

Landing Gear System Tutorial (AutoDesign)





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Edition Note

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

Table of Contents

Landing Gear System Design Problem	4
Loading the Model and Playing a Control System	5
Defining the design variables	7
Defining the Analysis Responses	8
Running a Design Optimization1	.1
Comparison of analysis results1	.5



Landing Gear System Design Problem

RecurDyn provides the CoLink module that is used to model a control system. If you use CoLink in RecurDyn, you will make an approximate model for control system. That means that the CoLink can directly control the RecurDyn model. Thus, if the RecurDyn model is fully validated, this approach can be a virtual control system. Suppose that a PID controller system controls the actuating force of a landing gear system. The goal of



controller is to move the wheel into the bay and make it to be stable in 2 seconds.

As the CoLink directly uses the Parametric Values defined in RecurDyn, all gain values can be defined by using the parametric values. Also, the goal of control system can be represented by the Expressions. Thus, AutoDesign can find the optimal gain values easily to satisfy the goal of control system.

Open files related in Sample-F					
Comple	1	<install dir=""> \Help\Tutorial\AutoDesign\AutoDesign_F\Examples\Sample_F.rdyn</install>			
Sample	2	<install dir=""> \Help\Tutorial\AutoDesign\AutoDesign_F\Examples\Sample_F.clk</install>			
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Note: If you change the file path at discretion, it can be located in any folder that you specify.

Chapter

Loading the Model and Playing a Control System

To load the base model and view the animation:

- 1. On your Desktop, double-click the **RecurDyn** software.
- 2. RecurDyn starts and the **Start RecurDyn** dialog box appears.
- 3. Close **Start RecurDyn** dialog box. You will use an existing model.
- 4. In the Quick Access toolbar, click the **Open** and select `**Sample_F.rdyn**' from the same directory where this tutorial is located.
 - 5. The landing gear system appears on the window.

Start RecurDyn		×
∼ New Model – Name Unit <u>G</u> ravity	Modeff MMKS(Millimeter/Kilogram/Newton/Second) v -Y v	Setting Setting
Open Model Recent Mode	ls	Browse
Show 'Start	RecurDyn' Dialog when starting	



In the CoLink tab, click the Run CoLink icon. Then, the CoLink appears. In the toolbar, click open tool and select 'Sample_F.clk' from the same directory where 'Sample_F.rdyn' is located.





►

Run

7. Click the **Start** button in the **CoLink**.

8. Click the **Play** button in the **RecurDyn**.

The landing gear system moves into the bay. If not, the CoLink model is not connected to RD model. Retry to load CoLink Model or push the **Connect CoLink** button on **CoLink**



Defining the design variables

The design variables are the gain values of PID controller. Thus, create the three parameters and define the initial values.

Switch the window to **CoLink** window. Then, the three parameters are shown in the data base window. Next, you can link the parametric variables to P, I, and D gains, which is shown by the following Figure.

Desig	n Parai	meter L	ist							
Desig	ın Param	eter								
٩	Name	Туре	Prop.	Descripti	Curr	LB	UB	Design Cost	DP Form	DV
1	DP1	Direct		P_Gain	20.	1.	40.	0.	Value	
2	DP2	Direct		I_Gain	20.	0.	40.	0.	Value	✓
3	DP3	Direct		D_Gain	20.	0.	40.	0.	Value	
										v V
	Create		Insert	Direct	t Relatio	n		↓	Delete	
								ОК	Cancel	Apply



Now, click the **Design Parameter** icon and link the three parametric variables to the design parameters. The lower and upper bounds are arbitrarily selected except the P-Gain. In general, as P-Gain should be used conceptually, its lower bound is set to **'1**'.



Defining the Analysis Responses

The Plant represents the system model to be controlled. Thus, the Plant Input is the output of the controller and the Plant Output becomes the input responses for the controller.

In this model, the Plant Input is the axial force of the nose gear strut and the Plant Output is the relative position and the relative velocity between the wheel center and the target position along the vertical direction.

Properties of Axial1 [Current Unit : N/kg/mm/s/dec General Connector Axial Type Standard Axial Force Expression Name Ex1 EL Expression	
PIN(1) Force Display Inactivate Force Display Control of Cancel	

In order to link the **Plant Input** to the axial force, first, the **Plant Input** is represented by the Expression. Next, the **Expression** is used to define the axial force.

Also, the **Expression** is required to define the **Plant Output**. For more information of **CoLink**, refer to the **CoLink manual**.

The goal of controller is to minimize deviation between the wheel center and the target position in 2 second. The initial gain values give the following result. The deviation is not zero in 5.0 second.



Now, let's consider the design optimization problem:

Minimize the deviation in 2.0 second to satisfy the goal of controller.

For safety, the maximum transient response of the deviation should not hit the upper wall of the bay.

For manufacturing, the Plant Input should be less than a limit value.

Although the deviation is minimized, it is not guarantee that the value goes to zero. Thus, in order to enforce the deviation, go to zero, the following additional constrain is introduced.

The end value of the deviation should be zero.

Let's consider the Expression to represent the design formulation and define the Analysis Responses.

- 1. Define the deviation by using the Expression. The **STEP** function is used to filter the values only in **2.0 second**.
- 2. List the Expression. Among the Expressions, Ex1 is the Plant Input. Ex4 is the deviation between the wheel center and the target position. Ex5 is the filtered response of Ex4.
- 3. Next, create the **Analysis Response** as follows:

Vame	Ex5		
DY(1,2)* <u>S</u>	TEP(TIME, 1.99,0,2.0, 1)		
Available	Function expressions π Fortran 77 Functions π Simulation constants	Argument List ID Entity 1 nosegear.POINT1 2 nosegear.POINT2	
	gc Displacement gc Velocity gc Acceleration RG Generic force RG Specific force RG State element		

AR name	Expression name	Treatment
AR1	Ex4	Max Value
AR2	Ex1	Max Value
AR3	Ex5	RMS Value
AR4	Ex4	End Value

The detailed information between ARs and Expressions are listed as:

Chapter

Running a Design Optimization

The optimization problem is defined as: Minimize the RMS of the Deviation subject to

- The Maximum Peak of Transient response of the Deviation =< Limit value
- The Plant Input =< Limit Value
- The end value of Transient response of the deviation = 0
- 1. Click the **Design optimization** icon. Then, you can see the design variable list as below figure:

D	esign Op	otimization								
D	esign Var	iable Performance	Index Optimization	Control	Result Sheet	Summary Sheet				
	DV	DP	Description	Curre	nt LB	UB	Туре		Value	
	1	DP1	P_Gain	20.	1.	40.	Variable	-	0.	
	2	DP2	l_Gain	20.	0.	40.	Variable	-	0.	
	3	DP3	D_Gain	20.	0.	40.	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 **PI**s.

D	esign O	otimiza	ation								
Į	Design Va	riable	Performar	ice Ir	Optimization Cor	ntrol	Result Sheet	Summ	ary Sheet		
l	PI	Use	AR		Description		Definition		Goal		Weight/Limit Value
	1		AR3	-	Over Shooted Resp		Objective	•	MIN	-	1.
L	2		AR1	•	Y_Deviation Betwee		Constraint	-	LE	-	50.
	3		AR4	•	End_Response		Constraint	-	EQ	-	0.
	4		AR2	•	Plant Input 1		Constraint	-	LE	-	40000.

3. Click the **Optimization Control** tab. All the convergence tolerances use the default values. It is important to check the time step in Analysis setting before clicking the **Execution** button. Especially, when the **CoLink** is used, the sampling time step of dynamic analysis is equal to that of the **CoLink**.

Design Optimization	
Design Variable Performance Index Optimization Control Resul	t Sheet Summary Sheet
DOE Meta Modeling Methods	Methods
Convergence Tolerance	
Objective Change Rate in Consecutive Iterations	5.e-02
Equality Constraints	1.e-02
Inequality Constraints	1.e-03
Maximum Iteration of SAO	30.
Convergence Relaxation Control	OFF 💌
Simulation Type	Dynamic/Kinematic 💌
Save Results ISCD2	Number of Trials 5
Analysis Setting	Execution
·	OK Cancel Apply

4. Click the **Analysis Setting** button. Then, you can see the following information. The **End time** is **5 second** and the **number of Step** is **500**. Thus, The Expression values are nearly evaluated at the time interval of 0.01 second.

Dynamic/Kinematic Analysis		×
General Parameter Initial Con	dition	
End Time	5.	Pv
Step	500.	Pv
Plot Multiplier Step Factor	1.	Pv
Output File Name	ISCD2_DO	

5. Switch the window into the CoLink. Then, double click the **RecurDyn Plant**. Then, the sample time appears in the pop-up window. Both sample time should be equal. For more information, refer to the **CoLink manual**.



6. Click the **Execution** button. Check the **Execution** dialog box. If all selections are correct, then click the **OK** button.

No	DV	Description	Current	LB	UB	Туре	Value			
1	DP1	P_Gain	20.	1.	40.	Variable	e 0.			
2	DP2	I_Gain	20.	0.	40.	Variable	e 0.			
3	DP3	D_Gain	20.	0.	40.	Variable	e 0.			
form No	ance Index	es AR	Description	n	Definition	Goal	Weight/Limit Value			
1		AR3	Over Shooted Response in		Objective	MIN	1.			
2		AR1	Y_Deviation Betwee	Y_Deviation Between Nose		LE	50.			
3		AR4	End_Respon	End_Response		EQ	0.			
4		AR2	Plant Input	Plant Input 1		LE	40000.			
ta - N	Model									
In	nitial DOE N	Method	In	ncomplete S	mall Composite I	Design -2				
M	eta-Model	Method	Radial Basis Functions Model(Multi-Quadratic)							
	Polynomina	al Type	Auto							
	Trial M.	0			5					

 If the optimization is completed, then click the **Result Sheet** tab. The optimization runs 19 iterations. The final values of ARs are (2.062, 35681.28, 0.7808, -1.59e-003). The number of total analyses is only 24 including the initial sampling analyses. Next, see the **Summary Sheet**.

	iable Performance Inc	dex Optimization Co	ntrol Result Sheet	Summary Shee	t		
ptimizat	ion History of AR Value	s					
No	AR1	AR2	AR3	A	R4	Violation	
16	3.18617392159194	35821.0726444291	0.75085473713	8167 0.347494	381559045	0.337494381559045	
17	1.92983454828777	35674.2580311022	0.82774563523	6.983268	79264641e-	5.98326879264641e-	
18	2.16581475915291	35696.6274403635	0.7817739549	752 6.010016	50445596e-	5.01001650445596e-	
19	2.06269622424156	35681.2836928225	0.78084477817	2767 -1.59446	00434068e-	0.	
2 Pa	🗠 🕰 💽 🎕 🛙	I 🗘 🕀 🎯 🕸	1 E 🕺 🏁	1			- -
1300 1200 1100 900 800 600 500 400 300 200 100	0.00 0.00		9 10 11 12 1 A0 Iteration	3 14 15 16		 Normalized Object Maximum Violation 	t
ign Op ign Var	ntimization iable Performance In-	dex Optimization C	ontrol Result Shee	et Summary She	et	Cancel App	oly
ign Op sign Var esign Va	timization iable Performance In ariables	dex Optimization C	ontrol Result Shee	et Summary She	et		ply
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Comparison of analysis results

Let's compare the animations for the initial and the final design. The initial design uses the gain values as (**20, 20, 20**). The final design gives an optimal gain value set as (**9.529, 25.149, 27.872**). Figure F-5-1 shows the animation result for the initial design.



Figure F-5-1 The animation result for the initial design

Next, Figure F-5-2 shows the animation result for the final design. This design moves the wheel center position more up than the initial one.



Figure F-5-2 The animation result for the final design

Figure F-5-3 compares the deviation responses for the initial design and the final design. The red line is the final design. The blue line is the initial design. After 2.0 second, the final design makes the deviation to be zero.



Figure F-5-3 Comparison of the deviation responses

Thanks for participating in this tutorial!