

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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Sample

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				
	<install dir=""></install>				
Sample	\Help\Tutorial\AutoDesign\AutoDesign_G\Examples\Sample_G.rdy				
	n				
Solutio n	<install dir=""> \Help\Tutorial\AutoDesign\AutoDesign_G\Solutions\Sample_G.rdy</install>				
••	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。

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。

St	art RecurDyn		×				
ſ	New Model -						
	Name	Model1					
	Unit	MMKS(Millimeter/Kilogram/Newton/Second)	Setting				
	<u>G</u> ravity	-Y 💌	Setting				
			<u>O</u> K				
	Open Model Browse						
	Recent Mode	ls	Icons				
	RecurDyn.rdyn						
	Show 'Start RecurDyn' Dialog when starting						



- **%** 点击 **Dynamic/Kinematic** 键, 弹出如下对话框。
 - 5. 点击 Simulate 键。

Dynamic/Kinematic Analysis				
General Parameter Initial Condition				
End Time	1. Pv			
Step	200. Pv			
Plot Multiplier Step Factor	1. Pv			
Output File Name	Sample_G_DO			
Static Analysis				
Eigenvalue Analysis				
State Matrix				
Frequency Response Analysis				
Hide RecurDyn during Simulation				
Display Animation				
Gravity				
X 0.0 Y 0.0 Z 0.0 Gravity				
Unit Newton - Kilogram - Millimeter - Second				
Simu	late OK Cancel			

▶ 6. 点击 Play 键,查看结果。

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。

Desig	Design Parameter List										
Desig	n Param	eter									
۹.,	Name	Туре	Prop.	Descripti	Curr	LB	UB	Design Cost	DP Form	DV	
											Y
	Create		Incert	Dired	Pelatio	n			Delete	1	
	create		men		Relatio				Delete]	
								OK	Cancel	Ap	ply

- 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。

D	esig	n Parai	meter L	ist								
[Desig	n Param	eter									
	۹.,	Name	Туре	Prop.	Descripti	Curr	LB	UB	Design Cost.	DP Form	DV	T
												_
												V
												v
												<u> </u>
		Create		Insert	FESha	ape2 : Cy	linderi	ical Dis	stance 🔻	Delete		
L	_				Direct	Relation	n					
					FESha	pe1 : Tra	anslati lindari	onal R	elation	Cancel	Ap	ply
					EESha	ne3 : Sp	herica	l Dista	nce			

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

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

- 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**DV**5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。

FEShape1 : Translational 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		

i.

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		

定义分析响应

2

为了设计连杆,分析响应为质量和应力



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

- 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
 - Name: AR1 a.
 - Result type: Stress (NodeSet) b.
 - Stress (Node Set) : c. FF1exBody1. Stress
 - Response treatment: Max Value d.
 - Description:VonMises Stress e.
 - f. OK.

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

- **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) : FF1exBody1. Mass
 - d. Description: Mass
 - e. OK

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



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≤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 **DV**1 至 **DV**6, 如下图:

D	Design Optimization								
D	esign Var	iable Performance I	Index Optimization	Control Res	ult Sheet S	ummary 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. 点击 Performance Index 选项,可以看到下图。如果该窗口是空的,请创建 PIs。

D	esign O	ptimiza	tion								
[)esign Va	riable	Performar	ice Ir	Idex Optimization Cor	ntrol Result Sheet	Summa	ary Sheet			
	PI	Use	AR		Description	Definition		Goal		Weight/Limit Value	
										-	
	1		AR1	•	VonMises Stress	Constraint	-	LE	-	114.	

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

	Performance Index	Optimization Control	Result Shee	et Summary	/ Sheet		
DOE Meta M	lodeling Methods				Me	thods	
Convergence	Tolerance						
Objective C	hange Rate in Consec	utive Iterations			5.e-02		
Equality Co	nstraints				1.e-03		
Inequality C	onstraints				1.e-03		
Maximum It	Maximum Iteration of SAO						
Convergen	e Relaxation Control				OFF		
Simulation	lype				Dynamic/Kinematic	•	
	Analysis Set	ting			Execution		
	Analysis Set	ting			Execution		

	DV	Description	Current	LB	UB	Туре		Value
1	DP1	UR	1.	0.7	1.3	Variab	le	0.
2	DP2	BR	1.	0.8	1.2	Variab	le	0.
3	DP3	PY	1.	0.7	1.3	Variab	le	0.
4	DP4	NY	1.	0.7	1.3	Variab	le	0.
5	DP5	NZ	1.	0.6	1.4	Variab	le	0.
2		MNG						
2		Anz						
2		ANZ						
2		AIL			,			
2 ta - N	Aodel	AILE						
2 ta - N	Nodel	ANL						
2 ta - N	/lodel	Method	in	complete S	imall Composite I	Design -2		
2 ta - N Ir M	Model nitial DOE I eta-Model	Method Method	In Radia	complete S I Basis Fun	imall Composite I ctions Model(Mu	Design -2 Iti-Quadratic)	
2 ta - N Ir M	Model hitial DOE I eta-Model Polynomin	Method Method al Type	In Radia	complete S I Basis Fun	imall Composite I ctions Model(Mu Auto	Design -2 Iti-Quadratic)	

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内(小于 114Mpa)质量可以减小 58 %。

No	DV	Description	Current	LB	UB	Туре		Value
1	DP1	UR	1.	0.7	1.3	Variab	le	0.
2	DP2	BR	1.	0.8	1.2	Variab	le	0.
3	DP3	PΥ	1.	0.7	1.3	Variab	le	0.
4	DP4	NY	1.	0.7	1.3	Variab	le	0.
5	DP5	NZ	1.	0.6	1.4	Variab	le	0.
No 1 2		AR AR1 AR2	VonMises Str Mass	ess	Constraint Objective	LE MIN	weight	114. 1.
No 1 2		AR1 AR2	VonMises Str Mass	ess	Constraint Objective	LE MIN	weight	114. 1.
No 1 2 eta - M	Model	AR AR1 AR2	VonMises Str Mass	ess	Constraint Objective	LE MIN	weight	114. 1.
No 1 2 eta - N	Nodel	AR AR1 AR2 Method	VonMises Str Mass	ess complete S	Constraint Objective imall Composite	LE MIN Design -2		114. 1.
No 1 2 eta - N Ir M	Model nitial DOE eta-Model Polynomir	AR AR1 AR2 Method Method al Type	VonMises Str Mass Ir Radia	ess icomplete S I Basis Fun	Constraint Objective imall Composite I ctions Model(Mu Auto	LE MIN Design -2 Iti-Quadratic		114. 1.

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。

sign Variable	Performance Index	Optimization C	ontrol 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	PY	0.7	1.	0.7	1.3		
nalysis Respo	onses							
No	Nam	ie	De	scription		Optimum		
1	AR	1	VonN	/lises Stress	1			
-	4.01	-	Mass		1	1 45800523533158		
2 erformance Ir No	ndexes AR	De	escription	Definition	Goal	Weight/Limit Value		
2 erformance li	ndexes			IVIG33				
2 erformance lr No 1	AR AR AR	De VonI	escription Vises Stress	Definition Constraint	Goal	Weight/Limit Value		
erformance li No 1 2	AR AR AR AR1 AR2	Z De Vont	escription Mises Stress Mass	Definition Constraint Objective	Goal LE MIN	Weight/Limit Value 114. 1.		
2 erformance Ir No 1 2	AR AR AR1 AR2	De Vont	escription Alises Stress Mass	Definition Constraint Objective	Goal LE MIN	Weight/Limit Value 114. 1.		
2 erformance Ir No 1 2 SAO Initial DOE N	AR AR AR AR1 AR2 Incomplete S	De Vont	escription Alses Stress Mass Design -2	Definition Constraint Objective	Goal LE MIN	Weight/Limit Value 114. 1.		
2 erformance la No 1 2 SAO SAO Meta - Mode	AR AR AR AR AR AR2 Itthod Incomplete S	imall Composite	Aises Stress Mass Design -2 el(Multi-Quadratic)	Definition Constraint Objective Polynomi	Goal LE MIN nal Type	Weight/Limit Value 114. 1. Auto		
2 erformance It No 1 2 SAO Initial DOE N Meta - Mode Initial Sampl	AR AR AR AR AR AR2 Itethod Incomplete S I Radial Basis e Runs 9	imall Composite Functions Mode SAO	Alses Stress Mass Design -2 el(Multi-Quadratic) 5(0)	Definition Constraint Objective Polynomi Total Eval	Goal LE MIN nal Type uations	Weight/Limit Value 114. 1. Auto 14		
2 erformance Ir No 1 SAO SAO Initial DOE N Meta - Mode Initial Sampl Optimal Des	AR AR AR AR1 AR2 Incomplete S It Radial Basis e Runs 9 E:SVN/GT/Tr	imall Composite Functions Mode SAO unk'AddFile\Tut	Alses Stress Mass Design -2 el(Multi-Quadratic) 5(0) orial\10.AutoDesign	Definition Constraint Objective Polynomi Total Eval	Goal LE MIN nal Type uations odShape\Con	Weight/Limit Value 114. 1. 1. Auto 14 nnectingRodShape_Ch4_		

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!