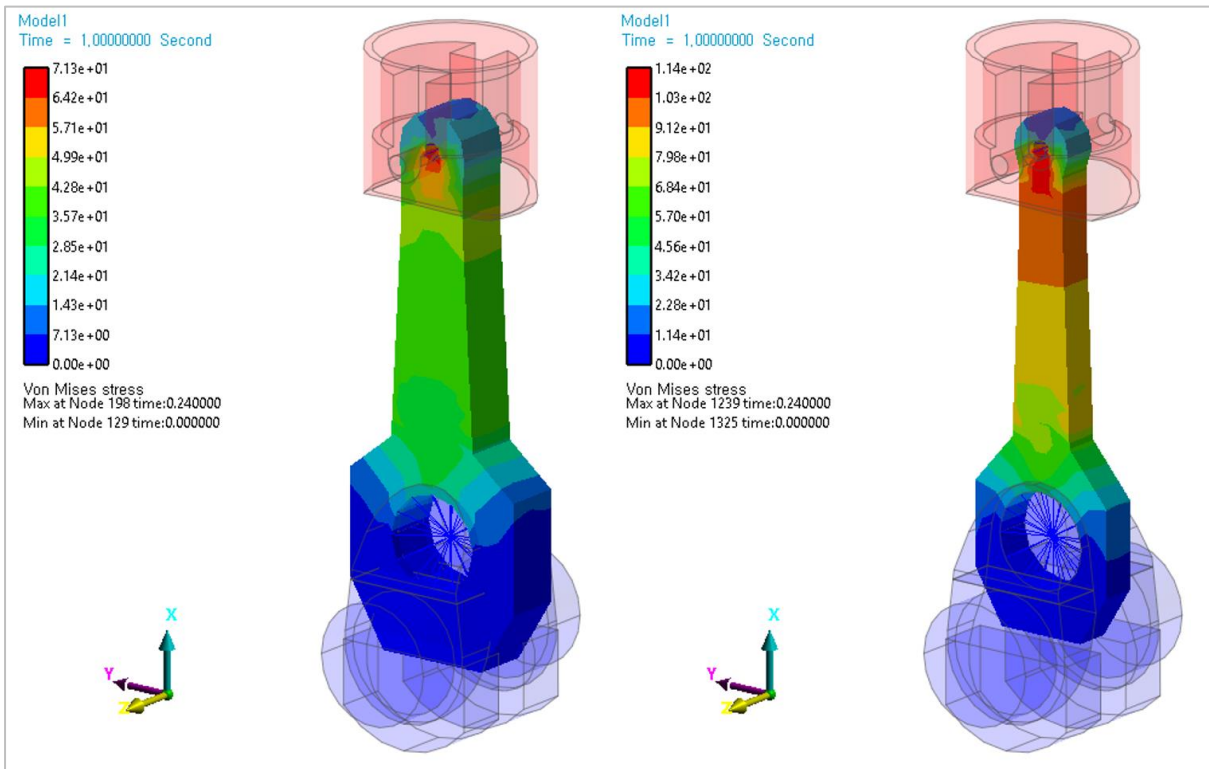


连杆形状优化教程 (AutoDesign)



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Edition Note

These documents describe the release information of *RecurDyn*[™] V9R1.

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连杆形状优化

本教程处理形状优化设计问题。设计对象是发动机连杆。连杆作用是将活塞的往复运动传递给曲轴的旋转运动。因此，设计目标是减少质量来提高能源效率和减少惯性力。同时还要考虑连杆是否有足够的强度承受活塞的压缩力。设计变量选择连杆的形状。

Import files related in Sample-G	
Sample	<Install Dir> \Help\Tutorial\AutoDesign\AutoDesign_G\Examples\Sample_G.rdy n
Solution	<Install Dir> \Help\Tutorial\AutoDesign\AutoDesign_G\Solutions\Sample_G.rdy n

注意: 如果想改变上述的文件路径, 它可以位于任何指定的文件夹。

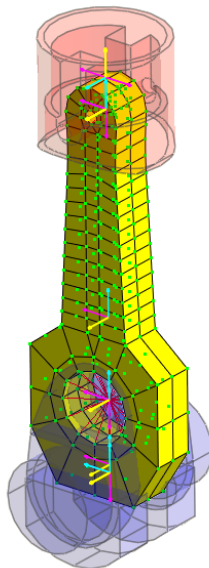
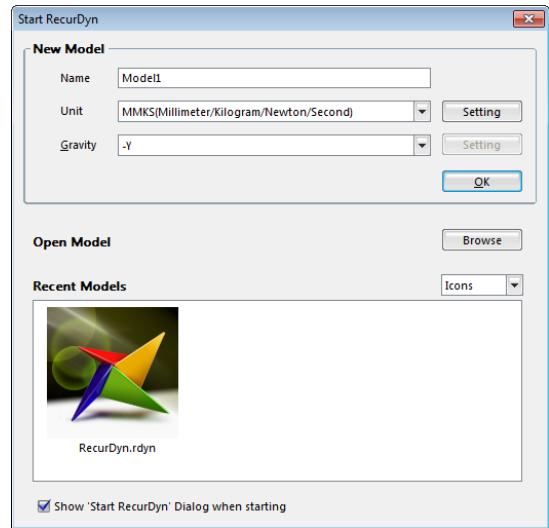
Chapter

1

加载与仿真模型



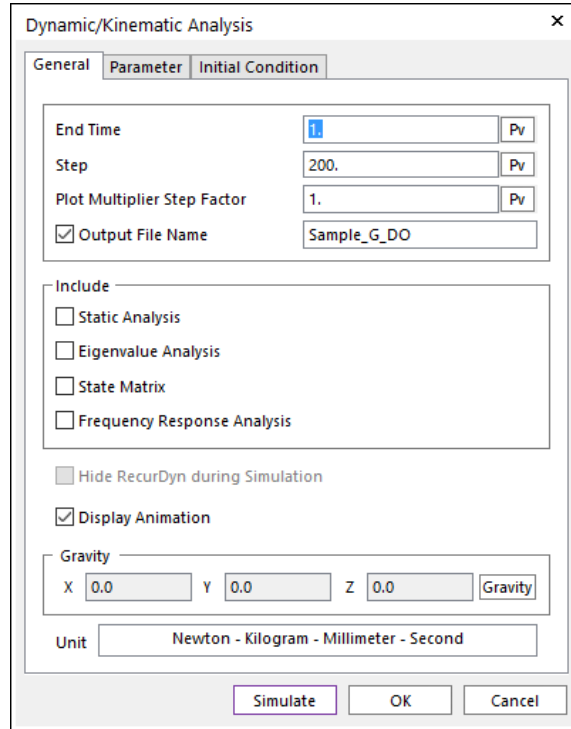
1. 双击桌面上的 **Recurdyn** 图标。
运行 **Recurdyn**，会弹出 **Start Recurdyn** 对话框。
2. 关闭对话框，将会使用一个现有的模型。
3. 在快速访问工具栏中，点击 **Open** 工具，在本教程的目录里选择 **Sample_G.rdyn**。
确定后，系统正式运行。





4. 点击 **Dynamic/Kinematic** 键，弹出如下对话框。

5. 点击 **Simulate** 键。

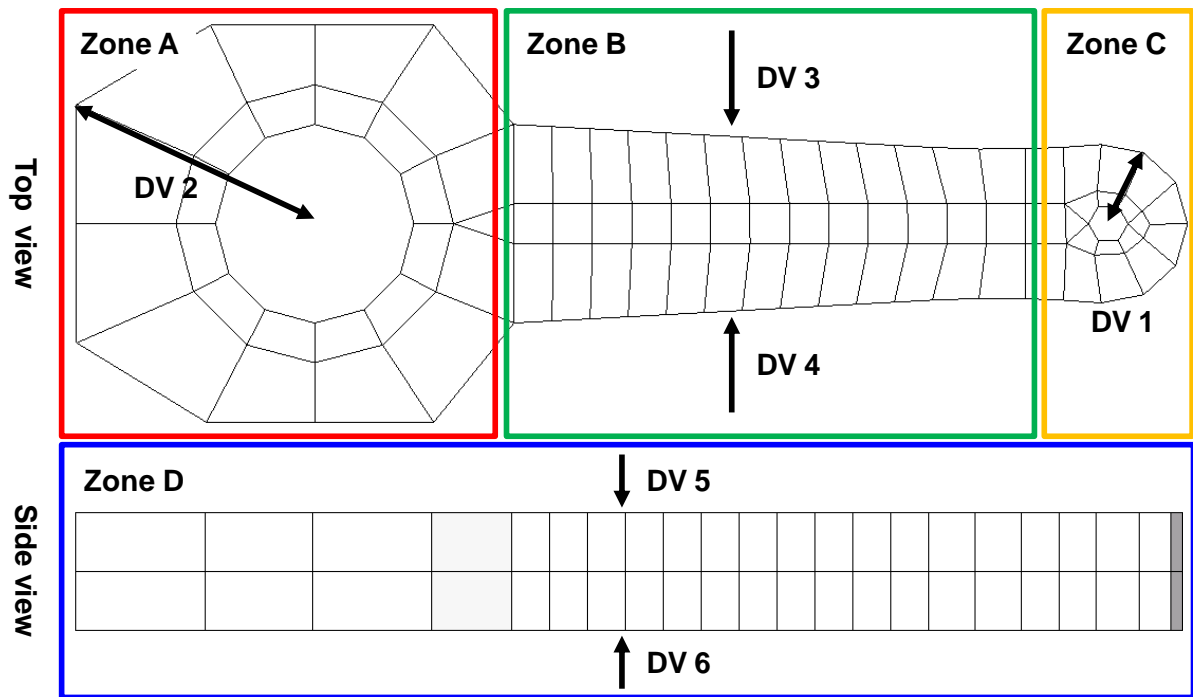


6. 点击 **Play** 键，查看结果。

Chapter 2

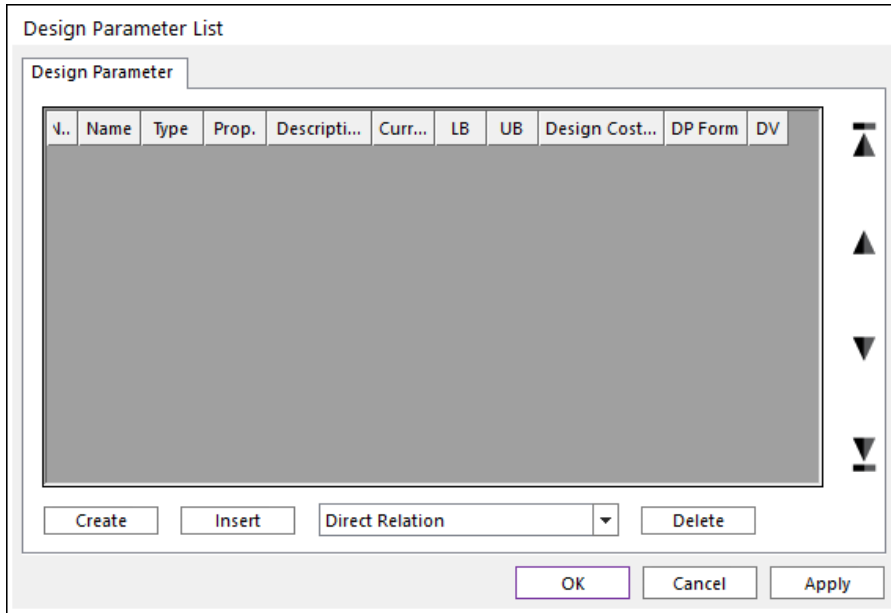
定义设计变量和设置

在下图中，设计变量选择连杆形状，连杆分为4个区域。其中 DV1 是 C 区圆的半径，DV2 是 A 区的半径，DV3、4 是 B 区的宽度，DV5、6 是 D 区的高度。



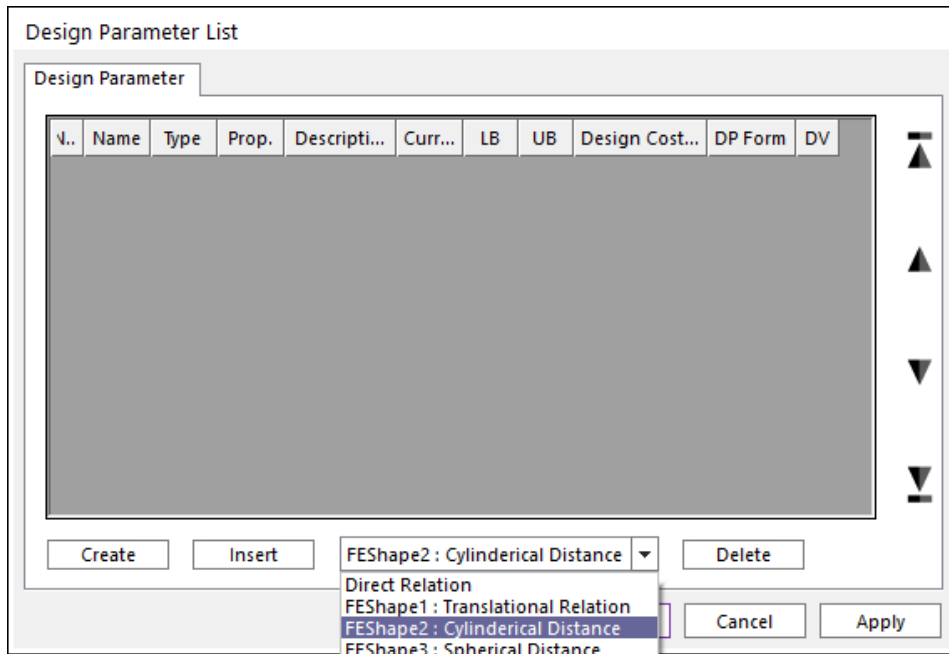


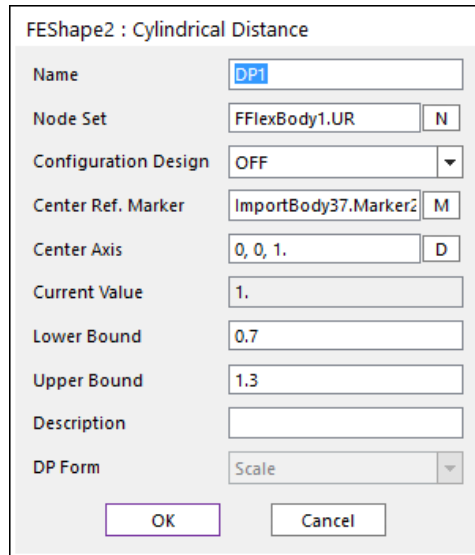
1. 在 **AutoDesign** 菜单中，点击 **design parameter**，将会弹出如下图所示的 **design parameter** 对话框。



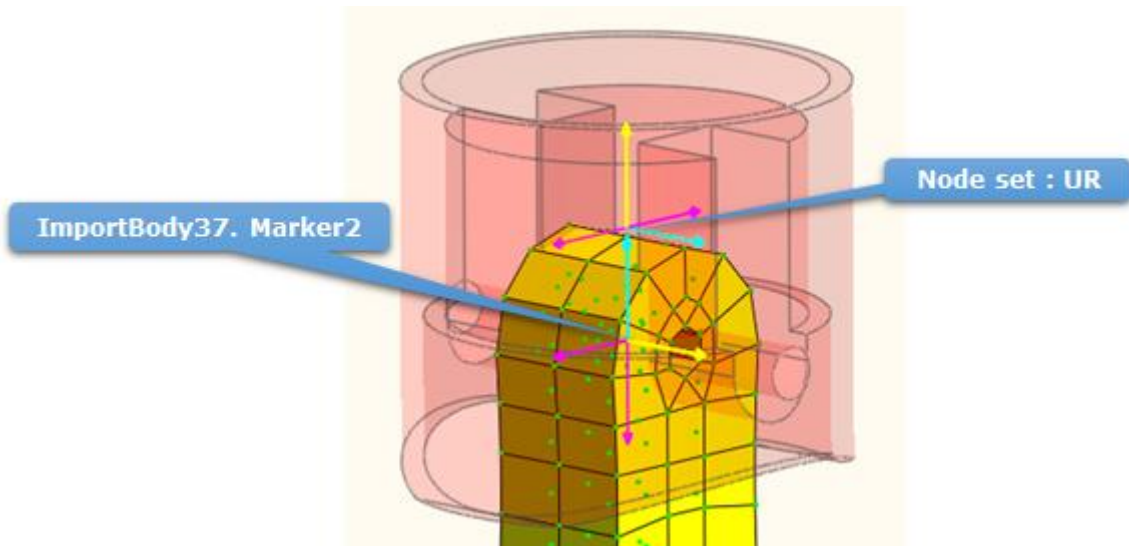
2. 设置 C 区设计变量 DV1

- a. 选择设计参数类型为 **FEShape2: Cylindrical distance**。然后点击 **Create** 键，将会弹出如下图所示的 **FEShape2: Cylindrical distance** 窗口。





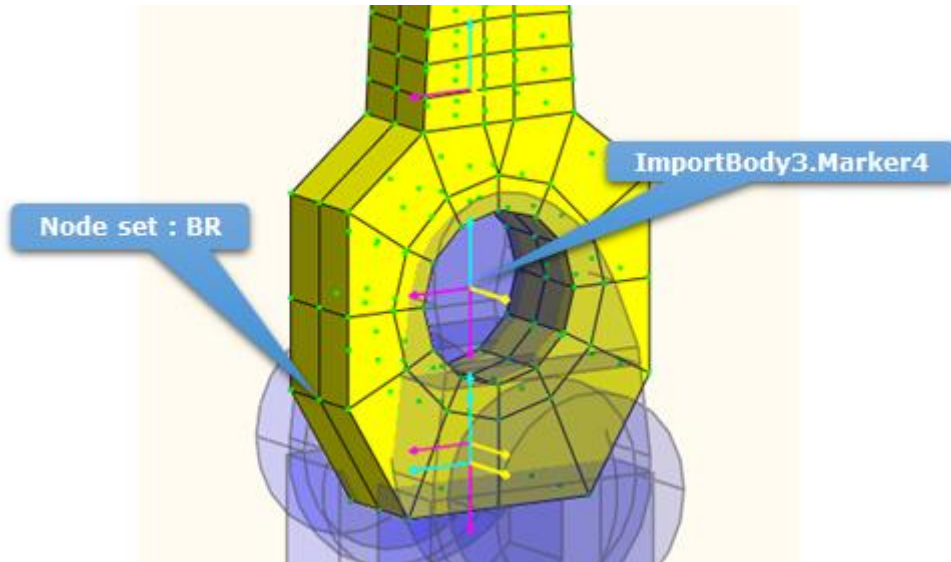
b. 结点集: C 区 UR



- c. **Configuration design** 项选择 off。
- d. **Reference marker** 项设置为 `importbody37. Marker2`。
- e. **Center Axis** 项设置为 0, 0, 1。
- f. **Lower bound** 和 **upper bound** 项依次设置为 0.7, 1.3。
- g. 点击 **OK** 键确定。

3. 设置 A 区设计变量 DV2

- a. 选择设计参数类型为 **FEShape2: Cylindricaldistance**。点击 **Create** 键，填写设计参数。
- b. 结点集：**A 区 BR**

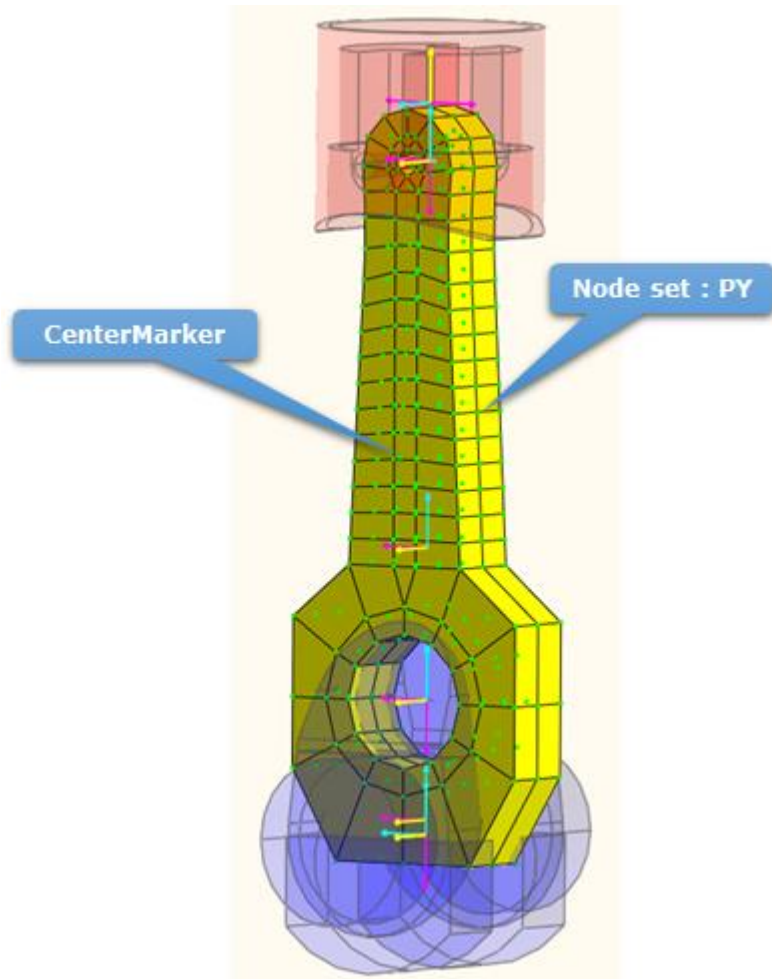


- c. **Configuration design** 项选择 **off**。
- d. **Reference marker** 项设置为 **importbody3. Marker2**。
- e. **Center Axis** 项设置为 **0, 0, 1**。
- f. **Lower bound** 和 **upper bound** 项依次设置为 **0.8, 1.2**。
- g. 点击 **OK** 键确定。

FEShape2 : Cylindrical Distance	
Name	DP2
Node Set	FFlexBody1.BR N
Configuration Design	OFF
Center Ref. Marker	ImportBody3.Marker2 M
Center Axis	0, 0, 1. D
Current Value	1.
Lower Bound	0.8
Upper Bound	1.2
Description	
DP Form	Scale
<input type="button" value="OK"/> <input type="button" value="Cancel"/>	

4. 设置 B 区设计变量 DV3, 4

- a. 选择设计参数类型为 **FEShape1: Translationalrelation**，然后点击 **Create** 键，将会弹出如下图所示的 **FEShape1: Translational relation** 窗口。
- b. 结点集：**B 区 PY**。



- c. **Configuration design** 项选择 **off**。
- d. **Reference marker** 项设置为 **Flexbody1. CM**。
- e. **Directional unit vector** 项设置为 **0, 1, 0**。
- f. **Lower bound** 和 **upper bound** 项依次设置为：**0.7, 1.3**。
- g. 点击 **OK** 键确定。
- h. 重复以上步骤设置 **DV4**，**DV4** 的结点集设置为 **NY**，其他相同。

FEShape1 : Translational Relation

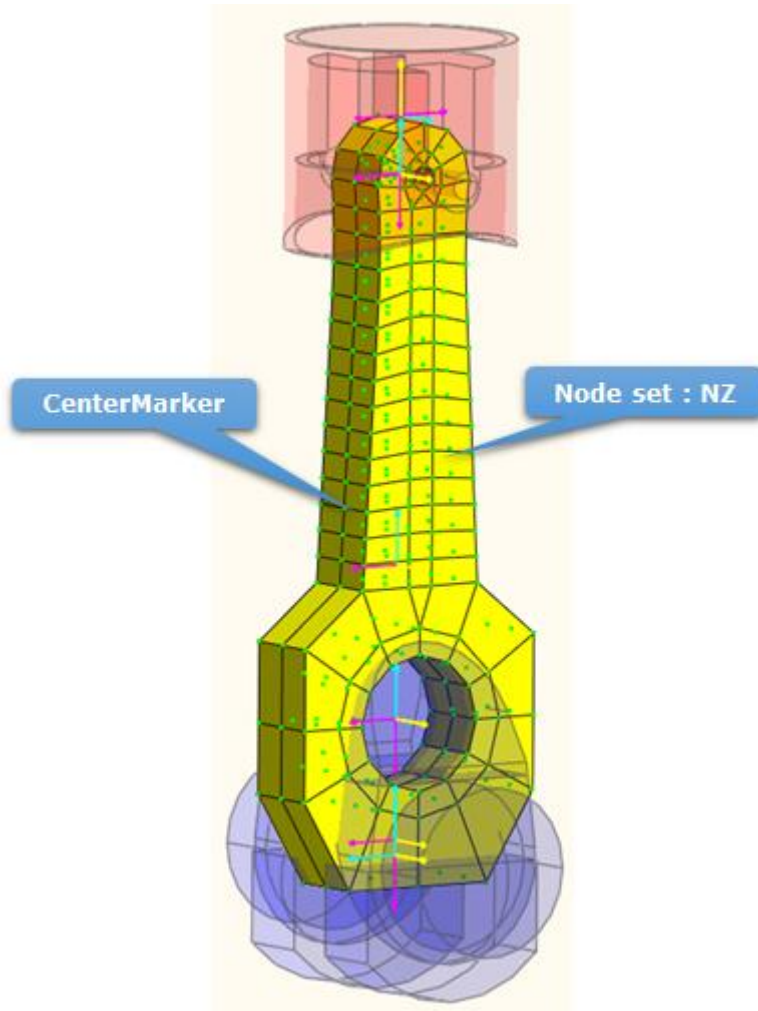
Name	<input type="text" value="DP3"/>
Node Set	<input type="text" value="FFlexBody1.PY"/> <input type="button" value="N"/>
Configuration Design	<input type="text" value="OFF"/> ▼
Reference Marker	<input type="text" value="FFlexBody1.CM"/> <input type="button" value="M"/>
Directional Unit Vector	<input type="text" value="0, 1., 0"/> <input type="button" value="D"/>
Current Value	<input type="text" value="1."/>
Lower Bound	<input type="text" value="0.7"/>
Upper Bound	<input type="text" value="1.3"/>
Description	<input type="text"/>
DP Form	<input type="text" value="Scale"/> ▼

FEShape1 : Translational Relation

Name	<input type="text" value="DP4"/>
Node Set	<input type="text" value="FFlexBody1.NY"/> <input type="button" value="N"/>
Configuration Design	<input type="text" value="OFF"/> ▼
Reference Marker	<input type="text" value="FFlexBody1.CM"/> <input type="button" value="M"/>
Directional Unit Vector	<input type="text" value="0, 1., 0"/> <input type="button" value="D"/>
Current Value	<input type="text" value="1."/>
Lower Bound	<input type="text" value="0.7"/>
Upper Bound	<input type="text" value="1.3"/>
Description	<input type="text"/>
DP Form	<input type="text" value="Scale"/> ▼

5. 设置 D 区设计变量 DV5 , 6

- a. 选择设计参数类型为 **FEShape1: Translational relation**, 然后点击 **Create** 键, 填写设计参数。
- b. **D 区 DV5** 结点集:**NZ**。



- c. **Configuration design** 项选择 **off**。
- d. **Reference marker** 项设置为 **Flexbody. CM**。
- e. **Directional unit vector** 项设置为 0, 0, 1。
- f. **Lower bound** 和 **upper bound** 项依次设置为:0. 6, 1. 4。
- g. 点击 **OK** 键确定。
- h. 重复以上步骤设置 **DV6**, **DV6** 的结点集设置为 **PZ**, 其它相同。

i.

FEShape1 : Translational Relation

Name	<input type="text" value="DP5"/>
Node Set	<input type="text" value="FFlexBody1.NZ"/> <input type="button" value="N"/>
Configuration Design	<input type="text" value="OFF"/> ▼
Reference Marker	<input type="text" value="FFlexBody1.CM"/> <input type="button" value="M"/>
Directional Unit Vector	<input type="text" value="0, 0, 1."/> <input type="button" value="D"/>
Current Value	<input type="text" value="1."/>
Lower Bound	<input type="text" value="0.6"/>
Upper Bound	<input type="text" value="1.4"/>
Description	<input type="text"/>
DP Form	<input type="text" value="Scale"/> ▼

FEShape1 : Translational Relation

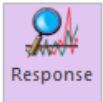
Name	<input type="text" value="DP6"/>
Node Set	<input type="text" value="FFlexBody1.PZ"/> <input type="button" value="N"/>
Configuration Design	<input type="text" value="OFF"/> ▼
Reference Marker	<input type="text" value="FFlexBody1.CM"/> <input type="button" value="M"/>
Directional Unit Vector	<input type="text" value="0, 0, 1."/> <input type="button" value="D"/>
Current Value	<input type="text" value="1."/>
Lower Bound	<input type="text" value="0.6"/>
Upper Bound	<input type="text" value="1.4"/>
Description	<input type="text"/>
DP Form	<input type="text" value="Scale"/> ▼

Chapter

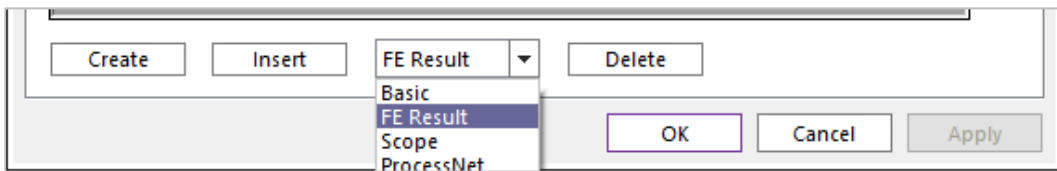
3

定义分析响应

为了设计连杆，分析响应为质量和应力

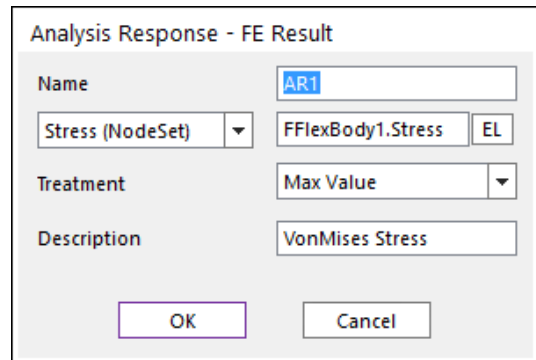


1. 点击 **Analysis Responses** 菜单，然后改变响应类型 (**FE-Result**) 如下图：

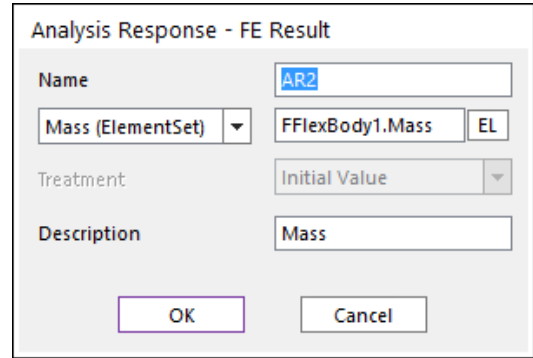


2. 点击 **Create** 键，弹出如下图所示的分析响应 **FE Result** 窗口
3. 设置压力的分析响应参数

- a. **Name:** AR1
- b. **Result type:** Stress (NodeSet)
- c. **Stress (Node Set) :**
FFlexBody1. Stress
- d. **Response treatment:** Max Value
- e. **Description:** VonMises Stress
- f. **OK.**



4. 点击 **Create** 键，弹出如右图所示的分析响应 **FE Result** 窗口
5. 设置质量的分析响应参数
 - a. **Name:** AR2
 - b. **Result type:** Mass (ElementSet)
 - c. **Mass (Element Set):** FFlexBody1.Mass
 - d. **Description:** Mass
 - e. OK



OKChapte r 4

运行优化设计

优化的主要内容是：在最小化连杆质量的同时，保证：
连杆应力 \leq 允许极限应力值。



1. 点击 **Design Optimization** 菜单，就可以看到先前的设计变量列表 DV1 至 DV6，如下图：

Design Optimization								
Design Variable		Performance Index	Optimization Control	Result Sheet	Summary Sheet			
DV	DP	Description	Current	LB	UB	Type		Value
1	DP1		1.	0.7	1.3	Variable	▼	0.
2	DP2		1.	0.8	1.2	Variable	▼	0.
3	DP3		1.	0.7	1.3	Variable	▼	0.
4	DP4		1.	0.7	1.3	Variable	▼	0.
5	DP5		1.	0.6	1.4	Variable	▼	0.
6	DP6		1.	0.6	1.4	Variable	▼	0.

2. 点击 **Performance Index** 选项，可以看到下图。如果该窗口是空的，请创建 PIs。

Design Optimization							
Design Variable		Performance Index	Optimization Control	Result Sheet	Summary Sheet		
PI	Use	AR	Description	Definition	Goal	Weight/Limit Value	
1	<input checked="" type="checkbox"/>	AR1	VonMises Stress	Constraint	LE	114.	
2	<input checked="" type="checkbox"/>	AR2	Mass	Objective	MIN	1	

3. 点击 **Optimization Control** 选项，直接使用默认值。然后点击 **Execution** 键，可以看到设计公式的总汇。检查设计变量、性能指标和元模型的信息。如果所有信息是正确的，点击 **OK** 键，开始运行优化过程

Design Optimization

Design Variable | Performance Index | **Optimization Control** | Result Sheet | Summary Sheet

DOE Meta Modeling Methods:

Convergence Tolerance

Objective Change Rate in Consecutive Iterations:

Equality Constraints:

Inequality Constraints:

Maximum Iteration of SAO:

Convergence Relaxation Control:

Simulation Type:

Save Results

Number of Trials:

Execution

Summary for Execution

Design Variables

No	DV	Description	Current	LB	UB	Type	Value
1	DP1	UR	1.	0.7	1.3	Variable	0.
2	DP2	BR	1.	0.8	1.2	Variable	0.
3	DP3	PY	1.	0.7	1.3	Variable	0.
4	DP4	NY	1.	0.7	1.3	Variable	0.
5	DP5	NZ	1.	0.6	1.4	Variable	0.

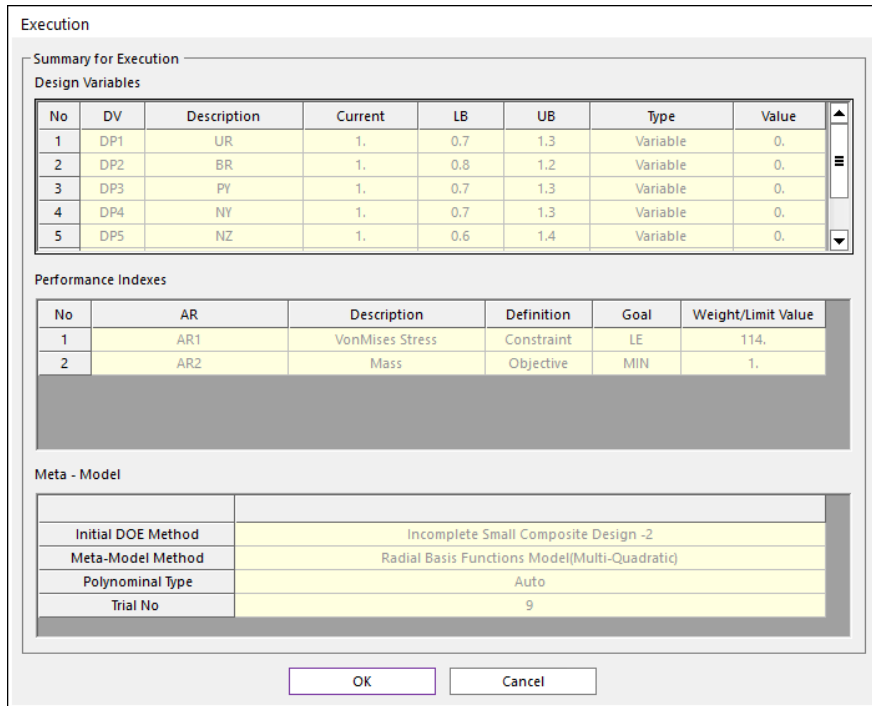
Performance Indexes

No	AR	Description	Definition	Goal	Weight/Limit Value
1	AR1	VonMises Stress	Constraint	LE	114.
2	AR2	Mass	Objective	MIN	1

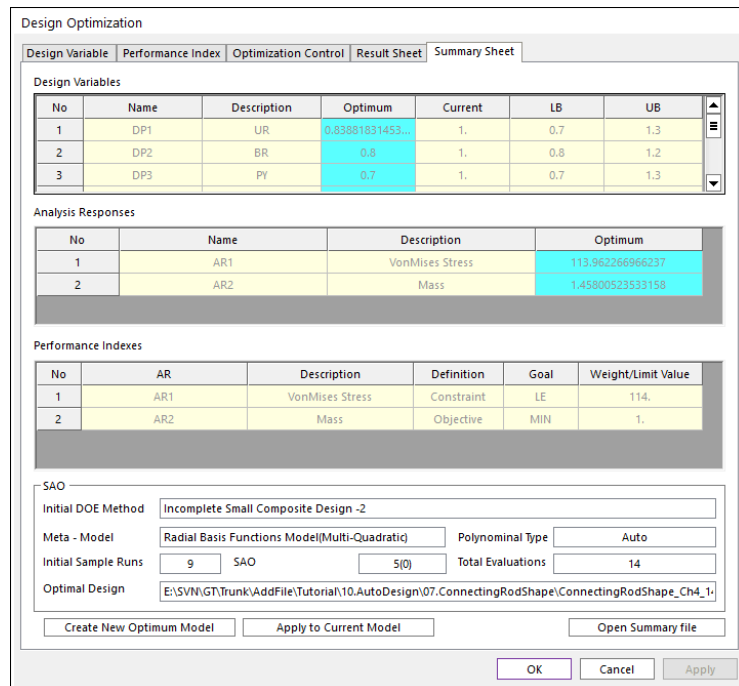
Meta - Model

Initial DOE Method	Incomplete Small Composite Design -2
Meta-Model Method	Radial Basis Functions Model(Multi-Quadratic)
Polynomial Type	Auto
Trial No	9

4. 当优化过程完成后，其 **result sheet** 选项窗口会自动弹出。优化过程只进行四次迭代收敛，因此，**AutoDesign** 只做了 **14** 次分析去解决有 5 个设计变量的连杆系统，其中包括 9 次初始条件分析。最后的优化设计结果显示 **AR1=113.96Mpa** 和 **AR2=1.458kg**，表示在应力处于允许的范围（小于 114Mpa）质量可以减小 58 %。



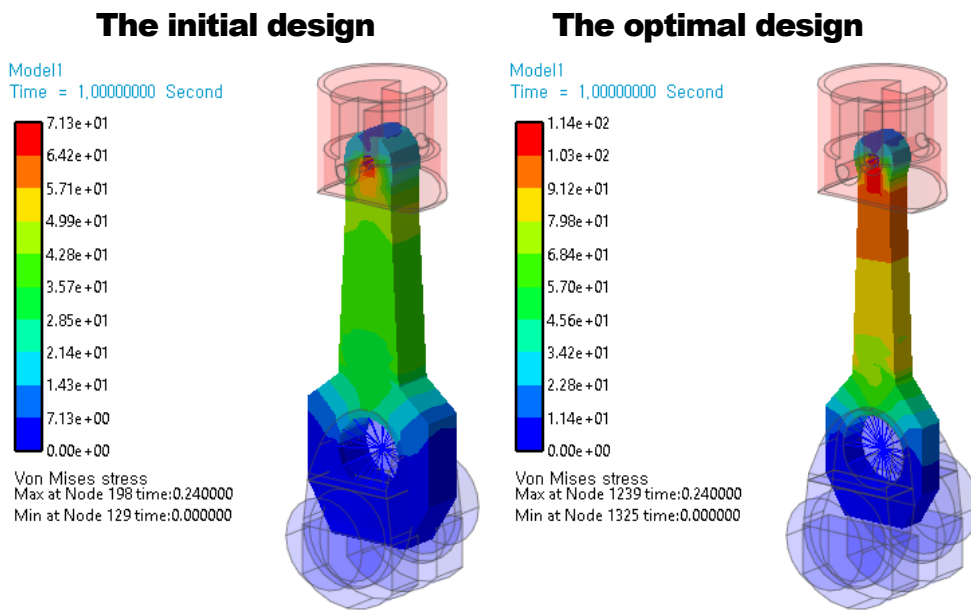
5. 优化结果汇总在设计变量和分析响应列表中。同时也汇总 **SAO** 相关信息，SAO 运行了 5 次。优化设计的分析结果保存为 ‘**DO_005**’ 文件。



Chapter 5

分析结果对比

最后，在质量和应力上对原始设计与优化设计进行对比，SAO5 是优化设计，DOE005 是原始设计。以下就是其对比结果。



	The initial design	The optimal design
Mass (Kg)	3.478	1.458
Stress (Mpa)	71.3	113.96

感谢学习本教程!