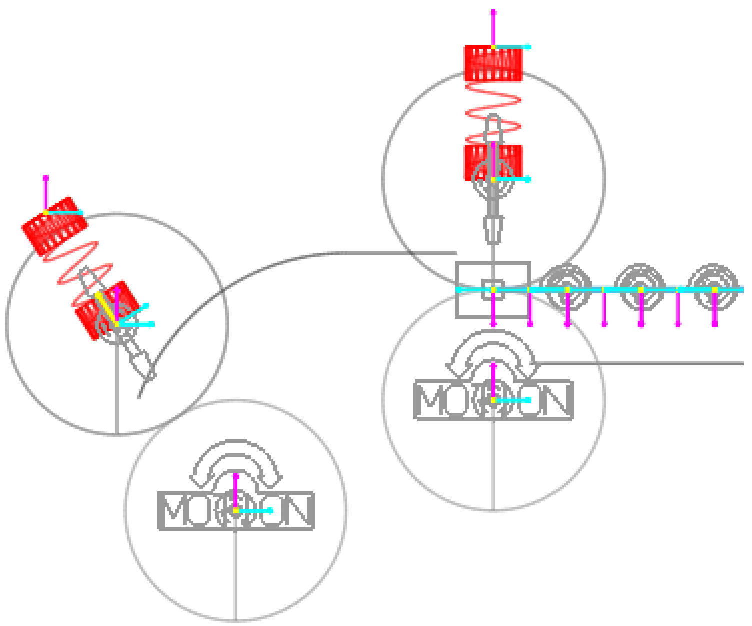
Media Transport System with Design Study Tutorial (MTT2D)



Edition Note

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

Table of Contents

Chapter

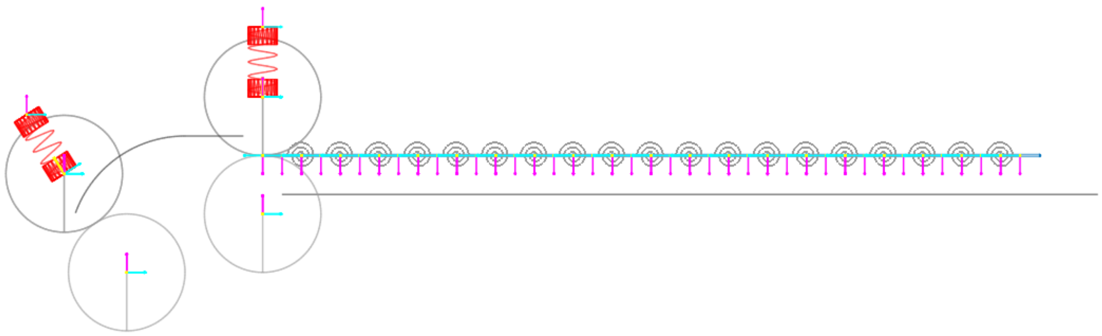
1

Getting Started

Objective

This tutorial will help you learn how to use the design study capability of **RecurDyn** with the **2D Media Transport Toolkit** (**MTT2D**). You will learn how to create design variables from parametric values and how to define performance indices. This tutorial uses the basic model defined in the first **MTT2D** tutorial as shown in the figure below. It contains three cases, each of which is progressively more sophisticated:

- In the first case, you perform a simple design study with a single parameter to analyze the effect of paper thickness.
- In the second case, you perform a design of experiments, which lets you analyze two variables: paper thickness and curl.
- In the third case, you also consider the x and y locations of two of the guides.



Audience

This tutorial is intended for experienced users of **RecurDyn** who previously learned how to create geometry, joints, force entities, and 2D contacts. All new tasks are explained carefully.

Prerequisites

You should first work through the 3D Crank-Slider, Engine with Propeller, and Pinball (2D contact) tutorials, or the equivalent. We assume that you have a basic knowledge of physics.

Procedures

The tutorial is comprised of the following procedures. The estimated time to complete each procedure is shown in the table.

Procedures	**Time (minutes)**
Simulation environment set up	10
Case 1: Parametric Study of Paper Thickness	20
Case 2: Design of Experiments with Paper Thickness and Curl	30
Case 3: Design of Experiments with a Moving Guide Assembly	45
Total	**105**

Estimated Time to Complete

60 minutes

Chapter

2

Setting Up Your Simulation Environment

Task Objective

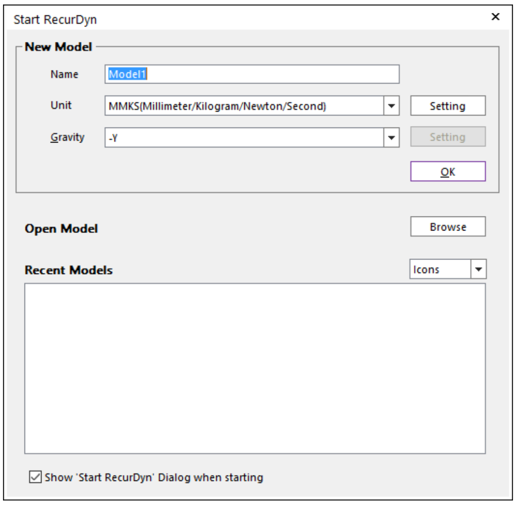
Learn how to set up the simulation environment and adjust the MTT2D model for the design studies

Estimated Time to Complete

10 minutes

Starting RecurDyn

To start RecurDyn and create a new model:



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

   RecurDyn starts and **Start RecurDyn** dialog box appears.

2. Exit the **Start RecurDyn** dialog box.
3. Open a copy of the RecurDyn model file that you created in the first **MTT2D** tutorial, and save it to a new file name, such as **MTT2D_DOE.rdyn**.
4. Enter the **MTT2D** subsystem by doing one of the following:
   - In the Database window, right-click MTT2D1 subsystem and select Edit.
   - In the modeling window, double-click the MTT2D subsystem geometry.

Adjusting the MTT2D Model from the First MTT2D Tutorial

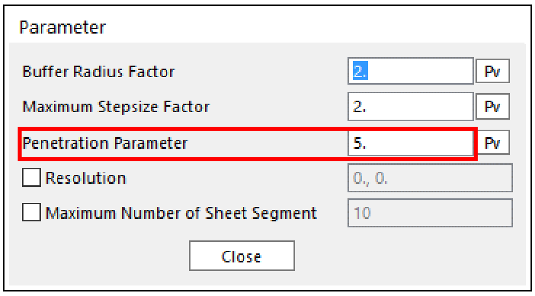
In this section, you will adjust the model you created for the first MTT2D tutorial by changing.

- The motion to move the rollers 20 times faster.
- The penetration parameter to 5 from the default of 2.

The penetration parameter is a scale factor used to set the guide contact to continue to act while the sheet penetrates a depth of the sheet thickness multiplied by the penetration parameter. You need a larger penetration parameter because of the increased sheet speed.

To adjust the model:

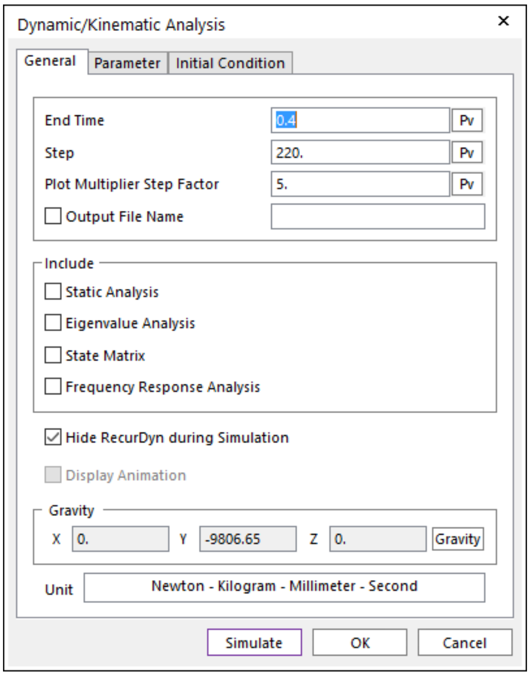
1. In the Database window, under the **Expression** category, right-click **Ex1**, and click **Properties**.
2. Adjust the motion expression to move the rollers 20 times faster by changing it to **40*TIME** rather than 2*TIME. Note that this change will affect both RevJoint20 and RevJoint22 because both of these joints reference EX1.
3. Display the Properties dialog box for the **MTT2DAssembly1** (last item in the Database window) and do the following:
   - In the **Contact List** tab, click **Parameter**.
   - Adjust the **Penetration Parameter** to **5**.



4. Display the **Dynamic/Kinematic** Analysis dialog box and set.
   - **End Time to 0.4**
   - **Step to 220**
   - **Plot Multiplier to 5**

   You can run the simulation for a shorter time because of the faster sheet speed.

5. Click **OK** to save the parameters and exit the dialog box.



Chapter

3

Case 1: Parametric Study of Paper Thickness

In this chapter, you will perform a parametric study to determine the effect paper thickness has on the behavior of the paper in the MTT2D model. The **RecurDyn** simulation results will show the results that are to be expected: that the paper sticks out more to the left as the paper thickness increases (less drooping of the paper).

Task Objective

Learn to:

- Set parametric and design variables
- Set the performance index, the simulation output that you will track
- Run a design study

Estimated Time to Complete

20 minutes

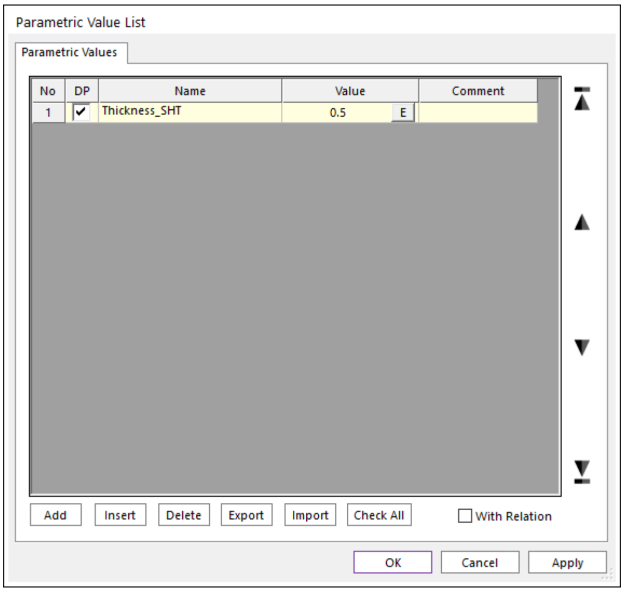
Setting Up the Parametric Variable for Paper Thickness

Your first step is to set up the parametric variable for paper thickness. This replaces the value of paper thickness with a variable.

To set up the parametric variable:

1. Display the Properties dialog box for the group, **SheetGroup1**.
2. In the **Sheet Group** tab, clear the **Sheet Thickness** check box. Then, click **Pv** (Parametric Value) next to **Sheet Thickness**.
3. In the **Parametric Value List** dialog box, click **Add**.
4. Set the parametric value name to **Thickness_SHT** and the value to **0.5**.
5. Click **OK** to exit the **Parametric Value List** dialog box.

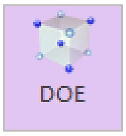
   The parametric value name appears in the Sheet Thickness text box in place of the value that was there previously.
6. Click **OK** to exit the **SheetGroup1 Properties** dialog box.



Setting Up the Design Variable for Paper Thickness

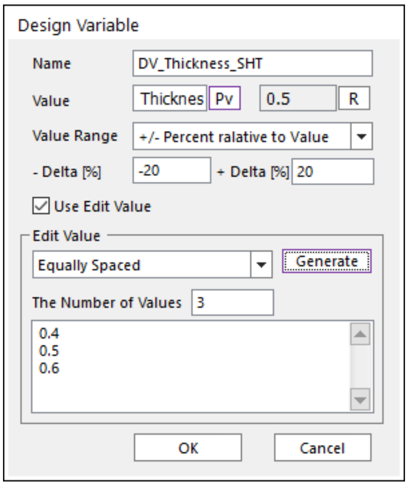
Now you will set the design variable for paper thickness based on the parametric value you just created for paper thickness. As you run the design study, **RecurDyn** varies this variable to find the optimum thickness for paper.

To set the design variable:



1. From the **Simulation Type** group in the **Analysis** tab, click **Design Study(DOE)**.
2. Under the **Design Variables** section, click **Add**.
3. In the **Design Variable List** dialog box, click **Create**.
4. In the **Design Variable** dialog box, next to the **Value** text box, click **Pv**.
5. Select the **Thickness_SHT** parametric value and click **OK**.
6. Set the name of the design variable to **DV_Thickness_SHT**.
7. The **Value Range** should be at its default setting of **+/- Percent relative to Value**.
8. Set the **Delta** values to be **-20%** and **+20%**

9. Check **Use Edit Value**.
10. Set **Edit Value** to **Equally Spaced** and set the **Number of Values** text box to **3**.
11. Click **Generate** and you should see the values of 0.4, 0.50, and 0.6.
12. Click **OK** to close the **Design Variable** dialog box and return to the **Design Variable List** dialog box.
13. Make sure that **Design Variable No. 1** is selected in the **Design Variable List** and click **OK** to close the dialog box and return to the **Design Study** dialog box.



Setting Up the Performance Index

For this simple example, you will track the minimum x value of the leading point of the sheet. This will be your performance index and will tell you how far the sheet extends to the left as it exits the second nip pair.

To set the performance index:

1. In the **Design Study** dialog box, under the Performance Indexes section, click **Add**.
2. In the **Performance Index List** dialog box, click **Add**.
3. In the **Performance Index List** dialog box, set the name of the **Performance Index to PI_Reach**.
4. Set **Type** to **Min Value**.
5. Click **EL** to open the **Expression List**.
6. Click **Create**.
7. Set the expression name to **SHT_Reach_Exp**.
8. Under the **Argument List** section, click **Add**.
9. In the Database window, expand **Bodies** → **SheetBody1** → **Markers**.
10. Drag **Marker3** into the text box with the ID of 1 under the Argument list.
11. Enter the expression **DX(1)**.

    The DX function with one argument outputs the displacement of the marker in the x-axis of the global coordinate system. The number 1 refers to Marker3 because it is in the Argument List with an ID of 1.
12. Click **OK** to exit the **Expression** dialog box.
13. With the **Expression No. 2** selected, click **OK** to exit the **Expression List** dialog box.
14. With the **Performance Index No. 1** selected, click **OK** to exit the **Performance Index List** dialog box.

Setting Up and Running the Design Study

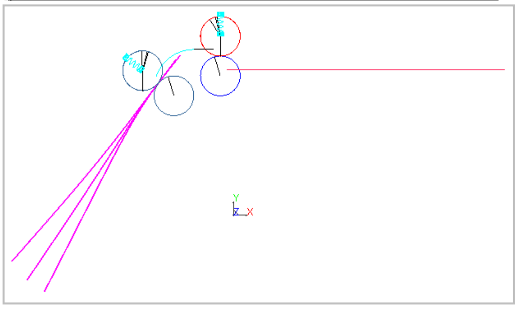
Now you will set up and run the design study. You will run three trials for each value of the design variable.

To set up and run the design study:

1. In the **Design Study** dialog box, notice that.
    - **Parametric Study** is selected because you have a single design variable. If you have two or more design variables, **RecurDyn** automatically selects the Design of Experiments option.
    - The number of levels is set to 3 because you set the number of values for the **DV_Thickness_Sht** design variable to 3.
2. Click **R** to recalculate the number of trials. This should now be 3.
3. Click **Simulate** to run the design study.

    RecurDyn runs three simulations, one for each value of the design variable.
4. In the **Design Study** dialog box, click **Result Sheet** to see a summary of the simulations as shown in the figure to the right. The results show that the paper sticks out more to the left as the paper thickness increases (less drooping because thicker paper is stiffer than thinner paper).

Trial	DV_Thickness_SHT	PI_Reach
1	0.4	-143.276898308807
2	0.5	-156.409655937031
3	0.6	-167.658407171584



5. Click **Close** to close the **Result Sheet**.
6. Click **OK** to close the **Design Study** dialog box

Chapter
4

Case 2: Design of Experimnets with Paper Thickness and Curl

In this chapter, you will run a design of experiments to determine the effect of paper thickness and paper curl. You will only need to create a variable for paper curl because you will use the variable you created for paper thickness in the previous case.

Task Objective

You will:

- Create parametric and design variables for paper curl
- Set up and run a design of experiments

Estimated Time to Complete

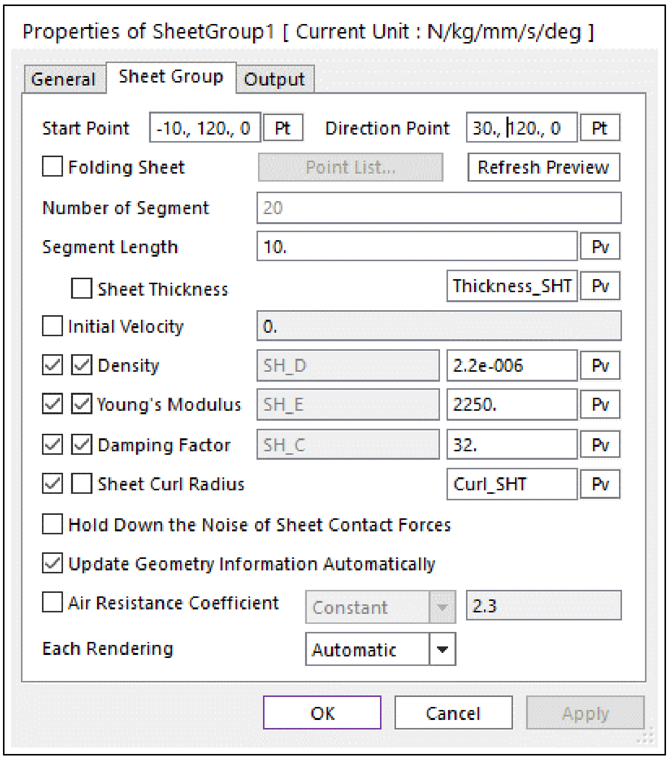
30 minutes

Setting Up the Parametric Variable for Paper Curl

To set up the parametric variable:

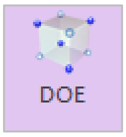
1. Display the Properties dialog box for **Sheet Group1**.
2. In front of **Sheet Curl Radius**, click the first check box and clear the selection of the second check box, as shown in the figure on the right.
3. Click **Pv** (Parametric Value) for Sheet Curl Radius.
4. In the Parametric Value dialog box, click **Add**.
5. Set the parametric value name to **Curl_SHT** and the value to **200**.
6. Make sure the row with the **Curl_SHT** parametric value is selected and click **OK**.

   The parametric value name appears in the **Sheet Curl Radius** text box in place of the value that defined the paper curl previously.
7. Click **OK** to exit the **SheetGroup Properties** dialog box.



Setting Up the Design Variable for Paper Curl

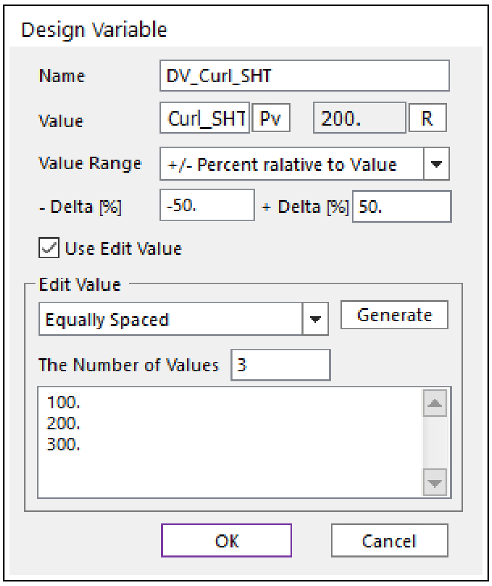
To set up the design variable for paper curl:



1. From the **Simulation Type** group in the **Analysis** tab, click **Design Study**.
2. Under the **Design Variables** section of the **Design Study** dialog box, click **Add**.
3. In the **Design Variable List** dialog box, click **Create.**

4. In the **Design Variable** dialog box, click **Pv**.
5. Select the **Curl_SHT** parametric value and click **OK**.
6. Set the name of the design variable to **DV_Curl_SHT**.
7. Set the **Percent relative to Value** to **-50%** and **+50%**.
8. Click **Use Edit Value**.
9. Set **Edit Value** to **Equally Spaced** and set the number of values in the **Values** text box to 3.
10. Click **Generate**.

    The values 100, 200, and 300 appear.
11. Click **OK** to return to the **Design Variable List** dialog box.



12. Make sure the **DV_Curl_SHT** Design Variable is selected and click **OK** to return to the **Design Study** dialog box.

Setting Up and Running the Design of Experiments

You will set up and run the design of experiments. You will run nine trials, one for each possible combination of values for the two design variables.

To set up and run the design of experiments:

1. Save the **RecurDyn** model file to a new file name, such as **MTT2D_DOE_Curl.rdyn**.
2. In the Design Study dialog box, notice that.
    - Design of Experiments option is selected because you have two design variables.
    - The Number of Levels is set to 3 because you set the number of values for both design variables to be 3.
3. Select **Built-in DOE Techniques** and **Full Factorial** if they are not already selected.
4. Click **R** to recalculate the number of trials.

    The number of trials changes to 9.
5. In the Design Study dialog box, click **Simulate** to run the design of experiments.

    RecurDyn runs nine simulations.

To review the results of the design of experiments:

1. Click **Result Sheet** to see a summary of the simulations as shown in the figure on the right.

   The results show that, in general, the paper sticks out more to the left as the paper thickness increases and as the curl radius decreases (tighter curl). The data for the sheet with a thickness of 0.6 mm and a curl of 100 mm is very different, however. Something dramatic must have happened.

Trial	DV_Thickness_SHT	DV_Curl_SHT	PI_Reach
1	0.4	100.	-206.19499459764
2	0.4	200.	-186.520109254452
3	0.4	300.	-174.158214331894
4	0.5	100.	-208.00234234385
5	0.5	200.	-196.428262293083
6	0.5	300.	-186.302037941158
7	0.6	100.	-54.0526184827568
8	0.6	200.	-203.32670009744
9	0.6	300.	-195.605541707739

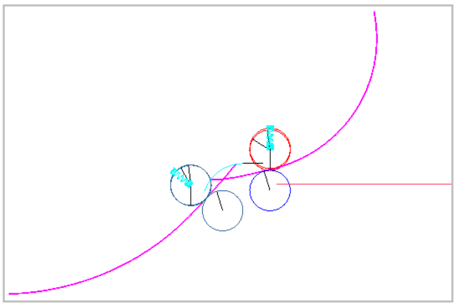
2. Click **OK** to exit the **Design Study** dialog box.

3. Review the animation data (**RecurDyn Animation Data** contained in files with a .rad file extension) for trials 7 and 8 using the **Import** command under the **File** menu.

   A set of rad files that have _1 through _9 added to the original file name appear.

   - Import the file for trial 7 and animate it
   - Import the file for trial 8 and animate it.
   - What can you conclude?

   The figure to the right superimposes the final position of trials 7 and 8. You should observe that in trial 7, a combination of a tight curl and thick (stiff) sheet causes the sheet to stub in the corner between the guide and the roller. In all other cases, the sheet is able to go through the second roller pair.



4. Save the **RecurDyn** model file with the current results.

Chapter
5

Case 3: Design of Experiments with a Moving Guide Assembly

In this chapter, you run a design of experiments that moves the linear and arc guides that guide the sheet between the first and second sets of rollers.

Task Objective

You will create parametric points that are needed to control the position of the guides:

- A center point controls the position of the arc guide.
- Starting and ending points control the position (and size) of the linear guide.

You will define the starting and ending points of the linear guide relative to the center of the arc guide. You will define a marker at the parametric point of the arc guide that will be used as reference for defining the location of the parametric points for the linear guide. You will define the x and y coordinates of the arc guide parametric point by specifying two parametric values. Given the above relationships, you will be able move the arc and linear guides as an assembly by adjusting the values of the two parametric values.

Estimated Time to Complete

45 minutes

Saving the Model to a New File Name

You will save the model to a new file name because the new setup for this DOE will disturb the previous DOE setup.

To save the file to a new name:

Use the Save As command under the File menu to save the **RecurDyn** model file to a new file name, such as **MTT2D_DOE_Move.rdyn**.

Defining Parametric Points

You will create a parametric point, called **PP_ArcGuide**, which acts as the reference point for two other parametric points, a marker, the arc guide, and the linear guide.

To define the parametric points:

1. From the **Parameter** group in the **SubEntity** tab, click **Parametric Point(PP)**.
2. Click **Add** in the **Parametric Point List** window.
3. Define a parametric point named **PP_ArcGuide** located at **-30, 95, 0** or the center of the arc guide.
4. Click **Apply**.

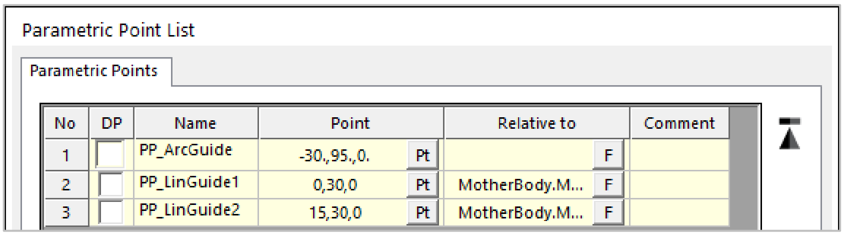
5. From the **Professional** tab of the **Marker and Body** group, click **Marker** to define a marker that is on the **Mother Body** and located at **the PP_ArcGuide** parametric point.
6. Display the Properties dialog box for the marker and check the origin definition. You should see the name **PP_ArcGuide** in the **Origin** text box under the **Origin & Orientation** tab.

Tip: If you see a set of numbers, click **Pt** and select the **PP_ArcGuide** icon in the modeling window. Do this until the parametric point name appears in the origin text box. Click **OK** to close the Marker Properties dialog box

---

7. Define two additional parametric points as shown in the figure on the below. Define them relative to the marker that you just created by clicking **F** and selecting the marker located at **the PP_ArcGuide** parametric point.

   The values in the Point text box are the relative coordinates from the center of the arc guide to the starting and ending points of the linear guide.

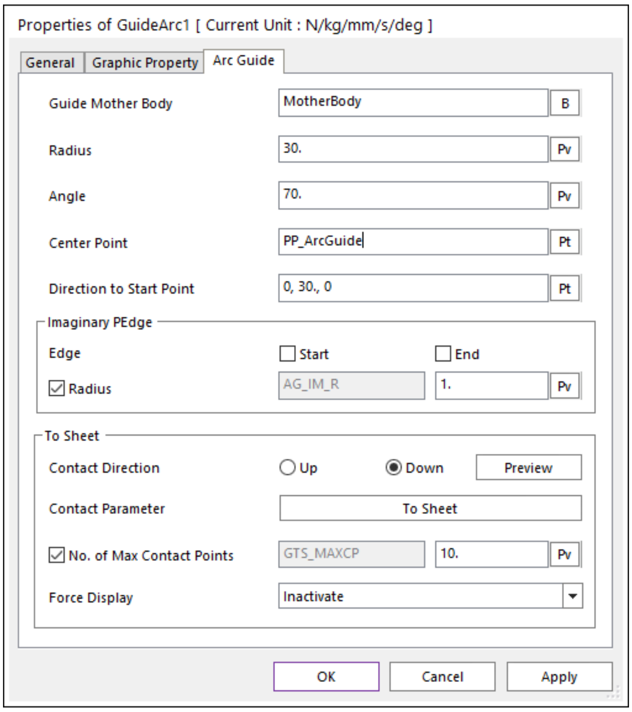


8. Click **OK** to exit the **Parametric Point List** dialog box. You should see three Parametric Point icons.

Add the Parametric Points to the Guide Definitions

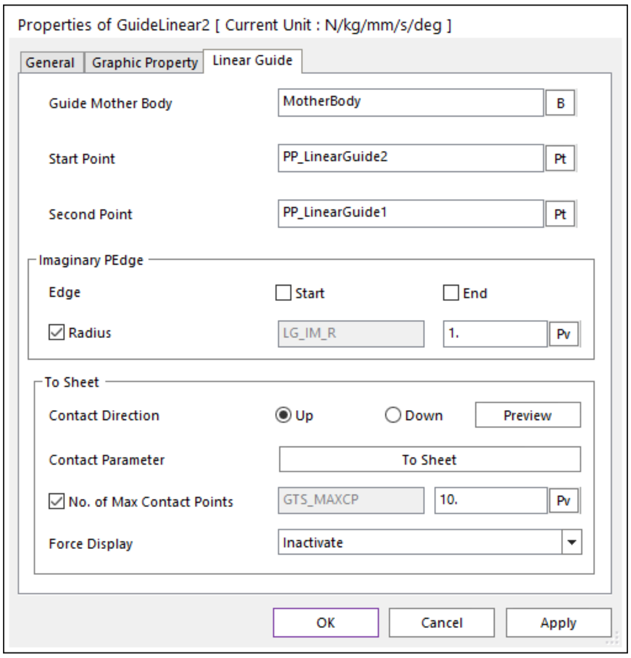
You will the guide definitions to include the parametric points. The parametric points will define the location of the guides.

1. Display the Properties dialog box for the arc guide (GuideArc1), click the **Pt** button for the Center Point of the arc guide, and click the **PP_ArcGuide** parametric point. The text box for the Center Point of the arc guide should now contain the name, **PP_ArcGuide**, as shown in the figure to the right.
2. Click **OK** to exit the **Arc Guide** dialog box.



3. Display the Properties dialog box for the linear guide located next to the arc guide (GuideLinear2), and then:
   - In the **Linear Guide** tab, click Pt for the Start Point of the guide, and click parametric point **PP_LinGuide2** (located at the right side of the guide).
   - Repeat the same step for the **End Point** of the guide and click parametric point **PP_LinGuide1** (located at the left side of the guide).

   The names of the parametric points should appear in the text boxes for the Start Point and Second point, as shown in the figure to the right.
4. Click **OK** to exit the **Linear Guide** dialog box.



To test the parametric points:

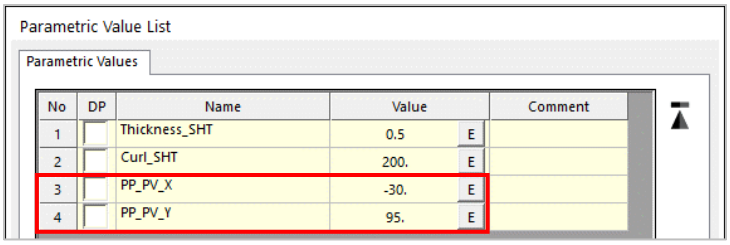
1. Select the **PP_ArcGuide** parametric point.
2. Use the **Object Control** dialog box to move the point back and forth 10 mm in the x and y directions. Check that all three parametric points, the marker, and both guides move together.
3. If not, review the definition procedure and get help as needed until the objects move together. Make sure the **PP_ArcGuide** parametric point is left in its original position.

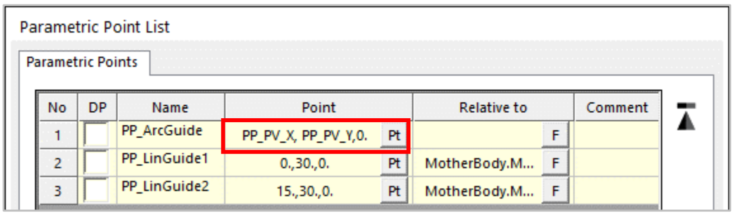
Creating Parametric Values to Control Location of the Assembly

You will create two parametric values to represent the x and y location of the parametric point.

To create parametric values:

1. Create two new parametric values to represent the x and y location of the parametric point as shown in the figure on the right (from the **Subentity** tab, click **Parametric Value**).
2. Display the Parametric Points dialog box (from the **Subentity** menu, click **Parametric Point**).
3. Manually enter the parametric values into the Point text box of the **PP_ArcGuide** parametric point as shown in the figure on the right.



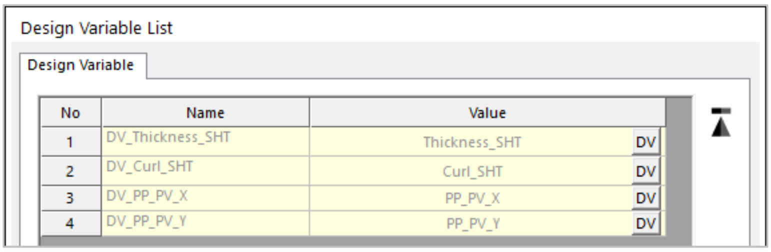


Setting Up and Running the Design of Experiments

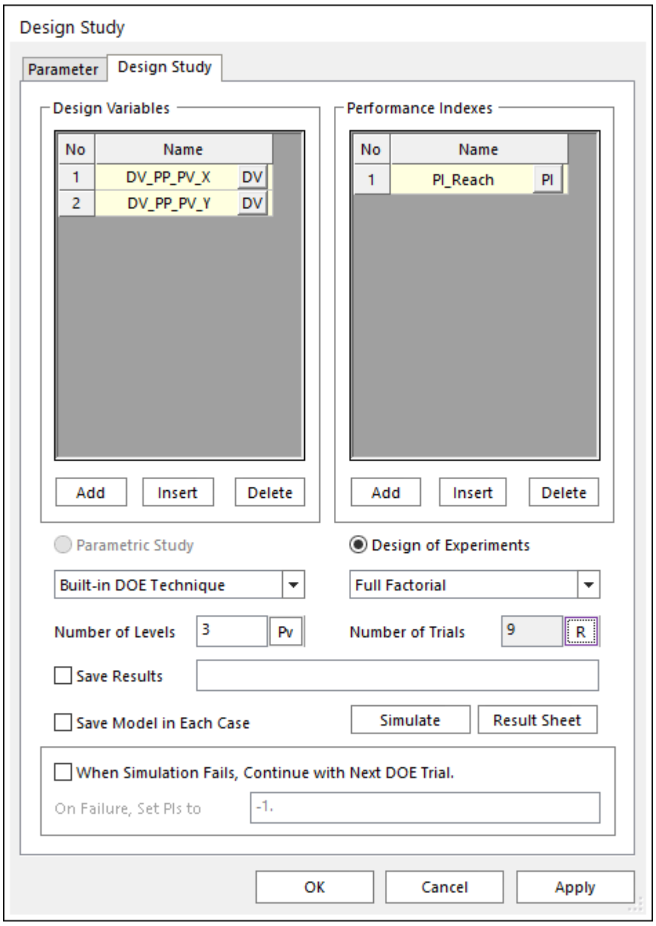
Now you will create design variables for the two parametric values you created in the previous section that control the position of the guide assembly. You will then set up and run the design of experiments.

To add the design variables and set up and run the design of experiments:

1. Add a design variable to the Design Variable dialog box (as shown in the figure on the right) for each of the new parametric values. For each design variable, set:



   - **Value Range to +/- Delta relative to Value.**
   - **–Delta to -4 and the +Delta to 4.**
2. Click **OK** to exit the **Design Variable List** dialog box.
3. In the **Design Study** dialog box, select the two new design variables to be the two design variables for this study. You want the Design Variable portion of the window to appear as shown in the figure on the right. You will do the following.



   - Click on the DV button for Design Variable No. 1
   - Select Design Variable DV_PP_X
   - Click OK to exit the Design Variable List dialog box.
   - Click on the DV button for Design Variable No. 2
   - Select Design Variable DV_PP_Y
   - Click OK to exit the Design Variable List dialog box.
   - There should only be two Design Variables in the Design Study window. If there is a row for a third Design Variable, select the row and hit the Delete button.
4. Be sure the **Design of Experiments** option is selected and set up as before as explained in the section, Setting Up and Running the **Design of Experiments**, on page 15.
5. Click **Simulate** to run the design of experiments.

   You will see the arc guide and linear guide move to different position in the graphics window as the various trials are run. **RecurDyn** runs nine simulations, one for each value of the variables. Remember that the sheet will have the nominal curl of **200 mm** that you set up in Case 2.

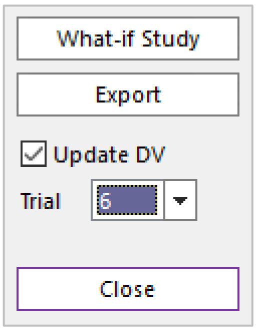
6. In the **Design Study** dialog box, click **Result Sheet** to see a summary of the simulations as shown in the figure on the right. The largest reach is with trial 4, where the guide is lowered from the original position. The lowest reach is for trial 6, and it appears that the sheet may not have been able to pass through both rollers. You will look at the animation for trial 6 in the next section.

Trial	DV_PP_PV_X	DV_PP_PV_Y	PI_Reach
1	-34.	91.	-195.514812713879
2	-34.	95.	-55.187362792394
3	-34.	99.	-56.8099212294265
4	-30.	91.	-204.666934444838
5	-30.	95.	-196.3873305979
6	-30.	99.	-54.9160275316081
7	-26.	91.	-143.807475643573
8	-26.	95.	-202.832030560103
9	-26.	99.	-199.592899208163

Reviewing the Results of the Design of Experiments

The review of the animation results for this DOE is different than the review of the previous DOE and design study because the model has a changing geometric configuration for the various trials. You will get a confusing animation if you display the various trials without adjusting the parametric values such that the guides are in the correct position. You will see the sheet follow along the guides in a different position that the guides being displayed. **RecurDyn** includes a feature that allows you to adjust the parameters efficiently before displaying the results of a trial.

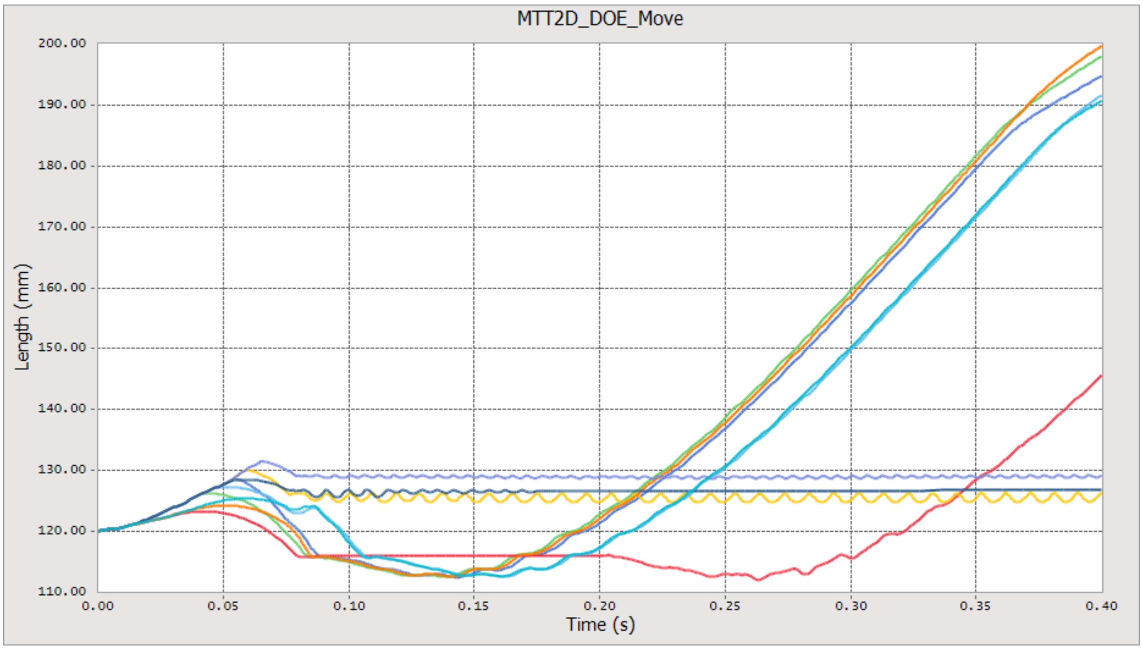
To view the animations for trial 6:



1. Click on the **Update DV** check box in the lower right of the Result Sheet window, as shown in the figure to the right.
2. Click **Close** to close the Result Sheet window.
3. Click **OK** in the **Design Study** window and you will see the guides move from their nominal position to the position used in Trial 6.
4. Click on the **Import** option in the File menu, set the File Type to RecurDyn animation data (.rad files) and select the file named **MTT2D_DOE_Move_6.rad**.
5. You will see that the sheet is caught in the corner between the arc guide and the movable roller in the second roller pair. That explains the low reach value of the sheet for trial 6.

To plot a family of curves for all of the trials:

1. Display the plot window and import the results for all of the trials (**MTT2D_DOE_Move_*.rplt** files) other than trial 6 (already loaded in the plot window).
2. (Under the **Bodies** category, expand **SheetBody1**, right-click on **Pos_TM** and select **MultiDraw**). The MultiDraw command will plot that output for all output cases that have been imported into the plot window. The figure below shows the results of plotting the magnitude of the translation of the first segment of the sheet.



Thanks for participating in this tutorial!