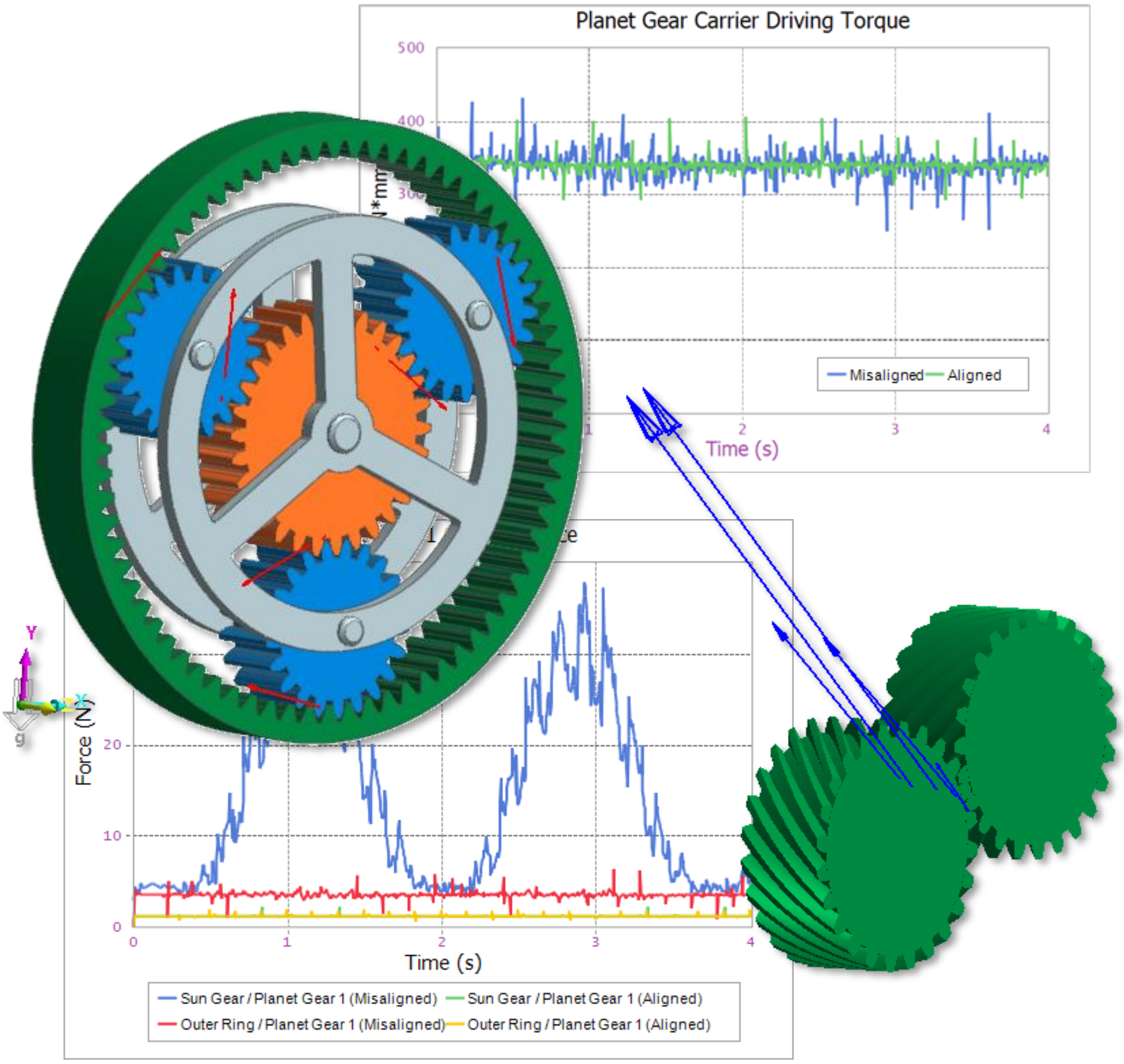
Planet Gear Tutorial (Gear)



FunctionBay

Edition Note

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

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Chapter

1

Getting Started

Objective

In this tutorial, you will simulate some simple gear systems to become familiar with the **RecurDyn/Gear** Toolkit. The first system will be a planetary gear set using spur gears. The effect of misaligning one of the gears will be studied. The second system will be two gear pairs, one using spur gears and the other using helical gears. This system will be used to compare the performance of the two different gear types.

Audience

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

Prerequisites

You should first work through the 3D Crank-Slider and Engine with Propeller 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)
Creating the Planetary Gear Set Model	20
Studying Misalignment Effects	15
Helical Gears	20
Total	**55**

Estimated Time to Complete

55 minutes

Chapter 2

Creating the Planetary Gear Set model

Task Objective

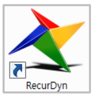
Learn how to create a simple gear system.

Estimated Time to Complete

20 minutes.

Creating a New Model and Gear Subsystem

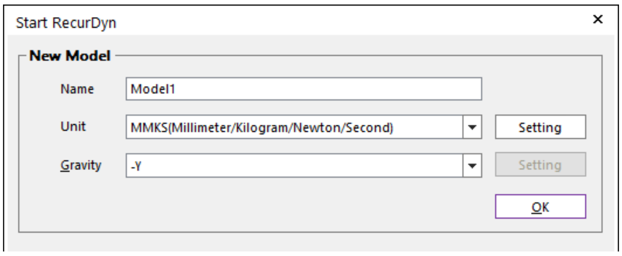
To create a new model:



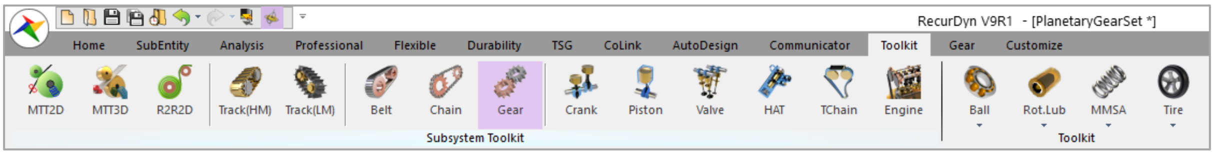
1. On your Desktop, double-click the **RecurDyn** tool.

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

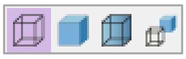
2. Enter **PlanetaryGearSet** as the Model Name.
3. Select **OK**.



To create a new gear subsystem:



1. From the **Render Toolbar**, select the **Wireframe** button.



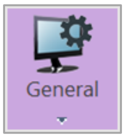
2. From the **Subsystem Toolkit** group in the **Toolkit** tab, click **Gear**.

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

Customizing Settings

You will now make some custom settings to the program and to the model.   You will improve the graphic display of the model and results, and you will turn off the "Shift when Pasting" option to make the future modeling steps easier.

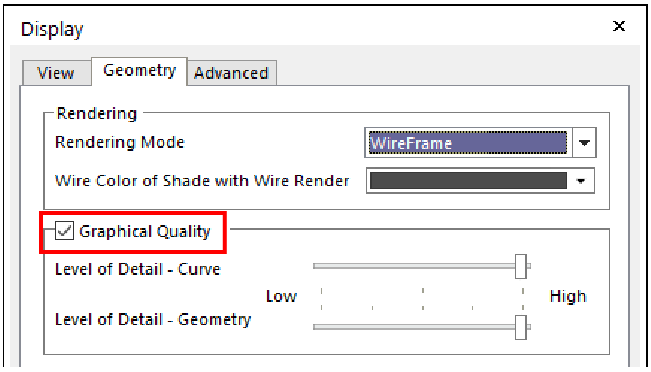
To improve the graphic display of the model and results:



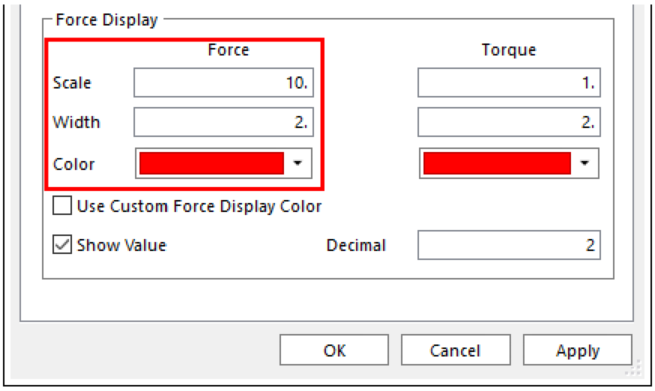
1. From **Model Setting** group in the **Home** tab, click **Display.**

   The **Display** dialog will be shown.

2. Check the box next to **Graphical Quality** in the **Geometry** tab.
3. Adjust the two slider bars to the right to improve the display quality.

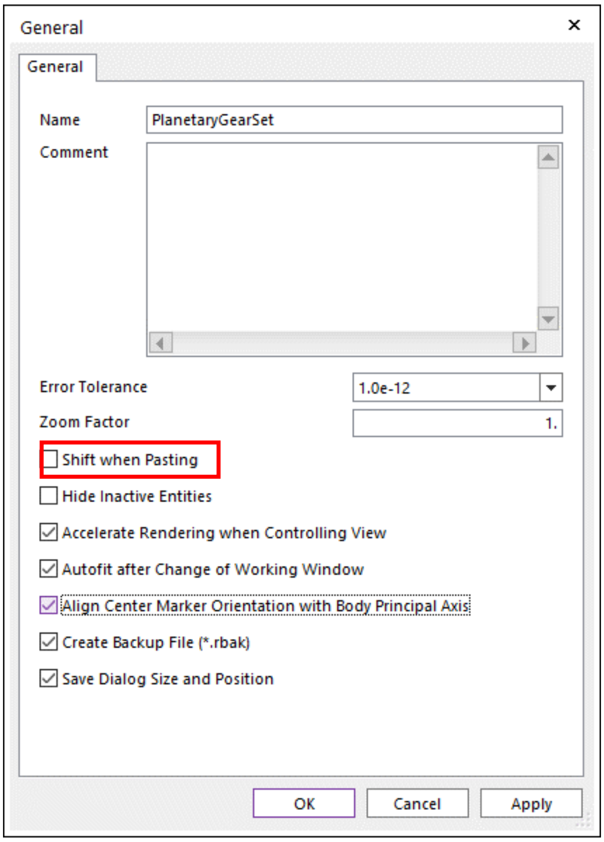


4. Select the **Advanced** tab.
5. Under **Force**, make the following settings:
   - **Scale: 10**
6. And, in the **Color** tab, Under **Force**, make the following settings:
   - **Color: Red**



To turn off Shift When Pasting

1. From **Model Setting** group in the **Home** tab, click **General.**
2. Deselect the checkbox next to **Shift When Pasting.**
3. Click **OK**.

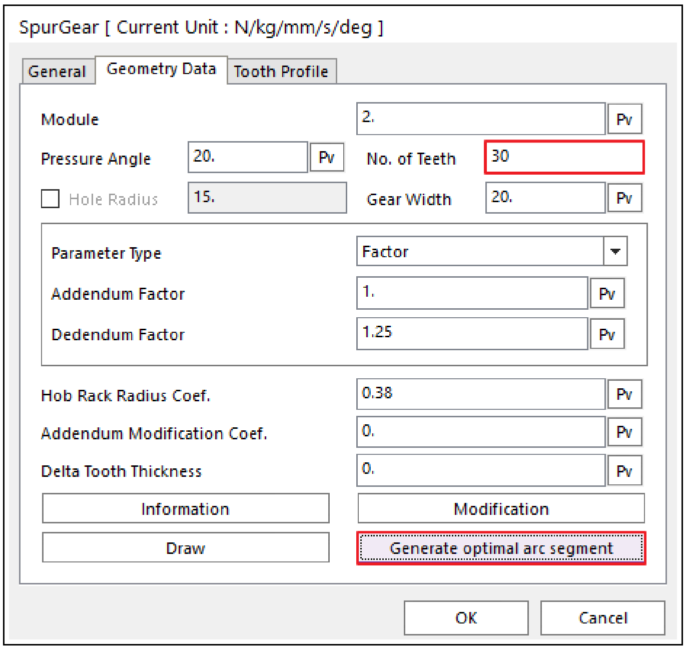


Creating the Gears

To create the sun gear:

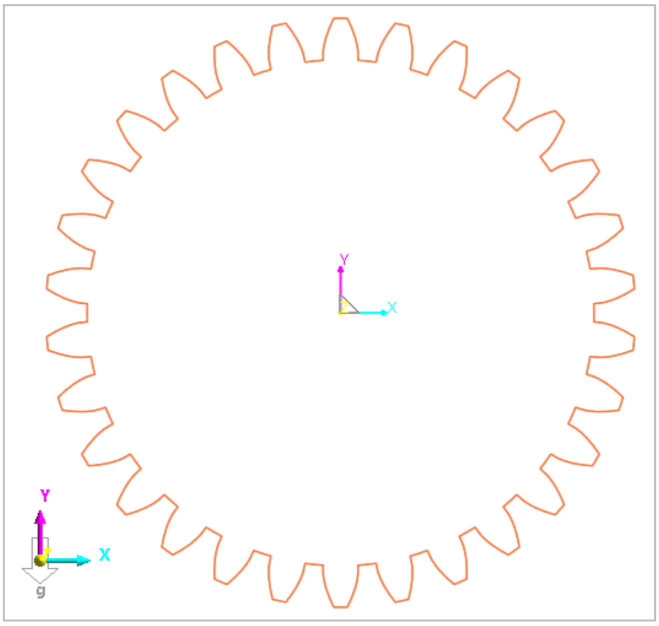
1. From the **Gear** group in the **Gear** tab, click **Spur**.
2. Select the point **0, 0, 0** in the Working window to define the center of the gear or type the values into in the Input windows toolbar.

   The **SpurGear** dialog will appear.
3. Select the **Geometry Data** tab.
4. Set the **Number of Teeth** to **30**.
5. Click **Generate optimal arc segment**.
6. Click **OK**.



7. In the **Database Window**, right-click on **SpurGear1**.
8. Select **Rename**.
9. Rename the gear to **SunGear**.

   The model should now appear as shown below.



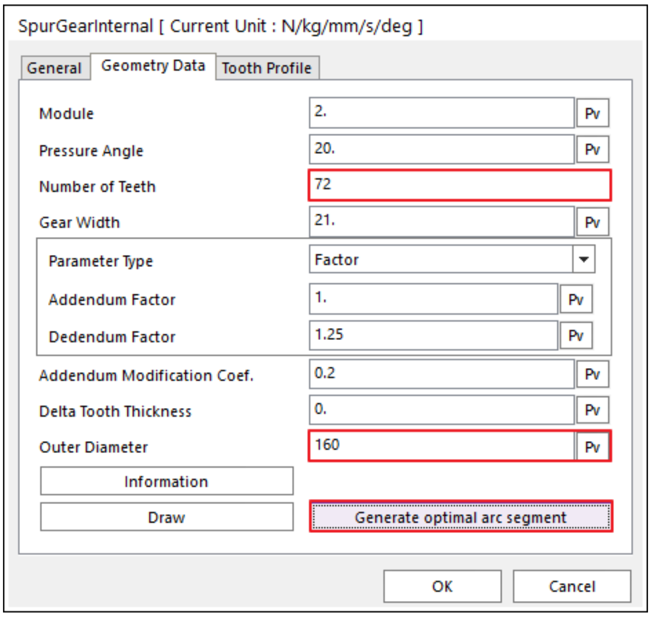
To create the planet gears:

1. Repeat the steps above to create another spur gear, this time with **21 teeth**, and named **PlanetGear1**.
2. In the Working window, select **PlanetGear1**, the gear you just created.
3. Type **Ctrl-C** to copy the gear.
4. Type **Ctrl-V** two times to create two more planet gears. You will move them to their correct location later.
5. Rename the other two planet gears to **PlanetGear2**, and **PlanetGear3** using the Database Window rename capability.

To create the outer ring gear:

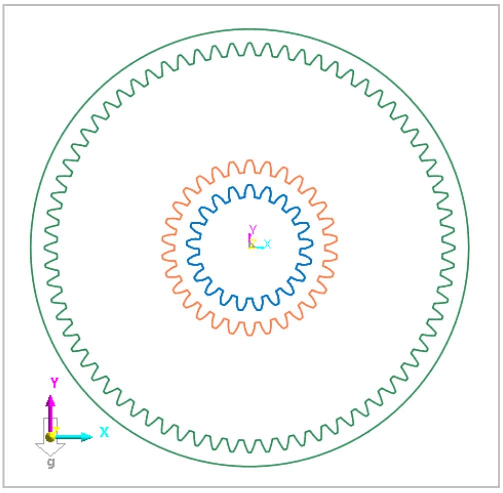
1. From the **Gear** group in the **Gear** tab, click **Int.Spur**.
2. Select the point **0, 0, 0** in the Working window to define the center of the gear.

   The **SpurGearInternal1** dialog will appear.



3. Select the **Geometry Data** tab.
4. Make the following settings, as shown at right.
   - **Number of Teeth: 72**
   - **Outer Diameter: 160**
5. Select **Generate optimal arc segment**.
6. Select **OK**.
7. Rename the gear to **OuterRingGear**.

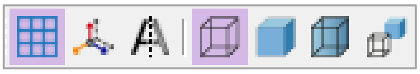
   Your model should now appear as shown at right.



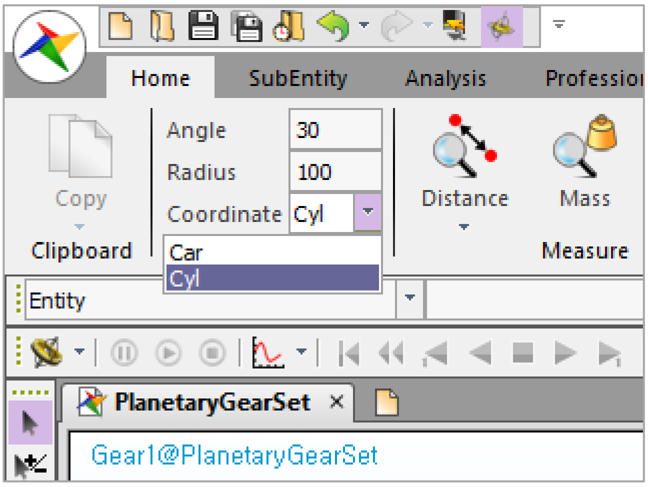
Arranging the Gears

You will now move the planet gears into position so that their teeth engage correctly with the sun gear.

To engage the first planet gear:



1. From the **View Control Toolbar**, select the **Grid On/Off** button to turn the grid display on.



2. From the **Working Plane** group in the **Home** tab, change the **Coordinate** from **Car** (Cartesian) to **Cyl** (Cylindrical), as shown at right.

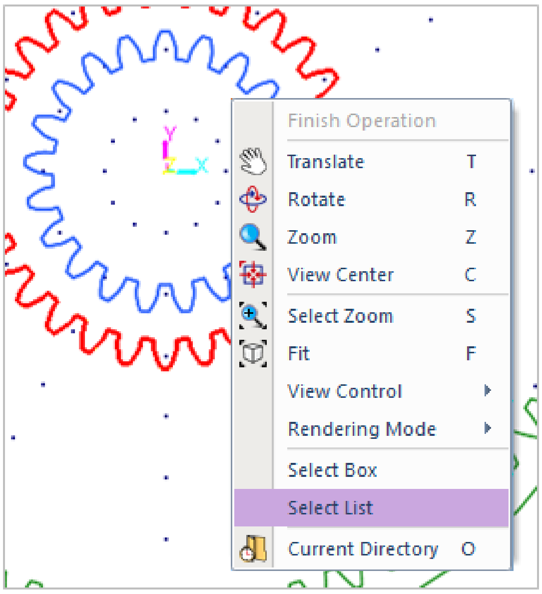
   This will change the grid display as shown at right, so you can easily select points exactly at 120° and 240° from the center of the sun gear.

3. Change the **Radius** to **10**.

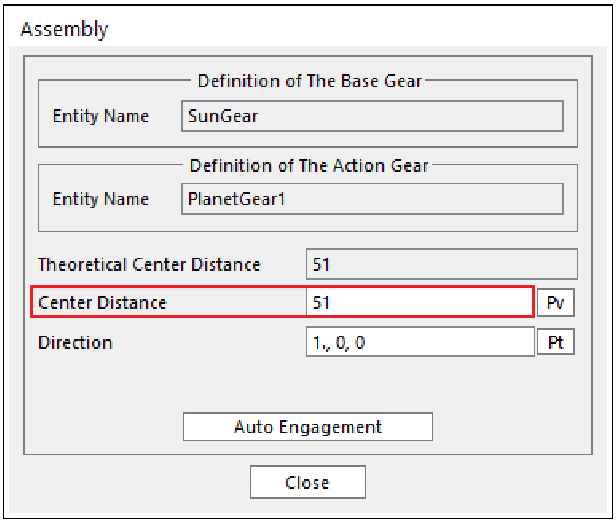
4. From the **Assembly** group in the **Gear** tab, click **Assembly**.
5. In the Working window, select **SunGear** as the base gear.
6. To select the action gear, in the Working window, right-click on the **planet gears**, and select **Select List**, as shown at right.

   A list of selectable entities will be brought up.

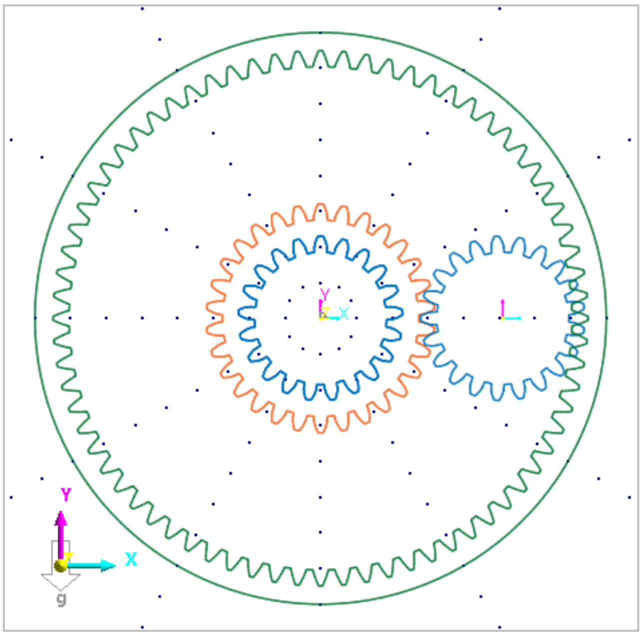
7. Select **PlanetGear1** from the list and click **OK**



8. For the **Center Distance**, enter **51**.
9. Click the **Auto Engagement** button.
10. Click **Close**.

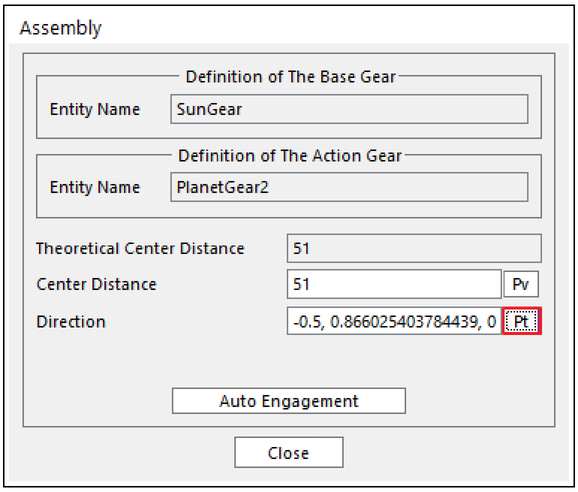


Your model should now appear as shown below

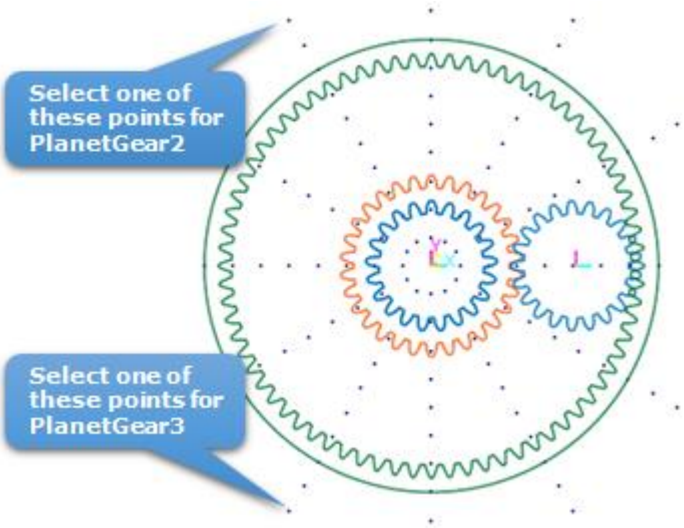


To engage the remaining two planet gears:

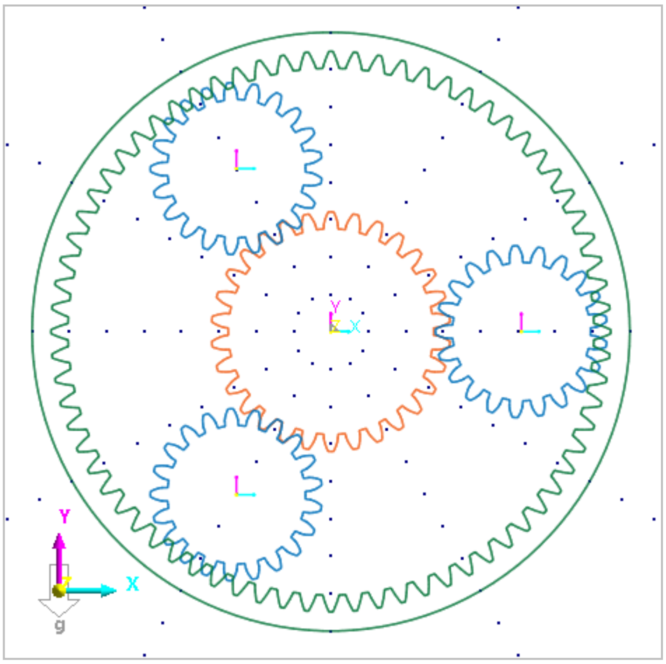
1. The assembly process, this time selecting **PlanetGear2** as the action gear.
2. This time, in the **Assembly** dialog, to the right of **Direction**, select the **Pt** button.



3. In the Working Window, select any grid point along the 120° line.
4. Again, select **Auto Engagement** and **Close** to move PlanetGear2 into place at 120° from the sun gear.
5. Repeat the assembly process for **PlanetGear3**, selecting any grid point along the 240° line.



The model should now appear as shown below.

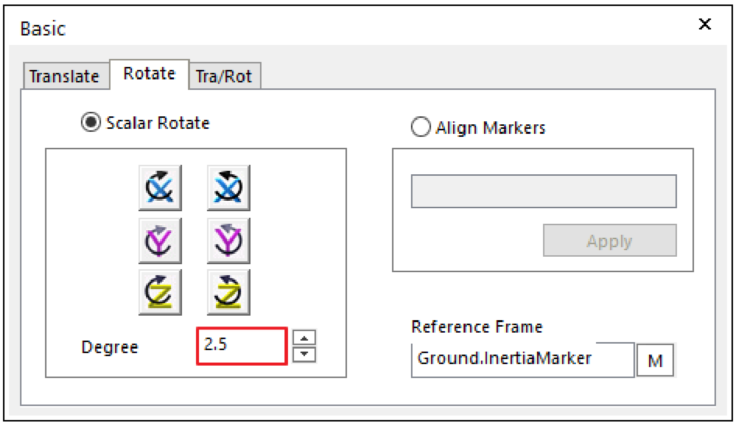


At this point, the outer ring gear should look correctly sized to mesh with the planet gears, however, the angle of the gear is off by half a gear tooth, or ½ × 360° / 72 teeth = 2.5°. You will now rotate the outer ring gear by that amount to align it correctly with the planet gears.

To align the outer ring gear:

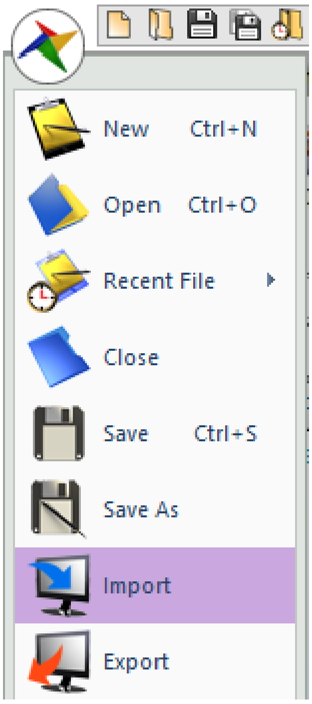
1. Select the **OuterRingGear**.
2. From the **View Control Toolbar**, select the **Basic Object Control** tool.

3. Select the **Rotate** tab.
4. Enter an angle of **2.5** degrees.
5. Click the **Counterclockwise** about **Z- axis** button.
6. Close the **Basic Object Control** dialog.



The outer ring gear teeth should now align with those of the planet gears.

Importing the Planet Gear Holder Geometry

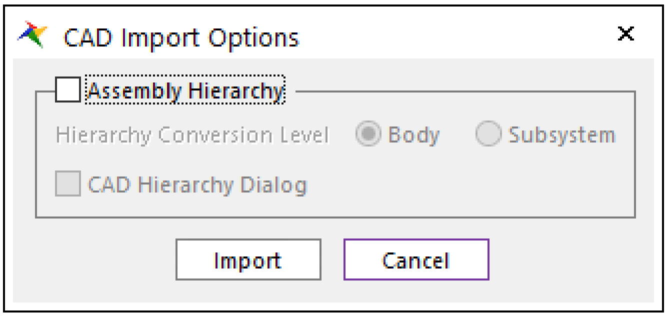


You will now import geometry representing the planet gear holder.

To import the planet gear holder:

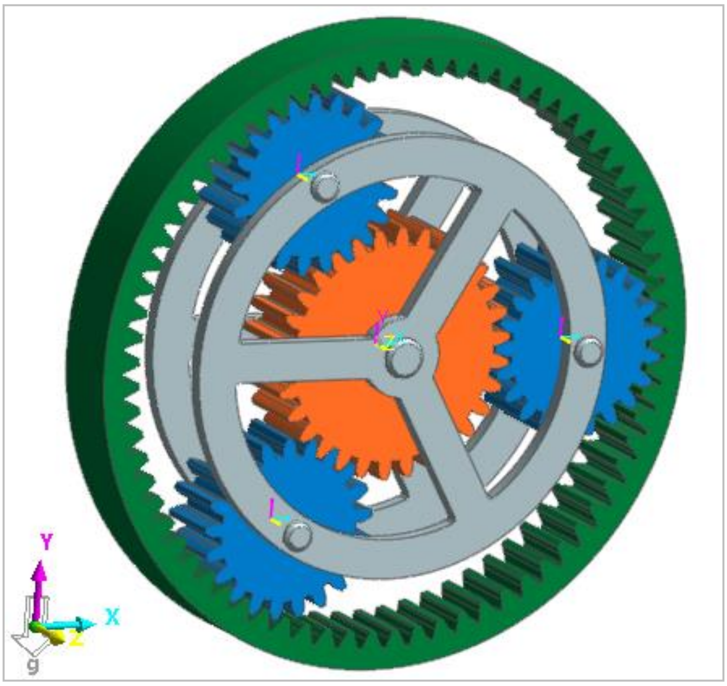
1. Select **System Button > Import**.

   The Import dialog will appear.
2. Change the file type to **ParaSolid File(*.x_t;*.x_b;*.xmt;*.xmt_bin)**.
3. Navigate to the Gear Tutorial directory and select the file **PlanetGearCarrier.x_t. (The file location:** <Install Dir> /Help /Tutorial /Toolkit /Gear /PlanetGear)
4. Click **Open**. The **CAD Import Options** window appears. Clear the **Assembly Hierarchy** checkbox and click the **Import** button.



5. Rename the new body, **ImportedBody1**, to **PlanetGearCarrier**.

The model should now appear as shown below.

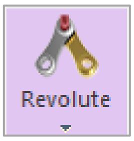


Creating the Joints

You will now create several revolute joints to connect the gears to the various bodies. The outer ring gear will be fixed to ground.

To create the joints:

1. From the **Joint** group in the **Professional** tab, click **Fixed**
2. Set the Creation Method toolbar to **Body, Body, Point**.
3. Select **MotherBody** as the base body by clicking in the background of the **Working window**.
4. Select **OuterRingGear** as the action body.
5. Enter **0, 0, 0** in the **Input Window** toolbar.



6. From the **Joint** group in the **Professional** tab, click **Revolute**.
7. Set the Creation Method toolbar to **Body, Body, Point**.
8. Select **MotherBody** as the base body.
9. Select **PlanetGearCarrier** as the action body.
10. Enter **0, 0, 0** in the Input Window toolbar.
11. Repeat **Steps 6-10** to create revolute joints between the following bodies (use the center of mass markers to place the revolute joints at the centers of the gears).

Joint	Base Body	Action Body
RevJoint2	MotherBody	SunGear
RevJoint3	PlanetGearCarrier	PlanetGear1
RevJoint4	PlanetGearCarrier	PlanetGear2
RevJoint5	PlanetGearCarrier	PlanetGear3

Creating the 2D Contacts

For quick simulations, **RecurDyn** allows the creation of 2D contacts which take into account the profile shape of the gear teeth. You will now create 2D contacts between the gears.

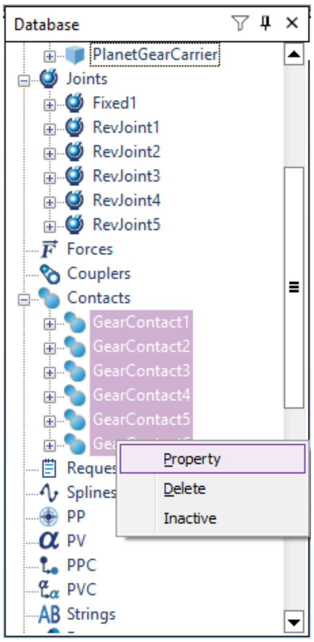
To create the 2D Contacts:

1. From the **Contact** group in the **Gear** tab, click **Cur-Cur** (2D Curve-to-Curve Contact).
2. Select **SunGear** as the base body.
3. Select **PlanetGear1** as the action body.
4. Repeat **Steps 1-4** above to create contacts between the following gears:

Contact	Base Body	Action Body
GearContact2	SunGear	PlanetGear2
GearContact3	SunGear	PlanetGear3
GearContact4	OuterRingGear	PlanetGear1
GearContact5	OuterRingGear	PlanetGear2
GearContact6	OuterRingGear	PlanetGear3

You will now modify the contact parameters to improve simulation speed and improve results for this model.

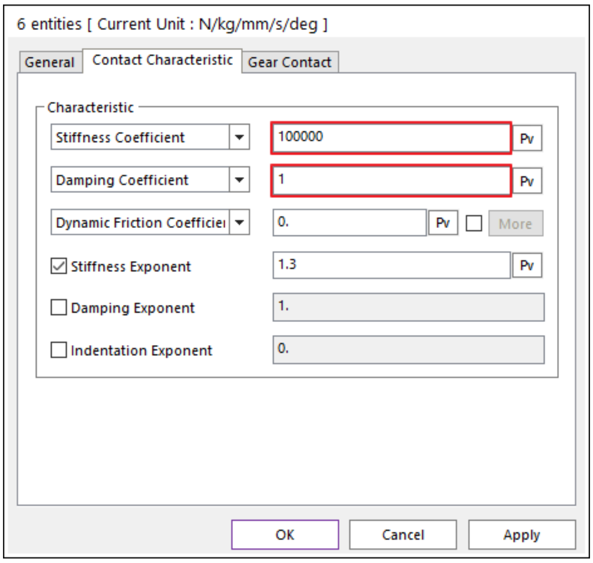
To modify the 2D Contact parameters:



1. In the **Database Window**, select **GearContact1 – GearContact6** by doing the following.
   a. Select **GearContact1**.
   b. Press and hold down the **Shift** key.
   c. Select **GearContact6**.
2. Right-click on one of the selected entities and select **Property**.

   A Properties dialog titled "**6 entities**" will be displayed.

3. Select the **Contact Characteristic** tab.
4. Make the following settings.
   - **Stiffness Coefficient: 100000**
   - **Damping Coefficient: 1**
5. Click **OK**.

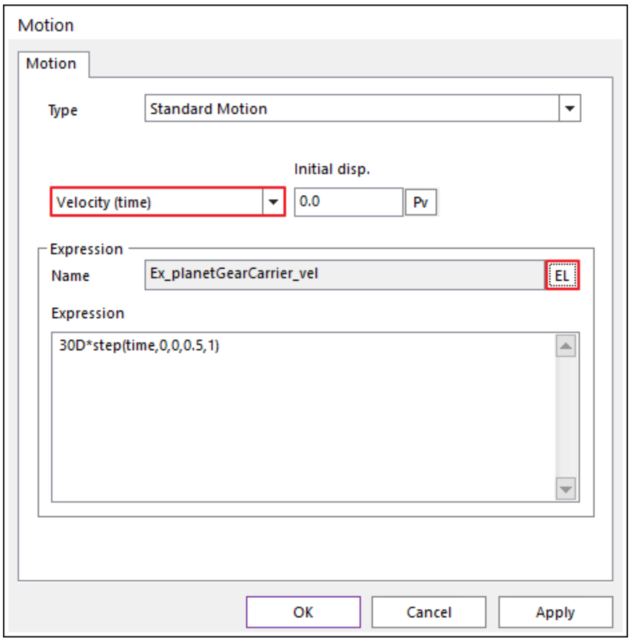


Applying a Motion Input and a Torque Load

You will now apply a motion input to the planet gear carrier and apply a resistive torque load onto the sun gear.

To apply a motion input:

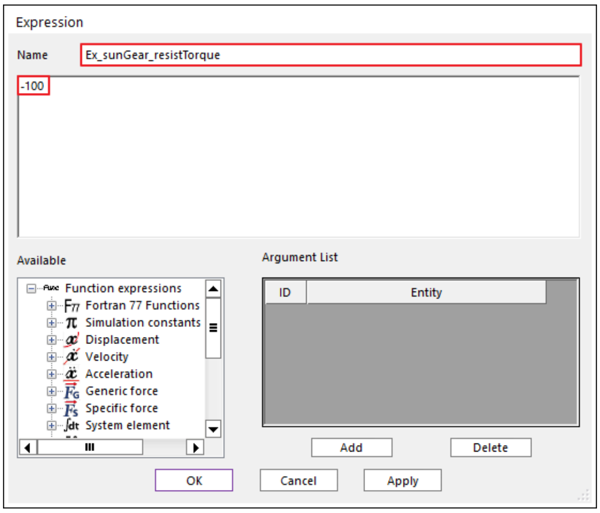
1. Open the **Properties** window for **RevJoint1**, the revolute joint between **MotherBody** and **PlanetGearCarrier**.
2. Select the **Include Motion** checkbox and click the **Motion** button.
3. Select **Velocity** from the dropdown menu.
4. Click the **EL** button.
5. Click **Create**.
6. Enter **Ex_planetGearCarrier_vel** as the expression name.
7. Enter the following for the expression.
   - **30D*step(time, 0, 0, 0.5, 1)**
8. Click **OK** four times to exit out of all the dialog windows.



To apply a resistive torque load:

1. From the **Force** group in the **Professional** tab, click **Rot.Axial**
2. Set the **Creation Method toolbar** to **Joint**.
3. Use the **Select List** to select **RevJoint2**, the revolute joint between **MotherBody** and **SunGear**.
4. Open the **Properties** dialog for **RotationalAxial1**.
5. Click the **EL** button.
6. Click the **Create** button.
7. Enter **Ex_sunGear_resistTorque** for the expression name.
8. Enter **-100** as the expression.
9. Click **OK** three times.

Construction of the model is now complete, and simulations can be run.



Running a Simulation

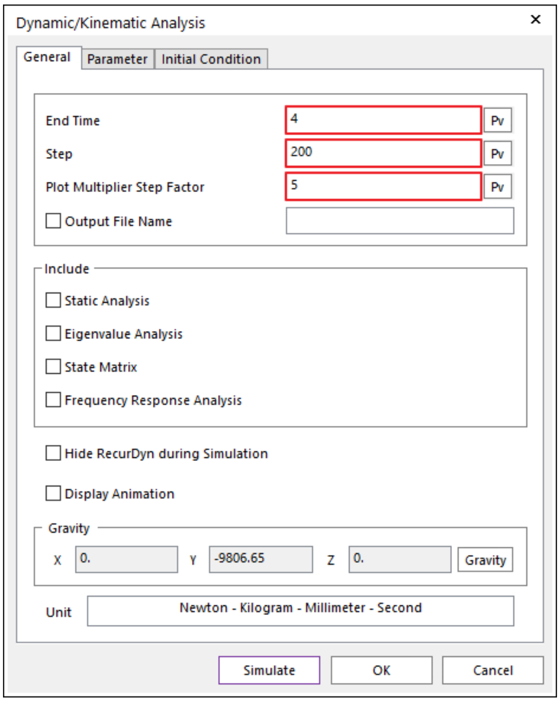
You will now simulate the model and verify the observed gear ratio between the planet gear carrier and the sun gear.

To run a simulation:

1. From the **Simulation Type** group in the **Analysis** tab, click **Dyn/Kin**
2. Make the following changes.
   - **End Time: 4**
   - **Step: 200**
   - **Plot Multiplier Step Factor: 5**
3. Click **Simulate**.

4. When the simulation finishes, you can play the animation by clicking the **Play** button in the **Toolbar**.

   The animation should show the planetary gear system working smoothly with no problems.



Chapter

3

Studying Misalignment Effects

Task Objective

Observe how misaligning one of the planet gears affects the planetary gear system.

Estimated Time to Complete

15 minutes

Switching to 3D Contacts

Because you will be misaligning one of the gears, using the 2D contacts is no longer valid since you want to study the non-ideal behavior of the system caused by 3D interactions between the gears. Therefore, the first step is to create new 3D gear contacts and deactivate the 2D contacts.

To create the 3D gear contacts:

1. From the **Contact** group in the **Gear** tab, click **Solid**.
2. Select **SunGear** as the base body.
3. Select **PlanetGear1** as the action body.
4. Repeat **Steps 1-3** above to create contacts between the following gears.

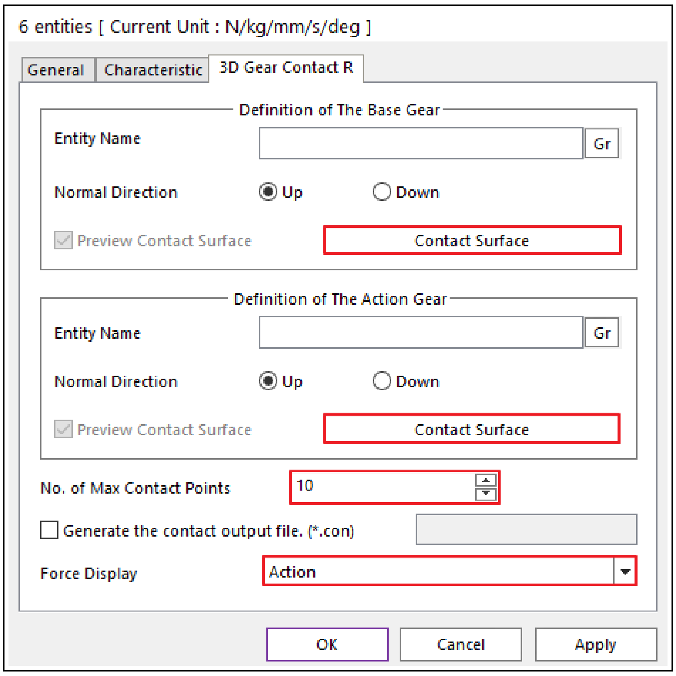
Contact	Base Body	Action Body
GearContact3DR2	SunGear	PlanetGear2
GearContact3DR3	SunGear	PlanetGear3
GearContact3DR4	OuterRingGear	PlanetGear1
GearContact3DR5	OuterRingGear	PlanetGear2
GearContact3DR6	OuterRingGear	PlanetGear3

You will now modify the contact parameters to improve simulation speed and improve results for this model.

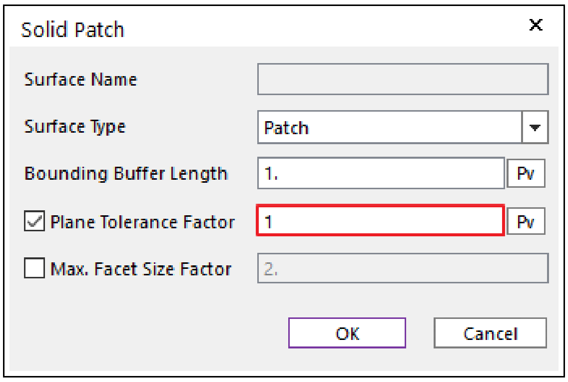
To modify the 3D Contact parameters:

1. In the **Database Window**, select **GearContact3DR1 – GearContact3DR6**, using the **Shift** key as done before.
2. Right-click on one of the selected entities and select **Property**.

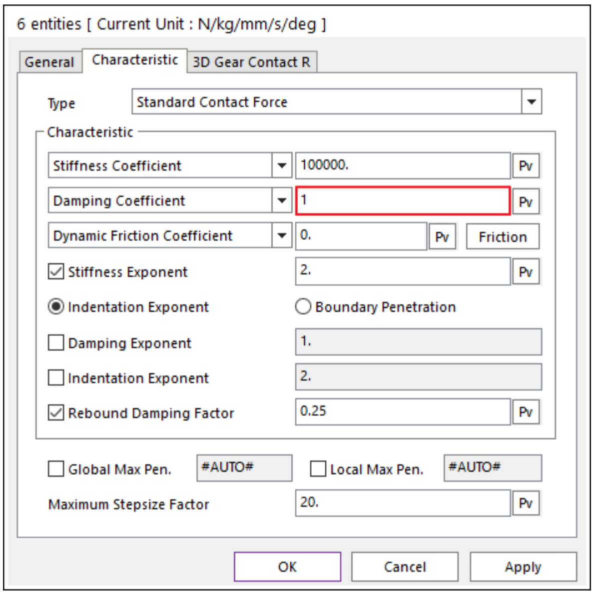
   A Properties dialog titled "6 entities" will be displayed.
3. Under the **3D Gear Contact R** tab, set **No. of Max Contact Points** to **10**.



4. Set the **Force Display** to **Action**.
5. In the **Base Gear** section, click the **Contact Surface** button.
6. Set the **Plane Tolerance Factor** to **1**.
7. Click **OK**.

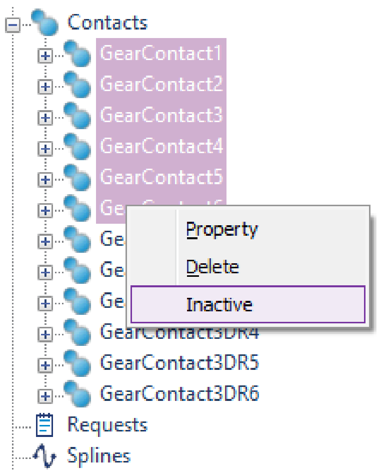


8. Repeat **Steps 5-6** above for the **Action Gear**.
9. Select the **Characteristic** tab.
10. Change the **Damping Coefficient** to **1**.
11. Click **OK**.



To deactivate the 2D gear contacts:

1. In the **Database Window**, select **GearContact1 – GearContact6**.
2. Right-click and select **Inactive**.



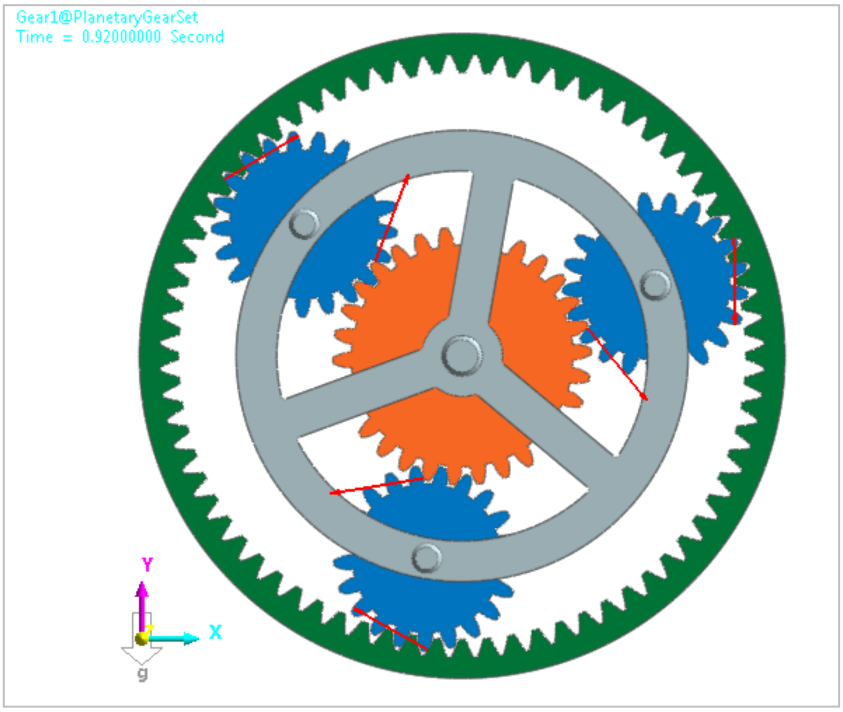
Simulating and Viewing the 3D Contact Results

Before misaligning one of the gears, you will simulate the aligned case with 3D contacts which you will be able to use as a case to compare the misaligned case with.

To simulate and view the results:

1. Simulate the model as done before.
2. When the simulation is done, play the animation results.

   The results should appear as shown below, with the contact force arrows appearing evenly distributed between all three planet gears. The contact force arrows should transition from tooth to tooth as the gears turn.



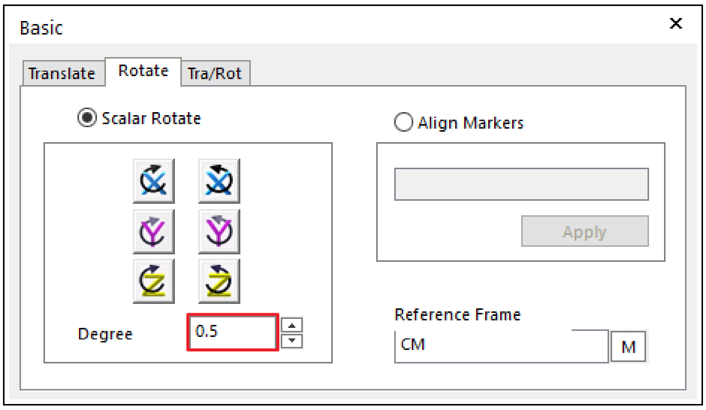
Misaligning a Planet Gear

You will now save the model under a different name and then misalign the planet gear on the right side.

To misalign a planet gear:

1. Select **System Button > Save As**.
2. Save the model as **PlanetaryGearSet_misaligned.rdyn**.
3. In the **Database Window**, right-click on **PlanetGear1**, and select **Edit**.

   You should now be in the body edit mode of **PlanetGear1**.
4. From the **Database Window**, select **SpurGear1**.
5. From the **Toolbar**, select the **Basic Object Control** tool.
6. Select the **Rotate** tab.
7. Enter an angle of **0.5** degrees.
8. Click the **Counterclockwise About Y-Axis** button.
9. Close the **Basic Object Control** dialog.



From the **Quick Access Toolbar**, select the **Exit** button to exit the body edit mode and return to the gear subsystem.

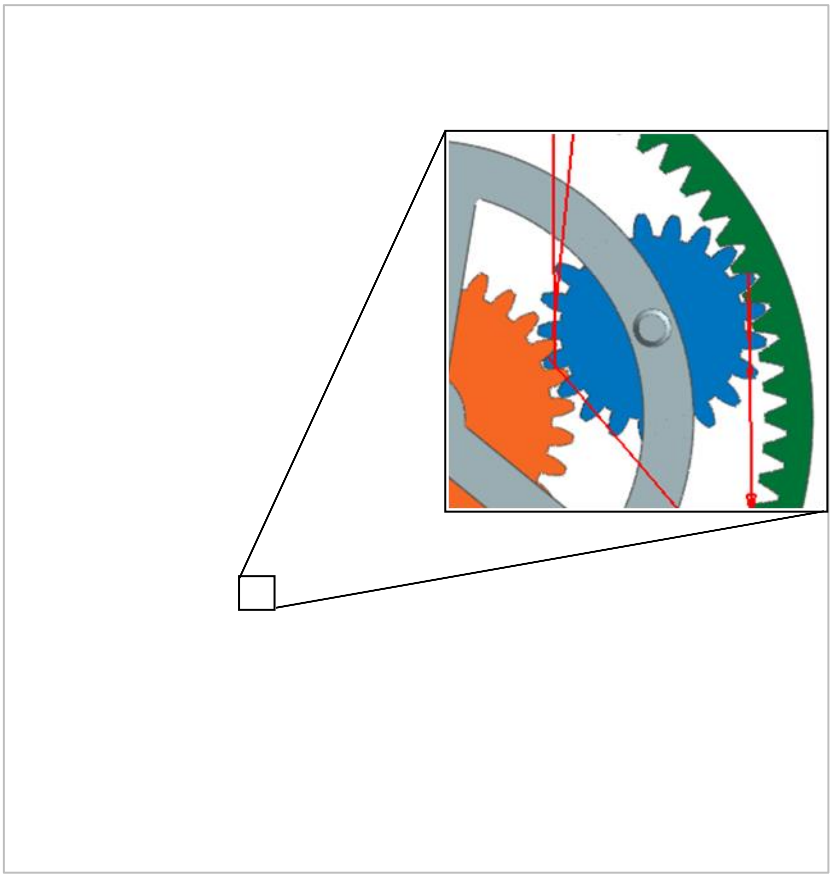
Simulating the Misaligned Model and Comparing Results

You will now simulate the model and then compare the results to those of the ideal model.

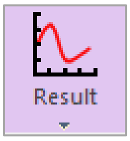
To simulate the model:

1. Simulate the model as before, changing the **End Time** to **4** sec if needed.
2. When the simulation is complete, play back the animation results.

   You should see, as shown below, that the gear tooth contact forces become very high at certain points of the simulation depending on the orientation of the misaligned gear with respect to the sun and outer ring gears.

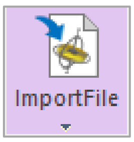


To compare the results:



1. From the **Plot** group in the **Analysis** tab, click **Result**.

   The plotting environment will be opened.



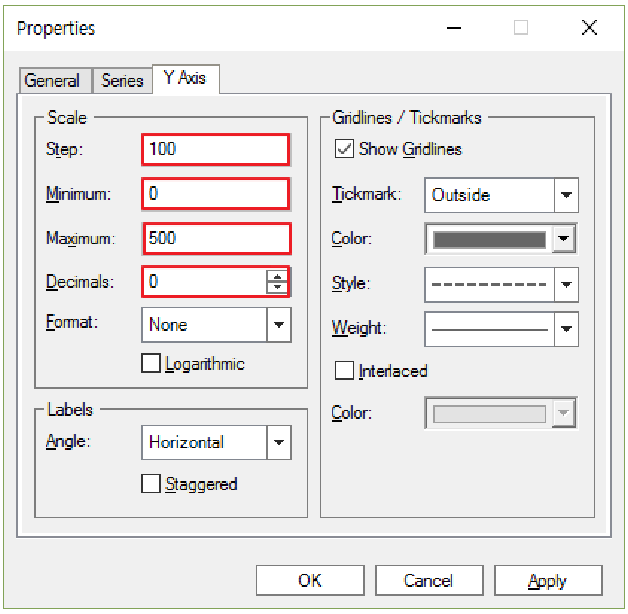
2. From the **Import and Export** group in the **Home** tab, click **Import**.
3. Select the file **PlanetaryGearSet.rplt** and click **OK**.

4. To plot the driving torque of **RevJoint1** for both sets of data.
   - Right-click on **PlanetaryGearSet_misaligned > Joints > RevJoint1 > Driving_Torque**.
   - Click **Multi Draw**.

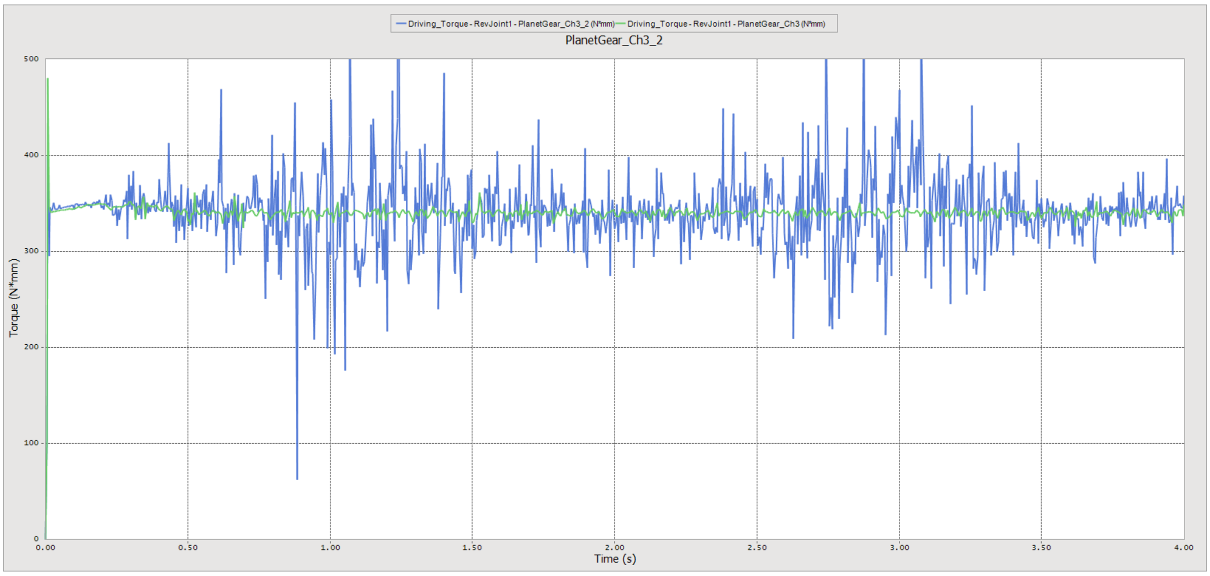
   There should be an initial negative spike in the plot which will cause the y-axis scale to be too large.

To adjust the y-axis scale:

1. Right-click on one of the y-axis number labels and select **Properties**.
2. Make the following settings, as shown at right.
   - **Step: 100**
   - **Minimum: 0**
   - **Maximum: 500**
   - **Decimals: 0**
3. Click **OK**.



The plot should now appear similar to the one shown below. While both curves show periodic fluctuation with the frequency at which the gear teeth mesh, the driving torque for the misaligned model is noisier and also shows more fluctuation during the times when the misalignment has its greatest effect.

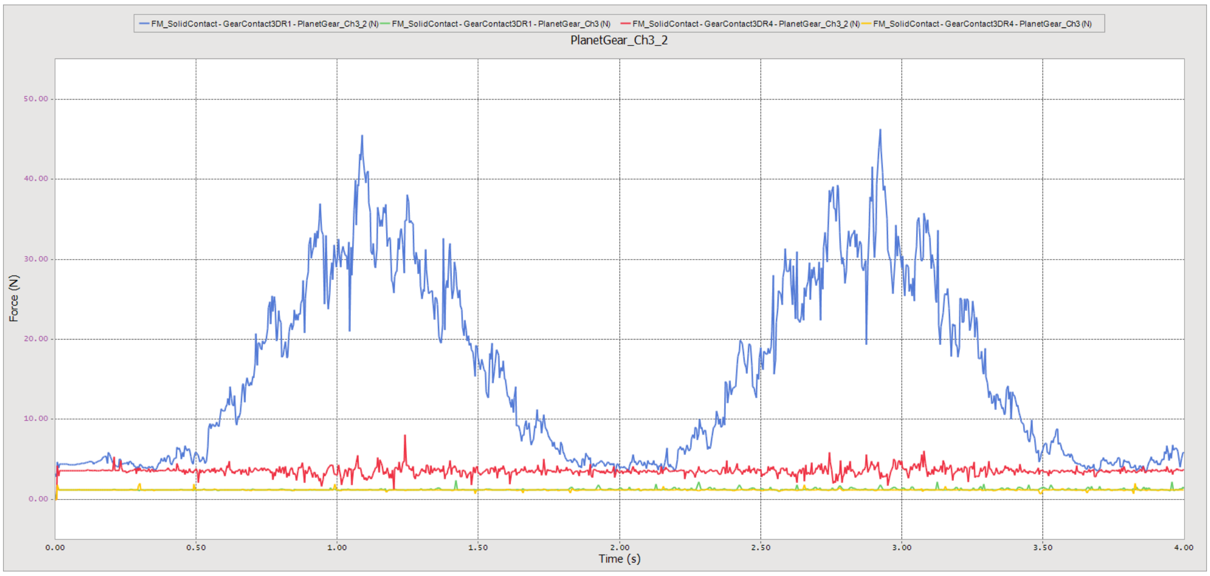


4. From the **Page** group in the **Home** tab, click **Add**.
5. Repeat the steps above to plot the following data for both models.
   - **Contact > Solid Contact > GearContact3DR1 > FM_SolidContact**

     (contact between the sun gear and planet gear 1)
   - **Contact > Solid Contact > GearContact3DR4 > FM_SolidContact**

     (contact between the outer ring gear and planet gear 1)

The plot should appear similar to the one shown below. Here, the periodic increase in contact force for the misaligned model can be seen easily, while the contact force for the aligned model is relatively constant.



Chapter

4

Helical Gears

Task Objective

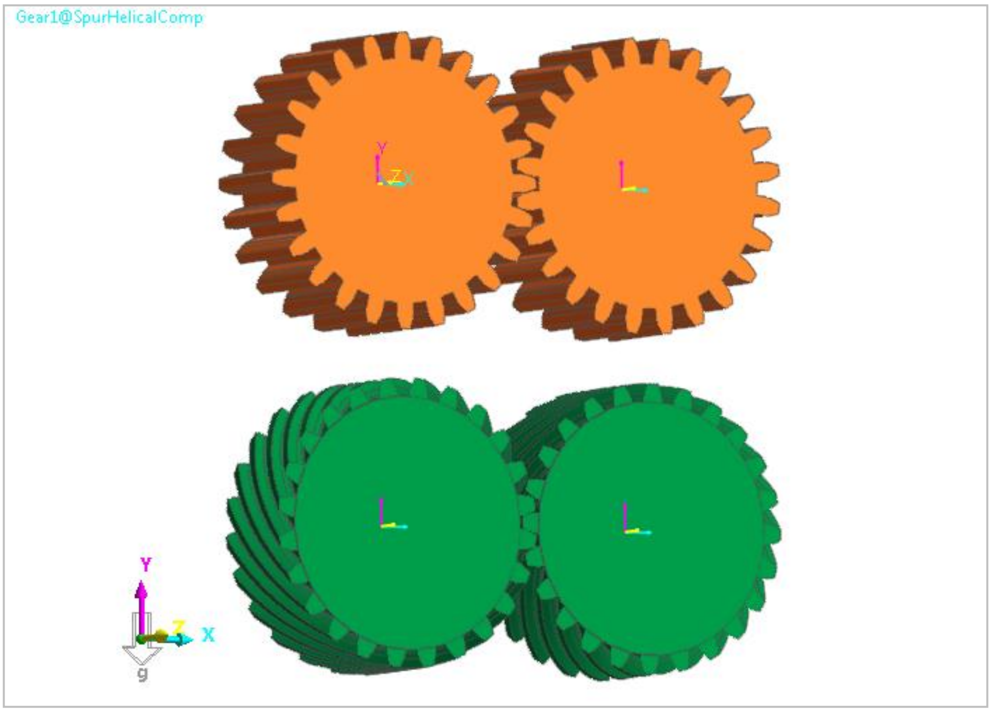
Helical gears are often used in place of spur gears when noise reduction and smoothness of operation are of concern. In this chapter you will learn to create a helical gear pair and compare its performance with an equivalent spur gear pair.

Estimated Time to Complete

20 minutes.

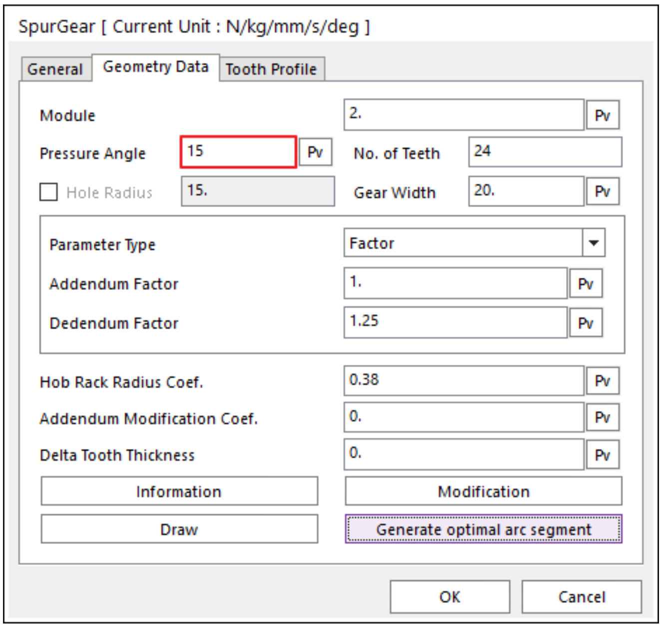
Creating the Model

You will now create a model which will contain both a helical and a spur gear pair. When you are done with this set of steps, the model should appear as shown below.



To create the spur gears

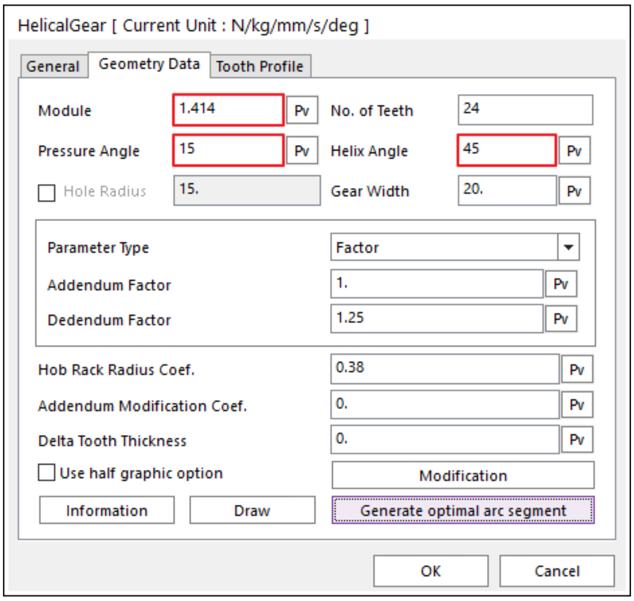
1. Create a new model, naming it **SpurHelicalComp**.
2. Create a **gear** subsystem within the new model.
3. From the **Gear** in the **Gear** tab, click **Spur**.
4. Select the point **0, 0, 0** as the gear center.
5. Select the **Geometry Data** tab.
6. Set the **Pressure Angle** to **15**.
7. Click **Generate optimal arc segment**.
8. Click **OK**.



9. Make a copy of the above gear and translate it **50** mm in the **+X** direction.
10. Use the **Assembly** tool to mesh the gears with centers at **48**mm apart.

To create the helical gears

1. From the **Gear** group in the **Gear** tab, click **Helical**.
2. Select the point **0, -60, 0** as the gear center.
3. Make the following settings, as shown at right.
   - **Module: 1.414**
   - **Pressure Angle: 15**
   - **Helix Angle: 45**



Note: To obtain a helical gear that is the same size as an equivalent spur gear, the module should be:

$$module_{helical} = module_{spur} \cdot \cos\,(helix\ angle)$$

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4. Click **Generate optimal arc segment**.
5. Click **OK**.
6. Make a copy of the gear you just created and translate it **50** mm in the **+X** direction.
7. Open the **Properties** dialog for the gear you just copied.
8. Under the **Geometry Data** tab, change the **Helix Angle** to **-45**. In order for helix gears lying in the same plane to mesh, the helix angles must be of equal magnitude and opposite sign.
9. Click **OK**.
10. Use the **Assembly** tool to mesh the gears with centers at **48** mm apart.

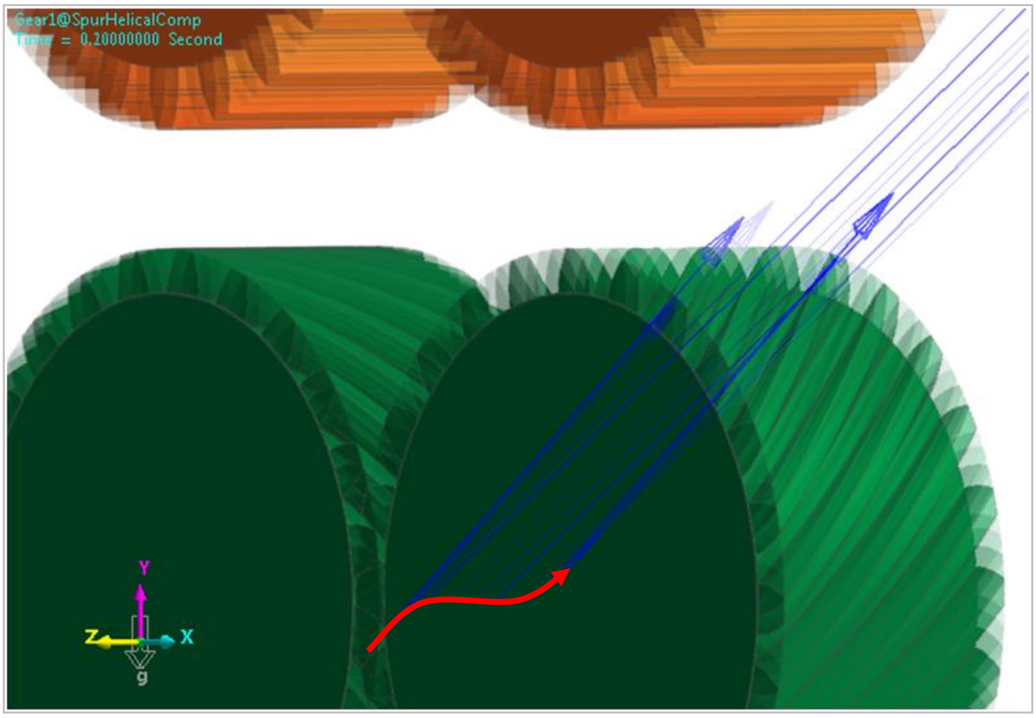
To finish and simulate the model

1. Create four revolute joints at the centers of the gears in the following order (specifying **MotherBody** as the base bodies and the gears as the action bodies).

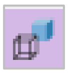
Joint	Gear Body
RevJoint1	SpurGear1
RevJoint2	C1_SpurGear1
RevJoint3	HelicalGear1
RevJoint4	C1_HelicalGear1

2. Create the following expression, naming it **Ex_drivGearDrive_vel**.
   - **600D*step(time, 0, 0, 0.5, 1)**
3. Assign this as the driving expression for the velocity of **RevJoint1** and **RevJoint3**.
4. Create two **RotationalAxial** forces applied at **RevJoint2** and **RevJoint4**.
5. Create the following expression, naming it **Ex_resistTorque**.
   - **1000**
6. Assign the above expression to the two **RotationalAxial** forces.
7. Create two **Solid(3DContactR)** contacts, one for the **Spur** gears and one for the **Helical** gears. Modify the contact settings as before, by making the following changes:
   - **Plane Tolerance Factor** (for both base and action gears)**: 1**
   - **No. of Max Contact Points: 10**
   - **Force Display: Action**
   - **Damping Coefficient: 1**
8. Simulate the model, using the following settings.
   - **End Time: 1**
   - **Step: 200**
   - **Plot Multiplier Step Factor: 5**

When the simulation stops, play the results animation. You should see from the contact force arrows that the contact points travel in a curved path from the front (+Z side) of the gear to the back (-Z side), as shown below.

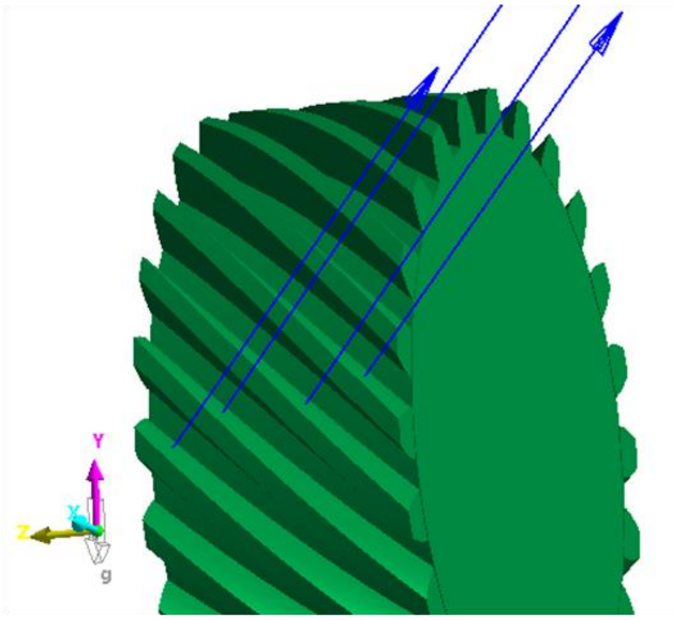


To understand what is happening in more detail, you can turn off the display of the helical gear on the right side.



9. In the **Toolbar**, select the **Render Each Object** button.
10. In the **Database Window**, right-click on **HelicalGear1**, and select **Shade**.
11. In the **Database Window**, right-click on **C1_HelicalGear1**, and select **Hide**.

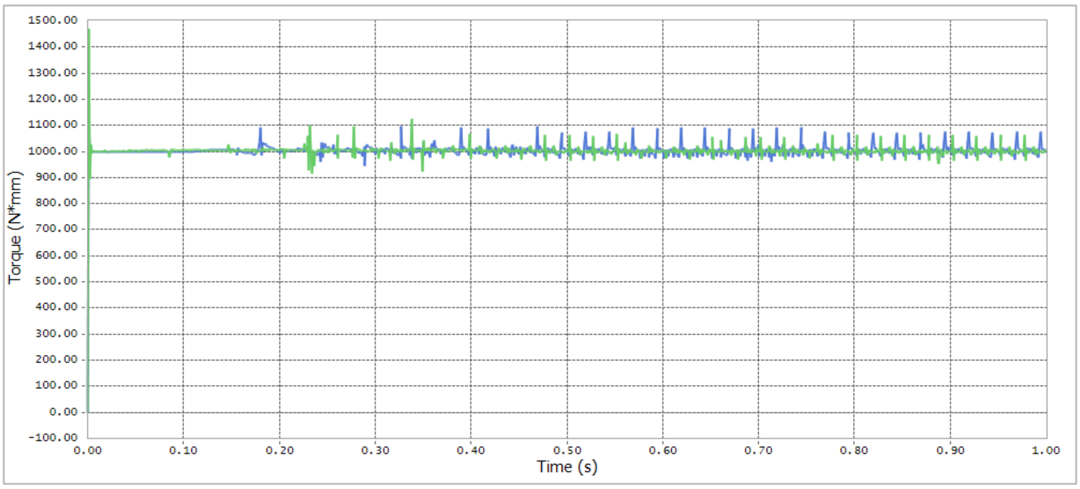
You should now be able to see, as shown at right, that each contact point is between its own pair of teeth, and that with the given gear specifications, four gear teeth pairs are always in contact. Each contact points begin at the front (+Z) end of the gear tooth face and advances backwards to the other (-Z) end of the gear tooth face at which point that particular pair of gear teeth is no longer in contact.   This sliding nature of the contact points, as well as the distribution of contact over four points, is why helical gears are quieter and operate more smoothly than spur gears.



To compare the driving torque results

1. Open the plotting environment.
2. Plot the driving torque for RevJoint1 and RevJoint3.
   - **Joints > RevJoint1 > Driving_Torque**
   - **Joints > RevJoint3 > Driving_Torque**

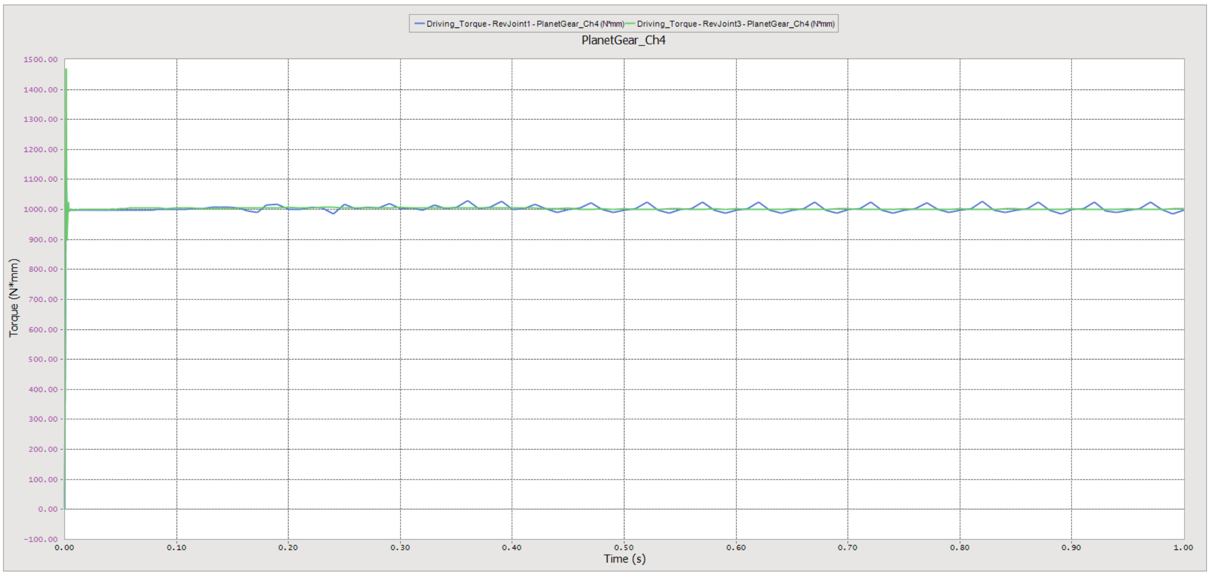
   You should see a plot similar to the one below.   The plot indicates that the driving torque is slightly smoother for the helical gear than the spur gear.



3. Plot the force in the Z direction exerted by ground on the driving gears:

   - **Joints > RevJoint1 > FZ_Reaction_Force**
   - **Joints > RevJoint3 > FZ_Reaction_Force**

   You should see a plot similar to the one shown below. This plot reveals one disadvantage of using helical gears, which is that due to the angle that the gear tooth faces are set at (the helix angle), an axial thrust is generated. This requires that special bearing be used which can withstand the axial load.



Thanks for participating in this tutorial!