
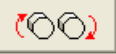





Motion and Transitional Constraints

Introduction

Motion and transitional assembly constraints are used to couple an open degree of freedom on one component to an open degree of freedom on a second component. In other words, if one component moves, so does the other component. Motion and transitional couples are commonly used to simulate the following mechanisms: belt and pulley (rotation motion), gears (rotation motion), rack and pinion (rotation-translation motion), and cam (transitional). Table 1 summarizes the relationships between the couples and the corresponding mechanisms:

Table 1

Couple	Type	Solution	Mechanism
Motion	Rotation 	Forward (Same) 	Belt & pulley
		Reverse (Opposite) 	Gears
	Rotation-Translation 	-	Rack & Pinion
Transitional	-	-	Cam

Motion and transitional couples are accessed with the Place Constraint  Constraint... +C tool. The Motion and Transitional tabs on the Place Constraint dialog box are shown in Figure 1. Note that it is not necessary for the coupled components to be in contact with one another.

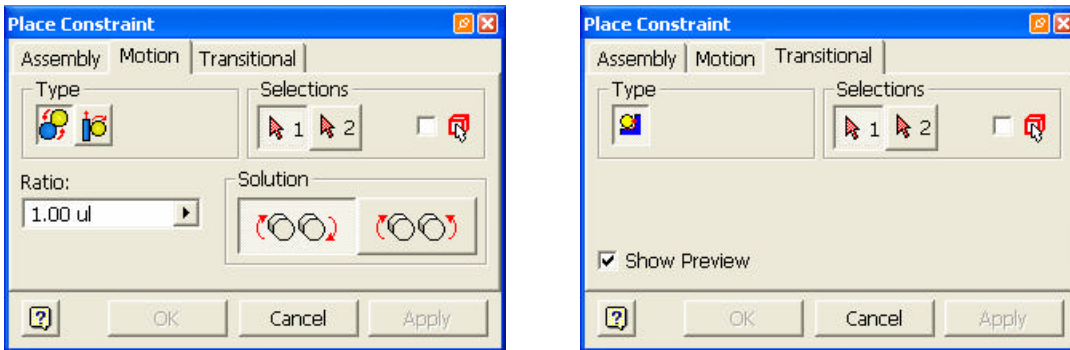


Figure 1

Gear Train Tutorial: Rotational Motion

The purpose of this model is to simulate the motion of a gear train where a gear reduction between the input and output shafts is affected. Rotation motion couples are used to accomplish this.

Download Files

Download the zip file *Geartrain.zip*. Create a new folder and extract the contents of the zip file into the folder.

Tutorial

Open the GearTrain assembly file. See Figure 2. This assembly file consists of four parts; a fixed lower support and three shafts. Insert constraints have been used to constrain the shafts to the lower support. A suppressed angle constraint will be used to drive the assembly.

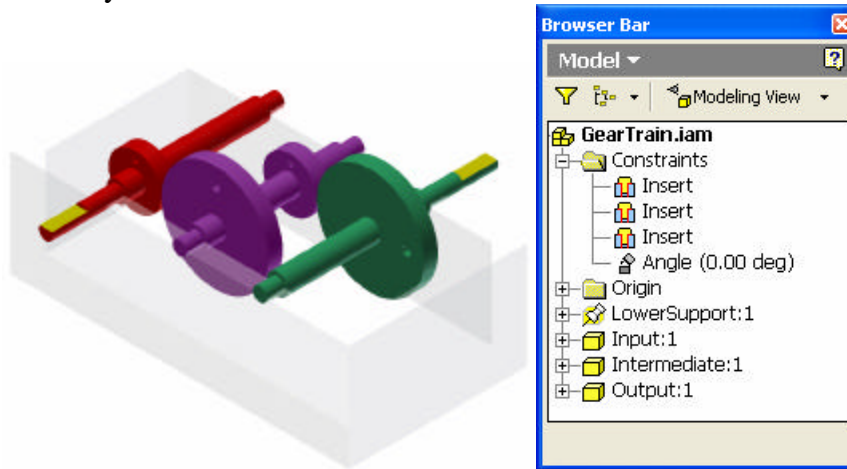


Figure 2

Start by coupling the motion between the Input and the Intermediate shafts. After selecting the Place Constraint tool, select the Motion tab. On the Motion tab, select the Rotation Type, and the Reverse Solution, as shown in the dialog box in Figure 3. In the graphics area, first select the largest diameter outer cylindrical surface on the Input shaft (upon selection, surface color is cyan), and then select the largest diameter outer cylindrical surface on the Intermediate shaft (also cyan after selection). In the dialog box, the Ratio will automatically change to 0.5, the ratio of the two selected diameters. Click the Apply button to create the Rotation couple, and then click Cancel to close the dialog box.

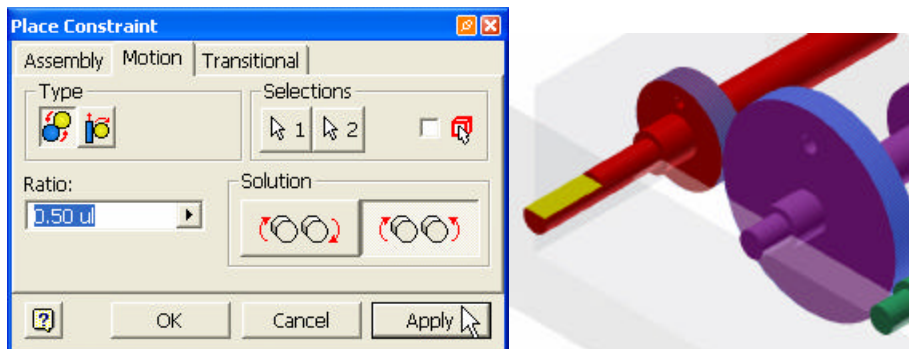



Figure 3

To test the Rotation couple, first position the cursor on the previously selected cylindrical surface on the Input shaft. Hold down the left mouse button and move the cursor in large

circles about the Input shaft axis. Notice that when the Input shaft rotates the Intermediate shaft also rotates, but more slowly and in the opposite direction. After testing the couple, click Undo  to return both shafts to their initial positions.

Now add a Rotation couple between the Intermediate and the Output shafts. Again select the Place Constraint tool, and then click on the Motion tab. With the Type set to Rotation (default), and the Solution set to Reverse, select the two cyan colored cylindrical surfaces shown in Figure 4. Note that the Ratio has been calculated automatically (0.5), and indicates that the smaller diameter cylindrical surface on the Intermediate shaft was selected first, and then the larger diameter surface on the Output shaft was selected. If the selection order is reversed, the calculated ratio would be 2. Either way, the resulting motion is the same.

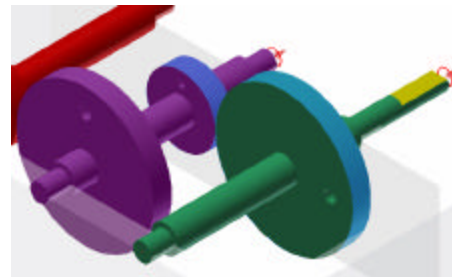
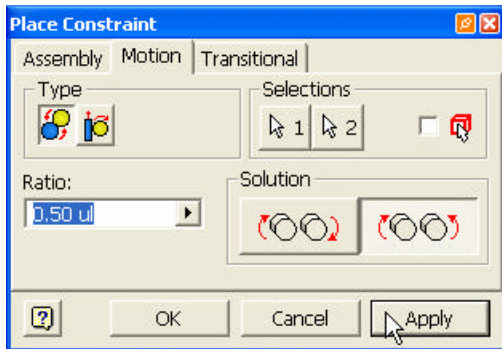


Figure 4

To test the motion, position the cursor on the Input shaft, then click and drag the cursor, again making large circular motions. The Output shaft should turn in the same direction as the Input shaft, but more slowly. For each complete revolution of the Output shaft, the Input shaft revolves how many times?

To drive the motion, right-click on the suppressed Angle constraint in the browser, and select Drive Constraint. Change the End angle to 1440 deg (4 revolutions), and then click the Forward button (shown in Figure 5) to simulate the motion of the gear train.

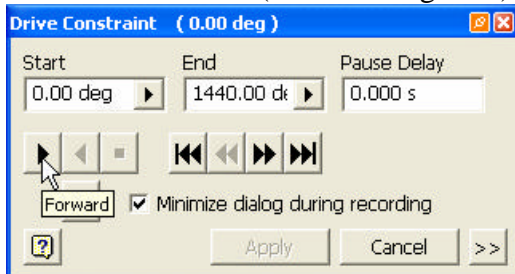




Figure 5

Rotation Motion Constraint Notes

In principal, the Forward  solution is used when both components rotate in the same direction (e.g., belt & pulley), whereas the Reverse  solution is used when

the selected components rotate in opposite directions (e.g., meshed gears). Be aware though, that this may not always be the case. Upon selecting the components, a positive rotation axis is indicated in red on each component (see Figure 4 on the right). If the positive rotation axis points in the same direction on both components, then the Forward and Reverse solutions will work as expected. If however, the positive direction arrows for the components are reversed, then the respective solutions will have an opposite effect.

If a cylindrical feature representing the gear pitch diameter is selected for both components, then the Ratio is calculated automatically as the ratio of the first selected diameter to that of the second selected diameter. This was the method used in the gear train tutorial above. Otherwise the ratio can be input manually. This would be necessary, for example, in the event that the gear teeth are modeled. In this case there is no single feature representing the gear pitch diameter, so the gear tooth ratio would be input manually.

Planetary Gear Train

A planetary gear train can also be used to achieve large speed reductions in a more compact space than a traditional gear train.

Download Files

Download the zip file *Planet.zip*. Create a new folder and extract the contents of the zip file into the folder.

Demonstration

Open the Planetary1 assembly file. The assembly file consists of four components; two subassemblies (Sun_handle and Carrier_output) and two parts (Ring and Planet). See Figure 6.

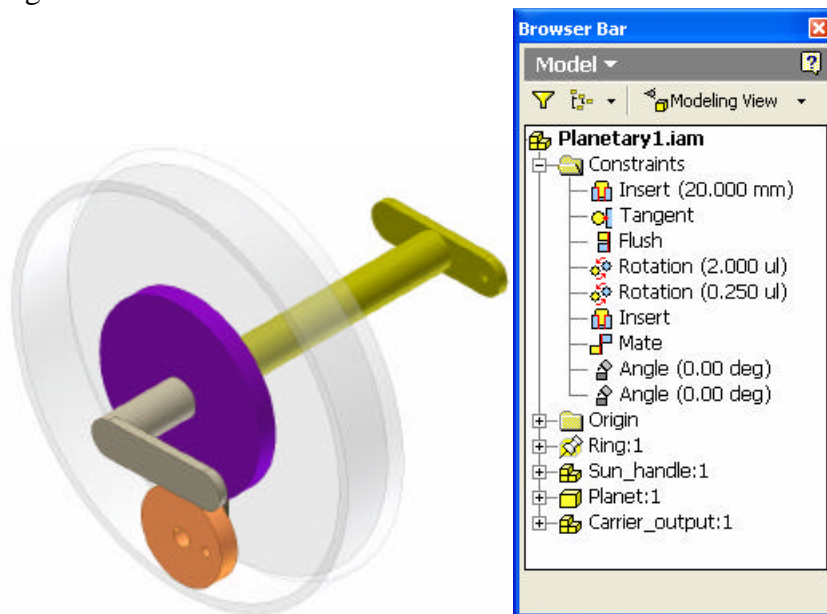


Figure 6

A planetary gear train works as follows: the input drive is applied to the sun gear, which in turn rotates the planet gear. While there are normally three or more planet gears, only one planet gear is used in this model. The planet gear teeth are also meshed with the internal teeth of a fixed ring gear. The planet gear is free to rotate about one end of a carrier link. The other end of the carrier link rotates freely about the gear train central axis. The combination of the planet gear being meshed with both the sun gear and the fixed ring gear causes the carrier to rotate in the same direction but at a slower speed than the sun gear. The output drive is rigidly attached to the carrier the central axis of the gear train.

Two rotation motion constraints or couples are used in the assembly. One Rotation constraint couples the motion of the sun and the planet gears. The other Rotation couple links the motion of the planet and ring gears.

To test the motion, place the cursor over the beige colored handle (a part of the Sun_handle subassembly). Click and drag in mouse, tracing large circles about the central axis of the gear train. The result is that the yellow colored output shaft (part of the Carrier_output subassembly) rotates in the same direction but more slowly than the input.

Use the first suppressed angle constraint to drive the assembly. Right-click on this constraint in the assembly browser, and then select Drive Constraint. After entering 1080 for the End angle click the Forward button to set the planetary gear train in motion. See Figure 7.

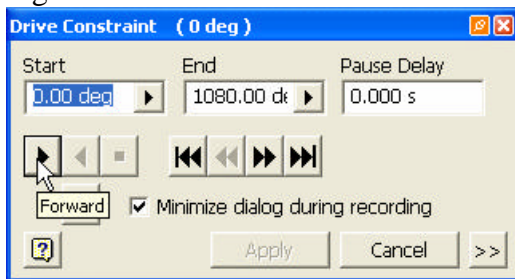


Figure 7

Elevator Tutorial: Rotation-Translation Motion


In this tutorial Rotation-Translation motion couples will be used to simulate the motion of an elevator, sheave, and counterweights.

Download Files

Download the zip file *Elevator.zip*. Create a new folder and extract the contents of the zip file into the folder.

Tutorial

Open the Elevator assembly file. See Figure 8. This assembly file consists of three parts and a subassembly. The Frame is fixed, while the Elevator and Counterweight parts are

free to translate vertically. Test the movement of these parts by clicking and dragging, click Undo  to reposition them.¹

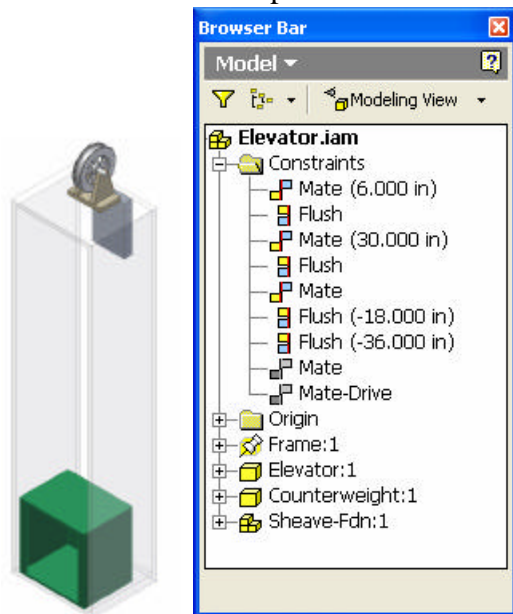




Figure 8

The Sheave part in the Sheave-Fdn subassembly is free to rotate about an axis. Before this works in the main assembly however, it is first necessary to make the subassembly adaptive. To do this, right-click on the Sheave-Fdn in the browser, and then select Adaptive in the context menu. You should now be able to rotate the Sheave in the main Elevator assembly.

We will start by adding a rotation-translation couple between the Sheave and the Elevator. Using the Place Constraint tool, select the Motion tab on the Place Constraint dialog box. Set the Type to Rotation-Translation . First select the inner diameter of the Sheave part (highlighted in cyan upon selection) in the graphics window. Next select an edge on the Elevator. Note that, based upon these selections, the red direction vectors (see Figure 9 on the left) indicate that when the sheave rotates counterclockwise the elevator will go up. This is the opposite of the desired motion. To correct this, it is

necessary to select the Reverse  Solution, as shown in the dialog box in Figure 9. Also note that based upon the selections, the Distance has automatically been calculated to be 150.8 inches. This is because the inner diameter of the sheave is 48 inches ($48 * 3.14 \cong 150.8$). Click Apply to apply the couple, and then click Cancel to close the dialog box.

Test the motion by clicking on the sheave, and dragging the mouse in a clockwise motion about the sheave axis. The Elevator should move up. If not, right-click on the

¹ The currently suppressed Mate and Mate-Drive constraints can be used to reposition the Counterweight and Elevator parts respectively. To do so, unsuppress the constraint, then suppress again.

Rotation/Translation constraint in the browser, select Edit from the context menu, change the Solution, and click OK.

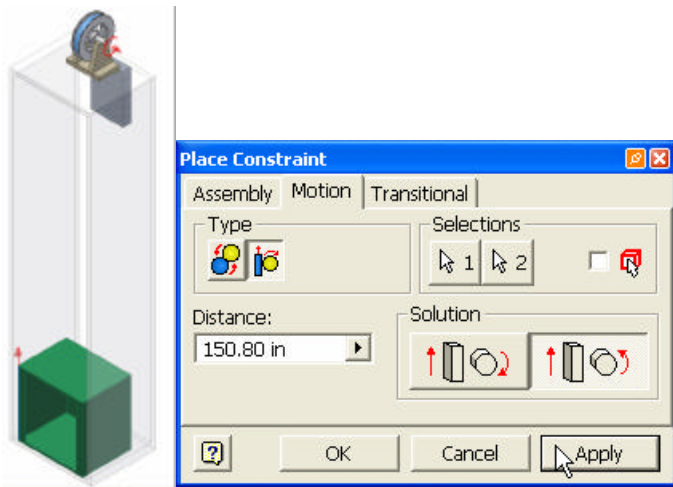


Figure 9

Now add a rotation-translation couple between the Sheave part and the Counterweight. First use Common View so that the Counterweight geometry can be easily selected. Once again select Place Constraint, Motion Tab, Rotation-Translation Type. Start by selecting the inner diameter of the Sheave. Next select an edge on the Counterweight. In Figure 10 a counterweight edge has been selected so that the red direction vector points up. Given a counterclockwise rotation of the Sheave, the Counterweight should in fact go up. Consequently there is need to change the Solution – Forward should yield the desired motion. If not, the constraint can always be edited. Click Apply, and then Cancel.

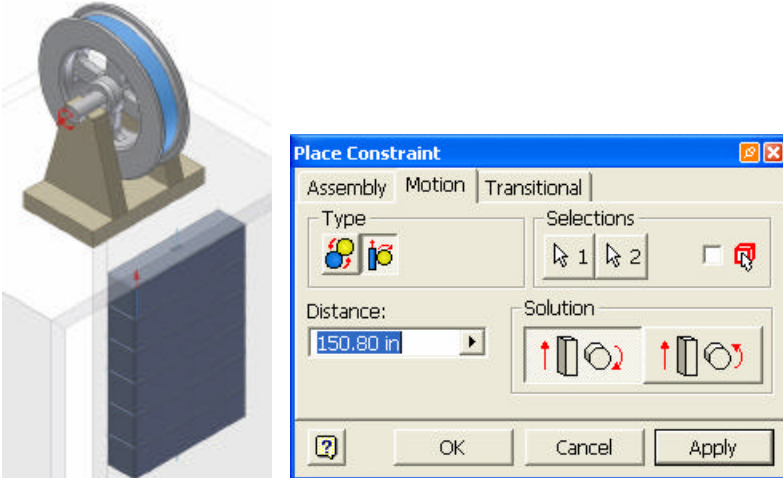




Figure 10

After changing back to the default isometric view, test the motion. With the Sheave rotated clockwise, the Elevator should move up, the Counterweight down.

At this point it is still possible for both the Elevator and the Counterweight to move outside of the Frame part. To place limits on the range of vertical motion for both of these

moving parts, we will use a drive constraint. Right-click on the currently suppressed Mate-Drive constraint in the browser, and select Drive Constraint. In the Drive Constraint dialog box set the End to a large number, say 1000 inches. Expand the dialog box by clicking the More  button, and then check the Collision Detection box. Now click the Forward  button to set the parts in motion. When the Elevator reaches the top of the Frame, the animation stops and a message box appears announcing that a collision has been detected. See Figure 11. Notice also that at the top of the Drive Constraint dialog box the length at which the collision occurred (373 inches) is indicated.

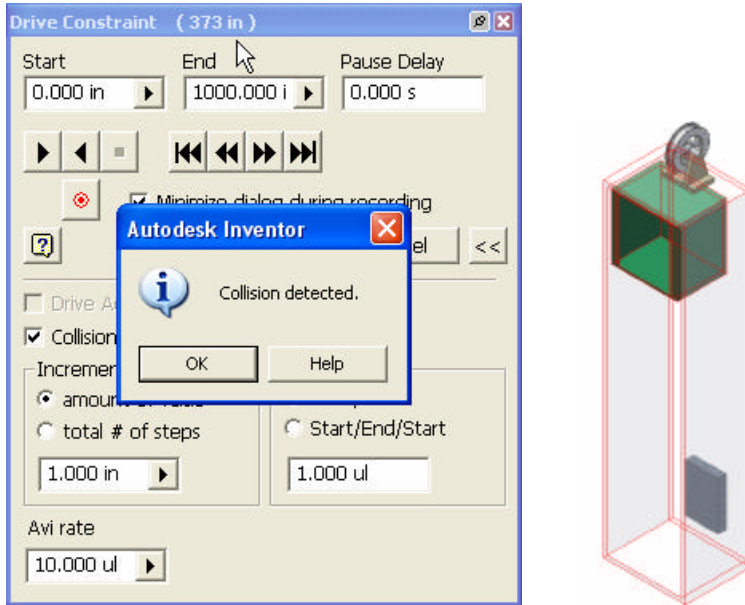



Figure 11

Click OK to close the message box, and the Reverse  button to return the parts back to their initial positions. Finally, change the End value to 372 (one less than the value at which the collision occurs) and run the animation again. We have just determined the range of motion of the Elevator. This concludes the tutorial.

Rotation-Translation Motion Constraint Notes

When applying a rotation-translation motion constraint, the first part selected must be the rotating (pinion) part. When selecting the translating (rack) part, it is necessary to select an edge (not a surface) on the part to be translated. If a cylindrical surface on the rotating part is selected, the Distance will automatically be calculated as πD , where D is the diameter of the selected surface.

Cam Tutorial: Transitional Motion

A transitional motion constraint forces a part (i.e., a follower) to move along a path contained on another part (i.e., a cam). In this tutorial a transitional motion constraint will be used to simulate the motion of a cam and follower mechanism.

Download Files

Download the zip file *Cam.zip*. Create a new folder and extract the contents of the zip file into the folder.

Tutorial

Open the Final assembly file. See Figure 12 on the left. To display the internal detail, right-click on both occurrences of the Housing1 part in the browser, and de-select Enabled. The housing is now are now transparent, and cannot be selected. See Figure 12 on the right.

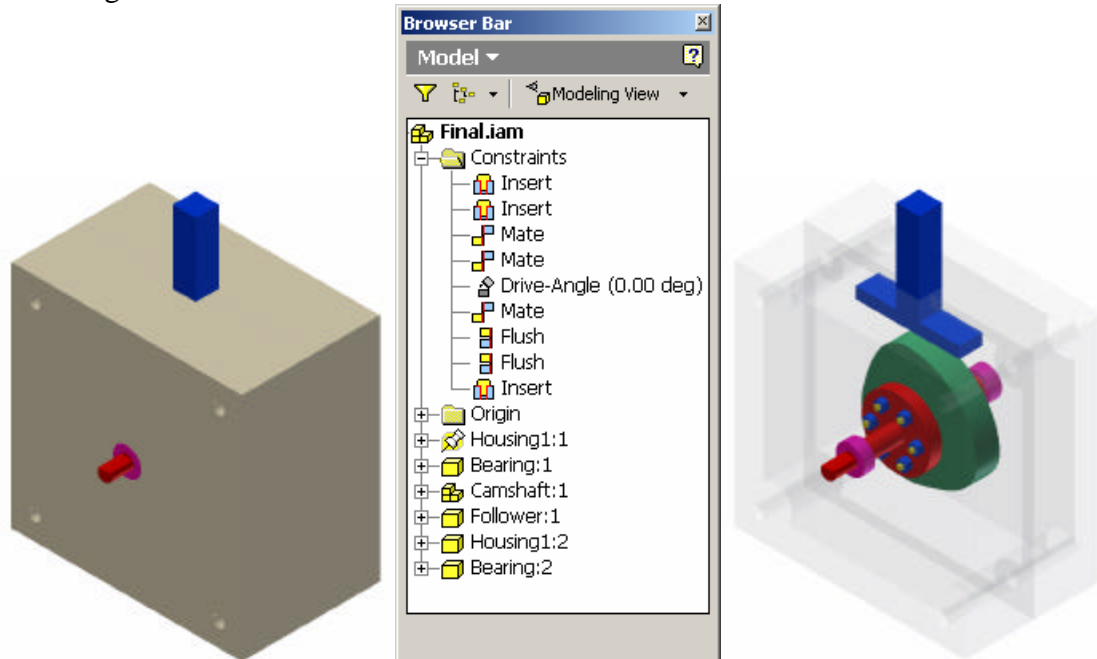


Figure 12

The (blue) Follower is free to translate vertically, while the Camshaft subassembly is free to rotate about the shaft axis. After testing these motions, click Undo to return the components to their original positions.

To couple the motion of the Camshaft and the Follower, use a transitional constraint. Select the Place Constraint tool, and then select the Transitional tab. First select the flat follower surface that will be in contact with the cam (Figure 13, on the left, shown in cyan color upon selection). Next select the cam contact surface (Figure 13, middle, also cyan upon selection). Click Apply, and then Cancel.

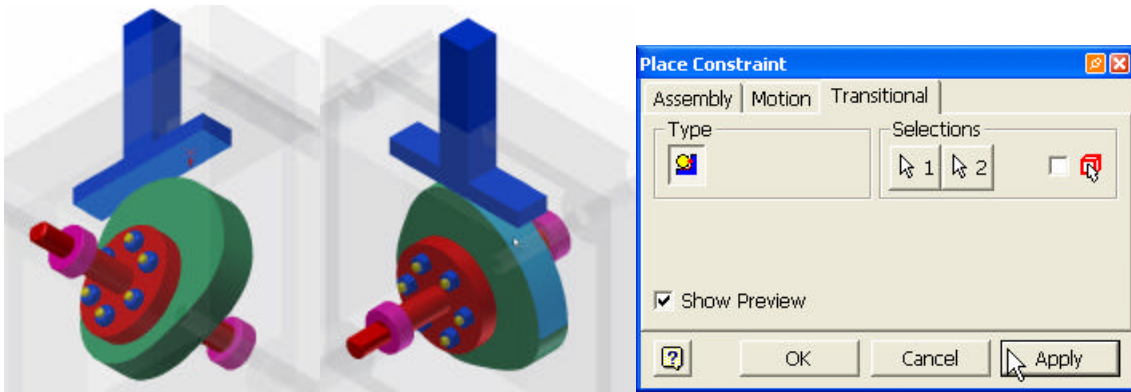


Figure 13

At this point the Camshaft subassembly and Follower part should be in contact. To test the coupled motion, click on the cam and drag the mouse slowly in a large circular path. Click Undo after verifying that the Follower remains in contact with the cam as the Camshaft is rotated. If the Camshaft locks and moves out of position, click Undo. Further testing will require that the mouse be moved more slowly.

To drive the assembly, right-click on the suppressed Drive-Angle constraint in the browser, and select Drive Constraint. Select the Forward button to animate the cam and follower. This completes the tutorial.

Transitional Motion Constraint Notes

When applying transitional motion between parts, only faces can be selected. The first face selected must be the moving (follower) face. The follower face can either be a planar or an arc surface. The second face selected is the transitional (cam) face. The cam face may consist of several contiguous surfaces. These surfaces can be composed of lines, arcs, and even splines.