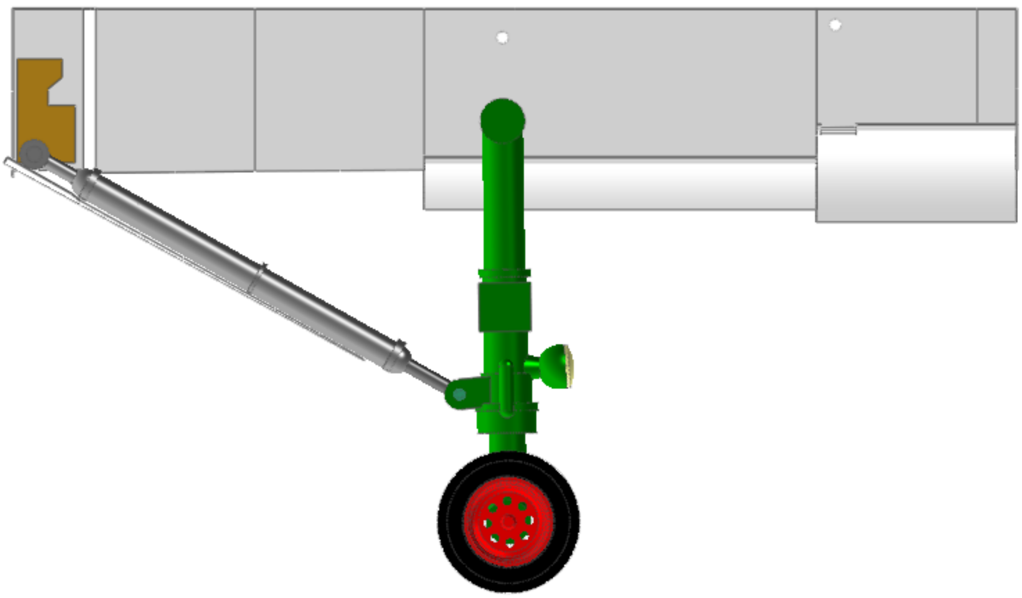
Landing Gear System Tutorial (AutoDesign)



FunctionBay

Edition Note

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

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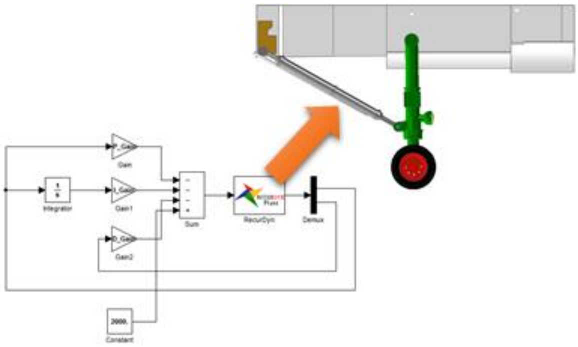
F

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.

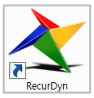
Open files related in Sample-F		
Sample	1	<Install Dir> \Help\Tutorial\AutoDesign\AutoDesign_F\Examples\Sample_F.rdyn
	2	<Install Dir> \Help\Tutorial\AutoDesign\AutoDesign_F\Examples\Sample_F.clk
Solution	1	<Install Dir> \Help\Tutorial\AutoDesign\AutoDesign_F\Solutions\Sample_F.rdyn
	2	<Install Dir> \Help\Tutorial\AutoDesign\AutoDesign_F\Solutions\Sample_F.clk

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

Chapter 1

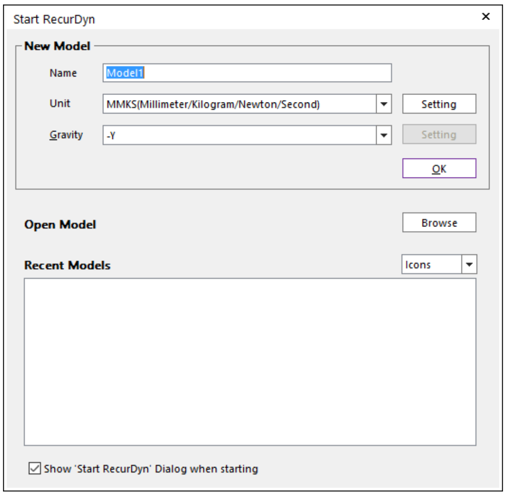
Loading the Model and Playing a Control System

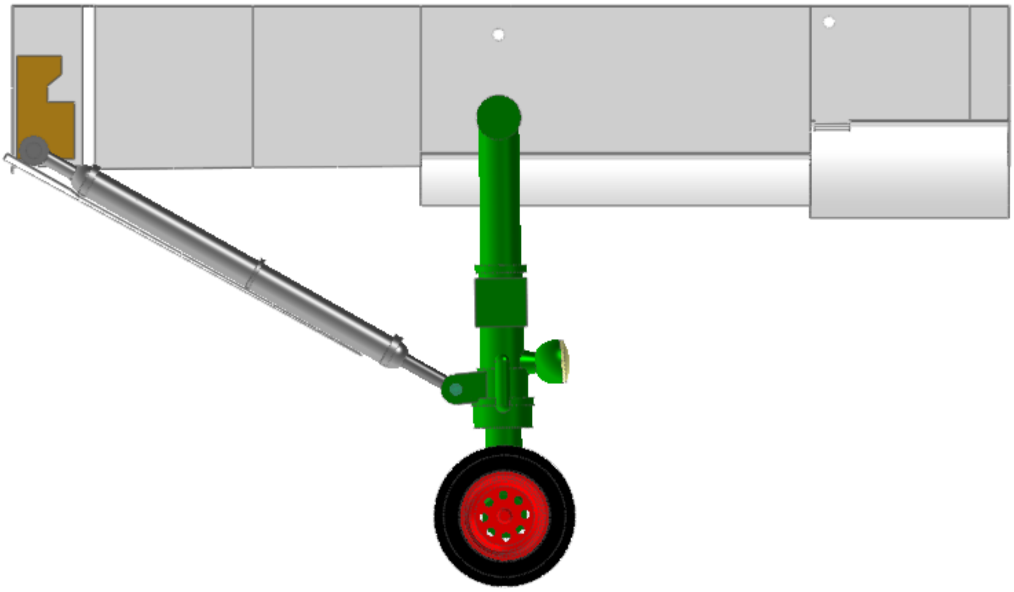
To load the base model and view the animation:



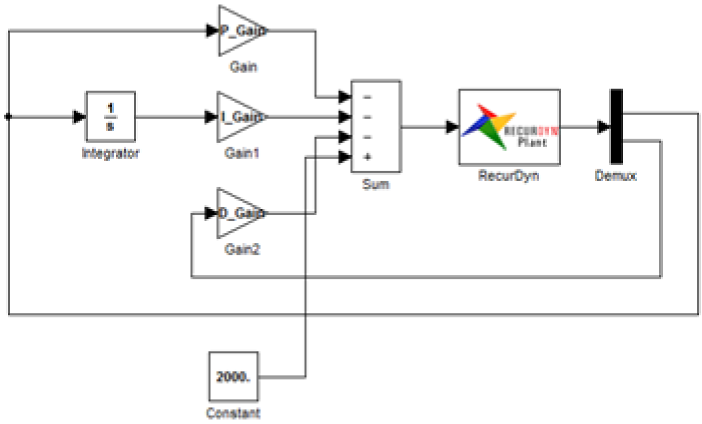
1. On your Desktop, double-click the **RecurDyn** software.
2. RecurDyn starts and the **Start RecurDyn** dialog box appears.
3. Close **Start RecurDyn** dialog box. You will use an existing model.

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.





6. 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.



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

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

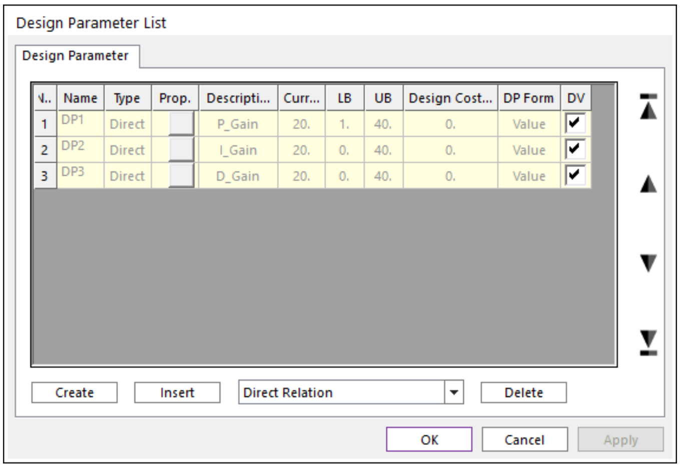
The landing gear system moves into the bay. If not, the CoLink model is not connected to RD model. Retry to load CoLink Model or push the **Connect CoLink** button on **CoLink**

Chapter

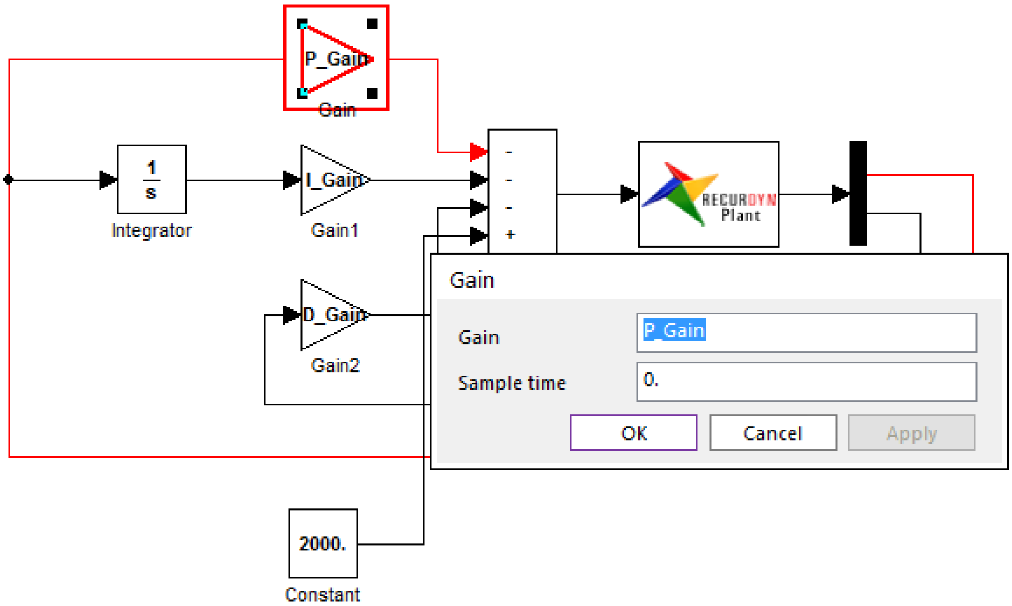
2

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.



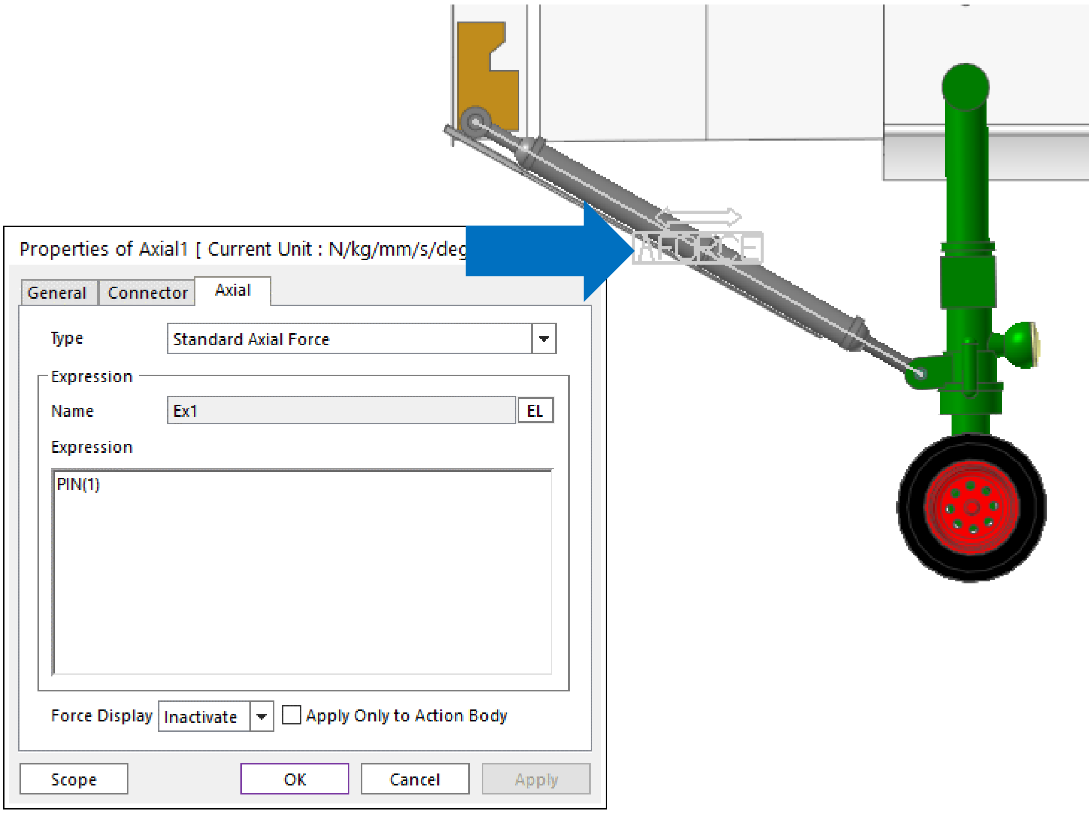
Now, click the **Design Parameter** icon and link the three parametric variables to the design parameters. The lower and upper bounds are arbitrarily selected except the P-Gain. In general, as P-Gain should be used conceptually, its lower bound is set to '**1**'.

Chapter 3

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.

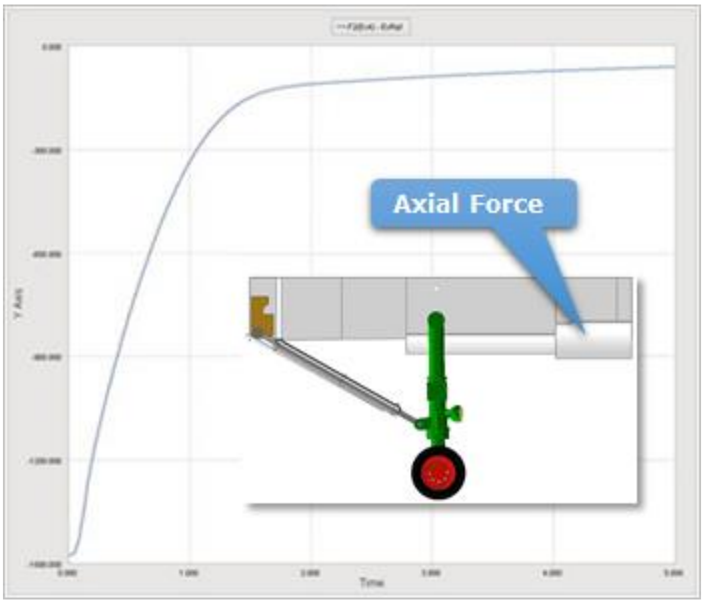
In this model, the Plant Input is the axial force of the nose gear strut and the Plant Output is the relative position and the relative velocity between the wheel center and the target position along the vertical direction.



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.

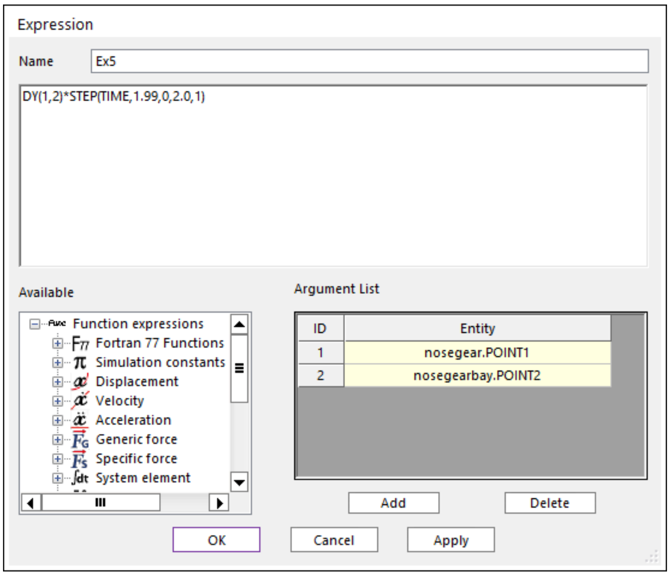
For manufacturing, the Plant Input should be less than a limit value.

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:



The detailed information between ARs and Expressions are listed as:

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

Chapter 4

Running a Design Optimization

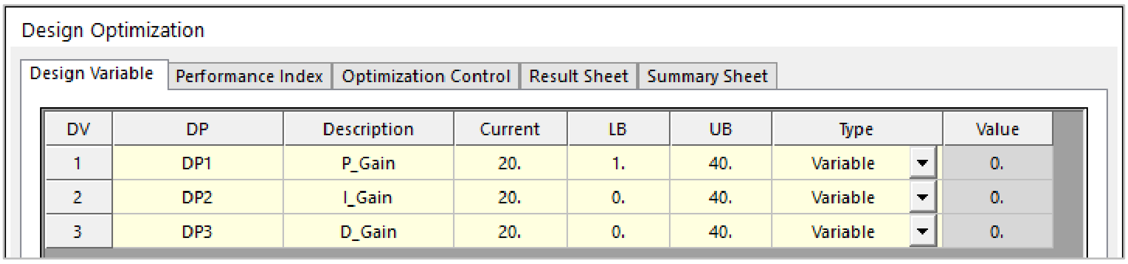
The optimization problem is defined as:

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:

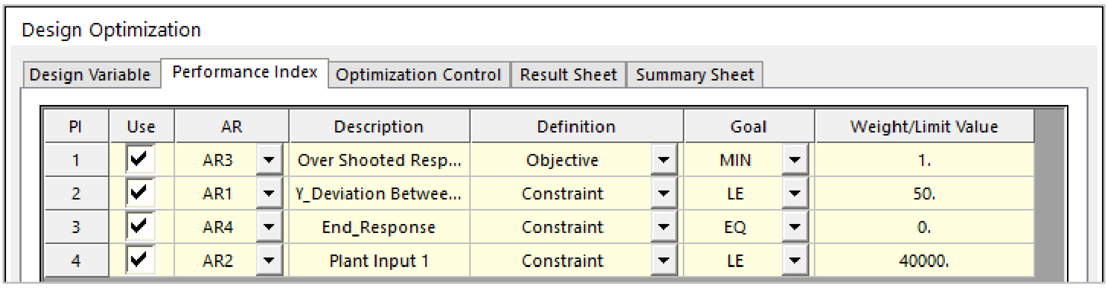


Design Optimization

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

DV	DP	Description	Current	LB	UB	Type	Value
1	DP1	P_Gain	20.	1.	40.	Variable	0.
2	DP2	I_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.

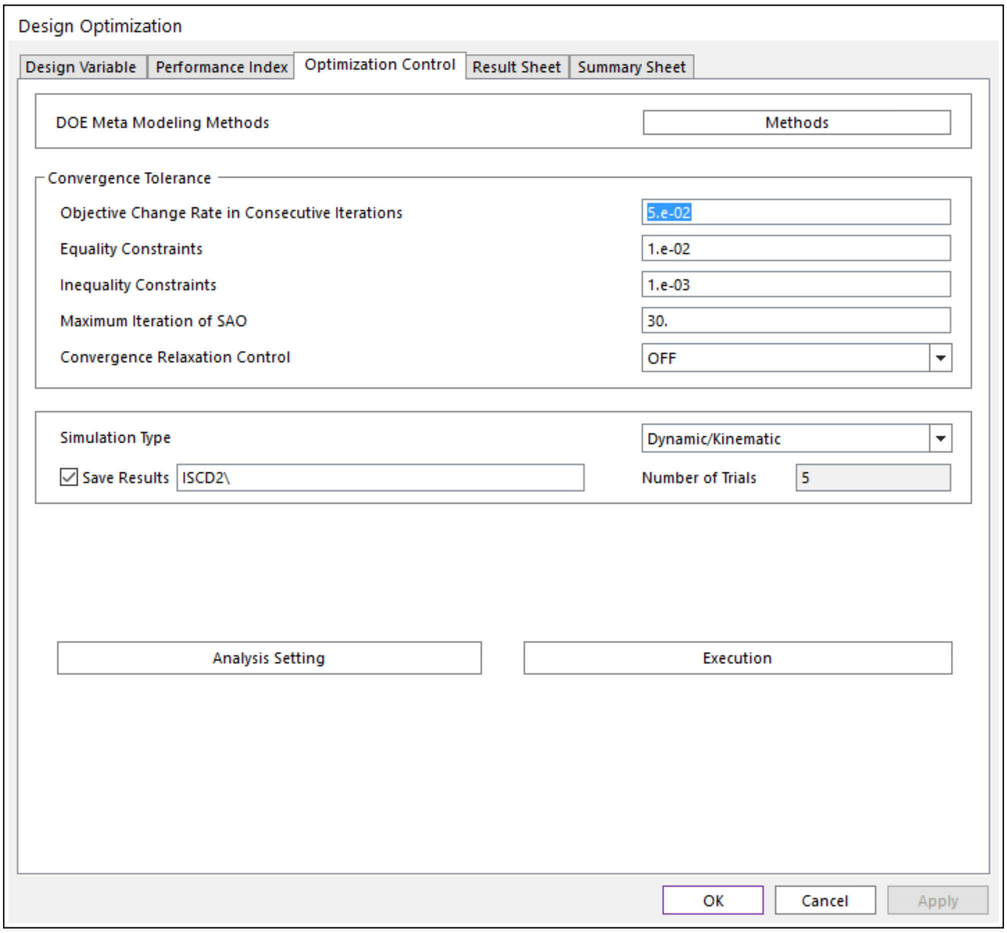


Design Optimization

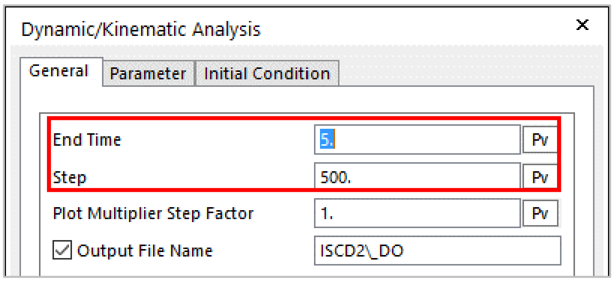
Design Variable | Performance Index | Optimization Control | Result Sheet | Summary Sheet

PI	Use	AR	Description	Definition	Goal	Weight/Limit Value
1	✔	AR3	Over Shooted Resp...	Objective	MIN	1.
2	✔	AR1	Y_Deviation Betwee...	Constraint	LE	50.
3	✔	AR4	End_Response	Constraint	EQ	0.
4	✔	AR2	Plant Input 1	Constraint	LE	40000.

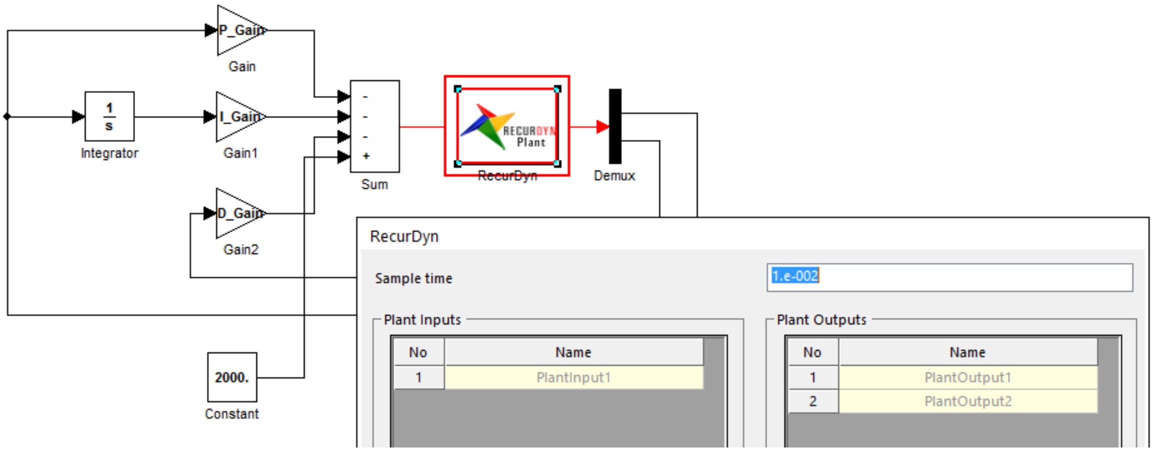
3. Click the **Optimization Control** tab. All the convergence tolerances use the default values. It is important to check the time step in Analysis setting before clicking the **Execution** button. Especially, when the **CoLink** is used, the sampling time step of dynamic analysis is equal to that of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



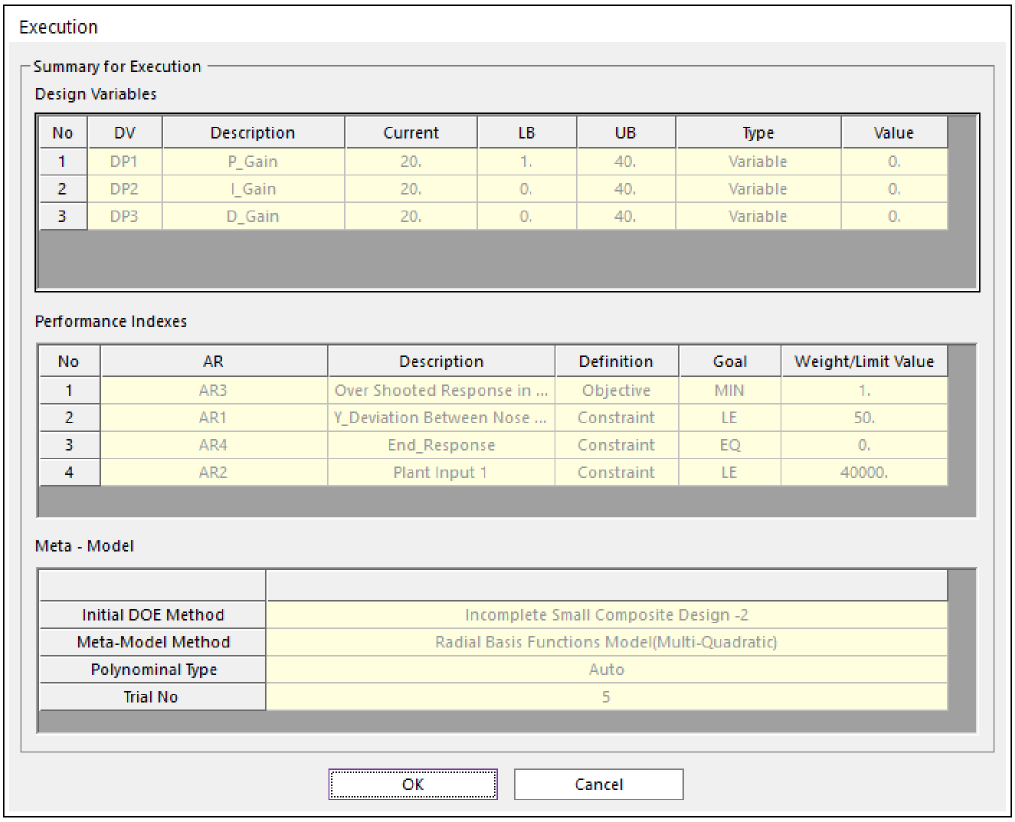
4. Click the **Analysis Setting** button. Then, you can see the following information. The **End time** is **5 second** and the **number of Step** is **500**. Thus, The Expression values are nearly evaluated at the time interval of 0.01 second.



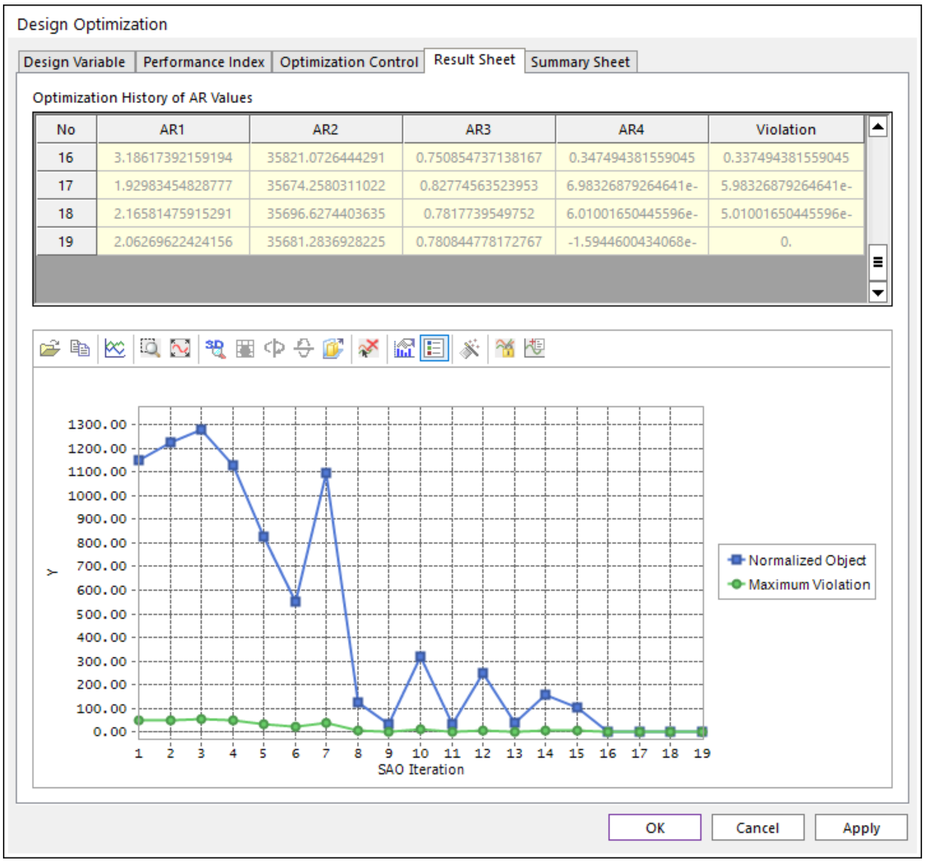
5. Switch the window into the CoLink. Then, double click the **RecurDyn Plant**. Then, the sample time appears in the pop-up window. Both sample time should be equal. For more information, refer to the **CoLink manual**.

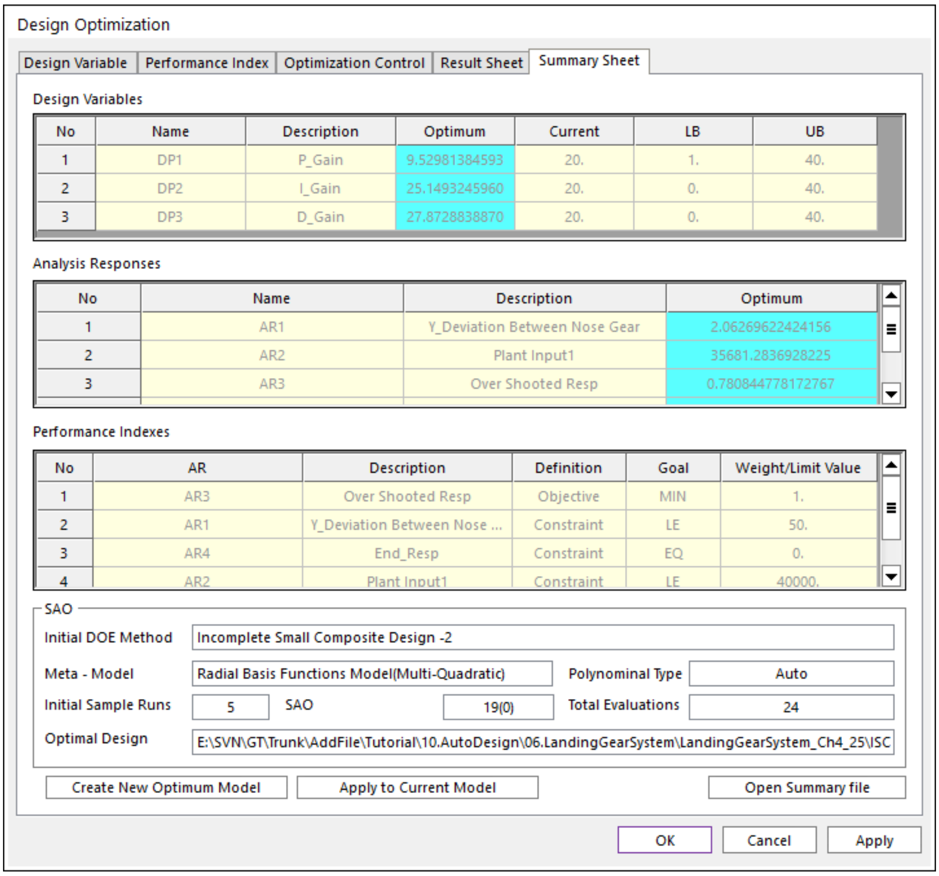


6. Click the **Execution** button. Check the **Execution** dialog box. If all selections are correct, then click the **OK** button.



7. 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**.


Design Optimization
Design Variable
Performance Index
Optimization Control
Result Sheet
Summary Sheet
Optimization History of AR Values
No | AR1 | AR2 | AR3 | AR4 | Violation
16 | 3.18617392159194 | 35821.0726444291 | 0.750854737138167 | 0.347494381559045 | 0.337494381559045
17 | 1.92983454828777 | 35674.2580311022 | 0.82774563523953 | 6.98326879264641e- | 5.98326879264641e-
18 | 2.16581475915291 | 35696.6274403635 | 0.7817739549752 | 6.01001650445596e- | 5.01001650445596e-
19 | 2.06269622424156 | 35681.2836928225 | 0.780844778172767 | -1.5944600434068e- | 0.
Normalized Object
Maximum Violation
Y
SAO Iteration
OK
Cancel
Apply


Design Optimization
Design Variable
Performance Index
Optimization Control
Result Sheet
Summary Sheet
Design Variables
No | Name | Description | Optimum | Current | LB | UB
1 | DP1 | P_Gain | 9.52981384593 | 20. | 1. | 40.
2 | DP2 | I_Gain | 25.1493245960 | 20. | 0. | 40.
3 | DP3 | D_Gain | 27.8728838870 | 20. | 0. | 40.
Analysis Responses
No | Name | Description | Optimum
1 | AR1 | Y_Deviation Between Nose Gear | 2.06269622424156
2 | AR2 | Plant Input1 | 35681.2836928225
3 | AR3 | Over Shooted Resp | 0.780844778172767
Performance Indexes
No | AR | Description | Definition | Goal | Weight/Limit Value
1 | AR3 | Over Shooted Resp | Objective | MIN | 1.
2 | AR1 | Y_Deviation Between Nose ... | Constraint | LE | 50.
3 | AR4 | End_Resp | Constraint | EQ | 0.
4 | AR2 | Plant Input1 | Constraint | LE | 40000.
SAO
Initial DOE Method
Incomplete Small Composite Design -2
Meta - Model
Radial Basis Functions Model(Multi-Quadratic)
Polynominal Type
Auto
Initial Sample Runs
5
SAO
19(0)
Total Evaluations
24
Optimal Design
E:\SVN\GT\Trunk\AddFile\Tutorial\10.AutoDesign\06.LandingGearSystem\LandingGearSystem_Ch4_25\ISC
Create New Optimum Model
Apply to Current Model
Open Summary file
OK
Cancel
Apply

Chapter

5

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.

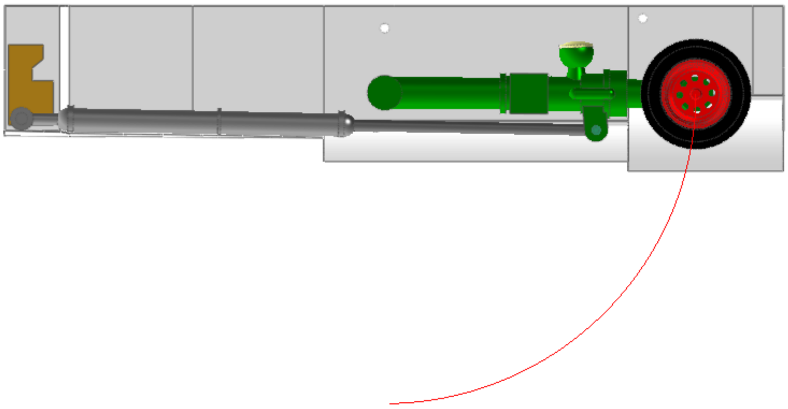


Figure F-5-1 The animation result for the initial design

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.

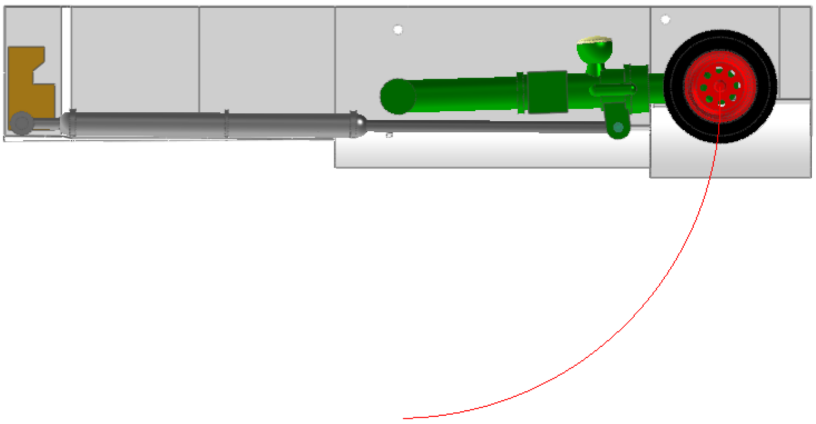


Figure F-5-2 The animation result for the final design

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.

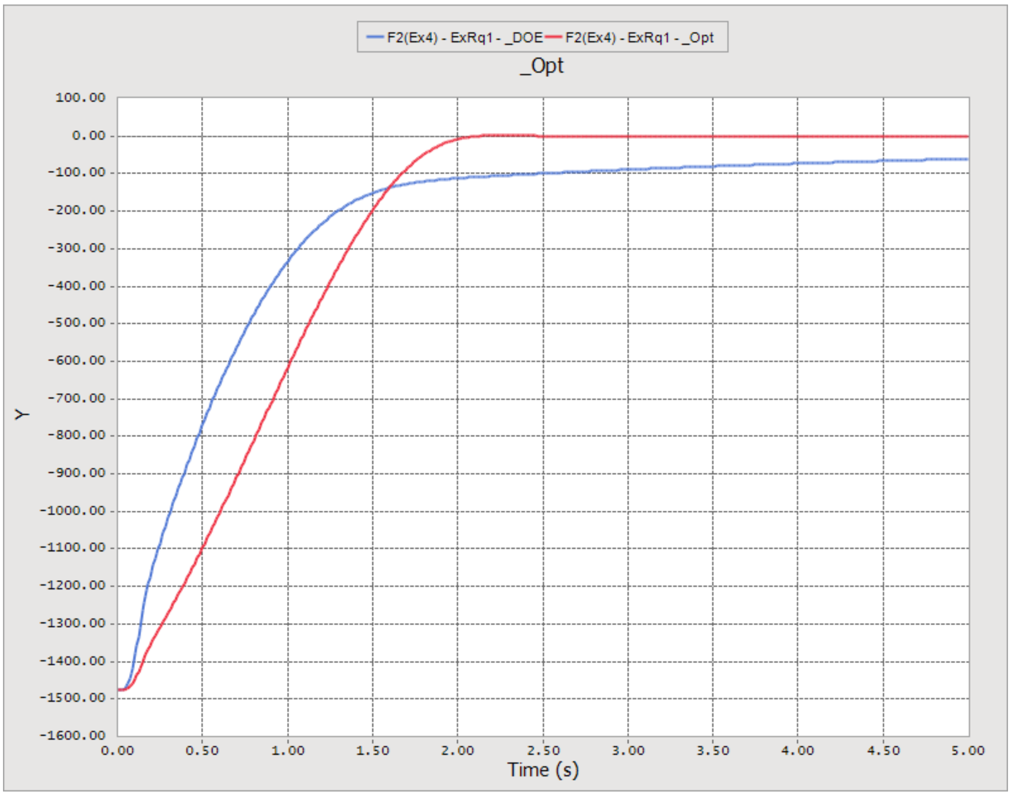


Figure F-5-3 Comparison of the deviation responses

Thanks for participating in this tutorial!