Motion Assembly Constraints

By Bill Fane

In last month's tutorial you learned about the dynamic assembly constraint analyzer in Autodesk Inventor® software. You discovered that the analyzer has no update function and that it continuously monitors changes to an assembly and makes any necessary updates in real time. You used your mouse to grab onto a partially constrained component and drag it to a new location, and you saw that any other components constrained to the component being dragged followed along. I hope you are now using the analyzer to test assembly constraints and to see if a mechanism is operating correctly.

This tutorial will move on, to explore the motion constraints in Autodesk Inventor, which provide yet another way to make sure your assemblies are operating correctly.

Wait a minute. Don't all assembly constraints prevent relative motion between parts in an assembly?

Yes, most of them do. Inventor, however, has two constraints that only partially limit motion. A better description would be to say that they control motion rather than constrain it. They are intended specifically for use in studying mechanism motions. This tutorial covers both variants of the Motion constraint—Rotation, for gears and pulleys and Rotation—Translation for rack-and-pinion mechanisms. A later tutorial will cover the Transitional constraint, used for cam mechanisms.

Disk Looks Like an Interesting File...

1. Download the accompanying ZIP file and the contents to a folder. (the BF-02-Disks.iam assembly file works with Inventor 5 and later).

Download (zip - 2110Kb)

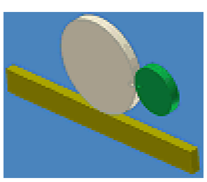

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Figure 1: Assembly file BF-02-Disks.

2. Start Autodesk Inventor, and open the assembly file **BF-02-Disks.iam**, which should look like Figure 1.

3. Click the Place Constraint function on the Inventor panel bar, which opens the Place

Constraint dialog box.

4. In this dialog box, click the Motion tab and then click on the right-hand Solution button. The dialog box should now look like Figure 2.

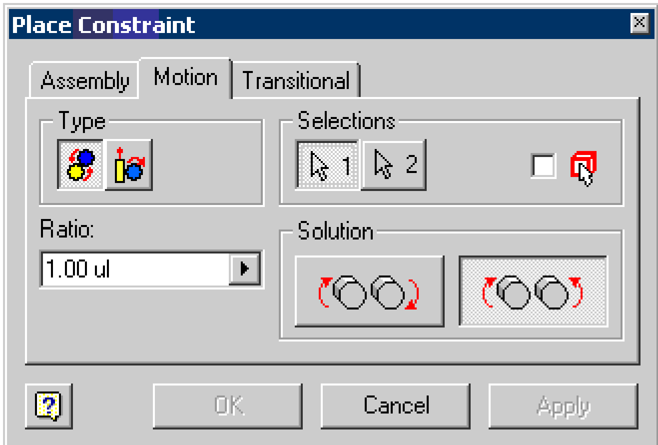

Figure 2: The Motion tab of the Place Constraint dialog box

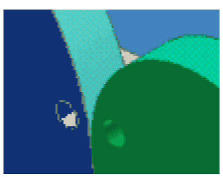

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Figure 3: The two disks with their circumferences selected for the circular motion constraint.

5. Click the outer rim of the larger circle in the assembly, and then click the outer rim of the smaller one. Your screen, including the dialog box, should now look like Figure 3.

Note: The Ratio text box automatically changes to 2.0 ul because the larger disk has a diameter of 2 units and the smaller one has a diameter of 1 unit. Autodesk Inventor automatically calculates the ratio between them.

6. Return to the dialog box, and click Apply and then Cancel.

7. Position the cursor within the larger disk.

8. Hold down the left mouse button and move the cursor in a circular motion.

9. Keep the cursor more or less within the disk and move it around the center of the disk.

Observe how the smaller disk obediently follows, turning two revolutions for each revolution of the larger disk. What happens if you move the smaller disk with your cursor? Try it.

Save your changes or leave the file open because you will return to it shortly.

Giving It the Gears…

1. Open the assembly file BF-02-Gears.iam, so you can apply a Motion constraint between the two gears in this drawing.

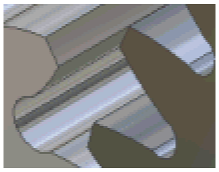

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Figure 4: Select the bore of the gear when applying the constraint.

2. Begin by repeating Steps 3 and 4 above.

3. Now click the bore of the larger gear, and then click the bore of the smaller gear. If necessary, scroll through the selection choices until each bore is highlighted, as shown in Figure 4.

4. The Ratio text box is highlighted automatically. Enter 39/20, which is the ratio of the gear teeth. You must manually apply the gear ratio because Inventor has no circular feature at the pitch diameter of the gears.

Note: Select the larger gear first. If you select the smaller one first, the ratio would be 20/39.TD>

5. Click Apply and click Cancel. This applies a Rotation constraint to the gears.

6. Now drag either gear in a circular motion and note that the other gear rotates at the correct ratio.

> **Note:** The gear teeth do not automatically mesh properly. They must be in the correct position before you apply the Motion constraint. If the example gets out of step:
>
> - Suppress the Rotation constraint.
> - Unsuppress both Angle constraints.
> - Suppress both Angle constraints again.
> - Unsuppress the Rotation constraint.

Now that you're familiar with the basic "gear," or circular type of motion constraint, a bit of experimentation will show you the following:

- From the Place Constraint dialog box, you can select gear (opposite rotation) or belt/chain (same rotation) solutions.
- The constrained parts don't need to actually touch each other. They can be displaced both radially and axially from each other.
- As with any constraint, you can edit the motion constraint. Simply right-click it in the browser, and select Edit from the context menu that opens. You can change the ratio, the solution, and you can even reselect the rotating elements.

Rack 'Em Up...

Return to the BF-02-Disks.iam assembly file. This time you will investigate the Rack-and-Pinion option of the Motion constraint.

1. Click the Place Constraint function on the panel bar, which opens the Place Constraint dialog box.

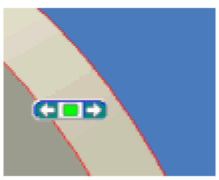

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Figure 5: Select the rim of the larger disk.

2. In that dialog box, click the Motion tab and then click the right-hand Type button, which opens the Translation-Rotation function.

3. Move your cursor onto the rim of the larger disk and observe how the red arrow points into the disk as shown in Figure 5. Click the rim, and its color changes to cyan.

Note: With this constraint, you *must* pick the rotating element first.

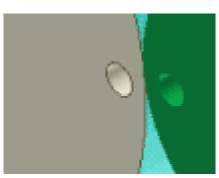

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Figure 6: Select the upper rear edge of the bar.

4. Select the upper **rear** edge of the bar, as highlighted in red in Figure 6.

Note: You must select an **edge** of the bar. If you select a face, the constraint doesn't work properly. Select an edge on the side of the bar to which the Disk Selection arrow was facing.

Once you select the edge of the bar, the Distance list box on the Motion tab is automatically highlighted. This box shows the distance that the linear object translates for each revolution of the circular object. By a strange coincidence, it always seems to be some multiple of 3.1415927…

5. Click Apply and then click Cancel.

6. Use your cursor to rotate either disk and to slide the bar back and forth. Observe how all three objects are connected by and driven by their motion constraints.

The Wheel Deal...

Now let's have a bit of fun with another assembly file, so that you can see some of the other things you can do with motion constraints.

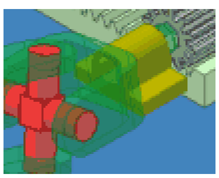

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Figure 7: The steering mechanism in assembly file BF-02-Steering.iam.

1. Open assembly file BF-02-Steering.iam. It should look like Figure 7.

2. Use your cursor to rotate the hand wheel, and watch in amazement as the entire mechanism works from the hand wheel, through the universal joints, and to the rack and pinion.

3. Use your cursor to drag the rack back and forth. The hand wheel and the U-joints follow along.

4. Return everything to approximately the original position.

5. Right-click the last item in the browser bar, which is the suppressed Angle constraint under the hand wheel, as highlighted in red in Figure 8.

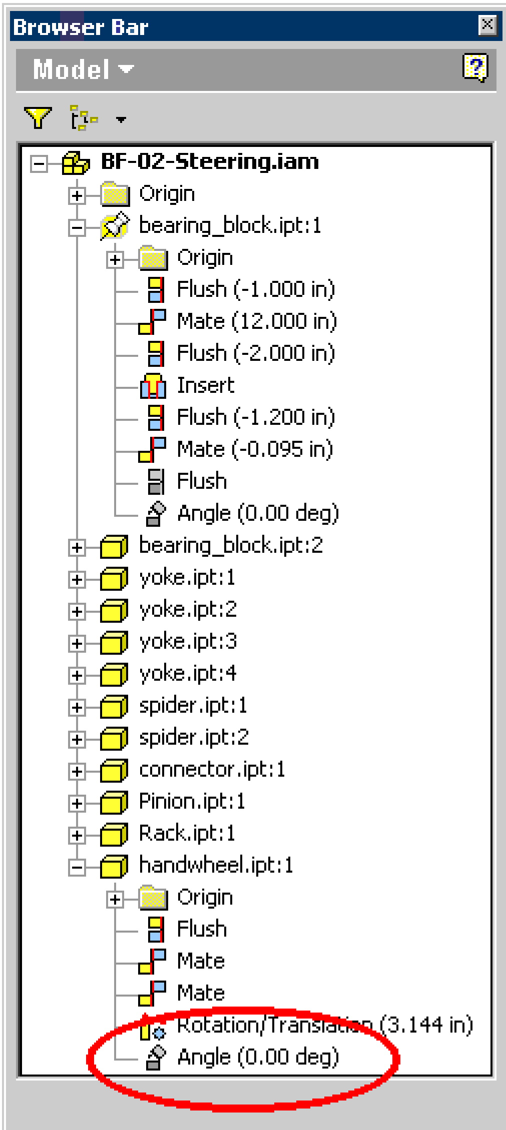

Figure 8: The angle constraint that drives the mechanism.

6. Click Drive Constraint in the context menu that appears, which opens the Drive Constraint dialog box.

7. Click the Forward button in this dialog box. The mechanism automatically goes through six cycles—out and back three times.

8. Click Cancel to return to the assembly.

Now that you have seen the basic motions, use these tips and pointers as you explore how to use this assembly.

- As you saw when constraining the gears, Autodesk Inventor does not automatically apply the correct ratio to a rack and pinion unless the pinion includes a circular feature at the pitch diameter. I entered the ratio manually, based on the pitch diameter of the pinion, when constraining the assembly.
- Inventor does not automatically mesh the rack-and-pinion teeth. I had to position everything correctly before applying the constraint. I used suitable constraints, as shown in figure 9, to set things up. I then applied the Rotation/Translation constraint, and then suppressed the setup constraints. I have left them in the assembly for you. Just follow this sequence if things get out of step:
    - Suppress the Rotation/Translation constraint.
    - Unsuppress the Flush and Angle constraints under Bearing Block 1.
    - Suppress the Flush and Angle constraints again.
    - Unsuppress the Rotation/Translation constraint.

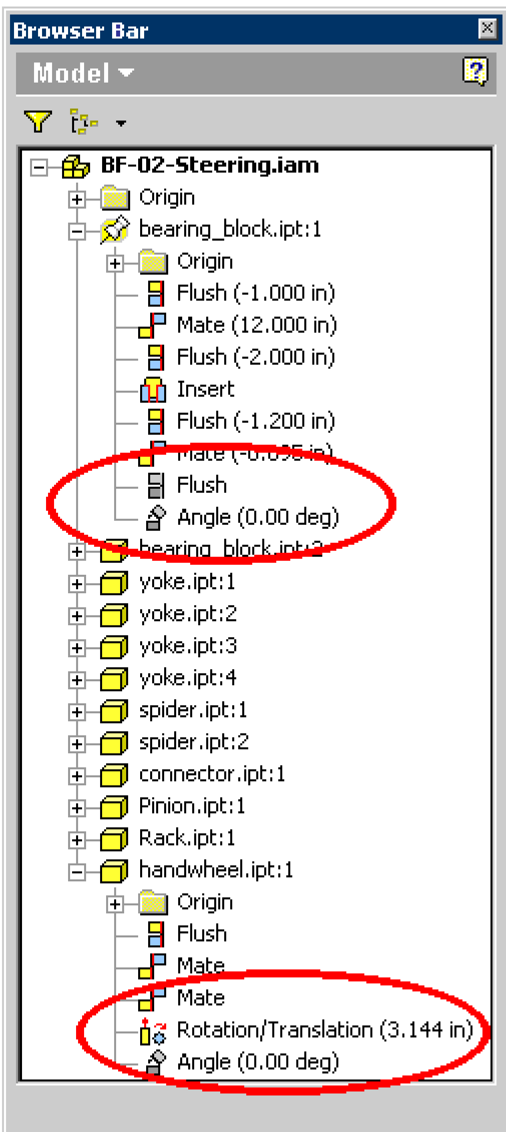

Figure 9: Use these constraints to reset the timing.

- You can use the first three constraints (Flush, Mate, Flush) under Bearing Block 1 to adjust the position of the second bearing relative to the first.
- Constrained objects do not have to touch each other. In this assembly, I applied the Rotation/Translation constraint between the hand wheel and the rack, rather than between the pinion and the rack. The constraints coming down through the universal joints then drive the pinion. That leads to better performance, especially when driving the hand wheel manually. I first tried constraining it the "logical" way, down from the hand wheel and through the U-joints. I then applied the Rotation/Translation constraint between the rack and the pinion, but I found that if I moved the hand wheel or the rack very quickly, I could confuse Inventor and the parts would get out of step.
- Constraints continue to work even if a component part has its visibility turned off or even if it is disabled completely.

And in Conclusion...

The previous tutorial showed you how to use dynamic constraints to test mechanisms and to demonstrate them to others. And because Autodesk Inventor supports creation of AVI animation files, you could send AVIs to team members who may not have access to Inventor. You can do the same things with motion constraints. They are a powerful set of tools to add to your analysis and demonstration arsenal.