Minimize P2		
5	🎯 Minimize P5		
6	[-] Domain		
7	[-] Static Structural (A1)		
8	📍 P1 - ds_web	<input checked="" type="checkbox"/>	
9	📍 P3 - Force Y Component	<input checked="" type="checkbox"/>	
10	Parameter Relationships		
11	[-] Results		
12	✓ [-] Candidate Points		
13	✓ [-] Tradeoff		
14	✓ [-] Samples		
15	✓ [-] Sensitivities		

27. Under Candidate Points, select candidate 2, RMB, and click Verify by Design Point Update

Candidate Point 2	Candidate Point 3
60.15	60.07
-924	
★ 0.00016	
★★ 2.611	

Copy
Explore Response Surface at Point
Insert as Design Point
Insert as Refinement Point
Insert as Verification Point
Insert as Custom Candidate Point
<b>Verify by Design Point Update</b>
Expand All
Collapse All

26

Here we can see how the results of the optimization compare to a full simulation for Candidate 2

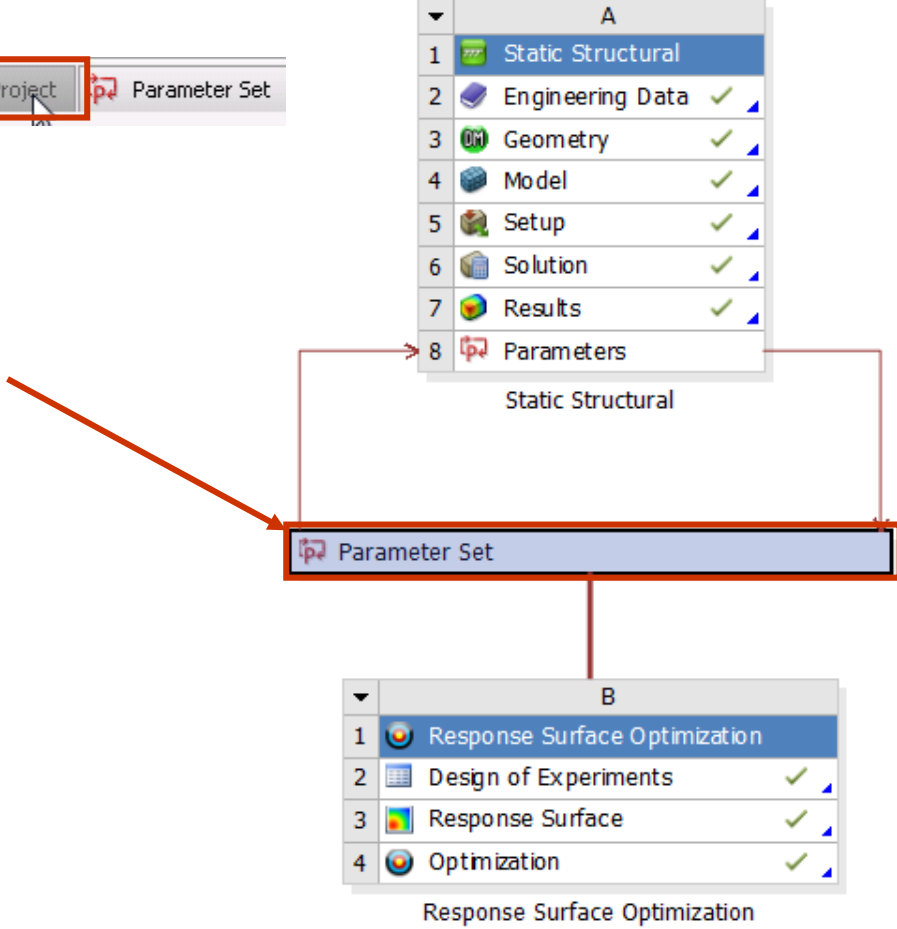
Table of Schematic B4: Optimization , Candidate Points										
	A	B	C	D	E	F	G	H	I	J
1	Reference	Name	P1 - ds_web	P3 - Force Y Component (N)	P2 - Geometry Mass (kg)		P4 - Equivalent Stress Maximum (MPa)	P5 - Total Deformation Maximum (m)		P6 - Safety Factor Minimum
2					Parameter Value	Variation from Reference		Parameter Value	Variation from Reference	
3	○	Candidate Point 1	60	-9000	★★★ 2.6112	-0.01 %	182.2	★ 0.00016239	-5.20 %	1.3721
4	○	Candidate Point 1 (verified)	60	-9000	★★★ 2.6112	-0.01 %	182.2	★ 0.00016239	-5.20 %	1.3721
5	○	Candidate Point 2	60.15	-9249	★★★ 2.6115	0.01 %	187.56	★ 0.00016669	-2.69 %	1.3336
6	○	Candidate Point 2 (verified) <span>DP 1</span>	60.15	-9249	★★★ 2.6115	0.01 %	183.52	★ 0.00016668	-2.70 %	1.3623
7	●	Candidate Point 3	60.07	-9499	★★★ 2.6113	0.00 %	192.46	↔ 0.0001713	0.00 %	1.2996
*		New Custom Candidate Point	70	-10000						

# Verify the Response Surface Optimization

28. Return to Project



29. Double click on Parameter Set

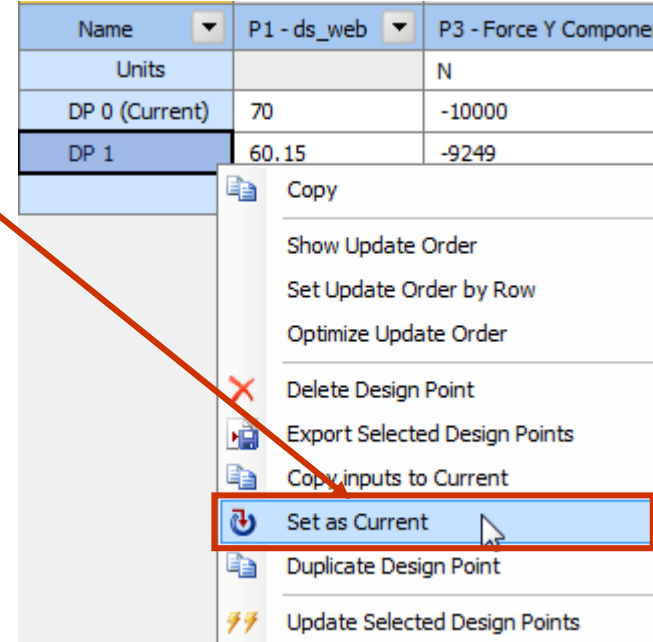


# Verify the Response Surface Optimization

30. RMB on DP 1 > Set as Current

31. Switch to Project

Name	P1 - ds_web	P3 - Force Y Compone
Units		N
DP 0 (Current)	70	-10000
DP 1	60.15	-9249



- Copy
- Show Update Order
- Set Update Order by Row
- Optimize Update Order
- Delete Design Point
- Export Selected Design Points
- Copy inputs to Current
- Set as Current**
- Duplicate Design Point
- Update Selected Design Points

# Verify the Response Surface Optimization

**33**

**33. Double click on solution and check the results**

Model, Environment

Parameter Set

Outline

- Project
- Model (A4)
  - Coordinate Systems
  - Mesh
  - Static Structural (A5)
    - Analysis Settings
    - Fixed Support
    - Force
    - Frictionless Support
  - Solution (A6)
    - Solution Information
    - Equivalent Stress
    - Total Deformation
    - Stress Tool

**A: Static Structural**  
Total Deformation  
Type: Total Deformation  
Unit: mm  
Time: 1  
2/22/2013 7:19 PM

0.16679 Max  
0.14826  
0.12973  
0.1112  
0.092664  
0.074131  
0.055598  
0.037066  
0.018533  
0 Min

Details of "Total Deformation"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	0. mm
Maximum	0.16679 mm

Outline

- Project
- Model (A4)
  - Coordinate Systems
  - Mesh
  - Static Structural (A5)
    - Analysis Settings
    - Fixed Support
    - Force
    - Frictionless Support
  - Solution (A6)
    - Solution Information
    - Equivalent Stress
    - Total Deformation
    - Stress Tool

**A: Static Structural**  
Equivalent Stress  
Type: Equivalent (von-Mises) Stress  
Unit: MPa  
Time: 1  
2/22/2013 7:20 PM

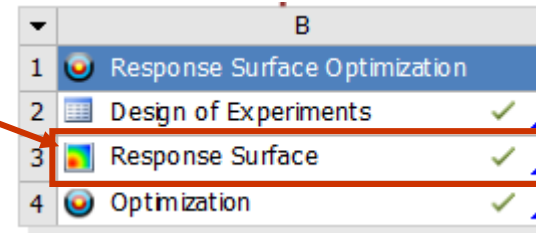
182.93 Max  
162.61  
142.3  
121.99  
101.67  
81.358  
61.044  
40.73  
20.417  
0.10292 Min

Details of "Equivalent Stress"

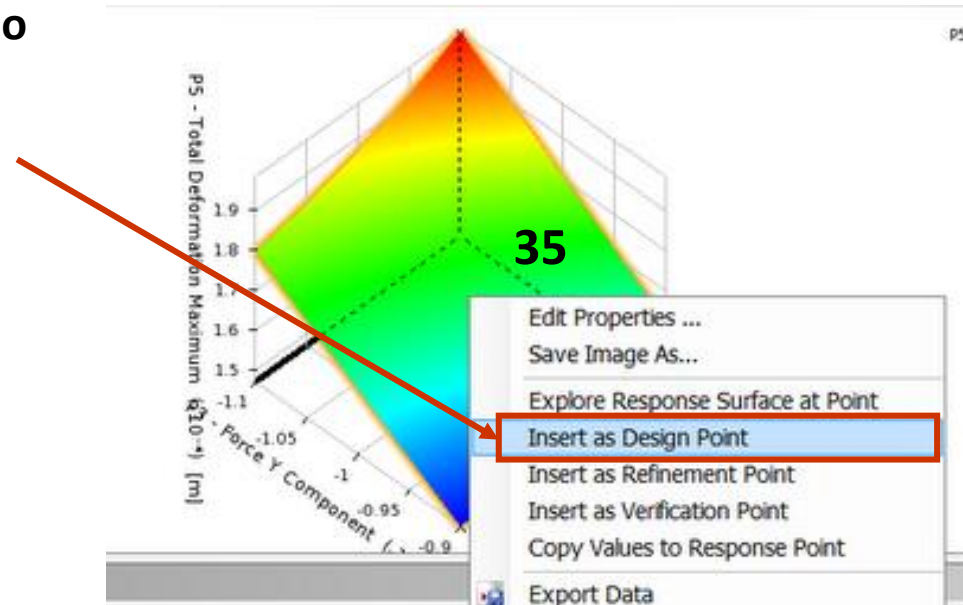
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Shell	Top/Bottom
Layer	Entire Section
Definition	
Type	Equivalent (von-M...
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Results	
Minimum	0.10292 MPa
Maximum	182.93 MPa

# Verify the Response Surface Optimization

34. Double click on Response Surface



35. RMB on the Response Surface to insert the point in the response surface Design Point



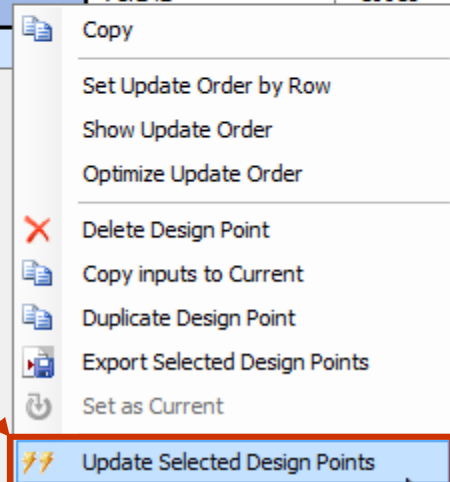
# Verify the Response Surface Optimization

36. Double click on Parameter Set

37. Retain DP 2 and Update Selected Design Point

38. You can see deformation and stress if you open Mechanical application

Table of Design Points			
	A	B	C
1	Name	P1 - ds_web	P3 - Force Y Component
2	Units		N
3	DP 0	70	-10000
4	DP 1 (Current)	60.15	-9249
5	DP 2	71.242	-10615
*			



A context menu is open over the row for DP 2. The menu items are: Copy, Set Update Order by Row, Show Update Order, Optimize Update Order, Delete Design Point, Copy inputs to Current, Duplicate Design Point, Export Selected Design Points, Set as Current, and Update Selected Design Points. The 'Update Selected Design Points' option is highlighted with a red box. A red arrow points from the text 'Update Selected Design Point' in step 37 to this menu item.