Mechanism Design

Mechanism design in Pro Engineer is very comprehensive. You can assemble components of the mechanism together using joints which accurately reflect their movements, you can animate the movement creating movie files which can be displayed on any PC and you can ask Pro Engineer to calculate the forces and movements of a mechanism to enable you to determine the suitability of the mechanism.

Degrees of Freedom

Understanding degrees of freedom is critical to selecting the appropriate joints for your mechanism. In mechanical systems, the number of degrees of freedom (DOF) represents the number of independent parameters required to specify the position or motion of every body in the system. A completely unconstrained body has six degrees of freedom, three translational and three rotational. Joint connections act as constraints, or restrictions, on the motion of bodies relative to each other, reducing the total possible degrees of freedom of the system. If you apply a pin joint to a body, you restrict the body's movement to rotation around the pin joint, and the degrees of freedom for the body reduce from six to one. Below is a table describing the joint connections you can create in Mechanism Design and the degrees of freedom corresponding to each joint.

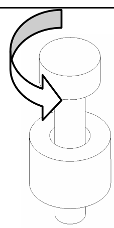
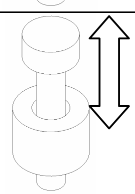
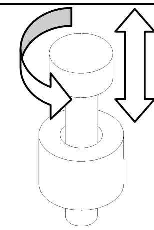
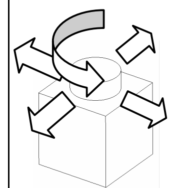
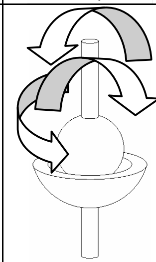
Joint	Diagram	No. of DOF		Description
		Rotate	Translate	
Pin		1	0	Rotates about an axis.
Slider		0	1	Translates along an axis.
Cylinder		1	1	Translation along and rotation about a specific axis.
Planar		1	2	Bodies connected by a planar joint move in a plane with respect to each other. Rotation is about an axis perpendicular to the plane.
Ball		3	0	A "ball-in-spherical-cup" joint allows rotation in any direction.
Bearing		3	1	Combination of a ball joint and a slider joint.
Weld		0	0	Glues two parts together.
Rigid		0	0	Glues two parts together while changing the underlying body definition. Parts constrained by a rigid connection constitute a single body.

Figure 1 : Degrees of Freedom with Joints

Mechanism Design

It will be valuable if you already understand the assembly process in Pro Engineer and have completed the assembly tutorial. We will use the pair of mole grips as a basis for explaining how to assemble mechanisms together. Mole grips are like a pair of pliers – with one additional function. They have an over centre mechanism so that when they are squeezed to grip a bar they stay locked until they are released by the user. To achieve this they must be correctly adjusted to the size of the bar using the adjuster screw on the end of the handle.

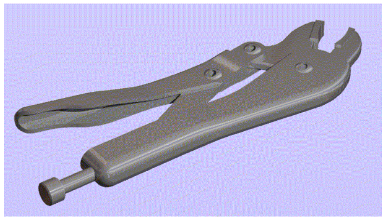


Figure 2 : Mole Grips

To design a mechanism in Pro Engineer you must first design the individual parts of the mechanism. The part files for this model can downloaded from the internet and can be found at http://www.staffs.ac.uk/~entdgc/ProeDocs in the Mechanism section. Save all 8 parts to your working directory.

Use FILE > NEW to create a new assembly called mole_grips using the Empty template.

Choose INSERT > COMPONENT > ASSEMBLE and choose the part mole_main. The main handle of the grips should be placed in the graphics window (If the component placement dialog appears you did not choose the Empty template for the assembly – start again!).

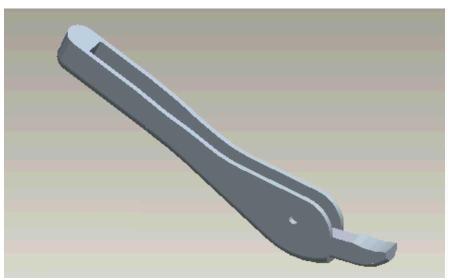


Figure 3 : Main Part Added

Choose INSERT > COMPONENT > ASSEMBLE and choose the part mole_jaws. The component placement dialog should appear this time. In this dialog click on the connect tab (see Figure 4) to show an alternative dialog which must be used for assemblies involving mechanisms.

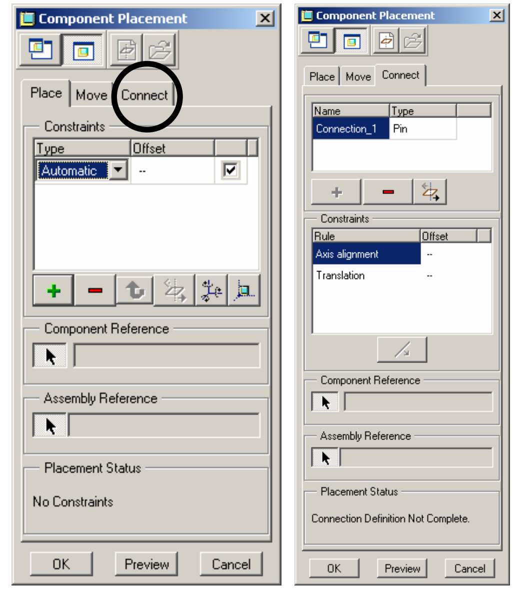


Figure 4 : Mechanism Connections

You should notice that the default joint type is PIN. This type of joint constrains a pin into a hole aligning their axes and also mates 2 faces. This is the correct type of joint in this case. Pick the cylindrical surfaces of the two matching holes on each part (see Figure 5).

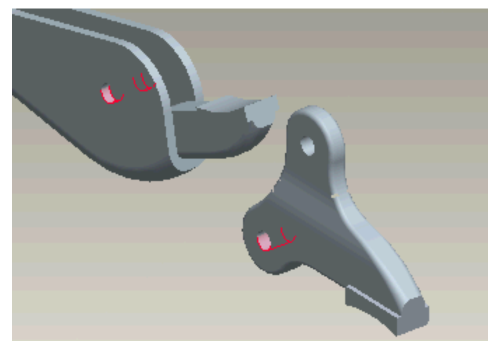


Figure 5 : Pin Join First Step

This will align the axes of the two holes and the jaws will move to make this alignment however you have not yet constrained the position of the jaws along this axis. You should notice that the Component placement dialog has moved on to Translation and is waiting for you to make further selections. To be correctly positioned the jaws must be in the centre of the mole_main part – in other words datum plane DTM3 on the jaws should be aligned with datum plane DTM3 of the mole_main part. Click on these two datums now and the joint should be made (Cant see any datums? Then choose TOOLS > ENVIRONMENT and tick next to Datum Planes). This is the only joint we need so click OK to finalise the placement of the jaws.

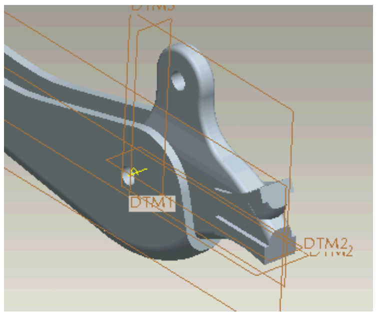


Figure 6 : Pin Joint Second Step

Joints are indicated by a yellow symbol in the graphics area. In the Model Tree you should notice a small square next to the name MOLE_JAWS.PRT (see Figure 7) – this is correct and indicates that this part is not fully constrained as the jaws are free to rotate around. You can prove this by clicking on the DRAG  icon (if you can't see this icon then choose APPLICATIONS > MECHANISM then MECHANISM > DRAG). You should now be able to click on the jaws and move them, spinning them around the joint!

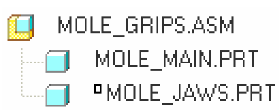


Figure 7 : Jaws Not Fully Constrained

The next part to assemble is mole_handle so choose INSERT > COMPONENT > ASSEMBLE to assemble this now. Don't forget to click on the CONNECTION tab in the component placement dialog (see Figure 4).

The joint definition is identical to the previous PIN joint so choose the correct two holes and DTM3 in the handle and jaws. IMPORTANT NOTE: All of the defining surfaces for a joint must come from the same pair of components – since the holes were in the handle part and the jaw part the two datums must be in these parts to. You could not for example pick DTM3 in the mole_main part. Close the dialog and perhaps try dragging  the mechanism.

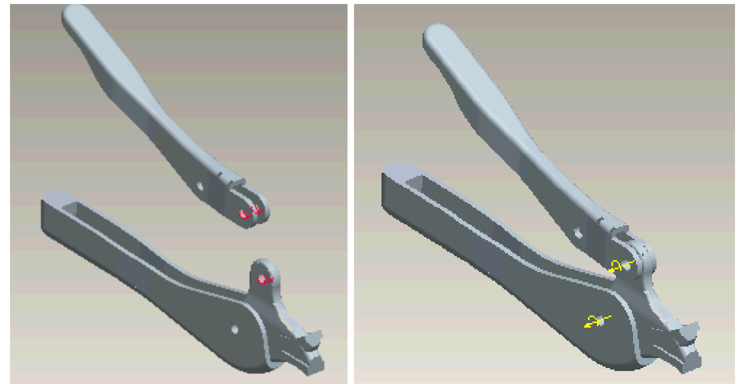


Figure 8 : Joint Two Definition

The third part to assemble is mole_strut for which the joint definition is identical to the previous PIN joints so choose the correct two holes and DTM3 in the handle and strut.

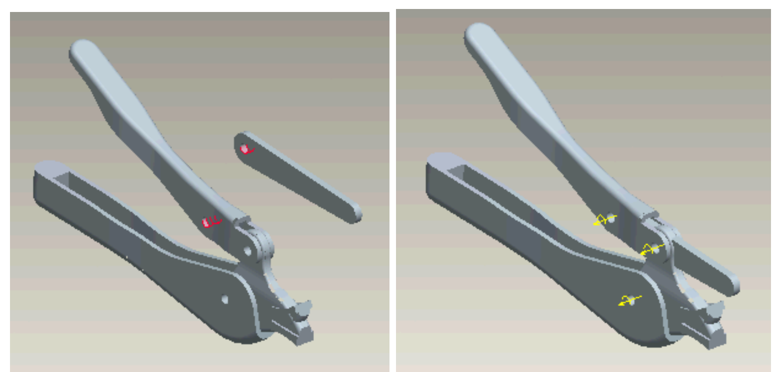


Figure 9 : Joint Three Definition

Drag the parts so the strut is in a more realistic position (See Figure 10).

The final part in the mechanism is mole_screw. This is the adjuster screw. As you turn the screw it moves in and out. The strut touches the end of the screw so that as the screw moves it has the effect of altering the distance between the jaws. Let's try and simulate this now so that you can understand it better.

Choose INSERT > COMPONENT > ASSEMBLE to assemble the mole_screw. Don't forget to click on the CONNECTION tab (see Figure 4). We need a different type of joint this time called a SLIDER so choose this now below the word TYPE. A slider joint allows movement along an axis so that we can move the screw in and out (we won't bother simulating the screw rotation). The joint definition is similar to the previous PIN joint. First we need two axes to align so choose the hole in the end of the mole_main part and the cylindrical surface of the mole_screw. A slider also requires two planar surfaces to stop rotation – pick DTM3 in mole_screw and DTM3 in mole_main (of course strictly speaking our screw does rotate but it does not matter). DO NOT close the Component Placement dialog yet!

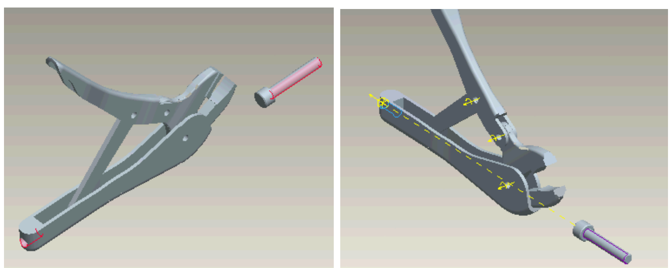
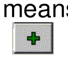


Figure 10 : Slider Joint

We now have to link the strut to the screw. This means we need an extra joint so the screw will have two joints. Click  in the Component Placement dialog to make a new joint. The type of joint we need here is a Cylinder so choose it now below Type. A cylinder joint is a PIN joint without the translation surfaces – it just needs two axes to align. If you look carefully you will see that the strut has an axis through the cylindrical surface at the end and the screw has an axis which has been especially created the same distance away from the end of the screw as the strut radius. They are both labeled A_2 and are highlighted in Figure 11. Pick these now to complete the joint. Don't worry if the pin moves to the wrong position along the axis. Close the placement dialog and try dragging the pin to a more realistic position.

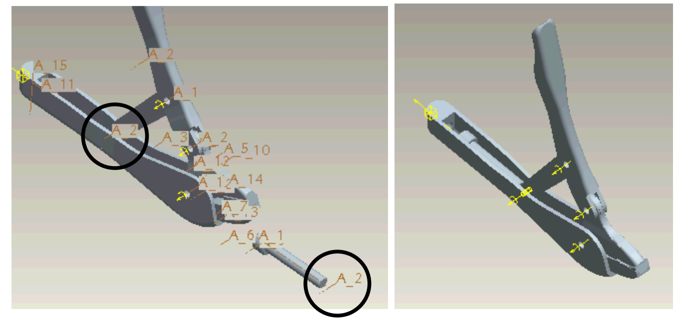


Figure 11 : Cylinder Joint

As you are dragging parts in this mechanism you may notice that when dragging the handle the screw moves in and out. In real mole grips the screw position would not change when moving the handle. How can we make this work correctly?

Go to APPLICATIONS > MECHANISMS and MECHANISM > DRAG and notice the DRAG dialog box. This has a tab called Constraints. Click on it now and then click on the body-body lock constraint icon . This allows you to restrict movement of a joint. Click on the mole_main part then click on the mole_screw part and choose OK. These two parts will be locked in their current position. You should now be able to drag the handle without the screw moving. You can remove this lock by removing the tick next to the body-body lock in the constraints tab. The screw is then free to move again and can then be locked again in a new position by adding the tick.

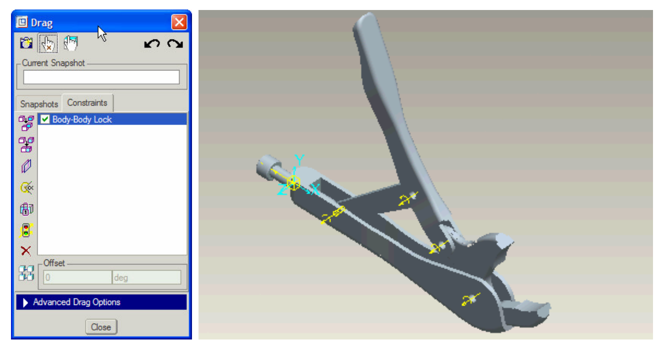


Figure 12 : Joint Constraints

Mechanism Animation

You have seen how by dragging you can move the mechanism through its range of movement. This can be used to generate a sequence of movements for the mechanism that can be replayed within Pro Engineer whilst modifying some design parameters or can be saved as a video in one of the standard Windows video formats then replayed outside of Pro Engineer in Windows Media player or similar.

To define an animation choose APPLICATION > ANIMATION. The screen will change with the important addition of an area below the main graphics window. This is where the timeline editor will appear. A timeline defines what events happen and at what they start/stop. But what are these events and how do we define them? In simple terms an event is a mechanism position. The model can be dragged to different positions and a snapshot taken of the model in that position. Here is how…

First let's set the mechanism up correctly. The command ANIMATION > SNAPSHOT is used to drag the mechanism. Choose this now and in the Constraints tab click on the body-body lock constraint icon. Click on the mole_main part then click on the mole_screw part and choose OK to lock the screw in place like before.

Make sure by dragging that the mole grips are in the closed position with the handle near horizontal. At the top of the drag dialog you will see the camera icon. Press this now and Snapshot1 should be created in the snapshots tab. This has memorized the position of the mechanism as it is now. Move the handle to the fully open position and press again. You should now have 2 snapshots. Go back to the Constraints tab and change the unlock (remove tick) the Body-Body lock. Move the screw to a new position then replace the tick to lock the screw movement. Take two more snapshots with handle closed (Snapshot3) and open (Snapshot4). Close the dialog. We have just defined 4 events that need to be turned into an animation.

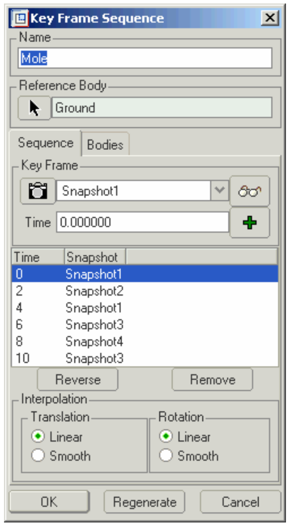


Figure 13 : Key Frame Editor

Press the icon or choose ANIMATION > KEY FRAME SEQUENCE. Choose NEW and the Keyframe Sequence Editor dialog appears (see Figure 13). Type Mole in the name field. Below Keyframe Snapshot1 should be listed and time 0.000. In the dialog press to add this Snapshot1 to the animation. Then select Snapshot2 from the list and change the time to 2 and press again. Press OK. You should see the Mole animation appearing in the timeline.

Now in the animation toolbar press or ANIMATION > START to generate all the intermediate frames between Snapshot1 and Snapshot2. Once generated you can press or ANIMATION > PLAYBACK to play the sequence again using the Animate dialog which has controls like a video recorder.

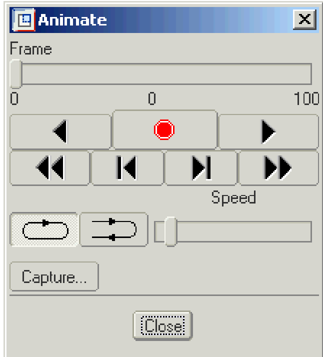


Figure 14 : Animate Dialog

You will see that the open of the mole grips happens in the first 2 secs of the animation. We can add more events to the animation. Click on the Mole animation in the timeline to select it then right click on it and choose EDIT KFS. The Keyframe Editor will be displayed. Select Snapshot1 from the dropdown list, type a time of 4 and press . Select Snapshot3 from the dropdown list, type a time of 6 and press . Select Snapshot4 from the dropdown list, type a time of 8 and press .Select Snapshot3 from the dropdown list, type a time of 10 and press . The events are all shown in Figure 13. Close the dialog. Now in the animation toolbar press or ANIMATION > START to generate all the intermediate frames again. Next press or ANIMATION > PLAYBACK to play the animation. The mole grips should open and close, the screw position should move and then they should open and close again.

In the Animate dialog the CAPTURE option can be used to capture an MPEG movie from the sequence which can be replayed in Media Player.

Review

So what should you have learnt?

- How to assemble mechanisms using different joint types.
- How to drag mechanisms.
- How to create and save animations.

Any problems with these? Then you should go back through the tutorial – perhaps several times – until you can complete it without any help.