

Connecting Rod Shape Optimization Tutorial (AutoDesign)





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Edition Note

This document describes the release information of **RecurDyn V9R4**.

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Connecting Rod Shape Optimization

This tutorial deals with the shape optimization design problem. Design target is a connecting rod in engine. Connecting rod function is a transferred reciprocating movement of the piston to crankshaft rotational movement. Therefore, design goal is a minimize mass for energy efficiency and reduce inertial force. Also, a design constraint is strength to withstand compressive forces of piston. Design variable select the shape on connecting rod.

	Open files related in Sample-G						
Sample	<install dir=""> \Help\Tutorial\AutoDesign\ConnectingRodShape\Examples\Sample_G.rdyn</install>						
Solution	<install dir=""> \Help\Tutorial\AutoDesign\ConnectingRodShape\Solutions\Sample_G.rdyn</install>						

Note: If you change the file path at discretion, it can be located in any folder that you specify.

Chapter

Loading and simulation the model



1. On your Desktop, double-click the **RecurDyn** icon.

RecurDyn starts and the Start RecurDyn dialog box appears.

- 2. Close **Start RecurDyn** dialog box. You will use an existing model.
- In the Quick Access toolbar, click the Open tool and select `Sample_G.rdyn' from the same directory where this tutorial is located.

The system appears on the screen.

Start RecurDyn		×
New Model -]
Name	Model1	
Unit	MMKS(Millimeter/Kilogram/Newton/Second)	Setting
<u>G</u> ravity	Ү.	Setting
		<u>O</u> K
Open Model		Browse
Recent Mode	els	Icons 💌
Recurf	Dyn.rdyn	
Show 'Start	RecurDyn' Dialog when starting	



ک Dyn/Kin

4. Click the **Dynamic/Kinematic** button.

5. Click the **Simulate** button.

Dynamic/Kinematic Analysis	Dynamic/Kinematic Analysis					
General Parameter Initial Conditi	ion					
End Time	1. P	v I				
Step	200. F	~				
Plot Multiplier Step Factor	1. P	~				
Output File Name	Sample_G_DO					
Static Analysis						
Eigenvalue Analysis						
State Matrix						
Frequency Response Analysis						
Hide RecurDyn during Simulat	Hide RecurDyn during Simulation					
Display Animation						
Gravity						
X 0.0 Y 0.0	Z 0.0 Grav	ity				
Unit Newton - Kilogra	m - Millimeter - Second					
Simula	ate OK Car	icel				

6. In order to view result, click the **play** button



Defining the design variables and setting

In the figure, design variable selects connecting road shape. Design variables divide into 4 design variable zones. And, DV1 is a radius in zone C and DV2 is radius in zone A. DV3 and 4 is a width in zone B. DV 5 and 6 is a height in zone D.





From the **Auto Design** menu, click **Design Parameter**. This will bring up the design parameter list dialog as shown below.

Design Para	meter L	ist								
Design Paran	neter									
N Name	Туре	Prop.	Descripti	Curr	LB	UB	Design Cost	DP Form	DV	
										v I
										•
										v I
									-	ř.
Create		Insert	Direc	Relation	n		•	Delete]	
-							ОК	Cancel	Apply	

2. To set design variable 1

Select design parameter type as FEShape2 : Cylindrical distance. And, click
 Create button to add design parameter. This will bring up the FEShape 2:
 Cylindrical distance window shown below.

Design Pa	ameter l	ist								
Design Par	ameter									
N. Nan	e Type	Prop.	Descripti	Curr	LB	UB	Design Co	st DP Form	DV	T
										v
										•
										Y
Creat	e [Insert	FESha	ape2 : Cy	linder	ical Dis	stance 🔻	Delete		
			Direct FESha FESha FESha	Relation pe1 : Tra pe2 : Cy pe3 : Sp	n Inslati linderi berica	onal R cal Dis	elation tance	Cancel	Ap	ply

FEShape2 : Cylindrica	l Distance
Name	DP1
Node Set	FFlexBody1.UR N
Configuration Design	OFF 💌
Center Ref. Marker	ImportBody37.Marker2 M
Center Axis	0, 0, 1. D
Current Value	1.
Lower Bound	0.7
Upper Bound	1.3
Description	
DP Form	Scale
ОК	Cancel

b. Node set: UR in zone C



- c. Configuration design: off
- d. Center Reference marker: importbody37.Marker2
- e. Center Axis: 0,0,1
- f. Lower & upper bound: 0.7,1.3
- g. OK

3. To set design variable 2

- a. Select design parameter type as **FEShape 2: Cylindrical distance**. And, click **Create** button to add design parameter.
- b. Node set: BR in zone A



- c. Configuration design: off
- d. Center Reference marker: importbody3.Marker2
- e. Center Axis: 0,0,1
- f. Lower & upper bound: 0.8,1.2
- g. OK

FEShape2 : Cylindrica	l 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 👻
ОК	Cancel

4. To set Design variable 3, 4

- Select design parameter type as FEShape 1: Translational relation. And, click Create button to add design parameter. This will bring up the FEShape 1: Translational relation window shown below.
- b. Node set: PY in Zone B



- c. Configuration design: off
- d. Reference marker: Flexbody1.CM
- e. Directional unit vector: 0,1,0
- f. Lower & upper bound: 0.7,1.3
- g. OK
- h. In like manner, To generate DV4 about node set:NY

FEShape1 : Translatio	nal Relation	FEShape1 : Translatio	nal Relation
Name	DP3	Name	DP4
Node Set	FFlexBody1.PY N	Node Set	FFlexBody1.NY N
Configuration Design	OFF 🔻	Configuration Design	OFF 💌
Reference Marker	FFlexBody1.CM M	Reference Marker	FFlexBody1.CM M
Directional Unit Vector	0, 1., 0 D	Directional Unit Vector	0, 1., 0 D
Current Value	1.	Current Value	1.
Lower Bound	0.7	Lower Bound	0.7
Upper Bound	1.3	Upper Bound	1.3
Description		Description	
DP Form	Scale 🔻	DP Form	Scale 💌
ОК	Cancel	ОК	Cancel

- 5. To set Design variable 5, 6
 - a. Select design parameter type as **FEShape 1: Translational relation**. And, click **Create** button to add design parameter.
 - b. Node set: NZ in zone D



- c. Configuration design: off
- d. Reference marker: Flexbody.CM
- e. Directional unit vector: 0,0,1
- f. Lower & upper bound: 0.6,1.4
- g. OK
- h. In like manner, To generate DV6 about node set: PZ

FEShape1 : Translatio	nal Relation
Name	DP5
Node Set	FFlexBody1.NZ N
Configuration Design	OFF 🔻
Reference Marker	FFlexBody1.CM M
Directional Unit Vector	0, 0, 1. D
Current Value	1.
Lower Bound	0.6
Upper Bound	1.4
Description	
DP Form	Scale 👻
ОК	Cancel

FEShape1 : Translational Relation					
Name	DP6				
Node Set	FFlexBody1.PZ N				
Configuration Design	OFF 💌				
Reference Marker	FFlexBody1.CM M				
Directional Unit Vector	0, 0, 1. D				
Current Value	1.				
Lower Bound	0.6				
Upper Bound	1.4				
Description					
DP Form	Scale 💌				
ОК	Cancel				

Chapter 3

T.

Defining the analysis responses

In order to design connecting rod, analysis response is a mass and stress



Click the **Analysis Responses** menu. Then, you can change the response type (FE-Result) as follow figure:

Create Insert	FE Result 💌	Delete
	FE Result Scope	OK Cancel Apply
	ProcessNet	

2. Click the **Create** button. Then you can see the analysis responses-**FE result** window as following figure.

Г

- 3. To set the analysis response of **stress** is defined as
 - a. Name: AR1
 - b. Result type: Stress(NodeSet)
 - c. Select Node Set: FFlexBody1.Stress
 - d. Response treatment: Max value
 - e. Description: VonMises Stress
 - f. OK.
- 4. Click the **Create** button. Then you can see the analysis responses-**FE Result** window as following figure.
- 5. To set the analysis response of **mass** is defined as
 - a. Name: AR2
 - b. Result type: Mass(ElementSet)
 - c. Select Element Set: FFlexBody1.Mass
 - d. Description: Mass
 - e. **OK.**

Analysis Response - FE	Result
Name	AR1
Stress (NodeSet) 🔻	FFlexBody1.Stress EL
Treatment	Max Value 🔻
Description	VonMises Stress
ОК	Cancel

Analysis Response - FE Result						
Name	AR2					
Mass (ElementSet) 💌	FFlexBody1.Mass EL					
Treatment	Initial Value 🔻					
Description	Mass					
ОК	Cancel					

Chapter

Running a design optimization

The optimization problem is defined as: Minimize the mass of the connecting rod Subject to

• The stress =< Limit value



1. Click the **Design Optimization** menu. Then, you can see the design variable list as following figure:

De	Design Optimization									
D	esign Var	riable Performance I	Index Optimization	Control Resu	It Sheet Su	mmary Sheet				
	DV	DP	Description	Current	LB	UB	Туре		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. Click the **Performance Index** tab. Then, you can see the following list. If this window is empty, then you create the following PIs.

D	Design Optimization										
	esign Va	riable	Performan	ce In	dex Optimization Cor	ntrol Result Sheet	Summ	ary Sheet			
	PI	Use	AR		Description	Definition		Goal		Weight/Limit Value	
	1		AR1	-	VonMises Stress	Constraint	-	LE	•	114.	
	2	>	AR2	-	Mass	Objective	-	MIN	•	1	

3. Click the **Optimization Control** tab. The default values are directly used. Then, click the **Execution** button. Then, you can see the summary of design formulation. Check design variables, performance index and Meta-Model information. If all information is correct, then click the **OK** button. Then, optimization process is progressed.

Design Optimization	
Design Variable Performance Index Optimization Control Result Sheet Summa	ary Sheet
DOE Meta Modeling Methods	Methods
Convergence Tolerance Objective Change Rate in Consecutive Iterations	5.e-02
Equality Constraints	1.e-03
Inequality Constraints	1.e-03
Maximum Iteration of SAO	50.
Convergence Relaxation Control	OFF 💌
Simulation Type	Dynamic/Kinematic 💌
Save Results	Number of Trials 9
Analysis Setting	Execution
	OK Cancel Apply

	DV	Description	Current	LB	UB	Туре		Value	Ŀ
1	DP1	UR	1.	0.7	1.3	Variabl	e	0.	1
2	DP2	BR	1.	0.8	1.2	Variabl	e	0.	1
3	DP3 PY		1.	0.7	1.3	Variabl	e	0.	
4	4 DP4 NY		1.	0.7	1.3	Variabl	e	0.	
5	DP5	NZ	1.	0.6	1.4	Variabl	e	0.	Ŀ
2 AR2		ARZ	IVIdSS		Objective	IMIIN			J
eta - I	Model								
eta - I	Model	Method			mall Composite	Design -2			
eta - I Ir M	Model nitial DOE	Method Method	Ir Radia	ncomplete S	imall Composite	Design -2			
eta - I Ir M	Model nitial DOE eta-Model Polynomir	Method Method	Ir Radia	ncomplete S I Basis Fun	imall Composite i ctions Model(Mu Auto	Design -2 Iti-Quadratic)			

4. When the optimization process is completed, the result sheet tab is automatically shown. The optimization process is converged only in 5 **iterations**. Thus, **AutoDesign** solves the connecting-rod system design having 6 design variables for **14 analyses** that includes **9** analyses for the initial sampling points. The final design gives that AR1=113.96 Mpa and AR2=1.458 kg which can minimize the Mass by 58 % and the Stress is satisfied with design constraint (less than 114 Mpa).



5. The optimization results are summarized in the design variables and analysis responses lists. Also, the SAO information is summarized, which shows that SAO 5 requires. The analysis result of optimal design is 'DO_005'.

	Performance Index	Optimization Cor	ntrol Result Shee	t Summary She	et	
esign Variabl	es					
No	Name	Description	Optimum	Current	LB	UB
1	DP1	UR	0.83881831453	1.	0.7	1.3
2	DP2	BR	0.8	1.	0.8	1.2
3	DP3	РҮ		1.	0.7	1.3
nalysis Respo	inses					
No	Nar	ne	Des	cription		Optimum
1	AR	1	VonM	lises Stress	1	
2	AR	2		Mass		1.45800523533158
No	AR	Des	cription	Definition	Goal	Weight/Limit Value
No 1	AR AR1	Des VonMi	cription ses Stress	Definition Constraint	Goal	Weight/Limit Value
No 1 2	AR AR1 AR2	VonMi	cription ses Stress Mass	Definition Constraint Objective	Goal LE MIN	Weight/Limit Value 114. 1.
No 1 2 SAO Initial DOE M	AR AR1 AR2 Iethod Incomplete	Small Composite D	cription ses Stress dass Design -2 Multi Quadratid	Definition Constraint Objective	Goal LE MIN	Weight/Limit Value 114. 1.
No 1 2 SAO Initial DOE M Meta - Mode Initial Sample	AR AR1 AR2 Iethod Incomplete I Radial Basis	Small Composite D	cription ses Stress Mass Design -2 Multi-Quadratic)	Definition Constraint Objective Polynom	Goal LE MIN inal Type	Weight/Limit Value 114, 1. Auto
No 1 2 SAO Initial DOE M Meta - Mode Initial Sample	AR AR1 AR2 Iethod Incomplete I Radial Basis e Runs 9	Small Composite D Functions Model(SAO	cription see Stress Aass Aass Aass Aass Aass Aass Aass A	Definition Constraint Objective Polynom Total Eva	Goal LE MIN inal Type	Weight/Limit Value 114, 1. Auto 14
No 1 2 SAO Initial DOE M Meta - Mode Initial Sample Optimal Desi	AR AR1 AR2 Iethod Incomplete I Radial Basis Runs 9 gn E\SVN\GNI	Small Composite D Functions Model(SAO	cription ses Stress Aass Aass Aass Aass Aass Aass Cesign -2 Multi-Quadratic) 5(0) riah/10.AutoDesign	Definition Constraint Objective Polynom Total Eva 07.Connecting	Goal LE MIN inal Type luations	Weight/Limit Value 114. 1. Auto 14 nnectingRodShape_Ch4_1



Comparison of analysis results

Finally, let's compare the mass and stress level for the initial design and the optimal design. SAO5 is the optimal design. Also, DOE005 is the initial design. The following figures show those comparisons.



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

Thanks for participating in this tutorial!