Optimum Design Course

Fall 2016

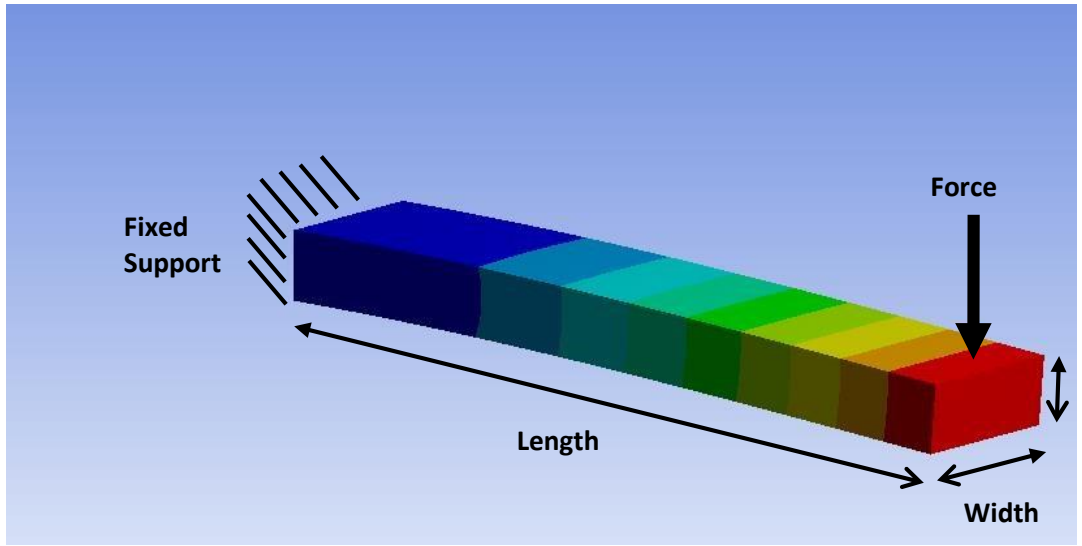
Ansys Tutorial 2

Parameter Correlation Analysis of a Beam

Problem 1 – Beam Description

- This workshop looks deeper into the options available in the Parameter Set and Parameter Correlation, as well as exposes you to creating parameters in DesignModeler and Mechanical
- The problem to be analyzed is a simple beam, fixed on one side, and with an applied force on the other. Below is a list of the parameters included in this analysis:

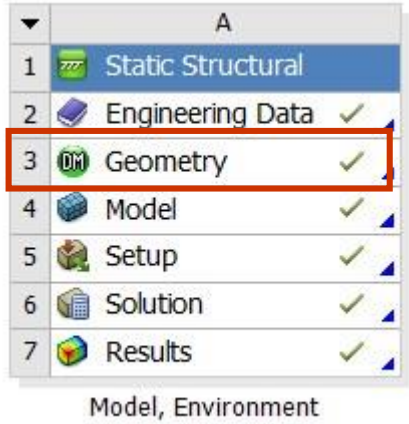
- Input
  - Height
  - Width
  - Length
  - Force
- Output
  - Mass
  - Equivalent Stress
  - Deformation



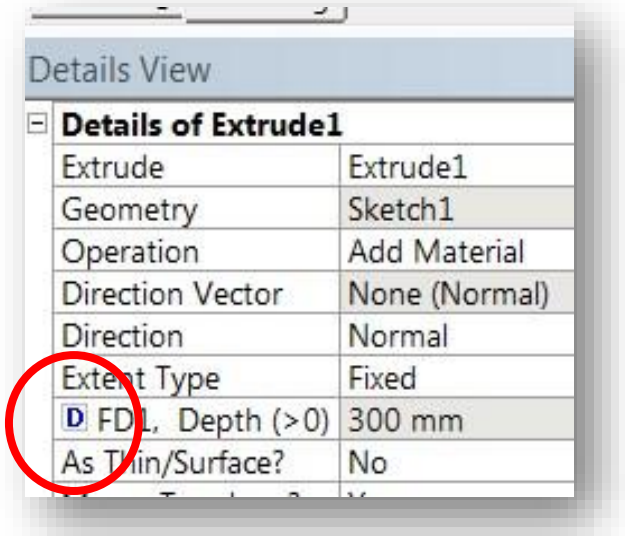
Project Startup

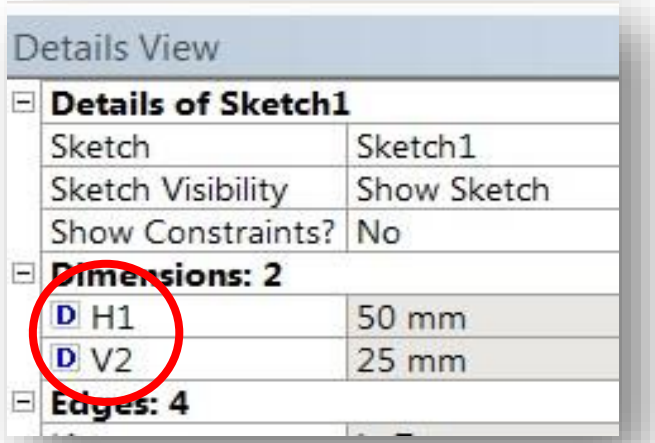
1. File> Open > Simple Beam.wbpj

2. Double click on Geometry to promote dimensions to input parameters

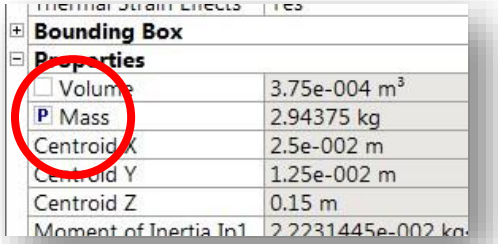


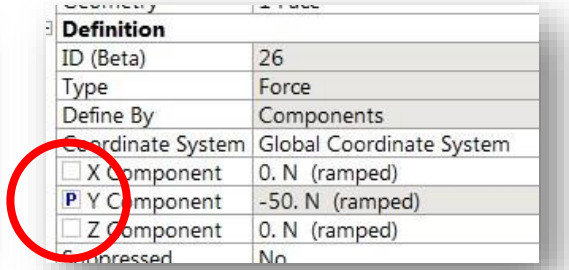
- ## Parameterize the dimensions in DesignModeler (DM):
  - **In the *Tree Outline*, select *Extrude1* and in the details view, enable the parameter box to the left of *FD1*. When prompted for a name, enter *length***
  - **In the Tree Outline, expand the Extrude1 branch and select Sketch1 > in the *Details* view, enable the parameter box to the left of *H1*. When prompted for a name, enter *width*. Repeat for V2 but use the name *height***

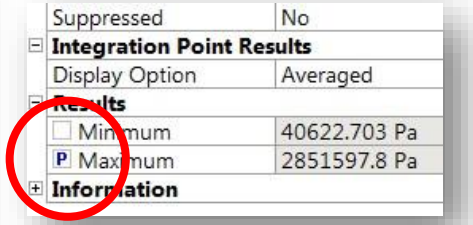


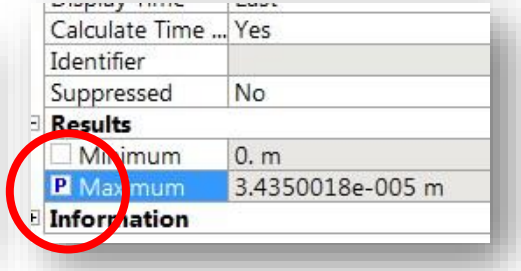


- **Parameterize the Mechanical analysis:**
  - **Double-click *Model***
  - **Parameterize the mass of the bar: In the *Outline* tree, expand the *Geometry* branch > click the *Solid* object > in the *Details* view, expand the *Properties* branch > enable the parameter box to the left of *Mass***
  - **Parameterize the y-force on the bar: In the *Static Structural* branch of the *Outline* tree, click *Force* > in the *Details* view, enable the parameter box to the left of *Y Component***
  - **Parameterize the Maximum Equivalent Stress: In the *Solution* branch of the *Outline* tree, click *Equivalent Stress* > in the *Results* branch of the *Details* view, enable the parameter box to the left of *Maximum***
  - **Parameterize the Maximum Total Deformation: In the *Solution* branch of the *Outline* tree, click *Total Deformation* > in the *Results* branch of the *Details* view, enable the parameter box to the left of *Maximum***



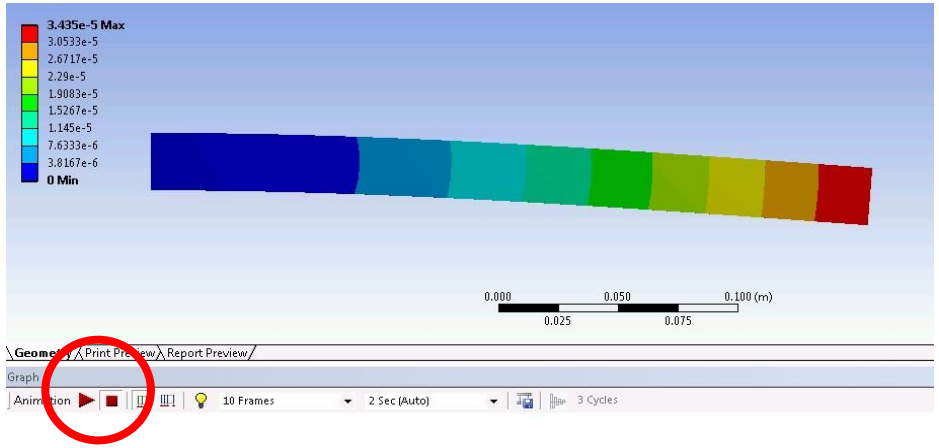






Review Model

- **Review the problem setup**
  - Click the *Static Structural* branch of the *Outline* tree. This will display all loads and supports in the 3D viewer. Notice that the beam deflects in the z-direction with +z and –z faces having a force load and fixed support, respectively
  - Review the Equivalent Stress distribution: In *Solution* branch of the *Outline* tree, click *Equivalent Stress*. Notice that the maximum stress is located near the fixed support on the +y and –y faces
  - Review the Total Deformation: In *Solution* branch of the *Outline* tree, click *Total Deformation*. Notice the maximum deformation is located at the free end of the beam. Click the animation *play* icon to view an animation of the deformation
  - Close the *Static Structural – Mechanical* window



Explore the Parameter Set bar

- Notice that in the *Project Schematic*, the *Parameter Set* bar is now visible. The *Parameter Set* bar becomes visible when parameters are created

- You will now use the Parameter Set bar to run the simulation under different conditions. <u>This is not required when conducting a Parameter Correlation study</u> and is only being included in the instructions to provide a deeper understanding of *What-if* studies
  - Double-click the *Parameter Set* bar
  - In *Table of Design Points*, notice that row 3 corresponds to the current setup. If you parameterized your model in a different sequence the P indices may not correspond to those shown in the image below

Table of Design Points

	A	B	C	D	E	F	G	H
1	Name	P1 - length	P2 - width	P3 - height	P5 - Force Y Component	P4 - Solid Mass	P6 - Equivalent Stress Maximum	P7 - Total Deformation Maximum
2	Units	mm	mm	mm	N	kg	Pa	m
3	DP 0 (Current)	300	50	25	-50	2.9438	2.8516E+06	3.435E-05
*								

Explore the Parameter Set bar

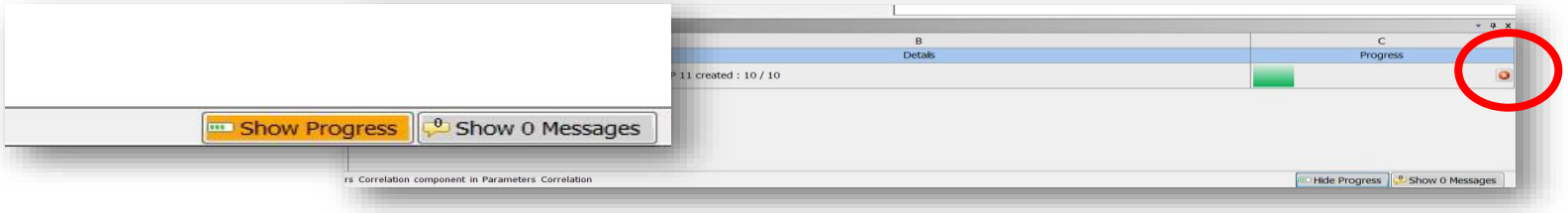
- **Create and run a new design point, saving the simulation files**
- **Create Design Point 1 (DP1): In row * of the *Table of Design Points*, input the following values:**
  - *length = 310 mm - height = 20 mm*
  - *width = 45 mm - Force Y Component = -60 N*
  - **Choose to Save Simulation Files: Enable the *Retain* box for row 4**
  - **Update DP1: Right-click anywhere in row 4 and select *Update Selected Design Points*. If a window pops up, click *OK*. A new sub-directory …\Simple Beam_files\dp1 will be created including the files associated with this design point**
  - **Notice that the *Current* row, row 3, still contains the original values. That means that if you were to open an editor, such as DesignModeler or Mechanical, the original values would still be used. If you want to see the results, such as *Equivalent Stress Maximum* or *Total Deformation Maximum* for DP1, you have to make that design point current. Make DP1 current:**
- **Right-click anywhere in row 4 and select *Set to Current*. Open editors may close during this operation**
- **Return to the *Project Schematic***
  - **Close the Parameter Set tab**

Conduct Parameters Correlation study

- **Drag and drop a Parameters Correlation System onto the Project Schematic > doubleclick Parameters Correlation**
- **Conduct a Spearman Correlation study**
  - **In *Outline of Schematic*, click *Parameters Correlation (A2)*. This will show the settings of the *Parameters Correlation* in the *Properties of Outline*. Keep the default settings. These settings will create 100 design points and solve them in batches of 10. If the statistics converge then no further runs will be conducted. Otherwise, another 10 design points will be solved and the process repeated until either 100 design points have been conducted or convergence reached**
  - **Convergence is calculated as follows. Correlation coefficients are calculated for each parameter pair after each new design point is solved. If the correlation coefficients have not changed much, then the correlation study is assumed converged. More specifically, if the mean and standard deviation of the correlation coefficients only change by 1% and 2%, respectively, then convergence is assumed**

Conduct Parameters Correlation study

- **In *Outline of Schematic*, click each input parameter and specify upper and lower bounds as follows:**
  - Length [280 to 350] -Height [15 to 35]
  - Width [35 to 50] -Force Y Component [-70 to -50]
  - **Click *Preview*. This will generate a list of the 100 design points that will be solved. It is good practice to review the design points and verify that the parameters are all within the desired ranges**
  - **Click *Update* and proceed to next stage. The design points will be solved in sequence. If your problem is large, this may take a some time. This study will take approximately 30 minutes of computation time**
  - **Instead of waiting for the runs to complete, stop the runs by clicking *Show Progress* > click the *Stop* icon > (as shown in image below) > click *Interrupt***



- **Close the current project and open *Simple Beam_Solved.wbpj***

Review Parameters Correlation study

- **Review the Correlation Matrix**

– **Double-click the *Parameters Correlation* cell**

– **In the *Charts* branch of the *Outline of Schematic*, click *Correlation Matrix*. The correlation matrix is displayed in numerical form in *Table of Schematic*. The correlation matrix is displayed in chart form in *Correlation Matrix***

- **Focus on the chart. Each colored box in the chart represents the correlation coefficient between two parameters. Strong positive correlations (i.e. an increase in one parameter is matched with an increase in the other parameter) are red, strong negative correlations (i.e. an increase in one parameter is matched with a decrease in the other parameters) are blue, and weak correlations are grey**

- **Notice that there is a very strong positive correlation between solid mass and height. Notice that there is a strong negative correlation between height and both equivalent stress maximum and total deformation. Finally, notice that there is a weak connection between Force Y component and both Equivalent Stress Maximum and Total Deformation Maximum. Do these correlations make sense?**

Review Parameters Correlation study

- ## Review the Correlation Matrix

Intuitively, greater forces result in greater stresses and deformations. So one would expect a very strong negative correlation between force Y component and both Equivalent Stress Maximum and Total Deformation Maximum. Why is the correlation only -0.107?

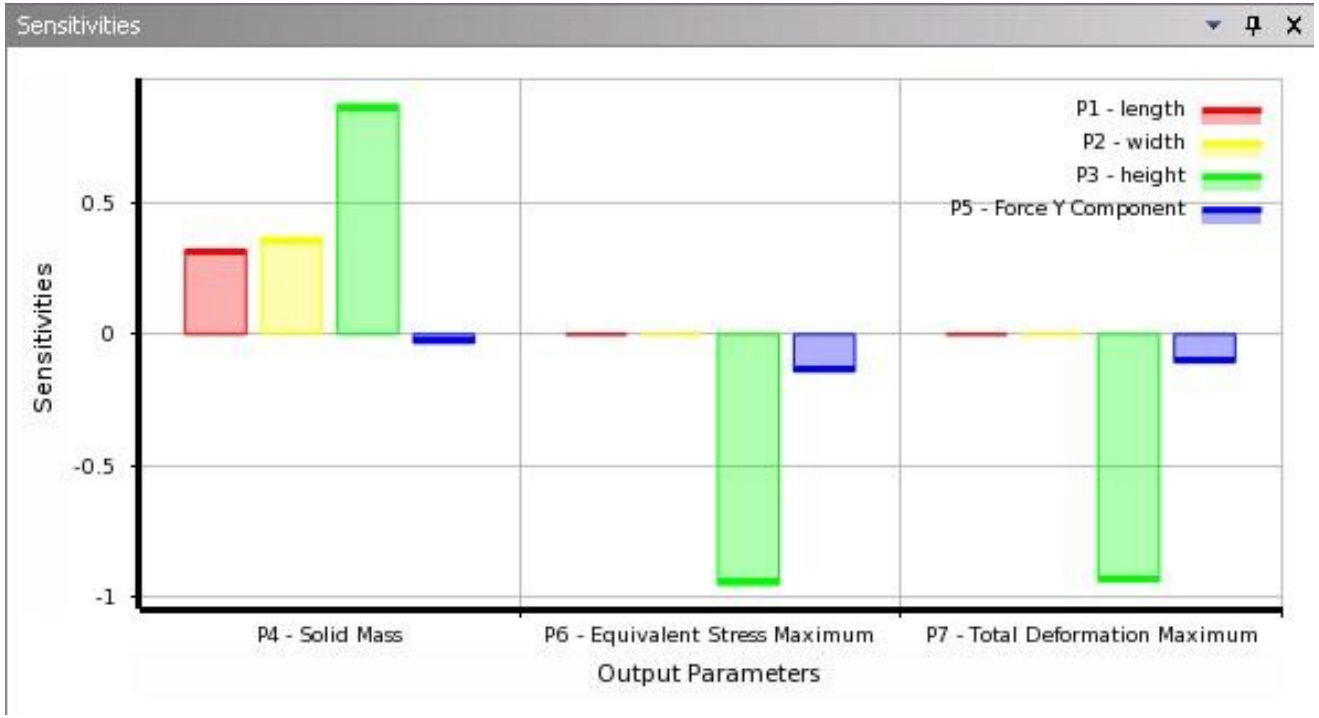
In these results, all parameters are taken into account. Here the force has a low impact on Stress and Deformation compared to the other parameters, and especially compared to the beam height

In this analysis, the most important parameter is height. However, if the ranges of each parameter were altered, then a different parameter may then be more important than height

<u>This is useful for determining which parameters can be ignored for the DOE</u>

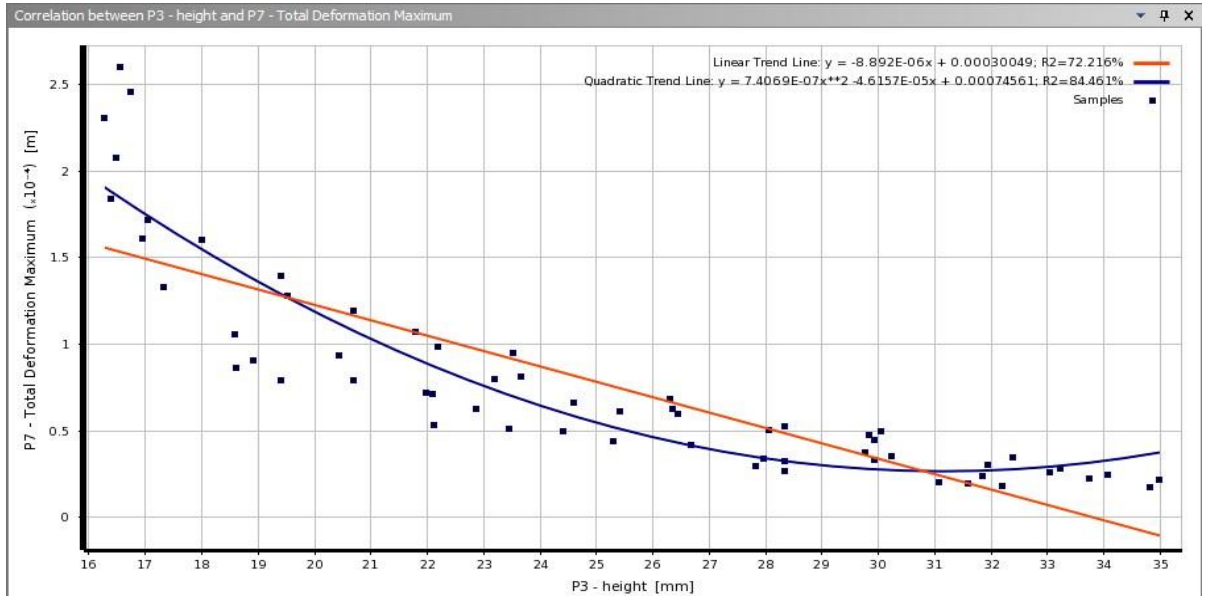
Review Parameters Correlation study

- **Review the Sensitivities**
  - In the *Charts* branch of the *Outline of Schematic*, click *Sensitivities*. The sensitivity of each output parameter is plotted with respect to all input parameters. Notice that a similar conclusion can be drawn, that all output are most sensitive to height



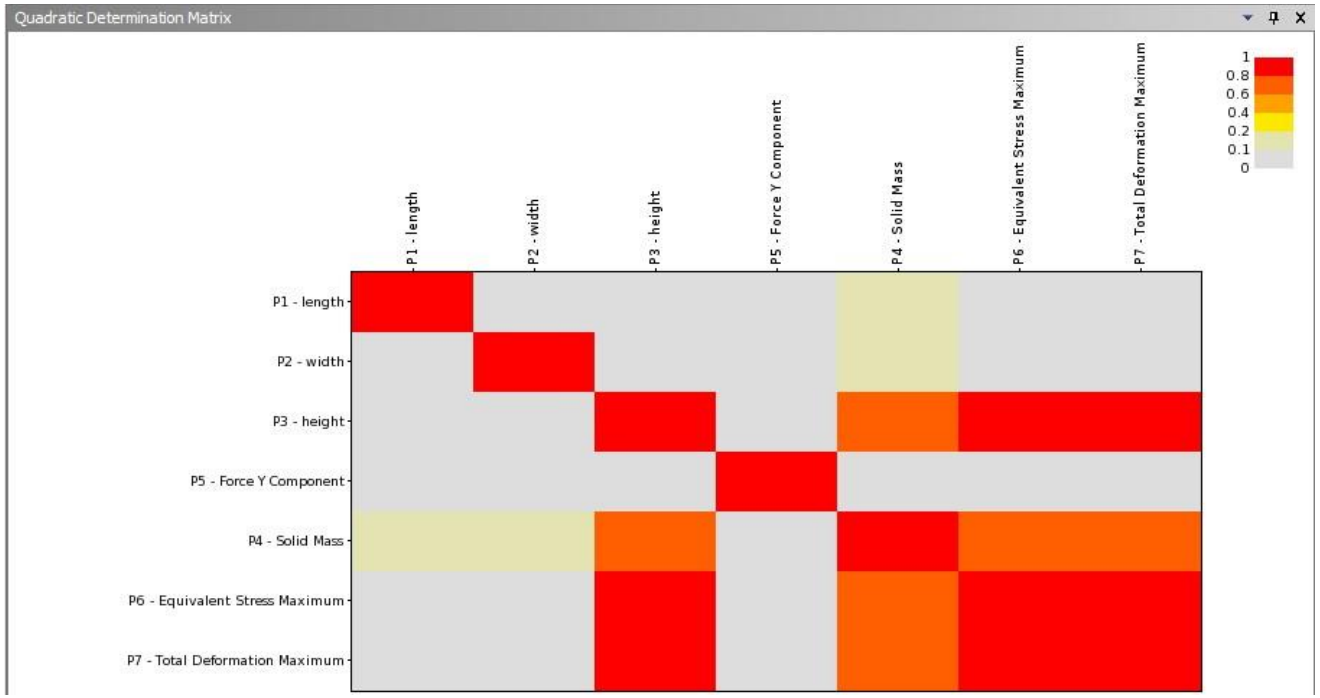
Review Parameters Correlation study

- **Review Correlation Scatter**
  - **In the *Charts* branch of the *Outline of Schematic*, click *Correlation Scatter***
  - **In the *Properties of Outline*, set the *X Axis* to *height* and the *Y Axis* to *Total Deformation Maximum*. Review the corresponding chart. A scatter plot of deformation versus height is displayed. Two trend lines are included, a linear and quadratic. In *Properties of Outline*, view the R2 (called R-squared) values in rows 8 and 9. These numbers indicate how well the data matches the two trend lines. In this case, the data fits the quadratic better**



Review Parameters Correlation study

- **Review Determination Matrix**
  - **In the *Charts* branch of the *Outline of Schematic*, click *Determination Matrix***
  - **The correlation matrix is displayed in numerical form in *Table of Schematic* and in chart form in *Quadratic Determination Matrix*. The values of the determination matrix correspond to the quadratic R-squared values**



Final Statements

- **In this workshop you parameterized dimensions and loads in DM and Mechanical, and explored the features within the Parameter Set and Parameters Correlation. In the Parameter Set you added a new design point and learned how to switch between them. In Parameters Correlation you conducted a Spearman Correlation study and determined the significance each input parameter has on the output parameters**

Problem 2 - Triangle Support Project

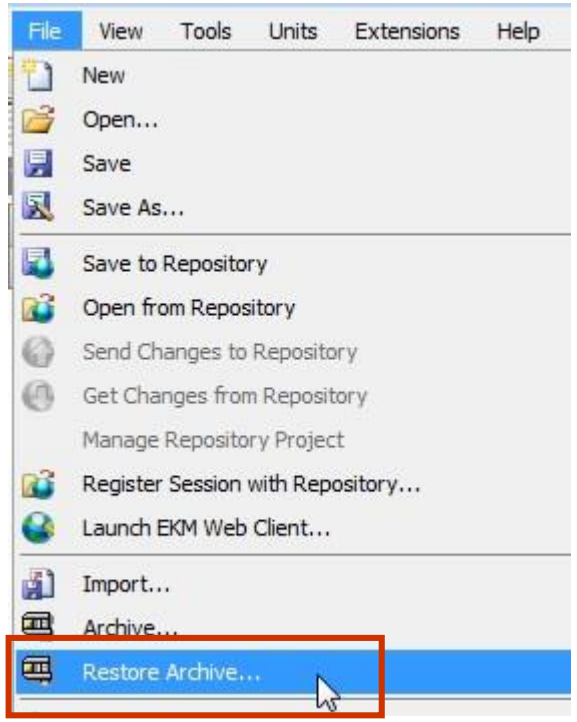
Another Project will be resolved now

- **Open another solved project and determine unimportant parameters (next slides)**

1 **File > Restore Archive… >**

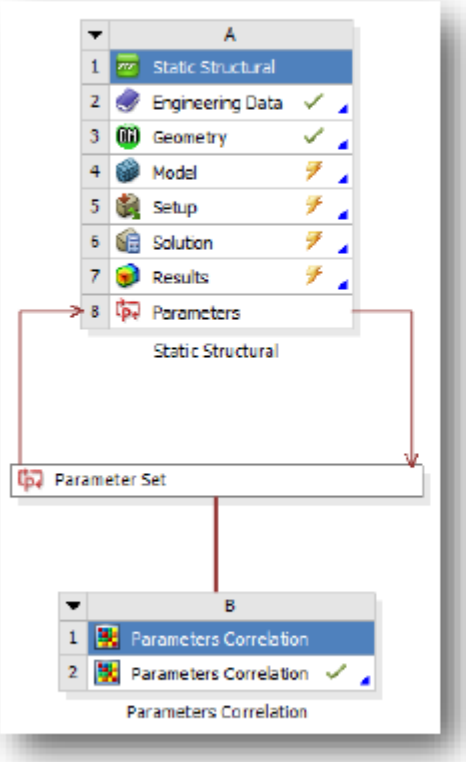
Tutorial-2-Input_File-2.wbpz

2 **Save as Tutorial 2- Problem 2.wbpj**

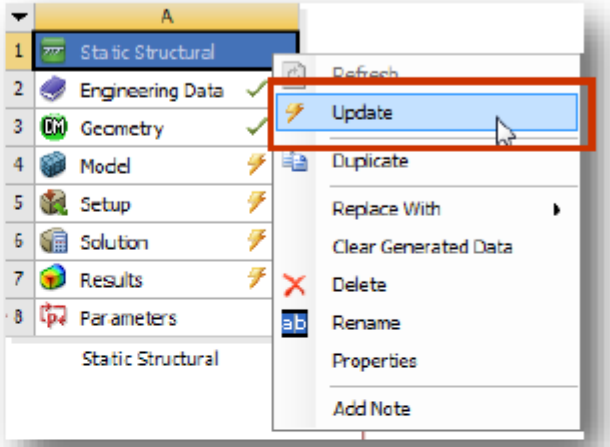


Problem 2 - Triangle Support Project

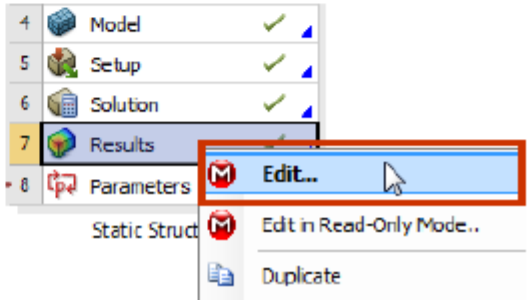
The Project is opened



4 Right click on Static Structural > Update

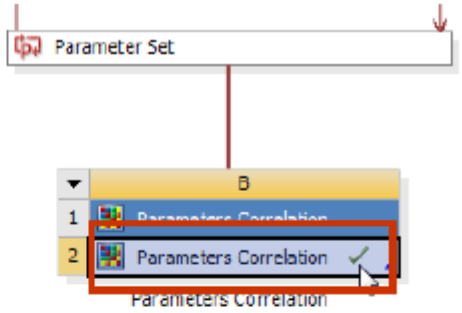


5 Check the model:
Right click on Results > Edit

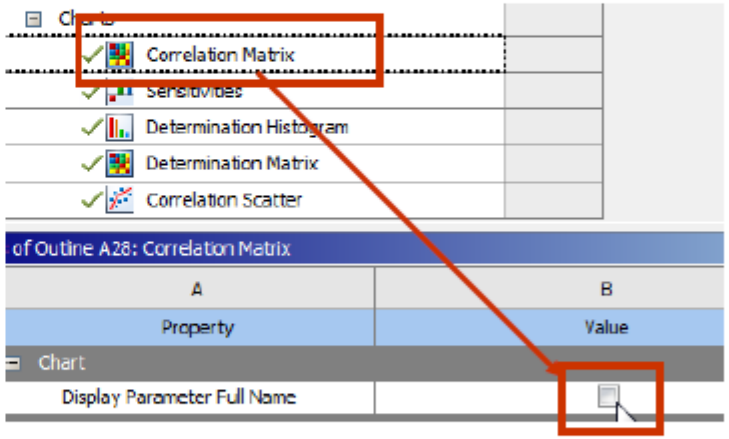


Problem 2 - Triangle Support Project

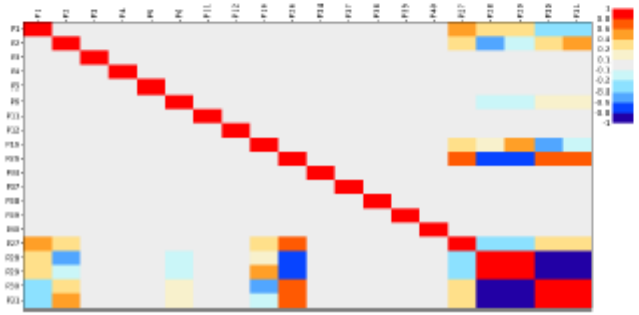
6 Check the Correlation results:
Double click on Correlation from the page project



7 Select the Correlation Matrix chart
Disable "Display Parameter Full Name

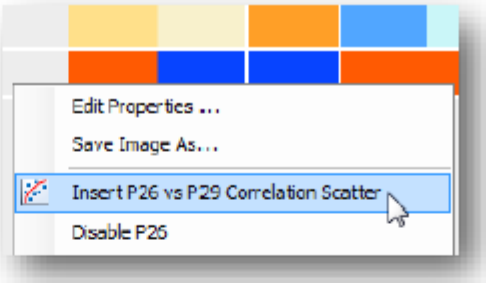


8 Identify important parameters from the chart

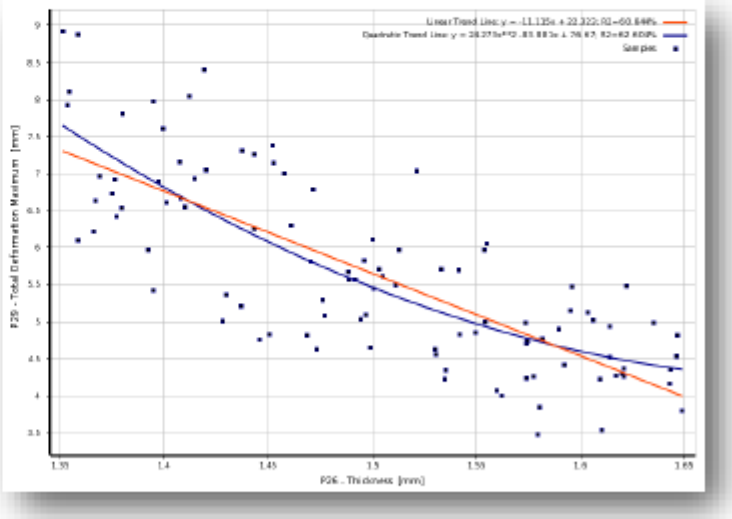


Problem 2 - Triangle Support Project

9 Right click on P26 vs P29 cell > Insert Correlation Scatter



The chart is created and displayed



10 In the Determination Histogram, verify that the Quadratic Full Model R2 is near 100%

Problem 2 - Triangle Support Project

Major Input Parameters				
Input Parameter	Best Relationship With Filtering Output Parameter			
	Relevance	Output Parameter	R2 Contribution	Correlation Value
P26 - Thickness	1	P27 - Surface Body Mass	0.42676	0.64634
P1 - Length	0.96594	P27 - Surface Body Mass	0.38463	0.64941
P2 - Height	0.88579	P31 - Safety Factor Minimum	0.33645	0.5578
P16 - Width	0.71386	P30 - Directional Deformation Minimum	0.19156	-0.47412

Minor Input Parameters				
Input Parameter	Best Relationship With Filtering Output Parameter			
	Relevance	Output Parameter	R2 Contribution	Correlation Value
P3 - Height (short dim)	0.28316	P27 - Surface Body Mass	0.0096885	0.30975
P4 - Upper Fringe	0.27326	P27 - Surface Body Mass	0.0087078	0.13114
P5 - Lower Fringe	0.26501	P27 - Surface Body Mass	0.0079429	0.079807
P6 - Stamping Depth	0.2383	P29 - Total Deformation Maximum	0.0076283	-0.13675
P12 - Stamping Length	0.21036	P30 - Directional Deformation Minimum	0.0049017	0.09914
P11 - Stamping Offset	0.18327	P31 - Safety Factor Minimum	0.0029797	0.16346
P38 - Hole2 Length	0.17901	P27 - Surface Body Mass	0.0024481	-0.021002
P37 - Hole2 Dist	0.17809	P29 - Total Deformation Maximum	0.0031839	-0.032571
P34 - Upper Holes Length	0.17581	P29 - Total Deformation Maximum	0.003063	0.024662
P40 - Hole2 Diameter	0.14753	P27 - Surface Body Mass	0.0013704	0.1382
P39 - Hole1 Diameter	0.14686	P27 - Surface Body Mass	0.0013517	0.095928