Moving Right Along

By Bill Fane

In a previous Autodesk Inventor® tutorial, you learned how to use two of the software's motion constraints—Rotation-Rotation (gears or pulleys) and Rotation-Translation (rack and pinion). With these constraints, as with the Transitional constraint you'll explore in this tutorial, you can analyze a mechanical assembly to ensure that the built part will function correctly and to demonstrate the function to other people.

I can best describe the motion of the Transitional constraint as a "cam and follower." You'll use this constraint to model and simulate a range of motions significantly more complex than those available with Rotation-Rotation and Rotation-Translation. A quick demonstration will show you the some of the power of this constraint.

What Goes Around...

1. Start by downloading the ZIP file containing the files you will need to complete the tutorial. They works with Inventor 5.0 and later.

Download (zip - 2013Kb)

2. Unzip the file content into a suitable folder.

3. Start Inventor, go to the folder where you placed the content, and open the assembly file BF-03-01.iam, which looks like Figure 1.

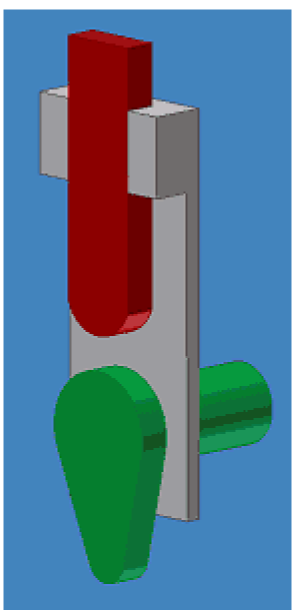
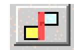


Figure 1: Assembly file BF-03-01.iam.

4. Click the Place Constraint function in the panel bar,  in R5.0 and 5.3 or  in R6.0 and 7.0. The Place Constraint dialog box opens.

5. Click the Transitional tab (see Figure 2).

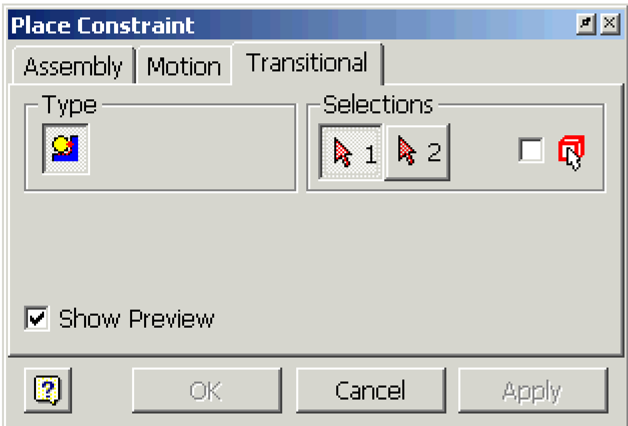
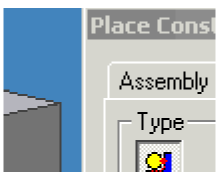


Figure 2: The Transitional tab of the Place Constraint dialog box.



View Larger

Figure 3: The follower and the cam, with their faces selected for the Transitional constraint.

6. To apply a Transitional constraint, click the curved face at the bottom of the red follower (see Figure 1), and **then** click the upper, curved face of the green cam. Your screen, including the dialog box, should now look like Figure 3.

Note: You must click the bottom, curved face of the red follower **before** you click the upper, curved face of the green cam. Do not click edges or any other faces.

7. In the Place Constraint dialog box, click Apply > Cancel, which adds a Transitional constraint as the last item in the Browser and closes this dialog box.

8. In the Browser, right-click the DRIVE ME angle constraint, which is just above the Transitional constraint.

9. When the context menu opens, click Drive Constraint, which opens the Drive Constraint dialog box.

10. Click the Forward button, and then watch in shock and awe as the green cam rotates three

revolutions while the red follower faithfully follows its contour.

11. When the motion has finished, click Cancel.

12. Move the cursor to a point within the region of the green cam's smaller arc.

13. Press and hold down the left mouse button.

14. Drag the cursor around in a circular motion, centered approximately on the center of the larger arc of the cam. As with other constraints in Inventor, you can drag the components around and the constraints update dynamically. The follower stays in contact with the cam and oscillates properly.

You have now applied and used the Transitional constraint in a fairly rudimentary way. (Keep in mind that I said earlier that this constraint offered a great range of motion.) So why is this constraint called Transitional? Take a close look at the green cam. Now, compare it to the one shown in Figure 4, which is a screen shot of assembly file BF-03-02.iam.

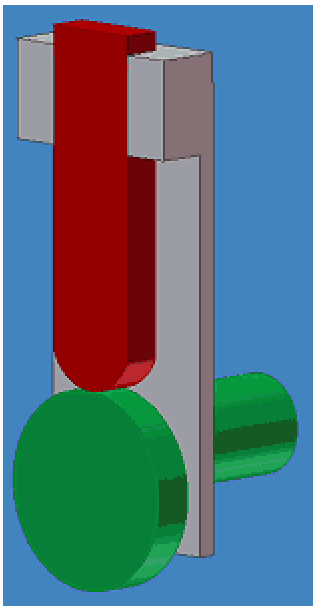


Figure 4: A simple circular cam.

The cam in Figure 4 consists of a simple, circular shape, extruded eccentrically to the shaft. The contact face of the cam consists of a single, continuous, constant-radius surface constrained with a Tangent constraint. In this instance, the follower has a simple reciprocating motion when you rotate the cam.

Now look at the cam in Figures 1 and 3. Its contact face consists of two arc portions that transition (hence, Transitional constraint) between two straight portions. The contact face actually consists of four surfaces. The unique Shape Manager technology within Inventor makes it possible for this transitional surface to work as a cam.

But Wait, There's More!

The transitions do not even have to be smooth tangencies.

1. Open the assembly file BF-03-03.iam, which looks like Figure 5.

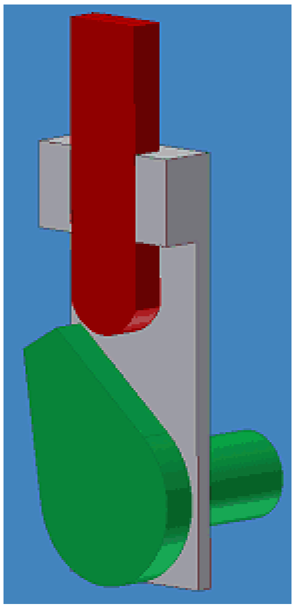


Figure 5: A sharp-cornered cam.

2. Apply a Transition constraint between the curved, lower face of the red follower and the flat, upper face of the green cam. Remember to select the follower first. The assembly should now look like the one shown in Figure 6.

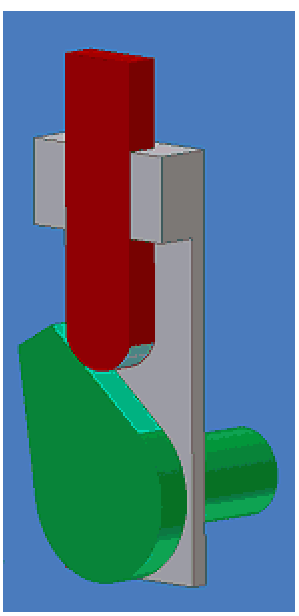


Figure 6: A Transition constraint applied to a sharp-cornered cam.

3. Click and drag the cam with a circular motion. The red follower faithfully stays in contact with the cam as it passes over the cam's sharp corners.

4. Try driving the DRIVE ME constraint. What happens?

It's A Flat World...

So far, you have been using a curved follower. The next exercise shows that a flat-faced follower works every bit as well.

1. Open the assembly file BF-03-03.iam, which looks like Figure 7.

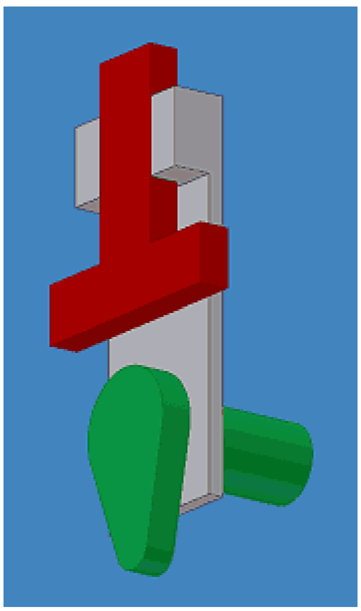


Figure 7: A flat-faced follower.

2. Apply a Transitional constraint between the flat underside of the red follower and the upper, curved face of the cam. Remember to select the follower first.

3. Click and drag the cam with a circular motion. The red follower faithfully stays in contact with the cam as it passes over the cam's sharp corners.

4. Try driving the DRIVE ME constraint. What happens?

It's A Really Flat World...

If you are impressed by what we have done so far, then watch this.

1. Open the assembly file BF-03-05.iam, which looks like Figure 8.

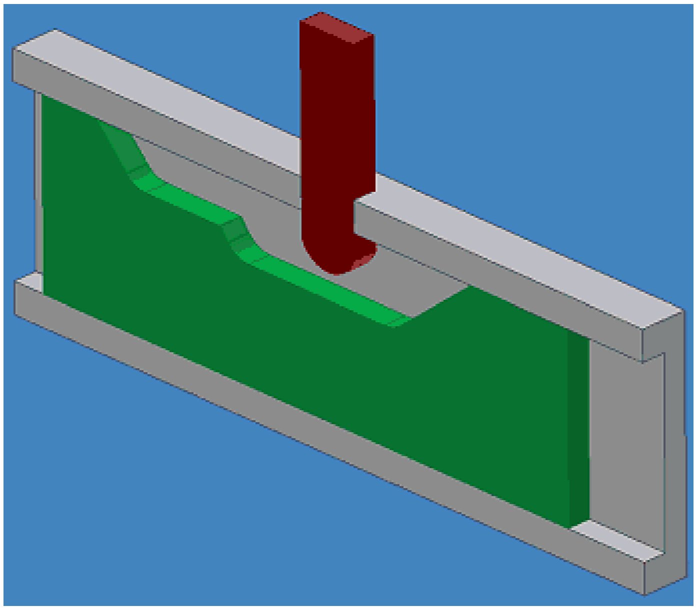


Figure 8: A flat cam and follower.

2. Apply a Transitional constraint between the curved underside of the red follower and the upper, flat face of the cam. Remember to select the follower first, and then pick any face on the top edge of the cam.

3. Click and drag the cam with a side-to-side motion. The red follower faithfully stays in contact with the cam as it follows the cam's side-to-side motion. The action may be a little "sticky" at first until Inventor does all its number-crunching.

Now that is magic! The Transitional constraint also works within a closed-slot cam profile. A plate cam does not necessarily have to be open-sided.

Now that you understand the basic principles, here are a few tips, tricks, and pointers.

- You must always select the follower face first and that face must be a single, flat or arc face.
- The cam face can be any combination of lines and arcs. Sharp corners work, but as in the real world you will find that things work more smoothly if you add small radii on the corners. For example, the cam in assembly file BF-03-03.iam (see Figure 5) does not really have sharp corners. Open the cam part in file BF-03-Cam-03.ipt, suppress the fillets, and see how that affects assembly operation.
- The Transitional constraint tends to mimic the real world in other ways. For example, assembly BF-03-06.iam is identical to BF-03-04.iam except that the contact face on the follower is narrower than the flat faces on the sides of the cam. Open BF-03-06.iam and try rotating the cam to see what I mean.

- Unlike other constraints, Transitional is not “infinite.” The follower face must always touch the cam face. No offset value spaces them radially apart as in other constraints. The faces must also touch in the axial direction. For example, BF-03-02.iam (see Figure 4) uses a simple Tangent constraint. You can increase the offset value of the Insert constraint between the cam and the frame, and the constraint still functions. Try the same thing in BF-03-01.iam (see Figure 1), however, and the Transitional constraint fails.
- The Transitional constraint also works if you use a spline to define the cam, as shown in assembly file BF-03-07.iam. It can be a little finicky, however, and often suddenly snaps over to some other face for the cam surface.
- You are not limited to having the follower slide linearly, as has been the case in my examples. A rocker arrangement, such as you might see in the valves of a car engine, also works.
- Mathematically, a hypercycloid is the “perfect” shape for a cam profile, but Autodesk Inventor does not have such a curve. I replicated one using a program that generated several hundred very small line segments, but because of the number crunching involved, the performance was abysmal when I tried to drag or drive the cam.
- Don’t forget, you can always lie. Open file BF-03-08.iam and drive the DRIVE ME constraint or drag the cam. Hey, you can’t produce an interrupted, noncontinuous cam motion! Yes you can. To see how I did this, turn on the visibility of the Driver part. Note that if you also turn off Enabled, the part does not contribute to mass calculations, but its constraints are still active. I have an assembly model of an electric fuel pump that demonstrates its function. The spring and diaphragm flex, the contacts operate, and the valves open and close. An invisible cam drives it all.

And in Conclusion…

In this tutorial you have learned about the Transitional constraint. With it, you can produce realistic cam motions to analyze assembly functioning before prototyping and manufacturing and to demonstrate mechanism operations to other people.