Mechanism Tutorial 1: Piston

Introduction

In the previous chapter, we have gone over the fundamentals of creating assembly models. In this chapter, we will examine assembly models that contain moving parts. The main task in creating an assembly is establishing the assembly relationships between parts through the use of assembly constraints. In Creo, designs containing moving parts can also be constrained through specially packaged constraint sets, known as joint connections. Placing the proper type of joint connections in between parts will allow the proper movements of the parts. One of the advantages of using joint connections in assembly models is the ability to transfer the assembly model into the Pro/Animation module to perform basic motion analysis.

In designing machines with moving parts, motion analysis is usually performed to confirm the proper assembly of the designs, also to check for any other potential problems. In Creo, several options are available to perform motion analysis, such as the Mechanism module, the Mechanica module, the Animation module and we can even perform 2D analyses in Creo Sketcher mode. The Mechanism module can be used to perform a very in-depth motion analysis, while the Animation module provides a relatively simple motion analysis that can be done in a relatively short time.

Animation: One main advantage of using the Animation module is the ability to validate the initial design concepts, check for potential problems and to explore design alternatives without actually creating a physical prototype.

Mechanism module does provide more kinematics motion analysis functionality than the Animation tool. The Animation module is more about showing the motion of a design concept. Motions of components are done by dragging the parts. Animation creates animation mostly by interpolating the different positions of the components in an assembly. The Animation module is actually a subset of the Mechanism module, and many of the tools procedures are the same in both modules.

Animation, two main approaches are commonly used to create animation: construct the animation by creating key frames of the different positions of parts, and/or the use of servo motors to provide more specific controls of parts. The general procedure for creating animations using key frames in Animation is similar to the creation of cartoon movies, where key frames are first created and the intermediate frames are then added. In Animation, servo motors are special controls that can be used to drive parts. This allows the simulation of the real life situation of the machines. Animations generated using the key frames approach typically require more work to achieve similar smoothness of motion compared with using the servo motors approach.

In this tutorial, a crank and slider mechanism, commonly seen in engines and compressors' is used to illustrate the basic concepts and procedures of creating assembly models with connections and animations in Animation. Advanced Assembly Modeling and Animation are Joint Connections.
Joint Connections

In CREO, joint connections are special types of packaged constraints that can be used to connect moving components. The applied joint connections will constrain the relative motion between the selected components. Each independent movement permitted by a constraint is called a degree of freedom (DOF). The degrees of freedom that a constraint allows can be translation and rotation about three perpendicular axes, as shown in the picture below.

Each component in an assembly has six degrees of freedom (DOF), or ways in which rigid 3D bodies can move: movement along the X, Y, and Z axes (translational freedom), plus rotation around the X, Y, and Z axes (rotational freedom).

In CREO, the available joint connections include Rigid, Pin, Slider, Cylinder, Planar, Ball, Weld, Bearing, General, 6DOF, and Slot. Joint connections are generally created by applying several of the assembly placement constraints, such as Align, Mate, and Insert. For some connection types, the references must be in the same two components of the assembly. Also, note that in an assembly with moving component, instead of completely locking all movements (removing all of the DOFs), certain DOFs are kept to allow designated movement. For example, a cylinder joint is created by aligning two datum axes in their respective bodies, allowing one translational DOF and one rotational DOF.

In CREO (while applying the joint connection constraints) and also in Animation, a small symbol identifying the type of connection is displayed next to the created joint connection. The symbol of a given joint also shows the translational and/or rotational DOF the joint is allowed. For assembly with moving components, there are four basic symbols: Pin, Slider, Planar and Cylinder.
Four Basic Joint Connections

**Pin:** To apply this type of connection, first Align an axis (or a revolved surface) of the moving component to the assembly and then Align/Mate a flat surface (or a datum plane) of the moving component to the assembly. Note that both sets of references must be to the same two components in the assembly. This connection type allows only one rotational motion, along the aligned axis.

**Slider:** To apply this type of connection, first Align an axis (or an edge) of the moving component to the assembly and then Align/Mate a flat surface (or a datum plane) of the moving component to the assembly. Note that both sets of references must be to the same two components in the assembly. This connection type allows one rotational motion (along the aligned axis), and two translational motions on the aligned surfaces.

**Cylinder:** To apply this type of connection, it is necessary to Align an axis (or a revolved surface) of the moving component to the assembly. Note that additional constraints can also be applied to further restrict the motion of the component. This joint connection allows one rotational motion and one translational motion along the aligned axis.

**Planar:** To apply this type of connection, it is necessary to Align/Mate a flat surface (or a datum plane) of the moving component to the assembly. Note that additional constraints can also be applied to further restrict the motion of the component. This connection type allows one rotational motion (perpendicular to the aligned surfaces) and two translational motions on the aligned surfaces.

**Servo Motor**

In Animation, servo motors are commonly used to generate a particular motion on a mechanism. Servo motors can be used to control a component by specifying a desired position, velocity, or acceleration as a function of time. The controlled motion can be translational or rotational motion. Note that Animation is using the term servo motors very loosely. A servo motor is typically an electronically controlled electric motor; the servo controller allows precise control of the motor shaft’s position. The motor shaft can be positioned and held to specific angular positions by the servo controller. In practice, servo motors are commonly used in computer controlled equipment. Such as plotters and robots. In Pro/Animation, the symbol of a curvy line is used to represent a servo motor as shown in the figure.

![Servo Motor Symbol](image)

**Bodies**

In Animation, a body represents a single rigid component that moves relative to the other bodies within the assembly. A body may consist of a single Creo part or several Creo parts fully constrained using placement constraints. Note that a body placed in three-dimensional space will have three translational and three rotational degrees of freedom (DOF). That is, a rigid body can translate and rotate along the X, Y, and Z-axes of a coordinate system.

**Ground Body**

A ground body (or frame) represents a fixed location in the three dimensional space where the assembly is referencing its motions. The first object placed in an assembly should typically be the fixed reference of the assembly. It is generally a good habit to assemble the ground piece first when building the assembly, although it is possible to change the ground body in both Creo and Animation.
Assembly Parts

Now we will assemble the Crank-Slider Assembly. It is important to note that the order in which one makes their Joint Connections can have dramatic effects on how the assemble will operate. This is why it is important to understand order of creating parts and the order of assembling them together.

1. New > Assembly > Crank-Slider > Ok
2. Assemble > BaseBlock > Fix Part into position
3. Assemble > CrankShaft > Use the following assembling details
   a. Switch from User Defined to Pin in the navigator window
   b. Axis Alignment Selection: Select the two axis lines to tell the software where you want the pin to spin inside of.
c. Translation Selection: Select the Front Datum from the BaseBlock and DTM1 from the Crankshaft > The Connection Status should say Connection Definition Complete > Green Check to accept the connection.

Select Front Datum from BaseBlock and DTM1 from CrankShaft to align the CrankShaft part of the piston hole.

d. Model Tab > Drag Component > Left Click on the CrankShaft > Move the mouse around to see how the CrankShaft moves. Notice it has a full 360 degrees of movement. (NOTE: Other tutorials will show how to limit the degree of movement) > Middle Mouse Button to exit out of this selection.

4. Assemble > ConnectingRod > Change User Defined to Pin > Create the following connections.

Change from User Defined to Pin.
a. Select the following axis lines to line up the Crankshaft and ConnectingRod

b. Translation Selection: Select Front Datum of the ConnectingRod and DTM1 from the Cranshaft > Make sure Connection Status is Complete > Green Check when Finished
c. Model Tab > Drag Component > Left Click on the CrankShaft or ConnectingRod > Move the mouse around to see how the CrankShaft moves. Notice it has a full 360 degrees of movement. (NOTE: Other tutorials will show how to limit the degree of movement) > Make sure the ConnectingRod is placed somewhat in the Piston hole before Middle Mouse Button to exit out of this selection.

5. Assemble > Piston > Change User Defined to Cylinder (this will make the Piston travel along the same path as the piston hole in the BaseBlock) > Create the following connections

a. Axis Alignment Selection: BaseBlock Center Axis of Piston Hole and Piston’s Center Axis (May have to flip the direction of the piston using the flip icon in the Placement Tab)
b. Now we will move the piston into place. Lining the piston with the ConnectingRod.
Click New Set in the Placement Tab (NOTE we have not Exited out of the Cylinder Connection) > Select Change User Defined to Pin > Select the following Axis Lines > Translation Connection Select Piston’s Right Datum and ConnectingRod’s Front Datum to Align > Be sure the Connection Status is complete and green check when finished.

6. Assemble > EndCap > This piece does not need any special connectors since it does not move. Assemble the piece into the following position

7. Use the Drag Component to grab the piston and move the assembly. Note if all pieces are not moving then there is a connection error. Go back and check that all Connections are complete.
Servo Motors

In the Animation Tutorial you learned out to take snapshots of the assembly to make it move. Here we will use Servo Motors to apply force onto our connections to make the assembly move.

Besides using the key frames approach we can also create an animation of the Crank-Slider mechanism though the use of a servo motor. In Animation a servo motor can be used to control a component by specifying a desired position, velocity, or acceleration as a function of time. This approach is very useful if the position for speed or acceleration of the driving component is known or can be estimated. In this section we will create animation using this approach for our Crank-Slider Assembly.

1. Click on the Applications Tab < Click on Animation > New Animation > Select Snapshot (Note this will give you the option to add servo motors to your connections) > Name the animation it or leave it as default > Click Ok
2. Select Servo Motor in the toolbar > Once Selected you will notice all of your Joint Connections on your part (see below)
3. A pop menu will appear that will control the properties of the servo motor.
   a. Name it Crankshaft
   b. First we must select the connection we want to attach a motor to. Select the Pin Connection that goes through the Crankshaft
   c. Select Profile Tab

Variables. Depending on the Magnitude chosen will determine how much information the user will have to supply for calculations of the speed of the motor.

Magnitude defines how the Specifications speed will be determined. Each will have a different formula for calculations and how the motion moves. Hold Cursor over the different options to see the formula used.

Options
1. Constant
2. Ramp
3. Cosine
4. SCCA
5. Cycloid
6. Parabolic
7. Polynomial
8. Table
9. User Defined

Will graph the speed of the motor over time. Select a couple of the Magnitudes and enter values for the variables and select the Graph to see the motion the motor. Some will be constant others will speed up or slow down over time.
d. Change the Profile Tab of your Servo Motor as follows
   i. Specification: Velocity
   ii. Magnitude: Constant
   iii. Variable A: 36 (This will represent 36 degrees of rotation per second; giving us a full 360 degree rotation over 10 seconds)
   iv. Select Graph to see the motion over time
   v. Select Apply > Select Ok
   vi. This will add the Servo Motor onto your Animation Time Line. Press Play and see what happens
   vii. Edit the Servo Motor > Right Click on the Servo Motor on the Time Line or The model > Select Edit Servo Motor. Try some other Magnitudes and Values to see what happens. Leave the cursor on each variable to see what the variable represents in the calculated formula

4. Press Play to see your animation. Notice how we only needed one Servo Motor to make the assembly animated. This is due to all of the Joint Connections we made as we assembled the Crank-Slider Assembly. It is important to note that the order in which one makes their Joint Connections can have dramatic effects on how the assemble will operate.

5. Add the following to your Animation
   a. Make at least 3 Changes in Views to show all aspects of the Animation
   b. Zoom in and out on the ConnectingRod-CrankShaft Connections (Note you may have to create new Saved Views)
   c. Make the BaseBlock disappear and reappear
   d. Extra Credit: Create the other half of the BaseBlock and Assembly that inside your assembly and make it transparent at some point in the time line

6. Export the final Animation as an .Mpeg. Be sure to be conscious of zoom factors. When animating. All parts should remain on the screen.