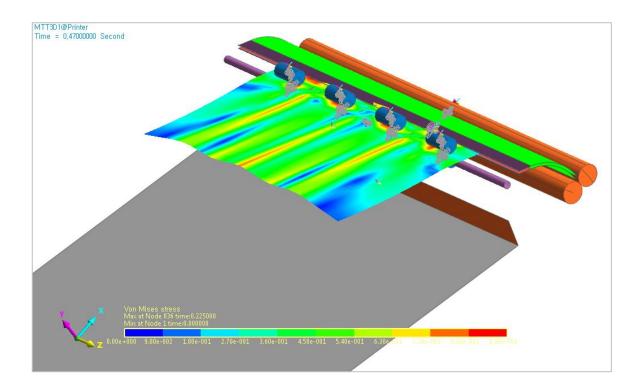


# Media Transport Toolkit 3D Tutorial (MTT3D)





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#### **Edition Note**

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

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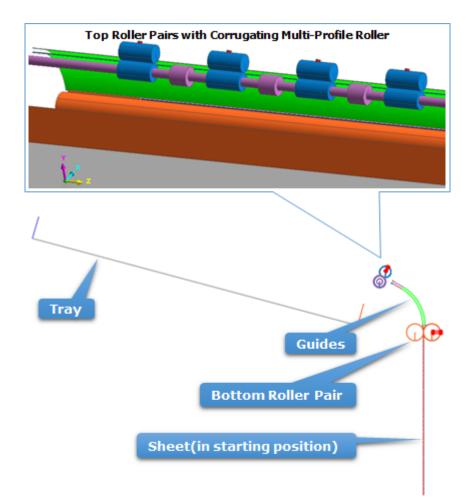
## **Getting Started**

### **Objective**

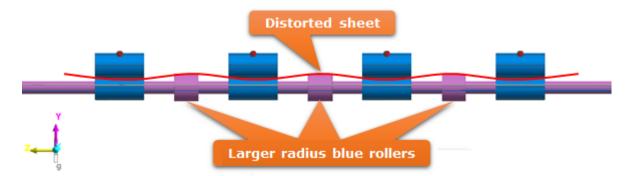
This tutorial introduces you to the special capabilities of the Media Transport Toolkit 3D (MTT3D). MTT3D allows you to model sheets progressing through complex paper paths in three dimensions, allowing you to study 3D phenomena such as sheet corrugation and misalignment. In this tutorial, you will examine sheet corrugation in part of a printer device.

### **Model Used**

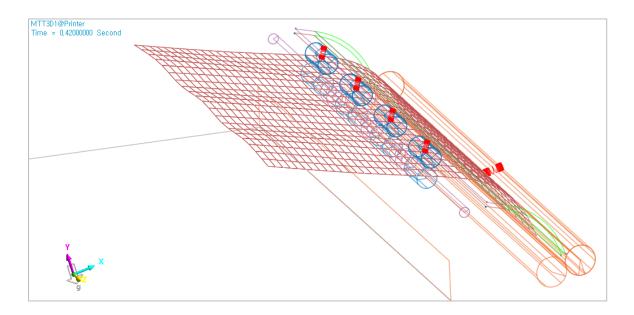
The model used in this tutorial is the final portion of the paper path of a laser printer, namely the path that the sheet passes through before landing in the tray. To prevent paper jams and allow for an orderly stack of sheets in the output tray, a special multi-profile roller is used to corrugate the sheet to keep it straight before falling into the tray. The corrugation of the paper prevents the leading edge of the sheet from hanging down and dragging along the surface of the tray (or the sheets that are already in the tray). A side view of the model is shown below.



As shown below, the corrugation roller works because the blue rollers have a larger radius than the lower purple rollers which rotate about the same axis. Therefore, the blue rollers push the sheet upwards in between the purple roller pairs, distorting the sheet.



If the corrugation effect is strong enough, the folds in the sheet cause it to resist gravityinduced bending, allowing the sheet to remain straight as it exits the printer, as shown below.



Due to the limited time you may have to complete this tutorial, the rest of the printer is not modeled. Also, to simplify the model further, the sheet used is half the size of a standard A4 sheet. Since the sheet is modeled as a mesh, this reduces the number of sheet bodies.

### Audience

This tutorial is intended for experienced users of **RecurDyn**. All new tasks are explained carefully.

### **Prerequisites**

Users 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 below.

Procedures	Time (minutes)
Creating the Model	30
Running a Simulation	10
Modifying the Design	10
Total	50



50 minutes



## **Creating the Model**

### **Task Objective**

Learn how to define rollers, guides, and sheet bodies.



30 minutes

### **Creating a New Model and MTT3D Subsystem**

#### To create a new model:

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

**RecurDyn** starts and the **Start RecurDyn** window appears.

- 2. Enter **Printer** as the Model Name.
- 3. Select OK.

tart RecurDyn		:
New Model		
Name	Model1	
Unit	MMKS(Millimeter/Kilogram/Newton/Second)	▼ Setting
<u>G</u> ravity	-Y	✓ Setting
		<u>O</u> K
Open Model		Browse
Open Model Recent Mod		

#### To create a new MTT3D subsystem:



1. From the **Subsystem Toolkit** group in the **Toolkits** tab, click **MTT3D**.

**RecurDyn** will bring you into the new **MTT3D** subsystem, and a new **MTT3D** tab will appear in the ribbon for the **MTT3D** functions.

#### To adjust the Icon Size in the model:

- 1. From the **Render Toolbar**, select the **Icon Control** tool.
  - 2. Change both the **Icon Size** and **Marker Size** from the default value of 10 to **3**.

#### To set the render mode to Wireframe:

From **Render Toolbar**, select the **Wireframe** rendering tool.



≷ Icon Control	×	
lcon On/Off		1
All Icons     Joint     Joint     Gontact     Sensor     Parametric Point     Initial Velocity     Wall / Vessel     General Marker     General Marker     Inertia Reference Fr		
lcon Size	3	
Marker Size	3	
Marker Z-Axis Width	2	
Initial Velocity Icon Width	2	
Show Center Marker Icon	n	

### **Creating the Bottom Rollers**

You will now create the bottom roller pair in which the sheet starts.

#### To create the bottom roller pair:



- 1. From the **Roller** group in the **MTT3D** tab, click **Pair**.
- 2. Select the point **0**, **0**, **0** in the **Working Window** to define the center of the fixed roller or type the values into in the **Input Window**.
- 3. Enter **7.5** in the **Input Window** and press the Enter key to set the radius of the fixed roller.
- Select the +X direction, by clicking on a point directly to the right of 0, 0, 0. The arrow which indicates the direction that will be selected should point directly to the right, as shown at right.
- 5. Enter **7.5** in the **Input Window** to set the radius of the movable roller.

You will now modify the bottom roller pair to have the correct properties.

#### To edit the bottom fixed roller:

- From the Database Window, open the Properties window for MTT3D1 > Groups > FixedRollerGroup1.
- 2. To the right of **Contact Parameter**, select the **To Sheet** button.

25	
0, 0, 0	₩ 1,,,0.0,

roperties of FixedRollerGroup1 [	Current Unit : N/k	g/mm/s/deg ]	
General Fixed Roller Group			
Base Body	MotherBody	В	
Center Point 💌	0, 0, 0	Pt	
Depth Direction	0, 0, 1.	Pt	
Radius 7.5	Pv Depth	300. Pv	
O CrownRoller Profile	۲	Multiple Roller Info.	
Mass 2.4661502e-002	Pv Ixx	0.82205008 Pv	
lyy 0.82205008	Pv Izz	1.2330751 Pv	
Include Motion		Motion	
To Sheet			
Contact Parameter		To Sheet	
No. of Max Contact Points	FRTS_MAXCP	10. Pv	
Force Display	Inactivate		
Match Center Marker Position with Graphic			
Match Joint Position with Grap	hic 🗌	Check Edge	
Each Rendering	Automatic	-	
	ОК	Cancel Apply	

- 3. Make the following settings:
  - Stiffness: 1.2
  - Maximum Damping: 1.2e-4

≷ Contact Parameter			×
Stiffness(K)	FRTS_K	1.2	Pv
🖂 Exponent	FRTS_K_EXP	1.	Pv
Maximum Damping (C)	FRTS_C	1.2e-4	Pv
Boundary Penetration	FRTS_B_PEN	0.1	Pv
O 🖾 Indentation Exponent	FRTS_I_EXP	2.	
Friction Type	STEP		
Friction Coefficient	FRTS_MU	1.	Pv
Threshold Velocity	FRTS_T_VEL	10.	Pv
RDF	FRTS_RDF	1.e-003	Pv
Overdrive Factor		0.	Pv
	Close		

**Note:** If the checkboxes next to a parameter is checked, the value displayed will be considered a Special Parametric Value (SPV) and be used for all other fixed rollers in the model which have the same checkbox checked. There are separate sets of SPVs for movable rollers and other model entities.

**Note:** Here, you increased the contact stiffness to prevent the roller from penetrating the sheet excessively, as you will be increasing the nip spring stiffness of the opposing roller from its default value later. Excessive contact penetration reduces the accuracy of the simulation. At the same time, increasing contact stiffness too much will slow down the simulation. Therefore, a general rule of thumb is to allow for penetration which is ~25% the thickness of the sheet.

Also, the damping was increased by the same factor as the stiffness. When adjusting stiffness and damping values, a good practice is to start with the default values and scale them both by the same factor. If necessary, they can be adjusted individually later.

- 4. Select **Close**.
- 5. Select OK.

To edit the bottom movable roller:

- From the Database Window, open the Properties window for MTT3D1 > Groups > MovableRollerGroup1.
- 2. Select the **Nip Spring Property** button.

	ble Roller Group				
Fixed Roller			[	FixedRollerGroup1	
Base Body			MotherBoo	dy	В
Center Point	t	-	15.05, 0, 0		Pt
Depth Direct	ion		0, 0, 1.		Pt
Translational	Direction (Degree)		0.		Pv
Radius	7.5	Pv	Depth	300.	Pv
Mass	2.4661502e-002	Pv	lxx	0.82205008	Pv
lyy	0.82205008	Pv	Izz	1.2330751	Pv
Nip Sprin	g		Nip	Spring Property	
	CrownRoller Profile	e		Accessories	
To Sheet —					
Contact Para	meter			To Sheet	
🗹 No. of Ma	ax Contact Points	MRT:	5_MAXCP	10.	Pv
Force Display	4	Inact	ivate		•
To Fixed Roll	er —				
Contact Para	ameter		То	Fixed Roller	
No. of Ma	ax Contact Points	MRT	R_MAXCP	10.	Pv
Force Displa	у	Inact	ivate		
. erec Dispid					
		with Gra	aphic	Higher Nip F	Force
Match Ce	nter Marker Position				
Match Ce	int Position with Grap			Check Edge	
Match Ce		Automa		Check Edge	
Match Ce	int Position with Grap Geometry Information	Automa	tically matic	Check Edge	•

#### 3. Uncheck the boxes next to **Stiffness**, **Damping**, and **Pre Load**.

**Note:** By unchecking the boxes, you are specifying that the parameter values set for this roller will not be linked to the Special Parametric Values used for other movable rollers in the model.

- 4. Make the following settings as shown right.
  - Stiffness: 0.1
  - Damping: 1e-2
  - Pre Load: 0.5
- Click the Close button to return to the Properties of MovableRollerGroup1 dialog.
- To the right of Contact Parameter, select the To Sheet button.
- 7. Make the following settings as shown at right.
  - Stiffness: 1.2
  - Maximum Damping: 1.2e-4
  - Friction Coefficient: 0.2

TSD Para	ameter			×
Action Po	int 15.	, 0., 0.		
Base Bod	y Mo	otherBody		В
🗹 Base F	Point 24.	, 0., 0.		
Stiffne	ess (K)		0.1	Pv
🗌 Dampi	ing (C)		1.e-2	Pv
Pre Lo	ad (F)		0.5	Pv
		Close		
Contact Paramete	er			×
Contact Paramete ☑ Stiffness(K)	er MRTS_	ĸ	1.2	× Pv
		·	1.2	
☑ Stiffness(K)	MRTS_	K_EXP		Pv
☑ Stiffness(K) ☑ Exponent	MRTS_ MRTS_ ing (C) MRTS_	K_EXP	1.	Pv Pv
☑ Stiffness(K) ☑ Exponent ☑ Maximum Damp	MRTS_ MRTS_ ing (C) MRTS_ enetration MRTS_	K_EXP C B_PEN	1. 1.2e-4	Pv Pv Pv

MRTS\_MU

MRTS\_T\_VEL

Close

0.2

10.

0.

Pv

Pv

Pv

**Note:** A lower friction coefficient of 0.2 was chosen for this movable roller, because we want to model its surface as plastic. The default friction coefficient of 1.0 was used for the fixed roller, on the other hand, because we want to model its surface as being rubberized so it can grip the sheet.

Friction Coefficient

Threshold Velocity

Overdrive Factor

- 8. Click Close.
- 9. Click **OK**.

### **Creating the Top Rollers**

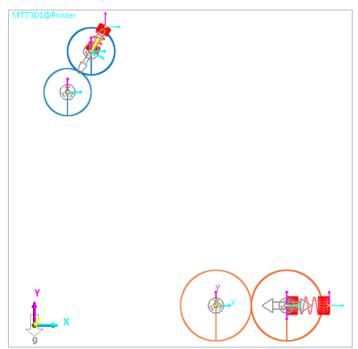
You will now create the top rollers, starting with the first top roller pair, which will be duplicated three times for a total of four roller pairs on top.

#### To create the first top roller pair:



- 1. Select the **Pair** tool from the **Roller** group under the **MTT3D** tab in the ribbon.
- 2. Enter the point **-31.446**, **45.228**, **81** in the **Input Window** for the center of the fixed roller.
- 3. Enter a radius of **5** in the **Input Window** for the fixed roller.
- 4. Enter a direction of **1**, **1.7321**, **0** in the **Input Window** to specify the movable roller location.
- 5. Enter a radius of **5** in the **Input Window** for the movable roller.

At this point, your model should appear as shown below.



You will now edit the top roller pair to have the correct properties before duplicating it.

#### To edit the first top fixed roller:

- From the Database Window, open the Properties window for MTT3D1
   > Groups > FixedRollerGroup2.
- 2. Enter a **Depth** of **20**.
- 3. Check the box next to **Check Edge** in the lower right of the dialog box.
- 4. Click **OK**.

Properties of FixedRollerGroup2 [	Current Unit : N/k	g/mm/s/deg ]			
General Fixed Roller Group					
Base Body	MotherBody	В			
Center Point 👻	-31.446, 45.228, 8	1. Pt			
Depth Direction	0, 0, 1.	Pt			
Radius 5.	Pv Depth	20. Pv			
CrownRoller Profile	۲	Multiple Roller Info.			
Mass 2.4661502e-002	Pv Ixx	0.82205008 Pv			
lyy 0.82205008	Pv Izz	1.2330751 Pv			
Include Motion		Motion			
To Sheet					
Contact Parameter		To Sheet			
No. of Max Contact Points	FRTS_MAXCP	10. Pv			
Force Display	Inactivate	<b>•</b>			
Match Center Marker Position v	Match Center Marker Position with Graphic				
Match Joint Position with Grap	hic 🔽	Check Edge			
Each Rendering	Automatic	▼			
L	ОК	Cancel Apply			

Properties of MovableRollerGroup2 [ Current Unit : N/kg/mm/s/deg ]

FixedRollerGroup2

▼ -26.446106502847, 53.8883155264 Pt

в

MotherBody

General Movable Roller Group

Fixed Roller

Base Body

Center Point

**Note:** The Check Edge option should be selected when a roller's radius is smaller than the length of an individual element in the sheet mesh. When this condition occurs, the contact between the ends of the roller and the sheet must be taken into account.

#### To edit the first top movable roller:

- From the Database Window, open the Properties window for MTT3D1 > Groups > MovableRollerGroup2.
- 2. Enter a **Depth** of **20**.
- 3. Check the box next to **Check Edge**.
- 4. Select the Nip Spring Property button.

Depth Direct	ion		0, 0, 1.		Pt
Translational	Direction (Degree)		0.		Pv
Radius	5.	Pv	Depth	20.	Pv
Mass	1.72787595947439e-(	Pv	box	6.83950900625278e-	Pv
lyy	6.83950900625278e-(	Pv	Izz	2.15984494934298e-	Pv
Nip Spring	9		Nip S	pring Property	
	CrownRoller Profile			Accessories	
To Sheet					
Contact Para	meter			To Sheet	
No. of Ma	x Contact Points	MRTS	_MAXCP	10.	Pv
Force Display	1	Inacti	vate		-
To Fixed Roll	er				
Contact Para	meter		То	Fixed Roller	
No. of Ma	ax Contact Points	MRTE	R_MAXCP	10.	Pv
Force Display	v	Inact	ivate		•
Match Ce	nter Marker Position w	ith Gra	phic	Higher Nip For	ce
🗹 Match Joi	nt Position with Graph	ic		🗸 Check Edge	
🗸 Update G	eometry Information A	utomat	tically		-
Each Render	ing	Auto	matic		•
			ок	Cancel	Apply

5. Make the following settings as shown at right.

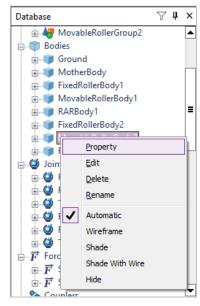
- Stiffness: 1e-2
- Damping: 1e-3
- Pre Load: 5e-2
- 6. Click Close.
- 7. Click OK.

TSD Parameter		×
Action Point	-26.4461065028	47, 53.8883155264186, 81.
Base Body	MotherBody	В
🗹 Base Point	-23.4461704045	553, 59.0845048422698, 81.
Stiffness (K)	NIP_TSD_K	1.e-2 Pv
🗹 Damping (C)	NIP_TSD_C	1.e-3 Pv
Pre Load (F)	NIP_TSD_F	5.e-2 Pv
	Close	]

Because the top movable rollers are small, spring mounted, and their rotation is not specified with a motion input, their behavior is highly influenced by the sheet and the corresponding fixed roller. Because of this, it is important to set the mass and inertia properties to reasonable values to ensure accurate results. In our model, we will specify that the roller is made of Nylon.

#### To edit the mass properties of the first top movable roller:

- 1. To bring up the Properties dialog for the body MovableRollerBody2 and not the group MovableRollerGroup2.
  - In the Database Window, locate <u>but do not click</u> <u>on</u> MTT3D1 > Bodies > MovableRollerBody2.
  - <u>Without selecting it first</u>, right-click on MovableRollerBody2, and select Property as shown at right.



2. Select the **Body** tab.

- 3. For **Material Input Type**, select **Library**. Click **OK** on the warning dialog that pops up.
- 4. For Material Type, select Nylon.
- 5. Click OK.

General		Graphic Property				
Orig	in & Orien	tation	Boo	dy	Ro	ller Body
Mater	ial Input Ty	pe	Library	1		
Mater	ial Type		Nylon			•
Mass	1.7278759	95947439e-03				
lxx	6.8395090	0625278e-02	lxy	0.		
lyy	6.8395090	0625278e-02	lyz	0.		
lzz	2.1598449	4934298e-02	Izx	0.		
Volum	ie	1570.79632	67949		Show Pr	operty
Cente	r Marker			СМ		
Inertia	a Marker	Cre	eate		IN	1
Initial Condition		Init	ial Velo	city		
Scope			ОК	0	ancel	App

The roller pair is ready to be duplicated. But first, you will want to change some of the program user settings to make copying and pasting easier.

#### To change the program user copy/paste settings:



- 1. From the **Home** tab in the Ribbon, select the **General** tool in the **Model Setting** group.
- 2. Uncheck the box next to **Shift when pasting**.
- 3. Click OK.

General				×
General				
	Printer			
Name	Printer			
Comment	4			
Error Tolerance			1.0e-12	<b></b>
Zoom Factor				1.
Shift when Pa	sting			
Hide Inactive	Entity			
Accelerate Rer	ndering in View C	ontrol		
Auto Fit for th	e Change of Wo	rking Window		
Align Center N	Marker Orientatio	n with Body Prin	cipal Axis	
Create Backup	File (*.rbak)			
Save Dialog Si	ize and Position			
		ОК	Cancel	Apply

You will now make copies of the second roller pair and array them through the -Z direction to create the row of top driving roller pairs.

#### To duplicate the first top roller pair:

- 1. In the Database Window, select both FixedRollerGroup2 and MovableRollerGroup2:
  - First select **FixedRollerGroup2**.
  - Then hold down the Ctrl key and select MovableRollerGroup2.

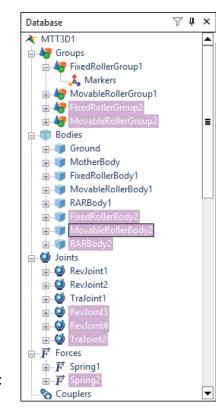
The associated bodies, joints, and forces will be selected automatically as shown at right.

- 2. From the **Clipboard** group under the **Home** menu, select **Copy**. (Or press **Ctrl-C**.)
- 3. From the **Clipboard** group under the **Home** menu, select **Paste**. (Or press **Ctrl-V**.)
- 4. Repeat the previous step (**Paste**) twice, so that there are a total of four identical roller pairs.

#### To move the duplicated roller pairs into place:

- In the Database Window, use the Ctrl key to select C1\_FixedRollerGroup2 and C1\_MovableRollerGroup2.
- 2. From the Advanced Toolbar, select the Basic Object Control tool.
  - 3. For the **Offset Value**, enter **54**.
  - 4. Click the **-Z** button.

The first copy of the nip pair should have been translated **54** mm in the -Z direction.



Basic	×
Translate Rotate Tra/Rot	
Scalar Translate	O Vector Translate
+Y -X -Z +Z	0, 0, 0 Apply
-Y	Reference Frame
Offset Value 54 🚔	Ground.InertiaMarker M

- 5. In the **Database Window**, use the **Ctrl key** to select **C2\_FixedRollerGroup2** and **C2\_MovableRollerGroup2**.
- 6. In the **Basic Object Control** dialog, click the **-Z** button **twice** to move it **108** mm in the -Z direction.
- 7. In the Database Window, use the Ctrl key to select C3\_FixedRollerGroup2 and C3\_MovableRollerGroup2.
- 8. In the **Basic Object Control** dialog, click the **-Z** button **three times** to move it **162** mm in the -Z direction.

## To create the multi-profile corrugating roller:



- 1. Select the **Fixed** tool from the **Roller** group under the **MTT3D** tab in the ribbon.
- 2. Enter -31.446, 45.228, 0 into the **Input Window** as the roller center.
- 3. Enter a radius of **2.5** in the **Input Window** for the fixed roller.
- 4. Open the **Properties** window of **FixedRollerGroup3**.
- 5. Check the box next to **Check Edge**.
- 6. Click the **Multiple Roller Info.** button.

	f FixedRollerGroup3	[ Curre	nt Unit : N/k	g/mm/s/deg ]	
neral Fi	xed Roller Group				
Base Body	/	Mo	therBody		В
Center P	oint 🔹	-31.	446, 45.228, 0	)	Pt
Depth Di	rection	0, 0	, 1.		Pt
Radius	2.5	Pv	Depth	300.	Pv
0	CrownRoller Profile		۲	Multiple Roller In	fo.
Mass	2.4661502e-002	Pv	lxx	0.82205008	Pv
уу	0.82205008	Pv	Izz	1.2330751	Pv
🗌 Includ	e Motion			Motion	
To Sheet					
Contact P	Parameter			To Sheet	
🗹 No. of	Max Contact Points	FRT	S_MAXCP	10.	Pv
Force Dis	play	Ina	ctivate		-
✓ Match	Center Marker Position	with Gr	aphic		
Match	Joint Position with Gra	phic		Check Edge	
	dering		omatic		

ОК

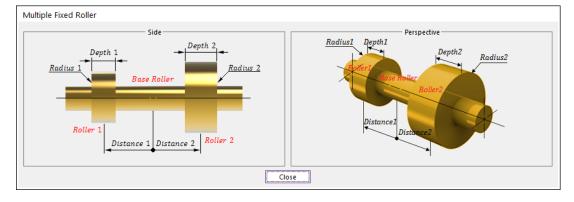
Cancel

Apply

7. Click the **Add** button three times and enter the following roller data as shown at right.

Radius	Depth	Distance
5.5	10	-54
5.5	10	0
5.5	10	54

Aultiple Roller Geometry Info				×		
No	Radius	Depth	Distance		Add	
1	5.5	10	-54		Insert	
2	5.5	10	0		insert	
3	5.5	10	54		Delete	
Dimension Information						
		Dimension	Information			

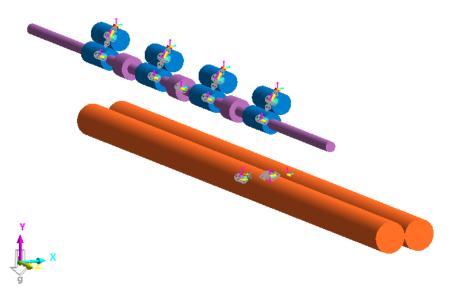


**Note**: To understand how the above variables apply to the rollers, click the **Dimension Information** button to display the diagram shown at above. When finished, click **Close** to close the window.

- 8. Click the **Close** button.
- 9. To the right of **Contact Parameter**, click the **To Sheet** button.
- 10. Uncheck the box next to Friction Coefficient.
- 11. Enter a Friction Coefficient of **0.2**.
- 12. Click Close.
- 13. Click **OK**.

Contact Parameter			×
Stiffness(K)	FRTS_K	1.2	Pv
Z Exponent	FRTS_K_EXP	1.	Pv
Maximum Damping (C)	FRTS_C	1.2e-04	Pv
O Boundary Penetration	FRTS_B_PEN	0.1	Pv
🔘 🖂 Indentation Exponent	FRTS_I_EXP	2.	
Friction Type	STEP		
Friction Coefficient		0.2	Pv
Threshold Velocity	FRTS_T_VEL	10.	Pv
Overdrive Factor		0.	Pv
	Close		

Your model should appear as shown below (rotated and rendered in the Shaded mode).



14. Save your model.

### **Adding Motion to the Fixed Rollers**

You will now add motion to the fixed rollers, defining expressions which will ramp the rotational velocity up from zero to end values which will move the sheet at a linear velocity of 400 mm/sec. The end values will differ depending on the radius of the roller, but you will enter the expressions in such a way that **RecurDyn** will perform the calculations for you.

#### To add motion to the bottom fixed roller:

- From the Database Window, open the Properties window for MTT3D1 > Groups > FixedRollerGroup1.
- 2. Check the **Include Motion** checkbox and select the **Motion** button next to it.

roperties of FixedRollerGroup	o1 [ Curre	nt Unit : N/I	kg/mm/s/deg ]		
General Fixed Roller Group					
Base Body	Mo	therBody		В	
Center Point	▼ 0,0	), 0		Pt	
Depth Direction	0, 0	), 1.		Pt	
Radius 7.5	Pv	Depth	300.	Pv	
O CrownRoller Pro	file	۲	Multiple Roller I	nfo.	
Mass 2.4661502e-002	Pv	box	0.82205008	Pv	
lyy 0.82205008	Pv	Izz	1.2330751	Pv	
Include Motion			Motion		
– To Sheet – Contact Parameter			To Sheet		
No. of Max Contact Points	FR	IS_MAXCP	10.	Pv	
Force Display	Ina	ctivate		-	
Match Center Marker Position with Graphic Match Joint Position with Graphic Each Rendering					
		ОК	Cancel	Apply	

- 3. Choose **Velocity (time)** from the dropdown as the variable to control.
- 4. Select the **EL** button to open the Expression List dialog.

Motion		
Motion		
Туре	Standard Motion	-
	Initial disp.	
Velocity (ti	ime) 🔻 0.0 Pv	
Expression Name Expression		EL
	·	
		-
	OK Cancel	Apply

- 5. Select the **Create** button to create a new expression.
- 6. As shown below, enter a **Name** of **Ex\_bottomRollerVelocity**.

Expression	
Name Ex_bottomRollerVelocity	
(400/7.5)*STEP(TIME, 0, 0, 0.1, 1)	
Available	Argument List
$\blacksquare Function expressions \\ \blacksquare F_{\pi} Fortran 77 Functions \\ \blacksquare T_{x} Simulation constants \\ \blacksquare for C Displacement \\ \blacksquare for C Velocity \\ \blacksquare for C Celeration \\ \blacksquare F_{G} Generic force \\ \blacksquare F_{X} Specific force \\ \blacksquare for C System element \\ \blacksquare for C System eleme$	ID Entity Add Delete
ОК	Cancel Apply

- 7. Enter the following expression, which references the desired velocity and the roller radius:
  - (400/7.5)\*STEP(TIME, 0, 0, 0.1, 1)
- 8. Select **OK** four times.

#### To add motion to the top fixed rollers:

- 1. From the **Database Window**, use the **Ctrl key** to select the following.
  - FixedRollerGroup2
  - C1\_FixedRollerGroup2
  - C2\_FixedRollerGroup2
  - C3\_FixedRollerGroup2
- 2. **Right-click** on one of the items and select **Property**.
- 3. Check the box next to **Include Motion** and select the **Motion** button.
- 4. Choose to control **Velocity (time)** from the dropdown.
- 5. Select the **EL** button to open the **Expression List** dialog.
- 6. Select the **Create** button to create a new expression.

Expression	
Name Ex_topRollerVelocity	
(400/5) * STEP(TIME, 0, 0, 0.1, 1)	
l Available	Argument List
Force Function expressions     F     F     F     F     Fortran 77 Functions     F     T     Simulation constants     F     G	ID Entity Add Delete
ОК	Cancel Apply

- 7. As shown above, enter a **Name** of **Ex\_topRollerVelocity**.
- 8. Enter the following expression:
  - (400/5) \* STEP(TIME, 0, 0, 0.1, 1)
- 9. Click **OK** four times.

### **Creating the Guides**

You will now create the arc, linear, and edge guides which the sheet will proceed through.

To create the inner arc guide:

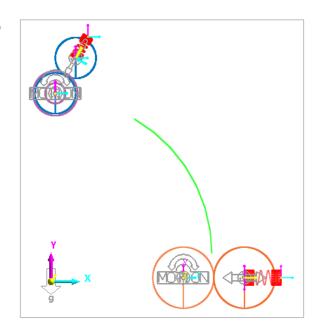
1. Return to view the standard X-Y plane. (Shortcut is the **Shift + x** key.)

Arc

2. Select the **Arc** tool from the **Guide** group under the **MTT3D** tab in the ribbon.

- 3. In the **Input Window**, enter a center point of **-31**, **6**.
- 4. Enter a start point of **7**, **6**.
- 5. Enter a reference direction of **0**, **1**.
- 6. Enter an angle of **60** degrees.

The first guide should now appear as shown at right. (You will duplicate this inner guide later to create an outer guide.)



- From the Database Window, select MTT3D1 > Guides > GuideArc1, and open the Properties dialog.
- 8. Check the box next to **Check Edge**.
- 9. To the right of **Contact Parameter**, select **To Sheet**.

Properties of GuideArc1 [ Current Unit : N/kg/mm/s/deg ]							
General Graphic Property Arc Guide							
Mother Body	MotherBody	В					
Reference Point	-31., 6., -150.	Pt					
Reference Direction	1., 0, 0	Pt					
Extruded Direction	0, 0, 1.	Pt					
Radius	38.	Pv					
Depth	300.	Pv					
Angle	60.	Pv					
Check Edge							
To Sheet							
Contact Direction	Up Oown Preview	v					
Contact Parameter	To Sheet						
No. of Max Contact Points	GTS_MAXCP 10.	Pv					
Force Display	Inactivate	•					
	OK Cancel	Apply					

10. Set the Friction Coefficient to 0.2.

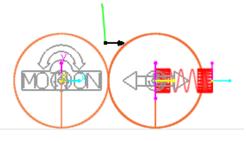
This will set the default friction coefficient for all guides to this value.

You will now adjust the contact direction to ensure that it points in the correct direction.

Contact Parameter			×
Stiffness(K)	GTS_K	1.2e-002	٧
Z Exponent	GTS_K_EXP	1. F	v
Maximum Damping (C)	GTS_C	1.2e-006 F	v
Boundary Penetration	GTS_B_PEN	0.1 F	v
O 🖾 Indentation Exponent	GTS_I_EXP	2.	
Friction Type	● STEP		
Friction Coefficient	GTS_MU	0.2 F	v
Threshold Velocity	GTS_T_VEL	10. F	v
Guide Velocity	0.	F	v
Friction Factor at Vertex o	f Sheet 1.	F	v
	Close		

11. Back in the **Properties of GuideArc1** dialog, to the right of **Contact Direction**, click the **Preview** button. Click on the **Up** button.

A small arrow indicating the direction of contact should appear, as shown at right.



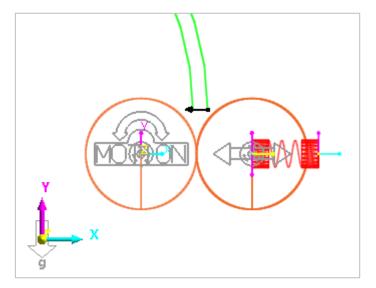
- 12. Press the **Esc key** to exit the preview mode.
- 13. If the arrow did not point in the direction shown at right, change the **Contact Direction** using the **Up** and **Down** radio buttons.
- 14. Click **OK** to exit the **Properties** window.

#### To create the outer arc guide:

- 1. In the **Database Window**, select **MTT3D1 > Guides > GuideArc1**.
- 2. Duplicate **GuideArc1** using the **Copy** and **Paste** commands as done before.
- From the Database Window, select MTT3D1 > Guides > C1\_GuideArc1 and open the Properties dialog.
- 4. Enter a Radius of 40.
- 5. Select Apply.

roperties of C1_GuideArc1 [ Current	t Onit : N/kg/mm/s/deg ]
General Graphic Property Arc Guide	
Mother Body	MotherBody B
Reference Point	-31., 6., -150. Pt
Reference Direction	1., 0, 0 Pt
Extruded Direction	0, 0, 1. Pt
Radius	40. Pv
Depth	300. Pv
Angle	60. Pv
☑ Check Edge ┌ To Sheet ────	
Contact Direction	O Up Oown Preview
Contact Parameter	To Sheet
☑ No. of Max Contact Points	GTS_MAXCP 10. Pv
Force Display	Inactivate 💌
	OK Cancel Apply

- 6. As before, ensure that the contact direction is pointing the right way. It should appear as shown at right.
- 7. Click OK.



#### To create the inner linear guide:



Linear

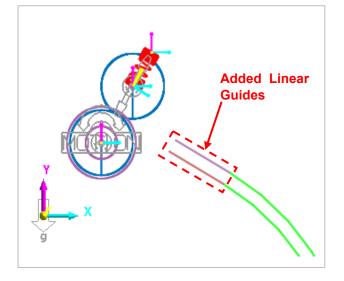
1. Select the **Linear** tool from the **Guide** group under the **MTT3D** tab in the ribbon.

- 2. In the **Input Window**, enter a start point of **-20.660**, **43.909**.
- 3. In the **Input Window**, enter an end point of **-12.000**, **38.909**.

#### To create the outer linear guide:

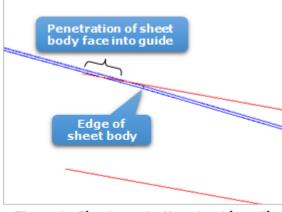
- 1. Select the **Linear** tool from the **Guide** group under the **MTT3D** tab in the ribbon.
- 2. In the **Input Window**, enter a start point of **-11.000**, **40.641**.
- 3. In the **Input Window**, enter an end point of **-19.660**, **45.641**.

The model should now look as shown below.



You now need to create small circular guides at the edges of the existing guides. It is always a good practice to do this in order to prevent penetration of the edges of the guides into the faces of the sheet bodies. The reason this is necessary is because the arc and linear guides

contact only the edges of the individual sheet bodies, while the circular guides contact both the faces and the edges of the sheet bodies.



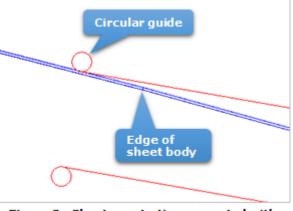


Figure 1: Sheet penetration at guides with no circular edges.

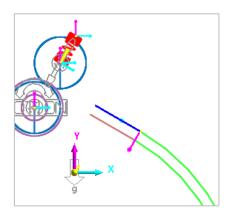
Figure 2: Sheet penetration prevented with circular guides.

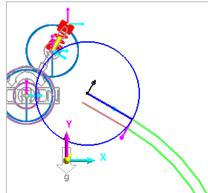
#### To create the circular guides:



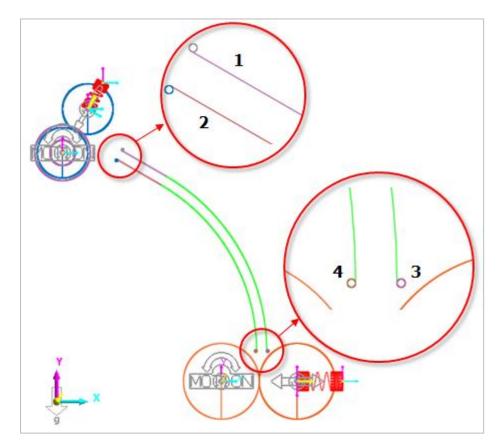
- 1. Select the **Circular** tool from the **Guide** group under the **MTT3D** tab in the ribbon.
- 2. In the **Modeling Window**, select the left end of the outer linear guide you just created (GuideLinear2), as shown at right.

3. In the **Modeling Window**, move the mouse pointer above the guide such that the OrthoDirection arrow points upwards, as shown at right, and click.





- 4. In the **Input Window**, enter a radius of **0.2**.
- 5. Repeat the steps above for the three other guides as shown below.



#### To create the printer tray:

1. Create three more linear guides, using the following start and end points.

	Start Point	End Point
GuideLinear3	-351, 6	-51, 6
GuideLinear4	-351, 26	-351, 6
GuideLinear5	-51, 6	-51, 26

- Open the Properties dialog for GuideLinear5, the guide on the right side of the tray.
- 3. To the right of **Contact Parameter**, select the **To Sheet** button.
- 4. Uncheck the boxes next to **Stiffness** and **Maximum Damping**.
- 5. Make the following settings.
  - Stiffness: 1.2
  - Maximum Damping: 1.2e-4

Contact Parameter			×
Stiffness(K)		1.2	Pv
🗹 Exponent	GTS_K_EXP	1.	Pv
Maximum Damping (C)		1.2e-04	Pv
Boundary Penetratio	n GTS_B_PEN	0.1	Pv
O 🖾 Indentation Exponen	t GTS_I_EXP	2.	
Friction Type	● STEP		
Friction Coefficient	GTS_MU	0.2	Pv
Threshold Velocity	GTS_T_VEL	10.	Pv
Guide Velocity	0.		Pv
Friction Factor at Vertex	of Sheet 1		Pv
	Close		

**Note:** The stiffness of the contact for GuideLinear5 should be increased to prevent contact penetration of the sheet edge into the guide at the end of the simulation. This can occur because after the sheet lands in the tray, it slides down until it hits GuideLinear5. Only the edge of the sheet contacts GuideLinear5, leaving less sheet bodies to react to the impact, and also the sheet's direction of travel is exactly normal to the guide. Both these conditions make this guide more susceptible to being penetrated by the sheet. Another setting, the Maximum Time Step of the simulation, will also be adjusted later to prevent the same event.

#### 6. Click Close.

#### 7. Click **OK**.

The model should now appear as shown below, with the tray flat. You will next rotate the tray about a reference marker at the right corner of the tray so that it is sloped.



#### To rotate the paper tray:

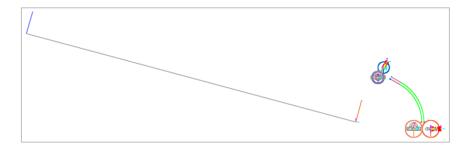


- 1. Select the **Marker** tool from the **Marker and Body** group under the **Professional** tab in the ribbon.
- 2. In the **Modeling Window**, click anywhere in the background to associate the Marker with the MotherBody.
- 3. In the **Input Window**, enter the coordinates **-51**, **6**. You will see a new marker at the right corner of the paper tray.
- 4. Using the **Ctrl key**, select the three guides that make up the tray.
- 5. From the Advanced Toolbar, select the Basic Object Control tool.

- 6. Select the **Rotate** tab.
- 7. Enter **15** degrees for the angle.
- 8. Under **Reference Frame**, click the **M** button.
- From the Modeling Window, select MotherBody.Marker8 (the marker you just created).
- 10. Click the **Clockwise about Z** button.
- 11. Close the **Basic Object Control** dialog.

Basic	×
Translate Rotate Tra/Rot	
Scalar Rotate	Align Markers
Image: Second state    Image: Seco	Apply Reference Frame MotherBody.Marker8 M

The tray should now appear as shown below.



### **Creating the Sheet**

You will now create the sheet and position the lower rollers around it.

#### To create the sheet:



- 1. Select the **Shell** tool from the **Sheet** group under the **MTT3D** tab in the ribbon.
- 2. In the Input Window, enter a start point of 7.525, 5.
- 3. In the **Input Window**, enter a direction of **0**, **-1**.

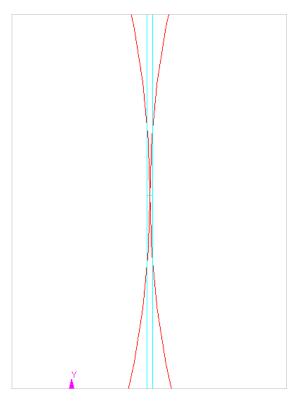
- 4. The **SheetShell** dialog should appear as shown right. If it does not, move the mouse pointer into the Modeling Window and it should appear.
- 5. Make the following settings in the **SheetShell** dialog shown at right.
  - Thickness: 0.05
  - Total Length (Longitudinal): 150
  - Number of Node (Longitudinal): 41
- 6. Select the checkbox next to Air Resistance Coefficient.
- 7. Click **OK**.

SheetShell [ Cu	urrent	Unit : N/kg	g/mm/	/s/de	g ]	
General Shee	et Shell					
Sheet Color	Au	tomatic	•		Display No	ode ID
Thickness	0.05 Pv				Material Property	
Start Point	7.525, 5	5., -105.				Pt
Parameter	-					
Mesh Rule Typ	oe [	Total Lengtl	h and M	lumb	er of Node	•
	L	Longi	tudinal		Lateral	
Direction		0, -1., 0		Pt	0, 0, 1.	Pt
Total Length		150		Pv	210.	Pv
Element Leng	th	9.9			10.5	
Number of No	ode	41			21	
Curl Radius		0.		Pv	0.	Pv
Number of In	ner CP	0			0	
🗌 Initial Long	gitudin	al Velocity	0.			
Air Resistance Coefficient Constant 👻 2.3 Pv						
💹 Update Ge	ometry	Information	n Auto	matica	illy	
					ОК	Cancel

The sheet has been created, but if you were to zoom into the sheet where it is between the rollers, you would see that it is penetrating the rollers and that the rollers have not been separated enough to accommodate the sheet, as shown at right. Therefore, the next step will be to align the sheet and rollers in a reasonable starting position.

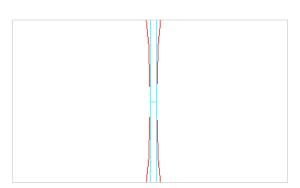
#### To align the sheet within the rollers:

- Align
- 1. Select the **Align** tool from the **Roller** group under the **MTT3D** tab in the ribbons.
- In the Modeling Window, select SheetShell1, the sheet group you just created.
- 3. In the **Modeling Window**, select **MovableRollerGroup1**, the roller to the right of the sheet.
- 4. Select **OK** when asked whether to align the sheet or not.



The sheet and movable roller should now have been moved into position as shown at right.

5. Save the model.





## **Running a Simulation**

### **Task Objective**

In this chapter, you will start a simulation and monitor its progress. Later, to save time, you will open a model identical to the one you created which will already have results for a complete simulation loaded and observe the results.



10 minutes

### **Improving Contour Plot Display**

Before running the simulation, you will change the Stress Recovery setting for the sheet body. This setting should be made in most models with flexible bodies for the contour plots to be interpreted correctly.

#### To set the stress recovery type to center:

- Select the Flexibility tool from the Model Setting group under the Home tab in the ribbon.
- 2. Select the **FFlex** tab.
- 3. In the **Stress Recovery Type** region, select **Center**.
- 4. Click **OK**.

	у						
Flex	RFlex	Flexible				 	
-Core	Option -						
	n Core			Ou	t Of Core		
Stre	s Recover	у Туре —					
٥	enter			⊖ Ext	rapolation		
A	utomatic	Outputs fo	or Markers				
		outputsite					
	aromatic	o alpuis re					
		oupus re					
		oupus					

### **Running a Simulation**

You will now start a simulation and monitor its progress.

#### To run the simulation:



- 1. Select the **Dyn/Kin** tool from the **Simulation Type** group under the **Analysis** tab in the ribbon.
- 2. Make the following settings, as shown at right.
  - End Time: 1
  - Step: 200

Dynamic/Kinematic Analysis	×
General Parameter Initial Condition	
End Time	1. Pv
Step	200. Pv
Plot Multiplier Step Factor	1. Pv .
Output File Name	
_ Include	
Static Analysis	
Eigenvalue Analysis	
State Matrix	
Frequency Response Analysis	
Hide RecurDyn during Simulation	
Display Animation	
Gravity	
χ 0. γ -9806.65	Z 0. Gravity
Unit Newton - Kilogra	am - Millimeter - Second
Export RSS Simula	ate OK Cancel

3. Select the **Parameter** tab.

#### 4. Change Maximum Time Step to 1e-3.

**Note**: For this simulation, the maximum time step should be reduced to prevent penetration of the sheet edge into GuideLinear5 on the right side of the tray. This can occur because near the end of the simulation, when the sheet is simply sliding down the tray, the integration time step can become too large since the motion of the sheet is very simple. The sheet continues to slide until it hits the bump stop at the right side of the tray, GuideLinear5. If the time step is too large at this point, the simulation can jump too quickly from one state in which the sheet edge is on one side of the bump stop to another in which the sheet edge is on the other side, without registering the sheet-to-guide contact correctly in between.

Dynamic/Kine	matic Analysis			×
General Para	ameter Initial Co	ndition		
Maximum Tir	me Step	1.e-003		Pv
Initial Time S	tep	1.e-006	;	Pv
Error Toleran	ice	5.e-003	1	Pv
Integrator Ty	pe	ADVHY	BRID	-
Numerical Da	amping	1.		Pv
Constant	Stepsize	1.e-005	i	
Jacobian Eva	luation for TPart	100.		Pv
Match So	lving Stepsize with	n Report Step		
Match Sin	nulation End Time	with User Input		
Stop Con	dition			
Export RSS		Simulate	ОК	Cancel

5. Click **Simulate** and allow the simulation to run for several minutes.

While the simulation is running, you can stop it and play the animation of the completed results to monitor its progress.

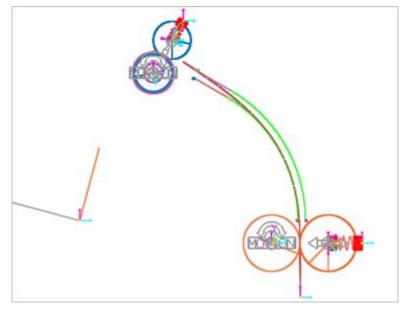
#### To monitor the simulation:

1. From the Simulation Toolbar, click the Pause Analysis button.

The animation controls should now become active.

2. From the Simulation Toolbar, click the Play button. You can use any of the animation controls to view the results as if the simulation were complete.

With the simulation at about 20% complete, you should see that the sheet has progressed through the guides and has started entering the corrugating roller pair, as shown below. At this point, the simulation will run slower due to the higher amount of sheet deformation and contact which will occur during its corrugation.



3. From the Simulation Toolbar, click the Resume Analysis button, in order to continue the simulation.

### **Viewing the Completed Simulation Results**

If you have a powerful desktop computer with multiple processing cores, the simulation can take less than one minute to complete. However, due to the limited time you may have to complete this tutorial, you will now open an identical model which already has results from a complete simulation loaded.

#### To open the completed model:

- 1. From the **Simulatoin Toolbar**, click the **Stop Analysis** button.
- 2. From the File menu, select Open.
- 3. Navigate to the tutorial subdirectory labeled **Printer\_complete**.
- 4. Select the file **Printer\_complete.rdyn**.
- 5. Select Open.

 $\cap$ 

- 6. Enter the **MTT3D1** subsystem.
  - In the Database Window, right-click on Subsystems > MTT3D1, and select Edit.

OR

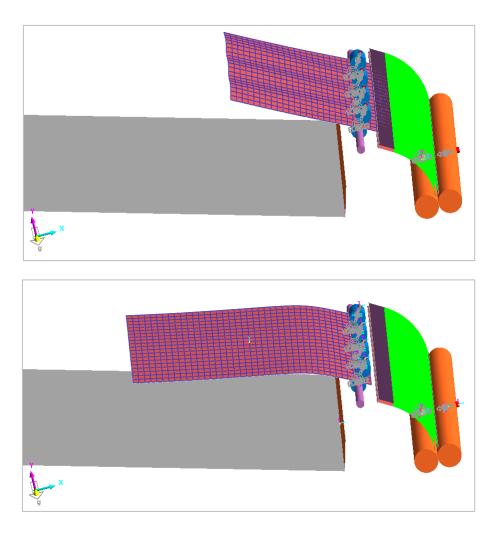
 In the Modeling Window, double-click on any geometric entity of the MTT3D1 subsystem.

If the animation controls are grayed out, you will need to import the animation results from the previously completed simulation.

#### To import the animation:

- 1. From the **File** menu, select **Import**.
- 2. Select the file **Printer\_complete.rad**.
- 3. Select Open.

You should now be able to view the results for a complete simulation of the system, by using the standard animation controls. You should see that the paper corrugates, but that it bends downward before exiting the corrugating roller pair, as shown below. This causes it to land awkwardly within the paper tray.



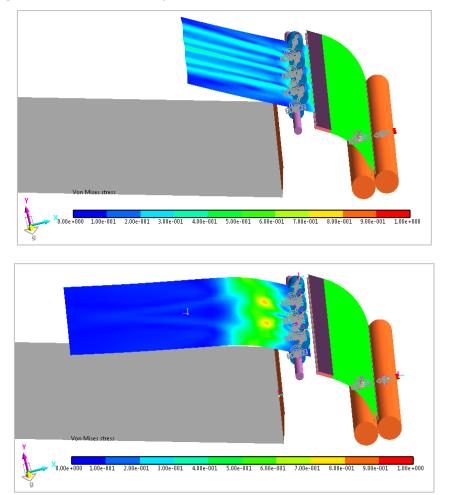
In order to see where the corrugation is occurring more easily, you can display the contour plot of stress within the sheet. To see the contour you need to run the simulation on your own computer so that the .erd, .rfa, and .srd FFlex output files are available.

#### To view the stress contour plot:



- 1. Select the **Contour** tool in the **Contour** group under the **MTT3D** tab.
- 2. In the **Contour Option** section, from the **Type** dropdown menu, select **Stress**.
- 3. Select **SMISES** from the displayed list of data types.
- 4. In the **Min/Max Option** section, from the **Type** dropdown, select **User Defined**.
- 5. Enter a **Max** value of **1**.
- 6. In the **Style Option** section, from the **Style** dropdown, select **Smooth**.
- 7. Also set the **Text Color** to be black.
- 8. Click OK.

The areas of high stress indicate where the corrugation is occurring as the sheet proceeds out of the rollers. In the second frame below, you can see when the corrugation dissipates due the increasing mass of the sheet away from the rollers, before the sheet is released.



The simulation shows that the design does not maintain the corrugation in the sheet for as long of a time as intended. In the next chapter, you will modify the design to increase the corrugation effect.



## **Modifying the Design**

### **Task Objective**

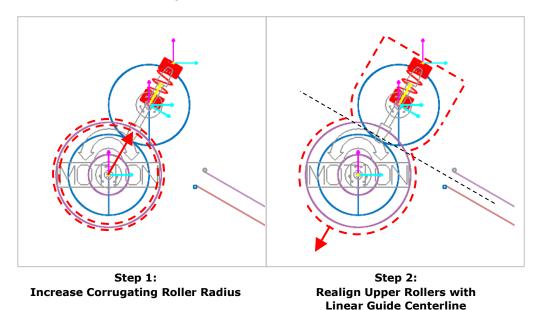
In this chapter, you will modify the design of the corrugation roller to increase the corrugation, in an effort to keep the sheet straight until it exits the printer. You will then import simulation results for the modified design and evaluate its performance.



10 minutes

### **Modifying the Design**

In order to increase the corrugation of the paper, the radius of the corrugating rollers will be increased. After that, all the upper rollers will be repositioned such that they remain aligned with the centerline of the linear guides, as shown below.



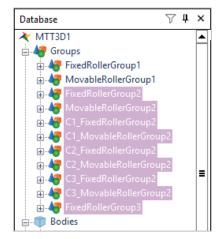
#### To increase the radius of the corrugating rollers:

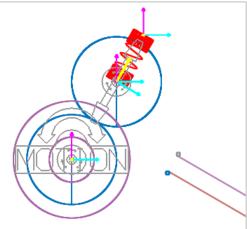
- 1. Return to your model.
- Open the Properties dialog of FixedRollerGroup3, the corrugating roller.
- 3. Click the **Multiple Roller Info**. button.
- 4. Change the **Radius** values to **6.5**, as shown at right.
- 5. Click Close.
- 6. Click OK.

∕lultip	le Roller Ge	>					
No	Radius	Depth	Distance	Add			
1	6.5	10.	-54.	Insert			
2	6.5	10.	0.	insert			
3	6.5	10.	54.	Delete			
		Dimensior	Information				
		Dimension Information Close					

#### To realign the upper rollers:

- In the Database Window, use the Shift key to select all the items under Groups except for FixedRollerGroup1 and MovableRollerGroup1.
  - Select FixedRollerGroup2.
  - Hold down the **Shift key**.
  - Select FixedRollerGroup3.
- 2. From the Advanced Toolbar, select the Basic Object Control tool.
- 3. Enter an **Offset Value** of **0.5**.
- 4. Under **Reference Frame**, click the **M** button.
- 5. In the **Modeling Window**, select a marker which is aligned with the axes of the springs, as shown at right.
- 6. Click the **-Z** button, or whichever button will move the rollers down and to the left.
- 7. Close the **Basic Object Control** dialog.
- 8. Save the model under a different name, such as **Printer\_update.rdyn**.





### **Evaluating the Design Change**

The revised model is ready to simulate, but as before, you can open an identical model with previously completed simulation results, to save time.

#### To open the previously completed model:

- 1. Open the file **Printer\_update.rdyn**, located again in the **Printer\_complete** tutorial subdirectory.
- 2. Enter the **MTT3D1** subsystem.
- 3. If the animation controls are grayed out, import the animation file **Printer\_update.rad**.
- 4. Enable the contour plots as done before.

The results should now show an increased amount of corrugation, enabling the sheet to successfully remain straight until exiting the printer, as shown in the following figures.

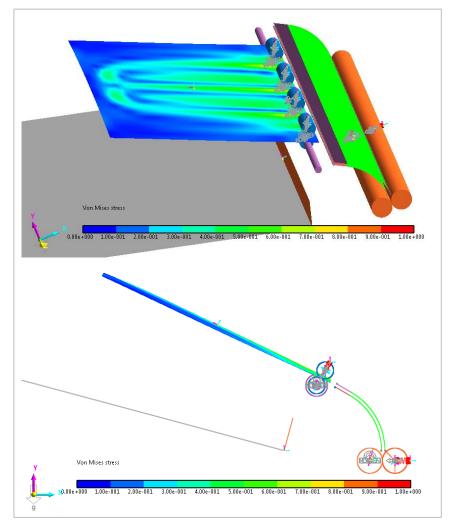


Figure 3: Sheet remains straight as it exits printer.

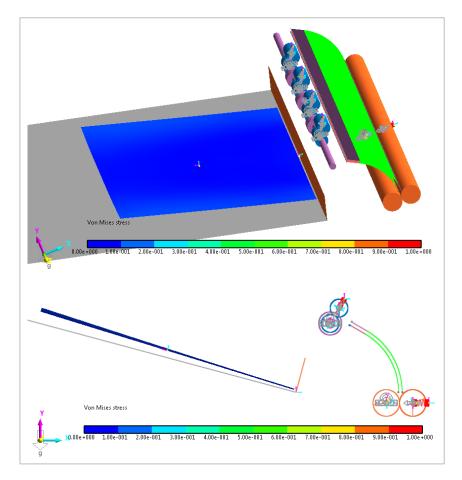
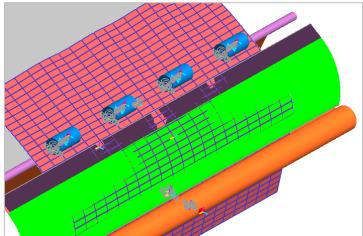
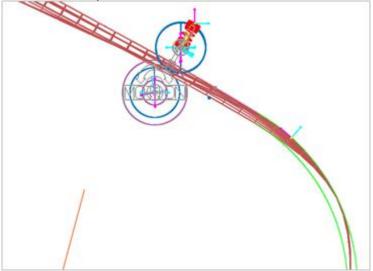


Figure 4: Sheet lands near flat in tray.

**Note**: In the modified model, you may notice some penetration of the sheet into the outer arc guide, as shown below.



Although this may appear to be a lot of penetration, it actually is not excessive. If viewed from the side, as shown below, you can see that the sheet is staying within the boundaries of the guides and the penetration is only on the order of 0.1 mm.



In addition, this penetration has little effect on the outcome of the simulation as the overall behavior of the sheet is very reasonable.

The penetration could be reduced if the contact stiffness of the guides were increased, however, this would also make the simulation slower by decreasing the integration step size. Therefore, a general rule of thumb is that the contact stiffness should be as low as possible while still enabling the model to behave reasonably.

Thanks for participating in this tutorial!