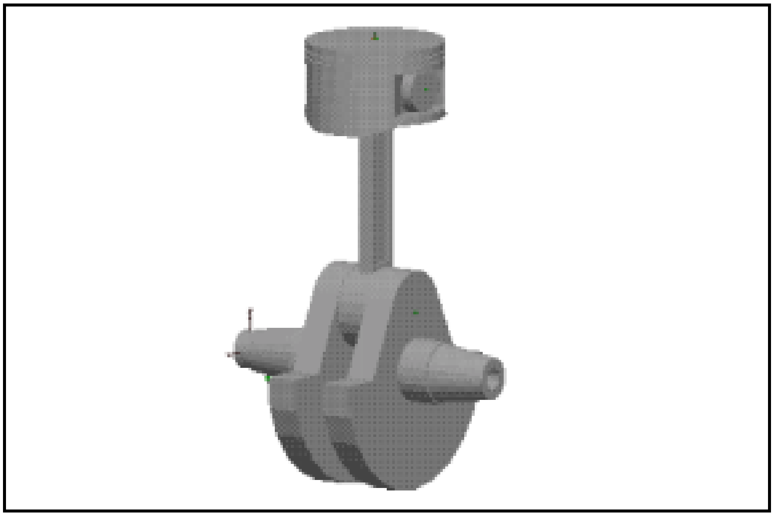
CHAPTER 6

Analyzing a Model



Objectives

In this exercise you will learn to

- Set the initial condition.
- Use simulation controls.
- Measure reaction forces.
- Display vectors.
- Specify the translucency of a body.
- Fine-tune a simulation and verify the result.

Software

MSC.visualNastran 4D or MSC.visualNastran Motion

Support Files

- Tutorials\Chapter 06\Piston.wm3

The MSC.visualNastran Desktop models that you analyze can be created by 1) exporting a model from your favorite CAD software as discussed in **Chapter 5**, **“Exploring CAD Integration and Associativity”**, 2) building a model from scratch in MSC.visualNastran Desktop, as discussed in **Chapter 7**, **“Building a Model”**, or 3) opening a CAD file within MSC.visualNastran Desktop.

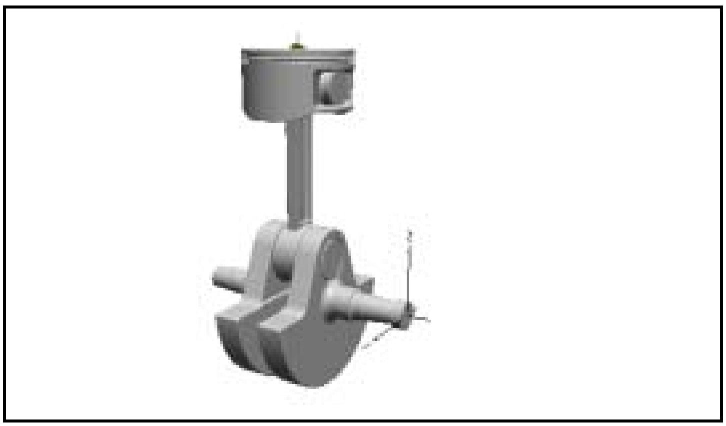
Open the Model File

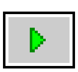
1. Launch MSC.visualNastran Desktop.

2. Choose **Open** from the **File** menu.

3. Browse to locate **Tutorials\Chapter 06\Piston.wm3** and click **Open**. The model of the piston assembly is displayed in the document window, as shown in the figure below.

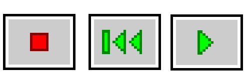
Figure 6-1
Model of a Piston Assembly





4. Click the **Run** button in the **Tape Player Control**.

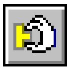
This base model shows the piston mechanism in motion, driven by the motor attached to the crankshaft. Since this is the first time the simulation is run, MSC.visualNastran Desktop calculates the dynamics and stores the data.



5. Repeat the simulation by clicking the **Stop** button, then the **Reset** button, and then the **Run** button again. The animation may be faster this time because the history has already been calculated.

Set the Initial Condition

MSC.visualNastran Desktop allows you to manipulate and configure parts without breaking the assembly constraints that were created when the model was built in MSC.visualNastran Desktop or in the CAD system. In this step, you will move the piston assembly's configuration so that the simulation starts halfway through the combustion or compression cycle.

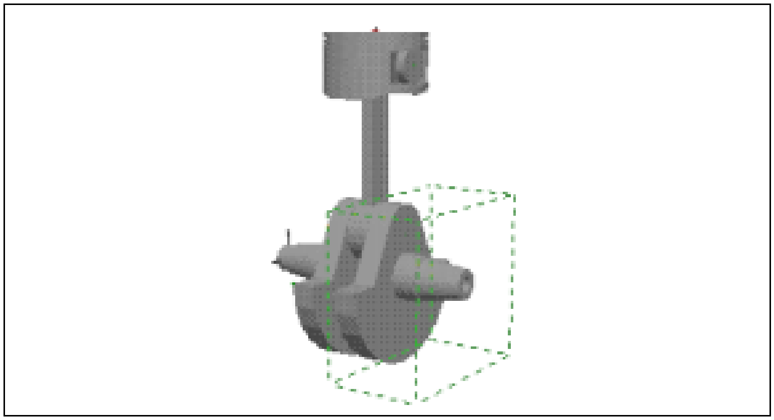


1. Click the **Move** tool in the **Edit** toolbar.

2. Move the mouse over the side surface of the crankshaft counterweight.

As you move the mouse over objects in the modeling window, a dashed box appears around them to show that they are framed.

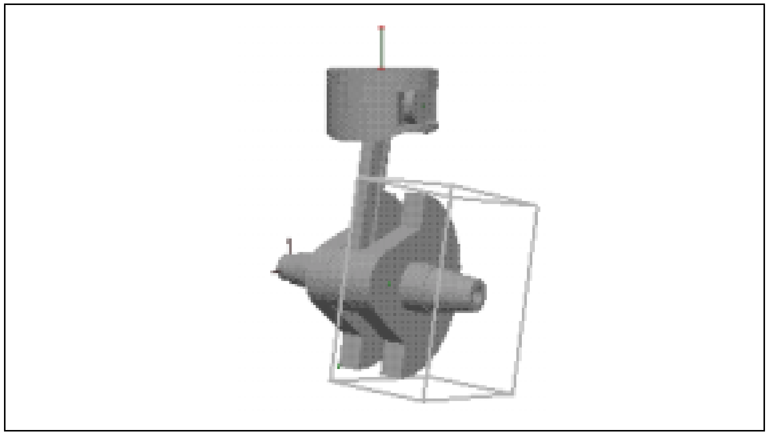
Figure 6-2
Bounding Box Showing Framed Object



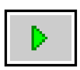
3. Hold the mouse button down, and drag the mouse to rotate the crankshaft. As you drag the mouse, the crank rotates around the crank pin.

4. Position the crankshaft so that the piston is halfway through the down stroke, as shown in the next figure.

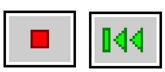
Figure 6-3
Piston Rotated Halfway through the Full Stroke



 You can change the configuration by using the **Move** tool to drag any of the moving parts in the model. Try dragging the piston head or the connecting rod. The movement stops when the parts are dragged to the mechanical limits imposed by the physical joints.



5. Click the **Run** button in the **Tape Player Control**. The simulation runs again, starting from its new initial position.



6. Click the **Stop** button, then reset the simulation by clicking the **Reset** button. The piston assembly returns to the new initial position, halfway through the full stroke.

Use Simulation Controls

You can add input sliders to dynamically change the properties of a constraint as the simulation is running. You can also use data from a table to control a simulation. Unlike input sliders, the table data input is not an interactive control. In the table, you specify values to be applied at listed times throughout the simulation.

Use an Input Slider as a Simulation Control

In this step, you will add an input slider that controls the angular velocity of the motor that turns the piston's crank.

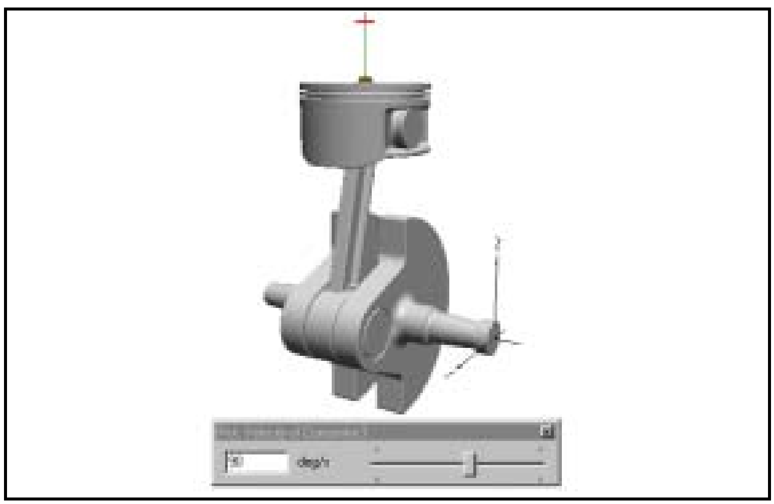
1. Select the revolute motor **Concentric1** in the **Object List**.

2. In the **Insert** menu, Choose **Control**, and then choose **Rotational Velocity** in the **Control** submenu. This displays the **Choose Input Type** dialog.

Figure 6-4
Choose Input Type Dialog

3. Choose **Slider** and click **OK**. An input slider window appears above the modeling window with the title **Rot. Velocity of Concentric1** as shown in the figure below.

Figure 6-5
New Input Slider for Rotational Velocity of Motor



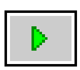
4. Select the input slider, then choose **Properties** in the **Edit** menu.

5. Click the **Appearance** tab in the **Properties** window, then enter Motor Rotational Velocity as the name for this input slider. The new name appears as the title of the input slider window.

__Figure 6-6__
Properties Window (Appearance Page) for Input Slider

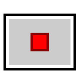
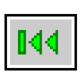
6. Click the **Input** tab in the **Properties** window, then enter 0 as the minimum value for the input range and 3600 as the maximum value. The numbers are interpreted in degrees per second.

__Figure 6-7__
Properties Window (Input Page) for Input Slider



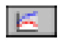
7. Close the **Properties** window.
8. Click the **Run** button in the **Tape Player Control**.
9. As the simulation runs, try dragging the input slider to higher and lower values.

As you drag the slider to the right, the angular velocity of the motor increases and the crank rotates more quickly. Conversely, as you drag the slider to the left, the crank rotates more slowly.

10. Click the **Stop** button, then reset the simulation by clicking the **Reset** button. The piston assembly returns to the initial position, halfway through the down stroke.
11. Close the input slider window.

The input slider is still available in the **Object List**, but it is temporarily hidden from view. You can re-display the input slider by double-clicking it in the **Object List**.



The slider is also listed on Charts and Meters page of the **Object Manager**.

Use a Table as a Simulation Control

You can also use data from tables to control a simulation. You can directly enter data in a table in MSC.visualNastran Desktop, or you can import the table data from a file.

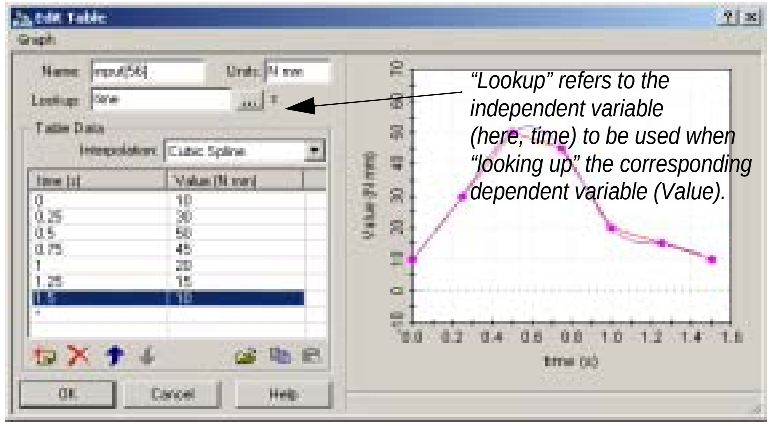
In this section, you will create a table that provides torque inputs to the revolute motor.

NOTE: The default table configuration is to index value parameters to time. However, you can index value parameters to any other variable. To do so, you use **Formulas** as shown below.

To create an input control for table data:

1. Select **Concentric1**, a revolute motor, in the **Object List**.
2. In the **Insert** menu, choose **Control**, and then choose **Torque** in the **Control** submenu.
3. Select Table as the Input Type and click **OK**. The **Insert Table** window is displayed.

Figure 6-8
Insert Table Window



4. Enter the **time** (independent variable) and **Value** (dependent variable) entries in the table as shown above. Use the data shown in the figure. You can also click the Browse (...) button to enter a formula for the **Lookup** value.

5. Click **OK**.

6. Run the simulation.

MSC.visualNastran Desktop applies the torque values at the time intervals specified in the table during the simulation.

7. Stop and reset the simulation.

Measure Reaction Forces

You can add meters to the model to measure the reaction forces in the piston assembly. For example, in this step, you will create a meter to measure the constraint force experienced by the revolute joint connecting the connecting rod and piston pin.

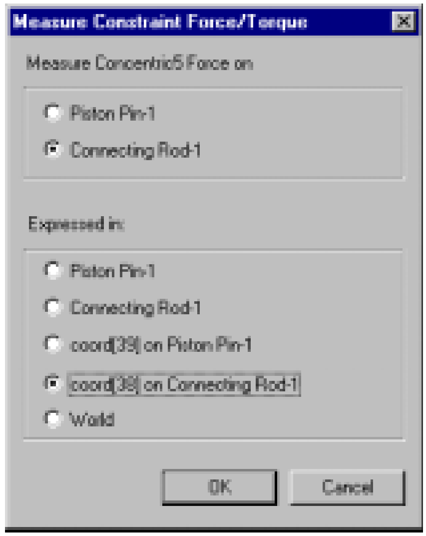
1. Select **Piston Pin-1** in the **Object List**. The list of constraints and Coords connected to the piston pin appears in the **Connections List**.

2. Select **Concentric5**, the revolute joint that connects the connecting rod to the piston pin, in the **Connections List**.

Note that **coord[39] on Piston Pin-1** and **coord[38] on Connecting Rod-1** are listed as the Coords attached to **Concentric5** in the **Connections List**.

3. Make sure that **Concentric5** is selected in the **Object List** and choose **Meter** in the **Insert** menu. Then choose **Constraint Force...** in the **Meter** submenu. The **Measure Constraint Force/Torque** dialog appears.

Figure 6-9
Constraint Force Settings Dialog



4. Choose to "Measure Concentric5 Force on **Connecting Rod-1** expressed in **coord[38] on Connecting Rod-1**" and click **OK**.

A new meter window opens, titled **Concentric5 Force on Connecting Rod-1 in coord[38] on Connecting Rod-1.**

5. The **Tiling Options** dialog appears. Select **Tile Horizontally** and click **OK** to display the model and the meter side-by-side.

The new meter will display the x, y, and z components and the total constraint force exerted by **Concentric5** on the **Connecting Rod-1** as separate curves on the same graph.

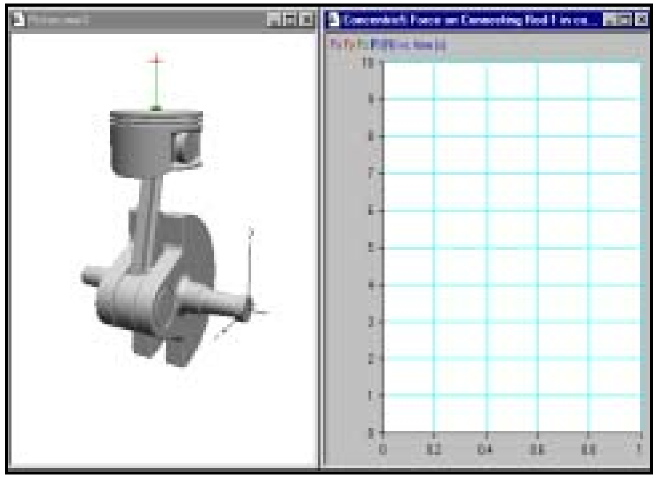
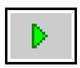


Figure 6-10
Constraint Force Meter Window



6. Click the **Run** button in the **Tape Player Control**.

As the simulation runs, the values of the x, y, and z components and the total constraint force between the piston pin and the connecting rod are plotted in the meter window. Notice how Fx and Fy oscillate as the crank rotates through a full stroke, as shown in figure below.

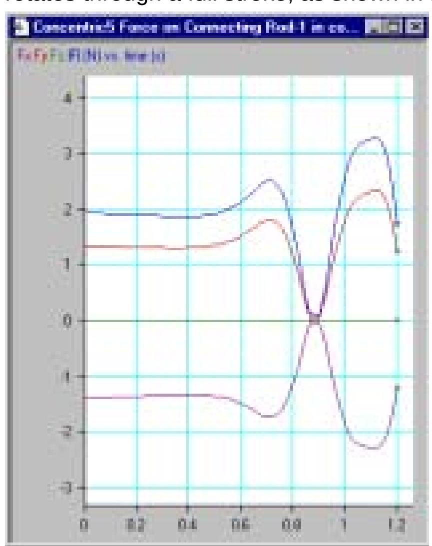
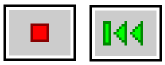


Figure 6-11
Constraint Force Meter Window

NOTE: Your results may not match the figure shown. The appearance of the plots depends upon the initial position of the crankshaft and the torque values entered in the table that drives the motor.



7. Click the **Stop** button. Reset the simulation by clicking the **Reset** button. The piston assembly returns to the initial position.

8. Close the meter window.

The meter is still available in the **Object List**, but it is temporarily hidden from view. You can redisplay the meter by double-clicking it in the meter page of the **Object List**.

Display the Angular Acceleration of the Connecting Rod

MSC.visualNastran Desktop allows you to visualize vectors in 3D space as the simulation runs. Although the animated simulation itself serves as a powerful visualization tool, hard-to-see qualitative data such as vectors reveal even more information that can't be seen in a physical prototype.

In this step, you will display vectors that show the acceleration of the connecting rod.

1. Double-click **Connecting Rod-1** in the **Object List**.

2. Click the **Vectors** checkbox in the **Properties List**.

The **Vectors** page is displayed in the **Properties** window, as shown in following figure.

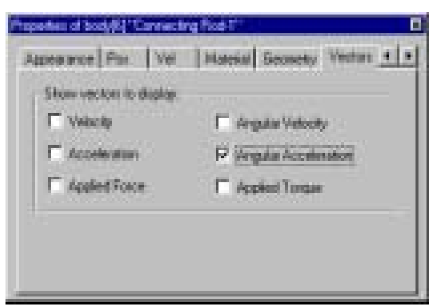
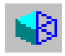


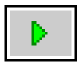
Figure 6-12
Properties Window (Vectors Page) for the Connecting Rod

3. Click the **Angular Acceleration** box to put a check mark in it. Close the **Properties** window.



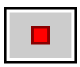
4. Click the **Toggle Wireframe** button in the **View** toolbar.

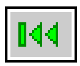
The modeling window changes to a wireframe rendering, which will make it easier for you to see the acceleration vector (which is often hidden by the sides of the crank) as the simulation runs.



5. Click the **Run** button in the **Tape Player Control**.

As the simulation runs, the angular acceleration vector is displayed, but can be difficult to see because of its size. In the next step, you will resize the acceleration vector to make it easier to see.





6. Click the **Stop** button, then reset the simulation by clicking the **Reset** button.

Make the Angular Acceleration Vector More Visible

You can change the size and color of the vectors displayed to make them more visible as the simulation runs.

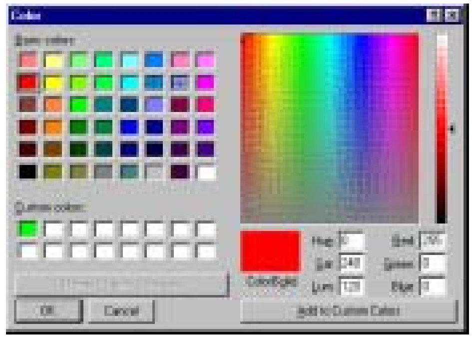
1. Choose **Display Settings** in the **World** menu and click **Vectors** in the **Display Settings** menu pane. The vector settings dialog appears.

Figure 6-13
Vector settings

2. Enter 0.07 for the scaling factor for the length of the **Angular Acceleration** vector and click the **Apply** button.

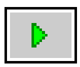
3. Click the color button next to the **Angular Acceleration** label. Click the **Other** button to select a different color for the vector. The **Color** dialog appears.

Figure 6-14
Color Dialog



4. Choose a bright red color and click **OK** to close the **Color** dialog. The angular acceleration vector will now be displayed in red.

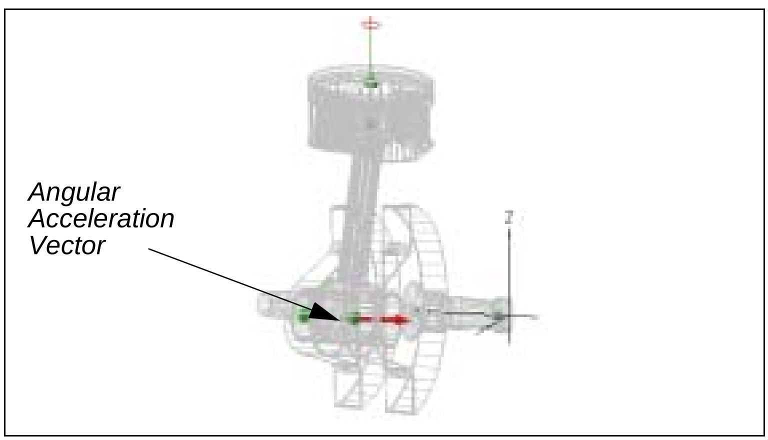
5. Close the vector settings dialog.

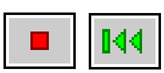


6. Click the **Run** button in the **Tape Player Control**.

As the simulation runs, note that the angular acceleration vector attached to the connecting rod switches sides (because the acceleration switches direction halfway through the full cycle), as shown in following figure.

Figure 6-15
Angular Acceleration Vector on Connecting Rod





7. Click the **Stop** button, then reset the simulation by clicking the **Reset** button.

See Through Bodies

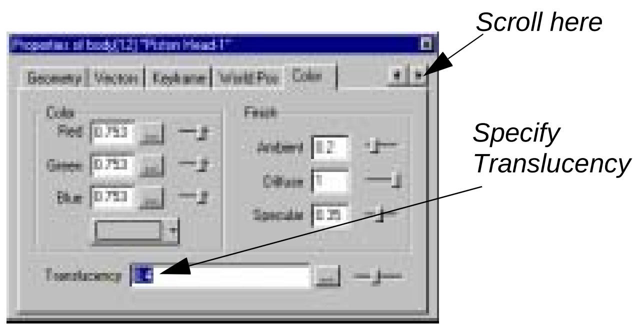
MSC.visualNastran Desktop provides an alternative to selecting a shaded or wireframe view of your drawing. The alternative is variable translucency, a feature that allows you to quickly render one or several bodies translucent. This is helpful when you want to view internal constraints and coords or obstructed bodies before or during a simulation.

1. Choose **Shaded** from the **View** menu.

2. Double-click the piston head to view its **Properties** window.

3. Click the **Color** checkbox in the **Properties List** of the **Object Manager**. The **Color** page appears as shown in the figure below.

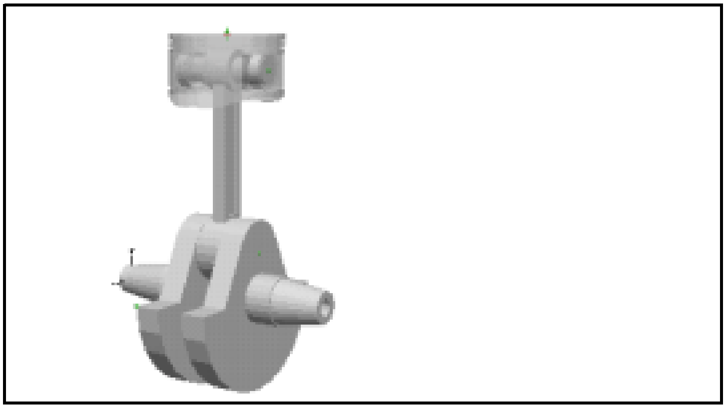
Figure 6-16
Properties Window Color Page



4. Enter 0.4 in the **Translucency** text region and press **Enter**.

You may have to move the dialog so that you can view the piston head in the modeling window.

Figure 6-17
Translucent Piston Head



5. Try entering different translucency values ranging from 0 (least translucent or opaque) to 1 (most translucent or invisible).

Fine-tune the Simulation

Up to this point, the piston mechanism has been driven by a motor constraint attached to the crankshaft. In a more realistic simulation of an internal combustion engine, a throttle force generated by a gas explosion in a cylinder chamber would push the piston down to torque the crankshaft. In this last step, you will fine-tune the model to simulate this more realistic scenario.

Convert the Motor

First, you will convert the motor to a revolute joint.

1. Double-click the revolute motor **Concentric1** in the **Object List**. The constraint's properties are displayed in the **Properties** window.

2. Click the **Constraint** tab.

3. Select **Revolute Joint** from the list of available constraints, as shown in the following figure. The motor is replaced by a revolute joint.

4. Close the dialog.

Figure 6-18
Constraint Settings Dialog

Attach a Force Load

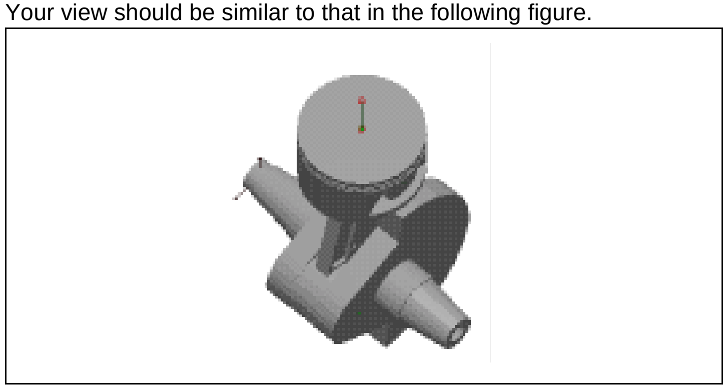
Next, you will attach a force load to the top of the piston to simulate the force generated by a gas explosion in a cylinder chamber.

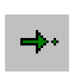
1. If you have not already done so, select **Shaded** from the **View** menu. The modeling window changes to a shaded rendering of the piston, which will make it easier to complete the next steps.

2. Click on the background to de-select everything and then press "T" on the keyboard so that you can see the top of the piston head. Click the **Rotate Around** tool in the **View** toolbar and use the mouse to rotate the piston.

Your view should be similar to that in the following figure.

Figure 6-19
Top of the Piston Head





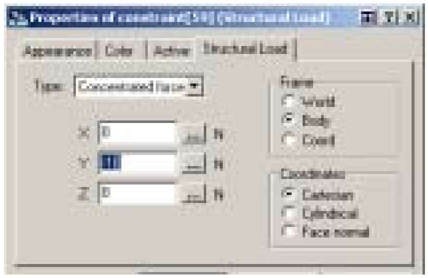
3. Click the **Force** tool in the **Sketch** toolbar.

4. Click the mouse pointer at the top of the piston, near the center. (The precise location of the attachment is not important for this exercise.)

5. Double-click the force icon in the modeling window or in the **Object List** to display the **Properties** window.

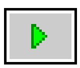
6. Click the **Structural Load** tab, then enter –10 in the y-field to apply a 10 Newton force downward. The force's Coord attachment dictates this orientation setting.

Figure 6-20
Properties Window (Structural Load Page)



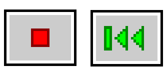
7. Close the dialog.

8. Choose **Go Home** in the **View** menu to restore the original view of the piston assembly.



9. Click the **Run** button in the Tape Player Control.

As the simulation runs, the piston behaves like a pendulum because the force is applied constantly, which isn't a realistic scenario.



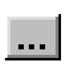
10. Click the **Stop** button, then reset the simulation by clicking the **Reset** button.

Modify the Force to Simulate Realistic Throttle

As a final step, you will modify the force to simulate realistic throttle by using a formula to control when the force is applied.

1. Double-click the force icon in the modeling window or in the **Object List** to display its **Properties** window.

2. Click the **Active** tab to go to the **Active** page of the **Properties** window.



3. Click the **Active while:** radio button, and then click the **(...)** button to display the **Formula Editor** dialog.

Figure 6-21
Formula Editor Dialog (Active Page) for Force

4. Enter the following formula, and click **OK**.

   and(body[12].v.z<=0, mag(body[4].w)<600 rpm)

The expression returns angular velocity in radians per second. The formula applies the explosive force only when the piston is coming down, and cuts off the push to limit the motor to approximately 600 rpm.

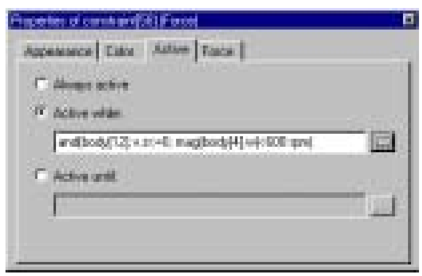


Figure 6-22
Properties Window (Active Page) for Force

5. Close the **Properties** window.
6. Run the simulation. The piston behaves as expected under the realistic throttle force.
7. Stop the simulation and click the reset button.

Verify the Result

You can verify that your model is accurate by creating a meter to measure angular velocity of the crankshaft, and setting the angular velocity unit system to RPM. The angular velocity of the crankshaft should settle at around 600 rpm.

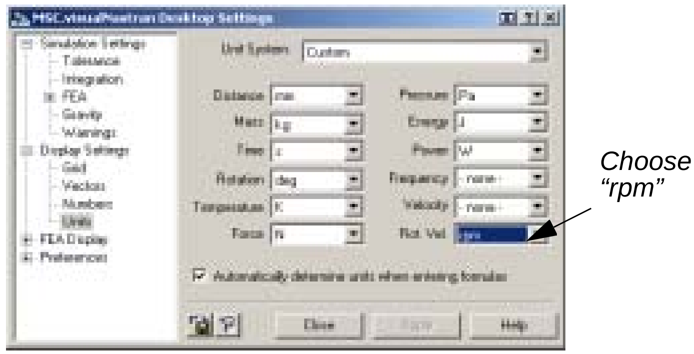
1. Select **Crank-1**, the left half of the crank, in the **Object List**.

2. Choose **Meter** in the **Insert** menu, and then choose **Angular Velocity** in the submenu. A new meter window appears.

3. Select **Tile Horizontally** and click **OK**.

4. Choose **Display Settings** in the **World** menu and click **Units** tab of the **Display Settings** menu.

Figure 6-23
Units Page



5. Choose **rpm** in the Rot. Vel. pull-down list.

6. Close the settings window.

7. Run the simulation.

As the simulation runs, the angular velocity, |W|, grows to approximately 600 rpm, then levels off, as shown in Figure 6-24.

8. Stop the simulation and click the reset button.

Figure 6-24
Angular Velocity Meter