



Model created in COMSOL Multiphysics 6.4

Transmission Ratios in a Planetary Gear Train

Introduction

Planetary gears, also known as epicyclic gear systems, are widely used in applications requiring a compact design and high torque transmission. Their ability to provide multiple gear ratios within a small footprint makes them ideal for use in automatic transmissions, electric power tools, and aerospace systems.

A planetary gear assembly typically consists of three main elements: a central sun gear, one or more planet gears that rotate around the sun gear, and an outer ring gear with internal teeth that mesh with the planet gears. The planet gears are mounted on a rotating carrier, which allows load sharing and efficient power transmission.

This example models a helical planetary gear train comprising a sun gear, ring gear, carrier, and five planet gears. Three configurations are analyzed by fixing different components:

- Ring gear fixed
- Sun gear fixed
- Carrier fixed

For each configuration, a transient multibody dynamic analysis is performed to determine the angular velocities of all gears under a specified input velocity. The resulting displacements and angular velocities are plotted, and the transmission ratios are compared for the three configurations.

Model Definition

Figure 1 shows the geometry of the planetary gear train. The system consists of a central sun gear, five evenly spaced planet gears, and an outer ring gear.

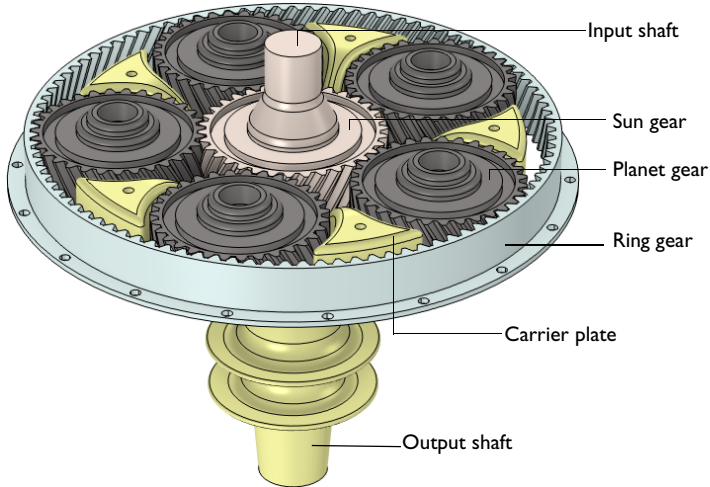


Figure 1: Geometry of the planetary gear train with a fixed ring gear. Input is applied through the sun gear shaft and output is delivered through carrier shaft.

The planet gears are mounted on a carrier plate and engage simultaneously with the central sun gear and the surrounding ring gear. As they rotate about their own axes, the planet gears also revolve around the sun gear while maintaining engagement with the ring gear. Two shafts are connected to the sun gear and the carrier plate, enabling power transmission through the system.

Planetary gear trains are widely used because they offer efficient speed reduction in a compact configuration while providing high torque transmission capability. Their versatility lies in the ability to achieve different speed reduction or speed multiplication ratios simply by varying which component is fixed, which serves as the input, and which acts as the output.

The performance of a planetary gear train is often characterized by its transmission ratio: the ratio of the angular velocity of the input component to that of the output component. This ratio depends primarily on the number of teeth on the sun and ring gears. By altering which element is held stationary, driving (input), or driven (output), different transmission ratios can be achieved.

A summary of the three configurations analyzed in this model, along with the corresponding transmission ratio, is given in [Table 1](#).

TABLE 1: DIFFERENT CONFIGURATIONS WITH TRANSMISSION RATIOS.

Configuration	Input	Output	Transmission ratio
Ring gear fixed	Sun gear	Carrier	$1+nr/ns$
Sun gear fixed	Ring gear	Carrier	$1+ns/nr$
Carrier fixed	Sun gear	Ring gear	$-nr/ns$

GEAR PROPERTIES

The properties of the different gears are given in [Table 2](#):

TABLE 2: GEAR PROPERTIES.

Properties		Sun gear	Planet gear	Ring gear
Number of teeth	n	34	31	96
Pitch diameter	d_p	102 mm	93 mm	288 mm
Pressure angle	α	25°	25°	25°
Helix angle	β	30°	30°	30°

All the gears and shafts are modeled as rigid bodies. To reduce the computation time, the gear mesh is also assumed rigid, neglecting any flexibility in the system. All components are made of steel AISI 4340.

TIME-DEPENDENT ANALYSIS

A time-dependent analysis is carried out for the three configurations. In each case, the input shaft is driven at a constant angular velocity of 100 rad/s, and the simulation is run for a total duration of 0.25 s.

Results and Discussion

The displacements of the system for the different configurations are shown in [Figure 2](#), [Figure 3](#), and [Figure 4](#).

To gain deeper insight into the dynamic behavior of the system, the time histories of the angular velocities for the major components are shown in [Figure 5](#), [Figure 6](#), and

Figure 7. These angular velocity plots are essential for understanding the load distribution and speed relationships between components.

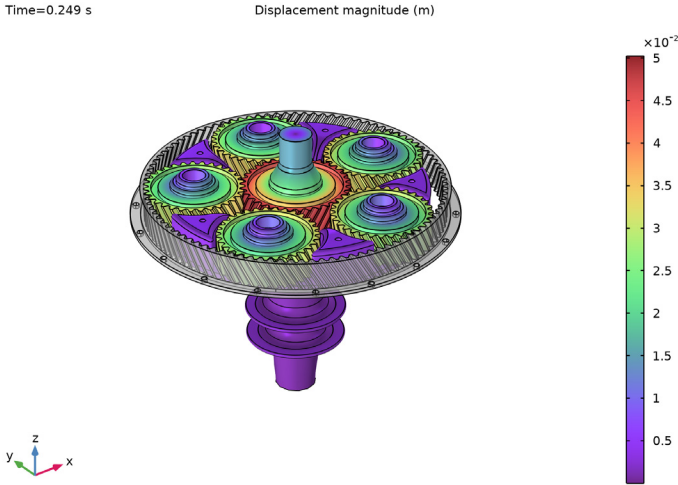


Figure 2: System displacement when the ring gear is fixed.

Time=0.249 s

Displacement magnitude (m)

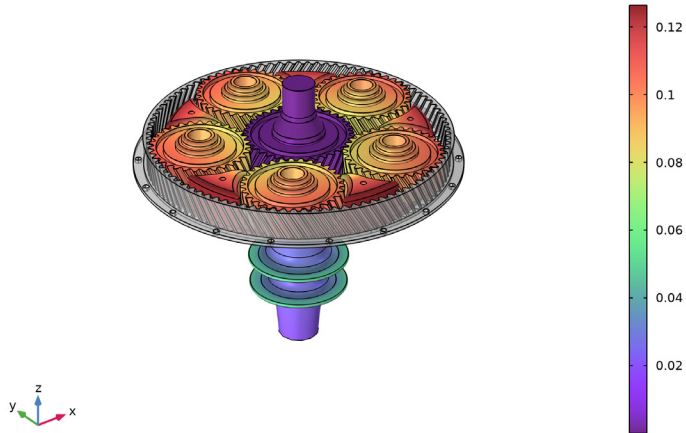


Figure 3: System displacement when the sun gear is fixed.

Time=0.249 s

Displacement magnitude (m)

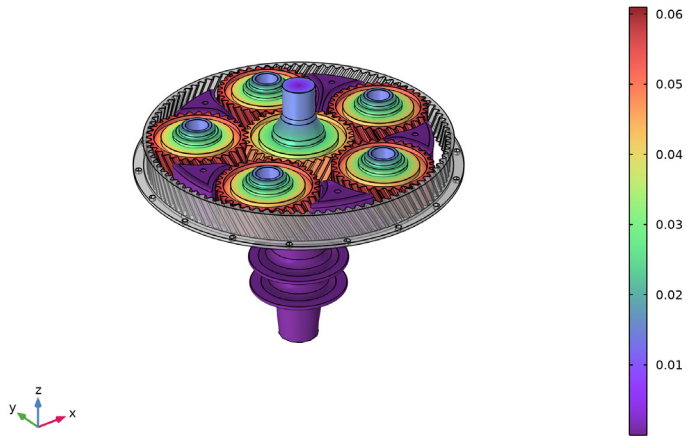


Figure 4: System displacement when the carrier is fixed.

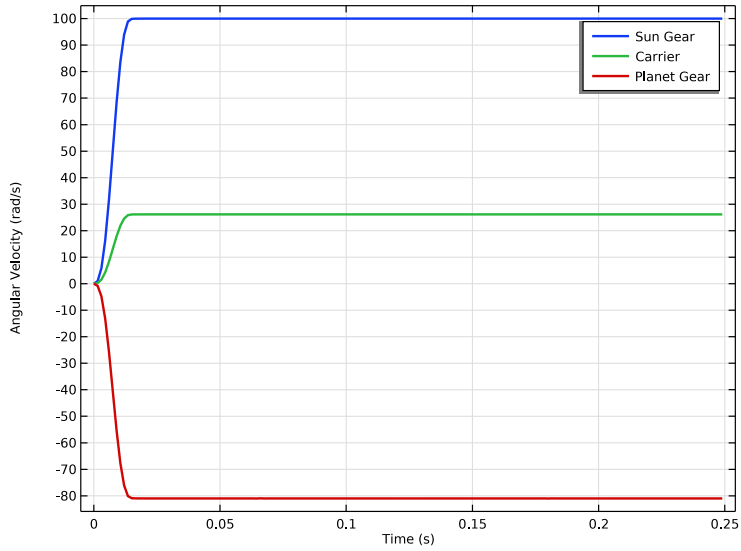


Figure 5: Angular velocities of different components versus time when the ring gear is fixed.

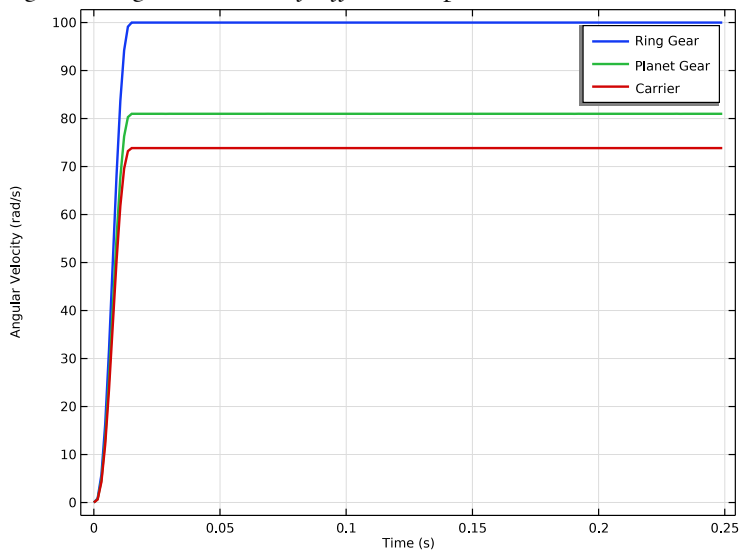


Figure 6: Angular velocities of different components versus time when the sun gear is fixed.

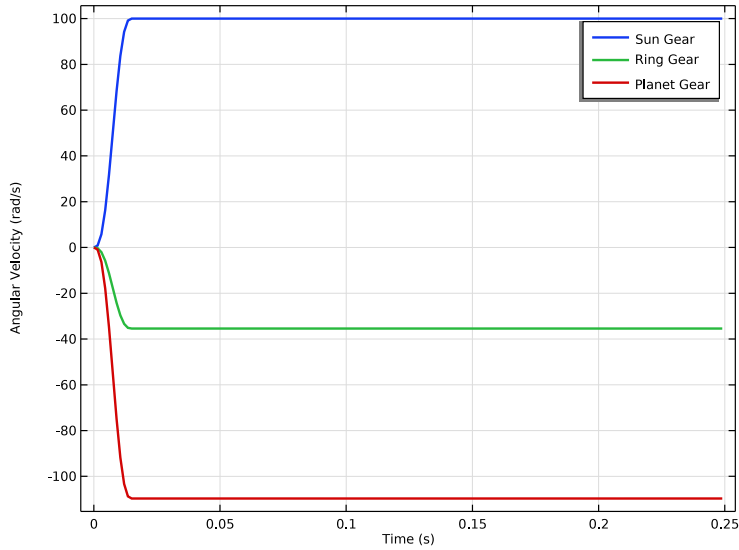


Figure 7: Angular velocities of different components versus time when the carrier is fixed.

In a planetary gear train, both the transmission ratio and the direction of rotation depend on which component is fixed. [Figure 8](#) compares the transmission ratios for the three configurations. When either the ring gear or the sun gear is fixed, the input and output shafts rotate in the same direction, and a speed reduction is achieved: the output shaft rotates more slowly than the input shaft. In contrast, when the carrier is fixed, the output shaft rotates in the opposite direction to the input shaft.

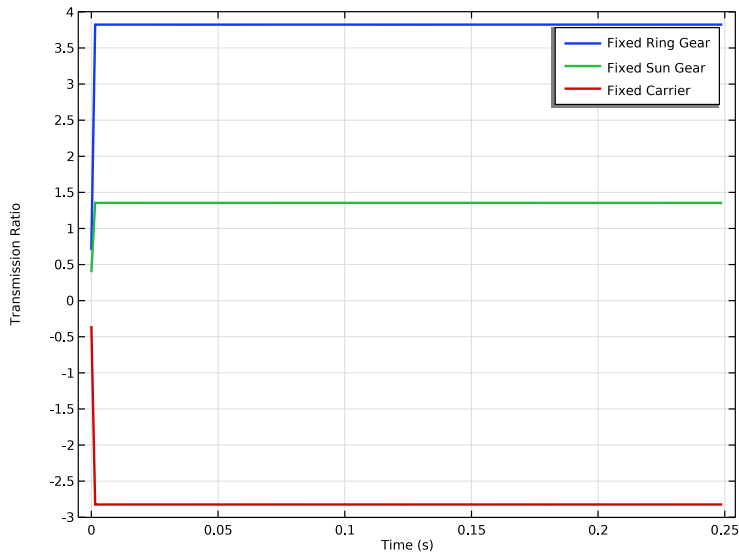


Figure 8: Transmission ratios for different configurations.

The motion of the planet gears is inherently complex and varies depending on which element is fixed. [Figure 9](#) illustrates the trajectories of three representative points on the first planet gear for the configuration with a fixed ring gear. The center point follows a circular trajectory around the sun gear, while the surface points trace more intricate paths due to the superposition of rotation about their own axes and revolution around the sun gear.

When the sun gear is fixed, the planet gears rotate around their own axes while orbiting around the stationary sun gear. As shown in [Figure 10](#), the path traced by a surface point on a planet gear is an epicycloid, a curve traced by a point on the circumference of a circle rolling around the outside of another fixed circle. This characteristic motion is the reason planetary gear trains are also referred to as epicyclic gear trains.

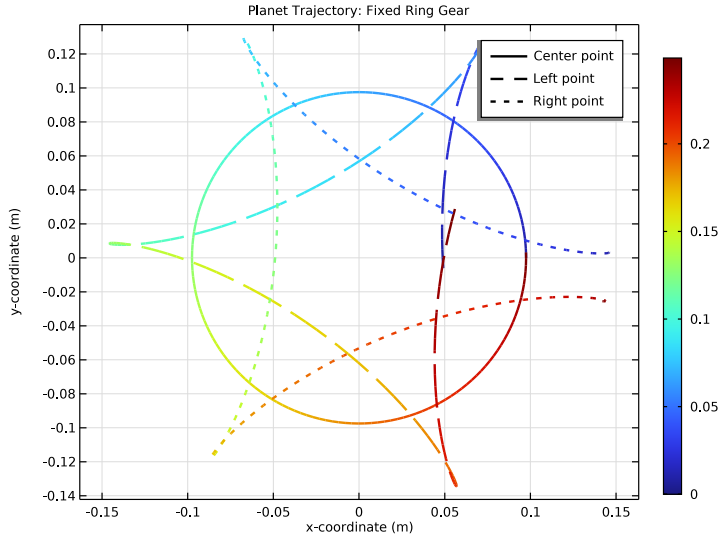


Figure 9: Trajectories of three sample points on the first planet gear when the ring gear is fixed.

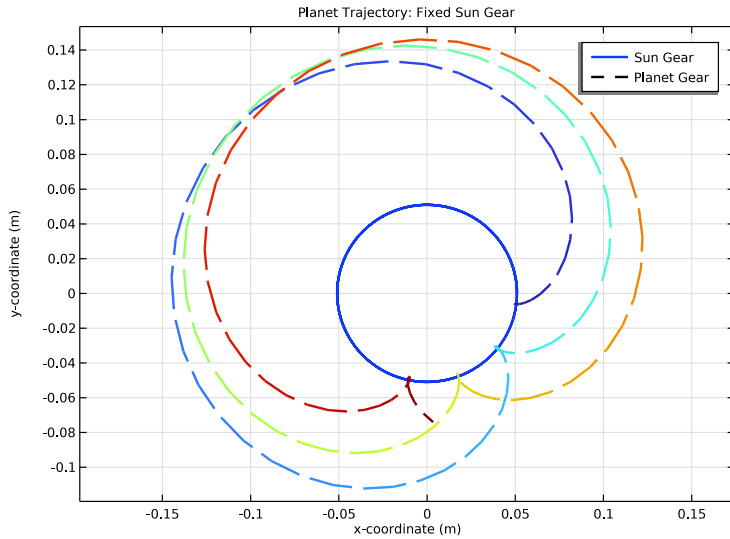



Figure 10: Epicycloid traced by the planet gear when the sun gear is fixed.

Application Library path: Multibody_Dynamics_Module/
Automotive_and_Aerospace/planetary_gear_train




Modeling Instructions

From the **File** menu, choose **New**.

NEW


In the **New** window, click  **Model Wizard**.

MODEL WIZARD

- 1 In the **Model Wizard** window, click  **3D**.
- 2 In the **Select Physics** tree, select **Structural Mechanics > Multibody Dynamics (mbd)**.
- 3 Click **Add**.
- 4 Click  **Study**.
- 5 In the **Select Study** tree, select **General Studies > Time Dependent**.
- 6 Click  **Done**.

GLOBAL DEFINITIONS

Parameters I




- 1 In the **Model Builder** window, under **Global Definitions** click **Parameters I**.
- 2 In the **Settings** window for **Parameters**, locate the **Parameters** section.
- 3 Click  **Load from File**.
- 4 Browse to the model's Application Libraries folder and double-click the file `planetary_gear_train_parameters.txt`.

GEOMETRY I


- 1 In the **Model Builder** window, expand the **Component I (comp I) > Geometry I** node, then click **Geometry I**.
- 2 In the **Settings** window for **Geometry**, locate the **Advanced** section.
- 3 From the **Geometry representation** list, choose **CAD kernel**.

Import 1 (imp1)

You can import the geometry of the gear train by browsing to the model's Application Libraries folder.

- 1 In the **Geometry** toolbar, click  **Import**.
- 2 In the **Settings** window for **Import**, locate the **Source** section.
- 3 Click  **Browse**.
- 4 Browse to the model's Application Libraries folder and double-click the file `planetary_gear_train.mphbin`.
- 5 Click  **Import**.


Form Union (fin)

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Geometry 1** click **Form Union (fin)**.
- 2 In the **Settings** window for **Form Union/Assembly**, locate the **Form Union/Assembly** section.
- 3 From the **Action** list, choose **Form an assembly**.
- 4 In the **Geometry** toolbar, click  **Build All**.


DEFINITIONS

Rearrange **Identity Boundary Pair** nodes to help automatic generation of hinge joints.


Identity Boundary Pair 5 (ap5)

- 1 In the **Model Builder** window, expand the **Component 1 (comp1) > Definitions** node, then click **Identity Boundary Pair 5 (ap5)**.
- 2 In the **Settings** window for **Pair**, click the  **Swap Source and Destination** button.
- 3 Drag and drop above **Identity Boundary Pair 1 (ap1)**.


Identity Boundary Pair 4 (ap4)

- 1 In the **Model Builder** window, click **Identity Boundary Pair 4 (ap4)**.
- 2 In the **Settings** window for **Pair**, click the  **Swap Source and Destination** button.
- 3 Drag and drop below **Identity Boundary Pair 5 (ap5)**.


Identity Boundary Pair 2 (ap2)

- 1 In the **Model Builder** window, click **Identity Boundary Pair 2 (ap2)**.
- 2 In the **Settings** window for **Pair**, click the  **Swap Source and Destination** button.
- 3 Drag and drop below **Identity Boundary Pair 4 (ap4)**.

Identity Boundary Pair 3 (ap3)


- 1 In the **Model Builder** window, click **Identity Boundary Pair 3 (ap3)**.
- 2 In the **Settings** window for **Pair**, click the  **Swap Source and Destination** button.

Identity Boundary Pair 1 (ap1)

- 1 In the **Model Builder** window, click **Identity Boundary Pair 1 (ap1)**.
- 2 In the **Settings** window for **Pair**, click the  **Swap Source and Destination** button.

Step 1 (step1)

Define a **Step** function to use in the expression of the input angular velocity.

- 1 In the **Definitions** toolbar, click  **More Functions** and choose **Step**.
- 2 In the **Settings** window for **Step**, locate the **Parameters** section.
- 3 In the **Location** text field, type $7.5e-3[s]$.
- 4 Click to expand the **Smoothing** section. In the **Size of transition zone** text field, type $1.5e-2$.


GEOMETRY 1

Explicit Selection 1 (sel1)



Now create selections of the geometry. You will use them later when setting up the physics and mesh.

In the **Geometry** toolbar, click  **Selections** and choose **Explicit Selection**.



GEOMETRY 1

- 1 In the **Model Builder** window, expand the **Component 1 (comp1) > Materials** node, then click **Component 1 (comp1) > Geometry 1 > Explicit Selection 1 (sel1)**.
- 2 In the **Settings** window for **Explicit Selection**, type Ring Gear in the **Label** text field.
- 3 Locate the **Color** section. From the **Color** list, choose **None** or — if you are running the cross-platform desktop — **Custom**. On the cross-platform desktop, click the **Color** button.
- 4 Click **Define custom colors**.
- 5 Set the RGB values to 205, 222, and 221, respectively.
- 6 Click **Add to custom colors**.
- 7 Click **Show color palette only** or **OK** on the cross-platform desktop.
- 8 On the object **fin**, select Domains 1 and 2 only.
- 9 Click  **Build Selected**.


Sun Gear

- 1 Right-click **Ring Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **Explicit Selection**, type Sun Gear in the **Label** text field.
- 3 Locate the **Entities to Select** section. Click the  **Clear Selection** button for **Entities to select**.
- 4 Locate the **Color** section. Click **Define custom colors**.
- 5 Set the RGB values to 226, 211, and 201, respectively.
- 6 Click **Add to custom colors**.
- 7 Click **Show color palette only** or **OK** on the cross-platform desktop.
- 8 On the object **fin**, select Domain 6 only.
- 9 Click  **Build Selected**.

Planet Gears

- 1 Right-click **Sun Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **Explicit Selection**, type Planet Gears in the **Label** text field.
- 3 Locate the **Entities to Select** section. Click the  **Clear Selection** button for **Entities to select**.
- 4 Locate the **Color** section. Click **Define custom colors**.
- 5 Set the RGB values to 126, 123, and 122, respectively.
- 6 Click **Add to custom colors**.
- 7 Click **Show color palette only** or **OK** on the cross-platform desktop.
- 8 On the object **fin**, select Domains 4, 5, and 7–9 only.
- 9 Click  **Build Selected**.

Carrier

- 1 Right-click **Planet Gears** and choose **Duplicate**.
- 2 In the **Settings** window for **Explicit Selection**, type Carrier in the **Label** text field.
- 3 Locate the **Entities to Select** section. Click the  **Clear Selection** button for **Entities to select**.
- 4 Locate the **Color** section. Click **Define custom colors**.
- 5 Set the RGB values to 233, 233, and 155, respectively.
- 6 Click **Add to custom colors**.
- 7 Click **Show color palette only** or **OK** on the cross-platform desktop.
- 8 On the object **fin**, select Domain 3 only.

9 Click  **Build Selected**.

Carrier (sel4), Planet Gears (sel3), Ring Gear (sel1), Sun Gear (sel2)

1 In the **Model Builder** window, under **Component 1 (comp1) > Geometry 1**, Ctrl-click to select **Ring Gear (sel1)**, **Sun Gear (sel2)**, **Planet Gears (sel3)**, and **Carrier (sel4)**.

2 Right-click and choose **Group**.

Selections

In the **Settings** window for **Group**, type Selections in the **Label** text field.

MATERIALS

Assign material properties. Use **Steel AISI 4340** from the built-in material library.

ADD MATERIAL

1 In the **Materials** toolbar, click  **Add Material** to open the **Add Material** window.

2 Go to the **Add Material** window.

3 In the tree, select **Built-in > Steel AISI 4340**.

4 Right-click and choose **Link in Component 1 (comp1)**.

5 In the **Materials** toolbar, click  **Add Material** to close the **Add Material** window.

MULTIBODY DYNAMICS (MBD)

Rigid Material: Carrier

1 In the **Physics** toolbar, click  **Domains** and choose **Rigid Material**.

2 Select Domain 3 only.

3 In the **Settings** window for **Rigid Material**, type Rigid Material: Carrier in the **Label** text field.

Fixed Constraint 1

In the **Physics** toolbar, click  **Attributes** and choose **Fixed Constraint**.

Helical Gear: Ring Gear

Add **Helical Gear** nodes and specify the gear properties.

1 In the **Physics** toolbar, click  **Domains** and choose **Helical Gear**.


2 In the **Settings** window for **Helical Gear**, type Helical Gear: Ring Gear in the **Label** text field.

3 Locate the **Domain Selection** section. From the **Selection** list, choose **Ring Gear**.


4 Locate the **Gear Properties** section. From the **Gear mesh** list, choose **Internal**.

- 5 In the n text field, type nr.
- 6 In the d_p text field, type dpr.
- 7 In the α text field, type alpha.
- 8 In the β text field, type -beta.
- 9 Locate the **Center of Rotation** section. From the list, choose **User defined**.

Helical Gear: Sun Gear


- 1 Right-click **Helical Gear: Ring Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **Helical Gear**, type Helical Gear: Sun Gear in the **Label** text field.
- 3 Locate the **Domain Selection** section. Click  **Clear Selection**.
- 4 From the **Selection** list, choose **Sun Gear**.
- 5 Locate the **Gear Properties** section. From the **Gear mesh** list, choose **External**.
- 6 In the n text field, type ns.
- 7 In the d_p text field, type dps.
- 8 In the β text field, type beta.

Helical Gear: Planet Gear 1

- 1 Right-click **Helical Gear: Sun Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **Helical Gear**, type Helical Gear: Planet Gear 1 in the **Label** text field.
- 3 Locate the **Domain Selection** section. Click  **Clear Selection**.
- 4 Select Domain 9 only.
- 5 Locate the **Gear Properties** section. In the n text field, type np.
- 6 In the d_p text field, type dpp.
- 7 In the β text field, type -beta.
- 8 Locate the **Center of Rotation** section. Specify the \mathbf{X}_c vector as

distp	x
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Helical Gear: Planet Gear 2

- 1 Right-click **Helical Gear: Planet Gear 1** and choose **Duplicate**.
- 2 In the **Settings** window for **Helical Gear**, type Helical Gear: Planet Gear 2 in the **Label** text field.
- 3 Locate the **Domain Selection** section. Click  **Clear Selection**.

4 Select Domain 8 only.


5 Locate the **Center of Rotation** section. Specify the \mathbf{X}_c vector as

$\text{distp} \cdot \cos(\text{ang})$	x
$\text{distp} \cdot \sin(\text{ang})$	y

Helical Gear: Planet Gear 3

1 Right-click **Helical Gear: Planet Gear 2** and choose **Duplicate**.

2 In the **Settings** window for **Helical Gear**, type Helical Gear: Planet Gear 3 in the **Label** text field.

3 Locate the **Domain Selection** section. Click  **Clear Selection**.

4 Select Domain 5 only.


5 Locate the **Center of Rotation** section. Specify the \mathbf{X}_c vector as

$\text{distp} \cdot \cos(2 \cdot \text{ang})$	x
$\text{distp} \cdot \sin(2 \cdot \text{ang})$	y

Helical Gear: Planet Gear 4

1 Right-click **Helical Gear: Planet Gear 3** and choose **Duplicate**.

2 In the **Settings** window for **Helical Gear**, type Helical Gear: Planet Gear 4 in the **Label** text field.

3 Locate the **Domain Selection** section. Click  **Clear Selection**.

4 Select Domain 4 only.


5 Locate the **Center of Rotation** section. Specify the \mathbf{X}_c vector as

$\text{distp} \cdot \cos(3 \cdot \text{ang})$	x
$\text{distp} \cdot \sin(3 \cdot \text{ang})$	y

Helical Gear: Planet Gear 5

1 Right-click **Helical Gear: Planet Gear 4** and choose **Duplicate**.

2 In the **Settings** window for **Helical Gear**, type Helical Gear: Planet Gear 5 in the **Label** text field.

3 Locate the **Domain Selection** section. Click  **Clear Selection**.

4 Select Domain 7 only.

5 Locate the **Center of Rotation** section. Specify the \mathbf{X}_c vector as

$\text{distp} \cdot \cos(4 \cdot \text{ang})$	x
$\text{distp} \cdot \sin(4 \cdot \text{ang})$	y

Helical Gear: Ring Gear

In the **Model Builder** window, click **Helical Gear: Ring Gear**.

Fixed Constraint 1

In the **Physics** toolbar, click  **Attributes** and choose **Fixed Constraint**.

Helical Gear: Sun Gear

In the **Model Builder** window, under **Component 1 (comp1) > Multibody Dynamics (mbd)** click **Helical Gear: Sun Gear**.

Fixed Constraint 1

In the **Physics** toolbar, click  **Attributes** and choose **Fixed Constraint**.


Select all gear features, and right click on **Group** to create a group.

Gears

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Multibody Dynamics (mbd)** click **Group 1**.
- 2 In the **Settings** window for **Group**, type Gears in the **Label** text field.

Gear Pair: Ring-Planet 1

Use **Gear Pair** nodes, with different properties to connect the gears.

- 1 In the **Physics** toolbar, click  **Global** and choose **Gear Pair**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Ring-Planet 1 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Wheel** list, choose **Helical Gear: Ring Gear**.
- 4 From the **Pinion** list, choose **Helical Gear: Planet Gear 1**.

Gear Pair: Ring-Planet 2

- 1 Right-click **Gear Pair: Ring-Planet 1** and choose **Duplicate**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Ring-Planet 2 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Pinion** list, choose **Helical Gear: Planet Gear 2**.

Gear Pair: Ring-Planet 3

- 1 Right-click **Gear Pair: Ring-Planet 2** and choose **Duplicate**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Ring-Planet 3 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Pinion** list, choose **Helical Gear: Planet Gear 3**.

Gear Pair: Ring-Planet 4

- 1 Right-click **Gear Pair: Ring-Planet 3** and choose **Duplicate**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Ring-Planet 4 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Pinion** list, choose **Helical Gear: Planet Gear 4**.

Gear Pair: Ring-Planet 5

- 1 Right-click **Gear Pair: Ring-Planet 4** and choose **Duplicate**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Ring-Planet 5 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Pinion** list, choose **Helical Gear: Planet Gear 5**.

Gear Pair: Sun-Planet 1

- 1 Right-click **Gear Pair: Ring-Planet 5** and choose **Duplicate**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Sun-Planet 1 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Wheel** list, choose **Helical Gear: Sun Gear**.
- 4 From the **Pinion** list, choose **Helical Gear: Planet Gear 1**.

Gear Pair: Sun-Planet 2

- 1 Right-click **Gear Pair: Sun-Planet 1** and choose **Duplicate**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Sun-Planet 2 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Pinion** list, choose **Helical Gear: Planet Gear 2**.

Gear Pair: Sun-Planet 3

- 1 Right-click **Gear Pair: Sun-Planet 2** and choose **Duplicate**.

- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Sun-Planet 3 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Pinion** list, choose **Helical Gear: Planet Gear 3**.

Gear Pair: Sun-Planet 4

- 1 Right-click **Gear Pair: Sun-Planet 3** and choose **Duplicate**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Sun-Planet 4 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Pinion** list, choose **Helical Gear: Planet Gear 4**.

Gear Pair: Sun-Planet 5

- 1 Right-click **Gear Pair: Sun-Planet 4** and choose **Duplicate**.
- 2 In the **Settings** window for **Gear Pair**, type Gear Pair: Sun-Planet 5 in the **Label** text field.
- 3 Locate the **Gear Selection** section. From the **Pinion** list, choose **Helical Gear: Planet Gear 5**.

Select all gear pair features, and right click on **Group** to create a group.

Gear Pairs

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Multibody Dynamics (mbd)** click **Group 2**.
- 2 In the **Settings** window for **Group**, type Gear Pairs in the **Label** text field.
Do as follows to generate **Hinge Joint** nodes between components.
- 3 In the **Model Builder** window, click **Multibody Dynamics (mbd)**.
- 4 In the **Settings** window for **Multibody Dynamics**, click **Physics Node Generation** in the upper-right corner of the **Automated Model Setup** section. From the menu, choose **Create Joints**.

Hinge Joint: Carrier-Planet 1

- 1 In the **Model Builder** window, expand the **Hinge Joints** node, then click **Hinge Joint 1**.
- 2 In the **Settings** window for **Hinge Joint**, type Hinge Joint: Carrier-Planet 1 in the **Label** text field.

Hinge Joint: Carrier-Planet 2

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Multibody Dynamics (mbd) > Hinge Joints** click **Hinge Joint 2**.

- 2 In the **Settings** window for **Hinge Joint**, type Hinge Joint: Carrier-Planet 2 in the **Label** text field.

Hinge Joint: Carrier-Planet 3

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Multibody Dynamics (mbd) > Hinge Joints** click **Hinge Joint 3**.
- 2 In the **Settings** window for **Hinge Joint**, type Hinge Joint: Carrier-Planet 3 in the **Label** text field.

Hinge Joint: Carrier-Planet 4

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Multibody Dynamics (mbd) > Hinge Joints** click **Hinge Joint 4**.
- 2 In the **Settings** window for **Hinge Joint**, type Hinge Joint: Carrier-Planet 4 in the **Label** text field.

Hinge Joint: Carrier-Planet 5

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Multibody Dynamics (mbd) > Hinge Joints** click **Hinge Joint 5**.
- 2 In the **Settings** window for **Hinge Joint**, type Hinge Joint: Carrier-Planet 5 in the **Label** text field.

Hinge Joint: Carrier

- 1 Right-click **Hinge Joint: Carrier-Planet 5** and choose **Duplicate**.
- 2 In the **Settings** window for **Hinge Joint**, type Hinge Joint: Carrier in the **Label** text field.
- 3 Locate the **Attachment Selection** section. From the **Source** list, choose **Fixed**.
- 4 From the **Destination** list, choose **Rigid Material: Carrier**.
- 5 Locate the **Center of Joint** section. Specify the \mathbf{X}_c vector as


0	x
0	y

Hinge Joint: Sun Gear

- 1 Right-click **Hinge Joint: Carrier** and choose **Duplicate**.
- 2 In the **Settings** window for **Hinge Joint**, type Hinge Joint: Sun Gear in the **Label** text field.
- 3 Locate the **Attachment Selection** section. From the **Destination** list, choose **Helical Gear: Sun Gear**.

Prescribed Motion 1

Prescribe the motion of the gear.

- 1 In the **Physics** toolbar, click  **Attributes** and choose **Prescribed Motion**.
- 2 In the **Settings** window for **Prescribed Motion**, locate the **Prescribed Rotational Motion** section.
- 3 From the **Prescribed motion through** list, choose **Angular velocity**.
- 4 In the ω_p text field, type $\text{omega}*\text{step1}(t)$.

Hinge Joint: Ring Gear

- 1 In the **Model Builder** window, right-click **Hinge Joint: Sun Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **Hinge Joint**, type Hinge Joint: Ring Gear in the **Label** text field.
- 3 Locate the **Attachment Selection** section. From the **Destination** list, choose **Helical Gear: Ring Gear**.

STUDY 1: FIXED RING GEAR


- 1 In the **Model Builder** window, click **Study 1**.
- 2 In the **Settings** window for **Study**, type Study 1: Fixed Ring Gear in the **Label** text field.

Step 1: Time Dependent

- 1 In the **Model Builder** window, under **Study 1: Fixed Ring Gear** click **Step 1: Time Dependent**.
- 2 In the **Settings** window for **Time Dependent**, locate the **Study Settings** section.
- 3 In the **Output times** text field, type $\text{range}(0, dt, tf)$.
- 4 Locate the **Physics and Variables Selection** section. Select the **Modify model configuration for study step** checkbox.
- 5 In the tree, select **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Rigid Material: Carrier > Fixed Constraint 1, Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Gears > Helical Gear: Sun Gear > Fixed Constraint 1, and Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Hinge Joints > Hinge Joint: Ring Gear**.
- 6 Right-click and choose **Disable**.



Solution 1 (sol1)

- 1 In the **Study** toolbar, click  **Show Default Solver**.
- 2 In the **Model Builder** window, expand the **Solution 1 (sol1)** node.

- 3 In the **Model Builder** window, under **Study 1: Fixed Ring Gear > Solver Configurations > Solution 1 (sol1)** click **Time-Dependent Solver 1**.
- 4 In the **Settings** window for **Time-Dependent Solver**, click to expand the **Time Stepping** section.
- 5 From the **Steps taken by solver** list, choose **Intermediate**.
- 6 In the **Study** toolbar, click  **Compute**.

Add another **Time Dependent** study and compute the solution for the configuration with fixed sun gear.

ADD STUDY

- 1 In the **Home** toolbar, click  **Add Study** to open the **Add Study** window.
- 2 Go to the **Add Study** window.
- 3 Find the **Studies** subsection. In the **Select Study** tree, select **Empty Study**.
- 4 Click the **Add Study** button in the window toolbar.
- 5 In the **Home** toolbar, click  **Add Study** to close the **Add Study** window.

STUDY 1: FIXED RING GEAR


Step 1: Time Dependent

In the **Model Builder** window, under **Study 1: Fixed Ring Gear** right-click

Step 1: Time Dependent and choose **Copy**.



STUDY 2: FIXED SUN GEAR

- 1 In the **Model Builder** window, right-click **Study 2** and choose **Paste Time Dependent**.
- 2 In the **Settings** window for **Study**, type Study 2: Fixed Sun Gear in the **Label** text field.
- 1 In the **Model Builder** window, under **Study 2: Fixed Sun Gear** click **Step 1: Time Dependent**.
- 2 In the **Settings** window for **Time Dependent**, locate the **Physics and Variables Selection** section.
- 3 In the tree, select **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Gears > Helical Gear: Sun Gear > Fixed Constraint 1** and **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Hinge Joints > Hinge Joint: Ring Gear**.
- 4 Right-click and choose **Enable**.

- 5 In the tree, select **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Gears > Helical Gear: Ring Gear > Fixed Constraint 1** and **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Hinge Joints > Hinge Joint: Sun Gear**.
- 6 Right-click and choose **Disable**.
- 7 In the **Model Builder** window, click **Study 2: Fixed Sun Gear**.
- 8 In the **Settings** window for **Study**, locate the **Study Settings** section.
- 9 Clear the **Generate default plots** checkbox.
- 10 In the **Study** toolbar, click  **Compute**.

Add another **Time Dependent** study and compute the solution for the case with fixed carrier.

ADD STUDY

- 1 In the **Home** toolbar, click  **Add Study** to open the **Add Study** window.
- 2 Go to the **Add Study** window.
- 3 Find the **Studies** subsection. In the **Select Study** tree, select **Empty Study**.
- 4 Click the **Add Study** button in the window toolbar.
- 5 In the **Home** toolbar, click  **Add Study** to close the **Add Study** window.



STUDY 1: FIXED RING GEAR

In the **Model Builder** window, under **Study 1: Fixed Ring Gear** right-click

Step 1: Time Dependent and choose **Copy**.

STUDY 3: FIXED CARRIER

- 1 In the **Model Builder** window, right-click **Study 3** and choose **Paste Time Dependent**.
- 2 In the **Settings** window for **Study**, type Study 3: Fixed Carrier in the **Label** text field.
- 1 In the **Model Builder** window, under **Study 3: Fixed Carrier** click **Step 1: Time Dependent**.
- 2 In the **Settings** window for **Time Dependent**, locate the **Physics and Variables Selection** section.
- 3 In the tree, select **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Rigid Material: Carrier > Fixed Constraint 1** and **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Hinge Joints > Hinge Joint: Ring Gear**.
- 4 Right-click and choose **Enable**.

- 5 In the tree, select **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Gears > Helical Gear: Ring Gear > Fixed Constraint 1, Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Hinge Joints > Hinge Joint: Carrier**, and **Component 1 (comp1) > Multibody Dynamics (mbd), Controls spatial frame > Hinge Joints > Hinge Joint: Ring Gear > Prescribed Motion 1**.
- 6 Click  **Disable**.
- 7 In the **Model Builder** window, click **Study 3: Fixed Carrier**.
- 8 In the **Settings** window for **Study**, locate the **Study Settings** section.
- 9 Clear the **Generate default plots** checkbox.
- 10 In the **Study** toolbar, click  **Compute**.

RESULTS

Follow the instructions below to plot the system displacement for different cases as shown in [Figure 2](#), [Figure 3](#), and [Figure 4](#).

Displacement: Fixed Ring Gear

- 1 In the **Model Builder** window, under **Results** click **Displacement (mbd)**.
- 2 In the **Settings** window for **3D Plot Group**, type **Displacement: Fixed Ring Gear** in the **Label** text field.



Selection 1

- 1 In the **Model Builder** window, expand the **Displacement: Fixed Ring Gear** node.
- 2 Right-click **Surface** and choose **Selection**.
- 3 In the **Settings** window for **Selection**, locate the **Selection** section.
- 4 From the **Geometric entity level** list, choose **Domain**.
- 5 Select Domains 3–9 only.

Surface 2

Right-click **Surface** and choose **Duplicate**.

Selection 1

- 1 In the **Model Builder** window, expand the **Surface 2** node, then click **Selection 1**.
- 2 In the **Settings** window for **Selection**, locate the **Selection** section.
- 3 Click to select the  **Activate Selection** toggle button.
- 4 Click  **Clear Selection**.
- 5 From the **Selection** list, choose **Ring Gear**.

Surface 2

- 1 In the **Model Builder** window, click **Surface 2**.
- 2 In the **Settings** window for **Surface**, locate the **Coloring and Style** section.
- 3 From the **Coloring** list, choose **Uniform**.
- 4 From the **Color** list, choose **Gray**.
- 5 Click to expand the **Title** section. From the **Title type** list, choose **None**.


Transparency 1

Right-click **Surface 2** and choose **Transparency**.


Displacement: Fixed Ring Gear

In the **Displacement: Fixed Ring Gear** toolbar, click  **Plot**.

Displacement: Fixed Sun Gear

- 1 In the **Model Builder** window, right-click **Displacement: Fixed Ring Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **3D Plot Group**, type Displacement: Fixed Sun Gear in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Study 2: Fixed Sun Gear/ Solution 2 (sol2)**.
- 4 In the **Displacement: Fixed Sun Gear** toolbar, click  **Plot**.

Displacement: Fixed Carrier

- 1 Right-click **Displacement: Fixed Ring Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **3D Plot Group**, type Displacement: Fixed Carrier in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Study 3: Fixed Carrier/ Solution 3 (sol3)**.
- 4 In the **Displacement: Fixed Carrier** toolbar, click  **Plot**.

Displacement: Fixed Carrier, Displacement: Fixed Ring Gear, Displacement: Fixed Sun Gear

- 1 In the **Model Builder** window, under **Results**, Ctrl-click to select **Displacement: Fixed Ring Gear**, **Displacement: Fixed Sun Gear**, and **Displacement: Fixed Carrier**.
- 2 Right-click and choose **Group**.

Displacement


In the **Settings** window for **Group**, type Displacement in the **Label** text field.

Velocity: Fixed Ring Gear


- 1 In the **Model Builder** window, under **Results** click **Velocity (mbd)**.
- 2 In the **Settings** window for **3D Plot Group**, type Velocity: Fixed Ring Gear in the **Label** text field.

Follow the instructions below to plot the angular velocities of the sun gear, first planet gear, ring gear and carrier for different cases as shown in [Figure 5](#), [Figure 6](#), and [Figure 7](#).

Graph Plot Style I

- 1 In the **Results** toolbar, click  **Configurations** and choose **Graph Plot Style**.
- 2 In the **Settings** window for **Graph Plot Style**, locate the **Coloring and Style** section.
- 3 Find the **Line style** subsection. From the **Width** list, choose **2**.
- 4 Locate the **Legends** section. Find the **Include in automatic mode** subsection. Clear the **Headers** checkbox.
- 5 Clear the **Point** checkbox.
- 6 Clear the **Solution** checkbox.
- 7 Select the **Description** checkbox.

Angular Velocity: Fixed Ring Gear

- 1 In the **Results** toolbar, click  **ID Plot Group**.
- 2 In the **Settings** window for **ID Plot Group**, type Angular Velocity: Fixed Ring Gear in the **Label** text field.
- 3 Click to expand the **Title** section. From the **Title type** list, choose **None**.
- 4 Locate the **Plot Settings** section.
- 5 Select the **y-axis label** checkbox. In the associated text field, type Angular Velocity (rad/s).
- 6 Click to expand the **Style Configuration** section. From the **Configuration** list, choose **Graph Plot Style I**.


Global I

- 1 Right-click **Angular Velocity: Fixed Ring Gear** and choose **Global**.
- 2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.
- 3 In the table, enter the following settings:

Expression	Unit	Description
mbd.hgj7.th_t	rad/s	Sun Gear

Expression	Unit	Description
mbd.hgj6.th_t	rad/s	Carrier
mbd.hgj1.th_t	rad/s	Planet Gear

Angular Velocity: Fixed Ring Gear

- 1 In the **Model Builder** window, click **Angular Velocity: Fixed Ring Gear**.
- 2 In the **Angular Velocity: Fixed Ring Gear** toolbar, click  **Plot**.

Angular Velocity: Fixed Sun Gear


- 1 Right-click **Angular Velocity: Fixed Ring Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type Angular Velocity: Fixed Sun Gear in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **None**.

Global 1

- 1 In the **Model Builder** window, expand the **Angular Velocity: Fixed Sun Gear** node, then click **Global 1**.
- 2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.
- 3 In the table, enter the following settings:

Expression	Unit	Description
mbd.hgj8.th_t		Ring Gear
mbd.hgj1.th_t		Planet Gear
mbd.hgj6.th_t		Carrier

Angular Velocity: Fixed Sun Gear

- 1 In the **Model Builder** window, click **Angular Velocity: Fixed Sun Gear**.
- 2 In the **Settings** window for **ID Plot Group**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Study 2: Fixed Sun Gear/Solution 2 (sol2)**.
- 4 In the **Angular Velocity: Fixed Sun Gear** toolbar, click  **Plot**.

Angular Velocity: Fixed Carrier


- 1 In the **Model Builder** window, right-click **Angular Velocity: Fixed Ring Gear** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type Angular Velocity: Fixed Carrier in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **None**.

Global 1

- 1 In the **Model Builder** window, expand the **Angular Velocity: Fixed Carrier** node, then click **Global 1**.
- 2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.
- 3 In the table, enter the following settings:

Expression	Unit	Description
mbd.hgj7.th_t	rad/s	Sun Gear
mbd.hgj8.th_t		Ring Gear
mbd.hgj1.th_t	rad/s	Planet Gear

Angular Velocity: Fixed Carrier

- 1 In the **Model Builder** window, click **Angular Velocity: Fixed Carrier**.
- 2 In the **Settings** window for **ID Plot Group**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Study 3: Fixed Carrier/Solution 3 (sol3)**.
- 4 In the **Angular Velocity: Fixed Carrier** toolbar, click  **Plot**.

Angular Velocity: Fixed Carrier, Angular Velocity: Fixed Ring Gear, Angular Velocity: Fixed Sun Gear


- 1 In the **Model Builder** window, under **Results**, Ctrl-click to select **Angular Velocity: Fixed Ring Gear**, **Angular Velocity: Fixed Sun Gear**, and **Angular Velocity: Fixed Carrier**.
- 2 Right-click and choose **Group**.

Angular Velocity

In the **Settings** window for **Group**, type Angular Velocity in the **Label** text field.

Follow the instructions below to plot the transmission ratios for different configurations as shown in [Figure 8](#).

ID Plot Group 8

In the **Results** toolbar, click  **ID Plot Group**.

Global 1

- 1 Right-click **ID Plot Group 8** and choose **Global**.
- 2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.

3 In the table, enter the following settings:

Expression	Unit	Description
$mbd.hgj7.th_t/mbd.hgj6.th_t$	1	Fixed Ring Gear

Global 2

- 1 Right-click **Global 1** and choose **Duplicate**.
- 2 In the **Settings** window for **Global**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Study 2: Fixed Sun Gear/Solution 2 (sol2)**.
- 4 Locate the **y-Axis Data** section. In the table, enter the following settings:


Expression	Unit	Description
$mbd.hgj8.th_t/mbd.hgj6.th_t$	1	Fixed Sun Gear

Global 3

- 1 Right-click **Global 2** and choose **Duplicate**.
- 2 In the **Settings** window for **Global**, locate the **Data** section.
- 3 From the **Dataset** list, choose **Study 3: Fixed Carrier/Solution 3 (sol3)**.
- 4 Locate the **y-Axis Data** section. In the table, enter the following settings:


Expression	Unit	Description
$mbd.hgj7.th_t/mbd.hgj8.th_t$	1	Fixed Carrier

Transmission Ratios

- 1 In the **Model Builder** window, under **Results** click **ID Plot Group 8**.
- 2 In the **Settings** window for **ID Plot Group**, type **Transmission Ratios** in the **Label** text field.
- 3 Locate the **Title** section. From the **Title type** list, choose **None**.
- 4 Locate the **Plot Settings** section.
- 5 Select the **y-axis label** checkbox. In the associated text field, type **Transmission Ratio**.
- 6 Locate the **Style Configuration** section. From the **Configuration** list, choose **Graph Plot Style 1**.
- 7 In the **Transmission Ratios** toolbar, click  **Plot**.

Follow the instructions below to plot the trajectory of different points in the planet gear as shown in [Figure 9](#).

Planet Trajectory: Fixed Ring Gear

- 1 In the **Results** toolbar, click  **ID Plot Group**.
- 2 In the **Settings** window for **ID Plot Group**, type Planet Trajectory: Fixed Ring Gear in the **Label** text field.
- 3 Locate the **Title** section. From the **Title type** list, choose **Label**.
- 4 Locate the **Style Configuration** section. From the **Configuration** list, choose **Graph Plot Style 1**.

Global 1

- 1 Right-click **Planet Trajectory: Fixed Ring Gear** and choose **Global**.
- 2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.
- 3 In the table, enter the following settings:

Expression	Unit	Description
mbd.hlg3.xcy+mbd.hlg3.v	m	y-coordinate

- 4 Locate the **x-Axis Data** section. From the **Parameter** list, choose **Expression**.
- 5 In the **Expression** text field, type mbd.hlg3.xcx+mbd.hlg3.u.
- 6 Select the **Description** checkbox. In the associated text field, type x-coordinate.
- 7 Click to expand the **Legends** section. Click **Override Settings in Style Configuration** in the upper-right corner of the **Legends** section.
- 8 From the **Legends** list, choose **Manual**.
- 9 In the table, enter the following settings:

Legends
Center point

Color Expression 1

- 1 Right-click **Global 1** and choose **Color Expression**.
- 2 In the **Settings** window for **Color Expression**, locate the **Expression** section.
- 3 In the **Expression** text field, type t.

Point Graph 1

- 1 In the **Model Builder** window, right-click **Planet Trajectory: Fixed Ring Gear** and choose **Point Graph**.
- 2 In the **Model Builder** window, click **Point Graph 1**.
- 3 Select Point 2536 only.

- 4 In the **Settings** window for **Point Graph**, locate the **y-Axis Data** section.
- 5 In the **Expression** text field, type y .
- 6 Locate the **x-Axis Data** section. From the **Parameter** list, choose **Expression**.
- 7 In the **Expression** text field, type x .
- 8 Click to expand the **Legends** section. Click **Override Settings in Style Configuration** in the upper-right corner of the **Legends** section.
- 9 Select the **Show legends** checkbox.
- 10 From the **Legends** list, choose **Manual**.
- 11 In the table, enter the following settings:

Legends



Left point

- 12 Click to expand the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Dashed**.

Color Expression 1

- 1 Right-click **Point Graph 1** and choose **Color Expression**.
- 2 In the **Settings** window for **Color Expression**, locate the **Expression** section.
- 3 In the **Expression** text field, type t .
- 4 Locate the **Coloring and Style** section. Clear the **Color legend** checkbox.


Point Graph 2

- 1 In the **Model Builder** window, under **Results > Planet Trajectory: Fixed Ring Gear** right-click **Point Graph 1** and choose **Duplicate**.
- 2 In the **Settings** window for **Point Graph**, locate the **Selection** section.
- 3 Click to select the  **Activate Selection** toggle button.
- 4 Click  **Clear Selection**.
- 5 Select Point 2821 only.
- 6 Locate the **Coloring and Style** section. Find the **Line style** subsection. From the **Line** list, choose **Dotted**.
- 7 Locate the **Legends** section. In the table, enter the following settings:

Legends

Right point

Planet Trajectory: Fixed Ring Gear

- 1 In the **Model Builder** window, click **Planet Trajectory: Fixed Ring Gear**.
- 2 In the **Settings** window for **ID Plot Group**, locate the **Axis** section.
- 3 Select the **Preserve aspect ratio** checkbox.
- 4 In the **Planet Trajectory: Fixed Ring Gear** toolbar, click  **Plot**.

Planet Trajectory: Fixed Sun Gear

- 1 Right-click **Planet Trajectory: Fixed Ring Gear** and choose **Duplicate**.
Follow the instructions below to plot the epicycloid curve traced by the planet gear, when sun gear is fixed as shown in [Figure 10](#).
- 2 In the **Settings** window for **ID Plot Group**, type Planet Trajectory: Fixed Sun Gear in the **Label** text field.
- 3 Locate the **Data** section. From the **Dataset** list, choose **Study 2: Fixed Sun Gear/ Solution 2 (sol2)**.

Global I

- 1 In the **Model Builder** window, expand the **Planet Trajectory: Fixed Sun Gear** node, then click **Global I**.
- 2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.
- 3 In the table, enter the following settings:

Expression	Unit	Description
mbd.grp6.xcp_pny	m	y-coordinate

- 4 Locate the **x-Axis Data** section. In the **Expression** text field, type mbd.grp6.xcp_pnx.
- 5 Locate the **Legends** section. In the table, enter the following settings:

Legends
Sun Gear

Color Expression I

- 1 In the **Model Builder** window, expand the **Global I** node.
- 2 Right-click **Color Expression I** and choose **Delete**.

Point Graph I

- 1 In the **Model Builder** window, under **Results > Planet Trajectory: Fixed Sun Gear** click **Point Graph I**.
- 2 In the **Settings** window for **Point Graph**, locate the **Legends** section.

3 In the table, enter the following settings:

Legends

Planet Gear

Point Graph 2

In the **Model Builder** window, right-click **Point Graph 2** and choose **Delete**.

Planet Trajectory: Fixed Sun Gear

1 In the **Model Builder** window, under **Results** click **Planet Trajectory: Fixed Sun Gear**.

2 In the **Planet Trajectory: Fixed Sun Gear** toolbar, click  **Plot**.

Planet Trajectory: Fixed Ring Gear, Planet Trajectory: Fixed Sun Gear

1 In the **Model Builder** window, under **Results**, Ctrl-click to select **Planet Trajectory: Fixed Ring Gear** and **Planet Trajectory: Fixed Sun Gear**.

2 Right-click and choose **Group**.

Planet Trajectory

In the **Settings** window for **Group**, type Planet Trajectory in the **Label** text field.

Displacement: Fixed Ring Gear

1 In the **Results** toolbar, click  **Animation** and choose **Player**.

2 In the **Settings** window for **Animation**, type Displacement: Fixed Ring Gear in the **Label** text field.

3 Locate the **Frames** section. In the **Number of frames** text field, type 200.

Displacement: Fixed Sun Gear

1 Right-click **Displacement: Fixed Ring Gear** and choose **Duplicate**.

2 In the **Settings** window for **Animation**, type Displacement: Fixed Sun Gear in the **Label** text field.

3 Locate the **Scene** section. From the **Subject** list, choose **Displacement: Fixed Sun Gear**.

Displacement: Fixed Carrier

1 In the **Model Builder** window, right-click **Displacement: Fixed Ring Gear** and choose **Duplicate**.

2 In the **Settings** window for **Animation**, type Displacement: Fixed Carrier in the **Label** text field.

3 Locate the **Scene** section. From the **Subject** list, choose **Displacement: Fixed Carrier**.