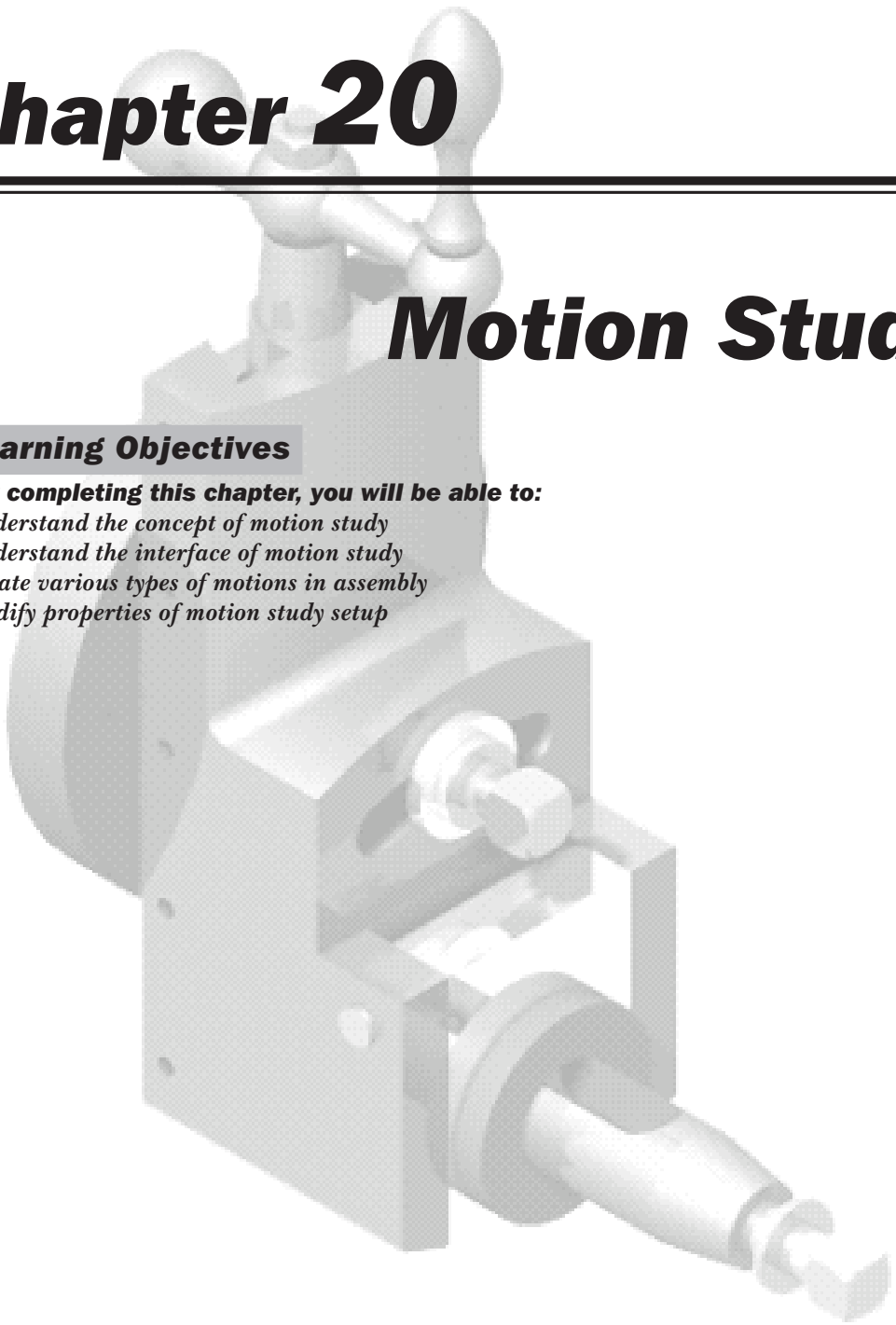
Chapter 20

Motion Study



Learning Objectives

After completing this chapter, you will be able to:

- *Understand the concept of motion study*
- *Understand the interface of motion study*
- *Create various types of motions in assembly*
- *Modify properties of motion study setup*

INTRODUCTION TO MOTION STUDY

Motion study is used to simulate the motion of the assembly components. In SOLIDWORKS, you can use the **MotionManager**, a time-line based interface, for defining the simulation of motion of an assembly. Note that the properties of the assembly being simulated will remain intact. The two types of motion studies are: Basic Motion and Animation.

Basic Motion

In the Basic Motion study, the motion between various components of an assembly can be defined by physical conditions such as motor, spring, gravity, and contact. To specify the physical conditions, you can use the tools such as **Motor**, **Spring**, **Gravity**, and **Contact**, available in the **MotionManager**.

Animation

In the Animation study, the motion between various components of an assembly is defined by assembly mates, free hand drag, and triad (for positioning). Also, you can use the key frames to animate a model.

SIMULATING THE MOTION OF AN ASSEMBLY

In SOLIDWORKS, you can simulate the motion of an assembly by using the **MotionManager**. To invoke the **MotionManager**, click on the **Motion Study 1** tab available below the graphics area, refer to Figure 20-1; the **MotionManager** will be displayed, as shown in Figure 20-1. Before you start simulating the assembly, it is important to understand the components of **MotionManager**. These components are discussed next.

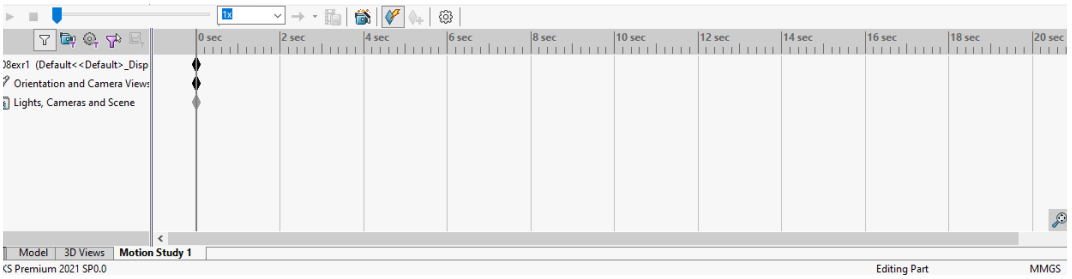


Figure 20-1** The **MotionManager

Timeline

The Timeline is used to specify the duration for the motion. The time taken for a complete motion will be highlighted in yellow color on the timeline. You can view the movement of the components at a specific time by clicking on the corresponding position in the timeline.

Timebar

This is a vertical gray line which is used to represent the current position of the components on the time scale, while in motion.

Keypoint

Keypoints are used to represent the start and end of the changing phase of the components in the motion. The space elapsed between two key points is called key frame.

MotionManager Design Tree

The **MotionManager Design Tree** controls various settings related to the camera, components of assembly, orientation of the model, mates applied on the components, and so on. The settings of **MotionManager Design Tree** will be discussed later in this chapter.

Toolbar

The toolbar in the **MotionManager** consists of various tools and options to perform the motion study of an assembly, refer to Figure 20-2. These tools and options are discussed next.

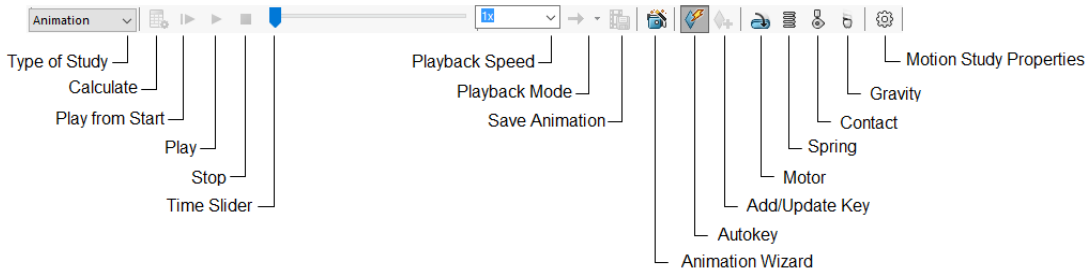


Figure 20-2 *The toolbar in the* ***MotionManager***

Type of Study

The options in this drop-down list are used to specify the type of study that you want to perform. There are three options available in this drop-down list: **Animation**, **Basic Motion** and **Motion Analysis**. By default, the **Motion Analysis** option will not be available in the **Type of Study** drop-down list. To make it available, select **Solidworks Motion** from **Solidworks Add-ins CommandManager**.

Calculate



This button is used to generate simulation of an assembly under some specified conditions. Note that every time you change the parameters related to an assembly motion study, you need to choose the **Calculate** button to simulate the assembly according to the new parameters.

Play from Start



This button is used to start the animation of current asssembly from the beginning.

Play



This button is used to play simulation from the last position in the timeline. Note that when you modify the parameters during the simulation and choose the **Play** button, the

changes will not be reflected in the simulation. To play the simulation with the modified parameters, you need to choose the **Calculate** button.

Stop

This button is used to pause a simulation at a specific position.

Time Slider

This slider is used to jump to a specific point of time in the animation. To do so, click at the location in the slider. Alternatively, you can drag the dragger in the time slider to a specific location.

Playback Speed

This drop-down list is used to specify the speed multiplier. The speed multiplier is the factor by which you increase or decrease the playback speed of animation. You can select an option from the predefined list or you can enter the desired multiplier number followed by x.

Playback Mode

The options available in the **Playback Mode** drop-down list are used to define the direction of animation. There are three options available in this drop-down list: **Playback Mode: Normal**, **Playback Mode: Loop**, and **Playback Mode: Reciprocate**. The **Playback Mode: Normal** option is used to play the animation in one direction only. Note that to play the animation again, you need to choose the **Play** button. The **Playback Mode: Loop** option is used to play the animation in a closed loop. Note that after completing the path, the animation will start again from the initial position automatically. The **Playback Mode: Reciprocate** option is used to play the animation in reciprocating manner. After completing the path, the animation will start again in the reverse direction.

Save Animation

This button is used to save the current animation. To do so, choose the **Save Animation** button from the **MotionManager** toolbar; the **Save Animation to File** dialog box will be displayed, as shown in Figure 20-3. After specifying the options in the dialog box, choose the **Save** button; the **Video Compression** dialog box will be displayed, as shown in Figure 20-4. The options available in the **Video Compression** dialog box are used to specify the type of compressor, Compression Quality, and number of Key Frames. After specifying the required parameters, choose the **OK** button from the dialog box; the **SOLIDWORKS** message box will be displayed as shown in Figure 20-5. In the dialog box, choose the **Yes** button to recalculate the results; the file will be saved with the calculated results.

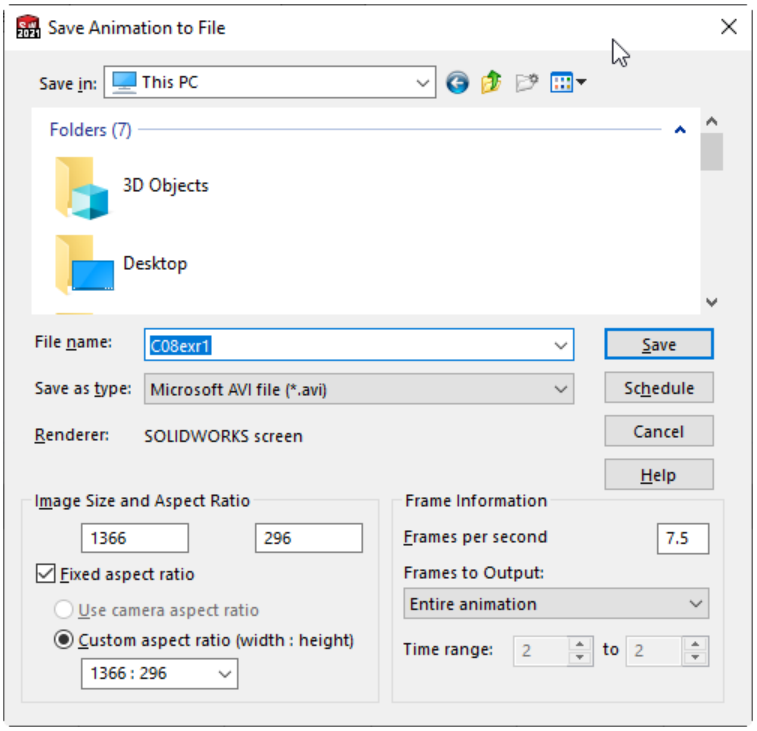


Figure 20-3 *The* ***Save Animation to File*** *dialog box*

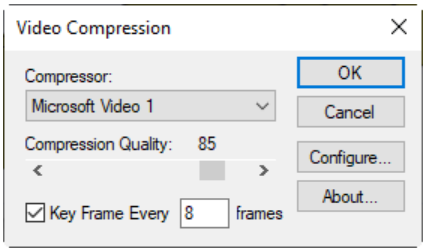


Figure 20-4 *The* ***Video Compression*** *dialog box*

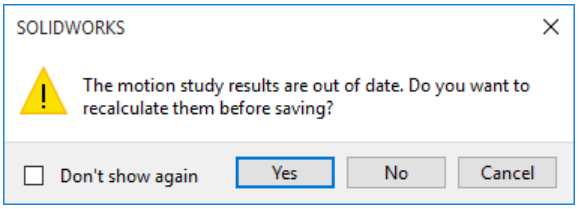


Figure 20-5 *The* ***SOLIDWORKS*** *message box*

Animation Wizard



This button is used to create animation for the whole assembly setup. To create an animation, choose this button; the **Select an Animation Type** dialog box will be displayed, as shown in Figure 20-6.

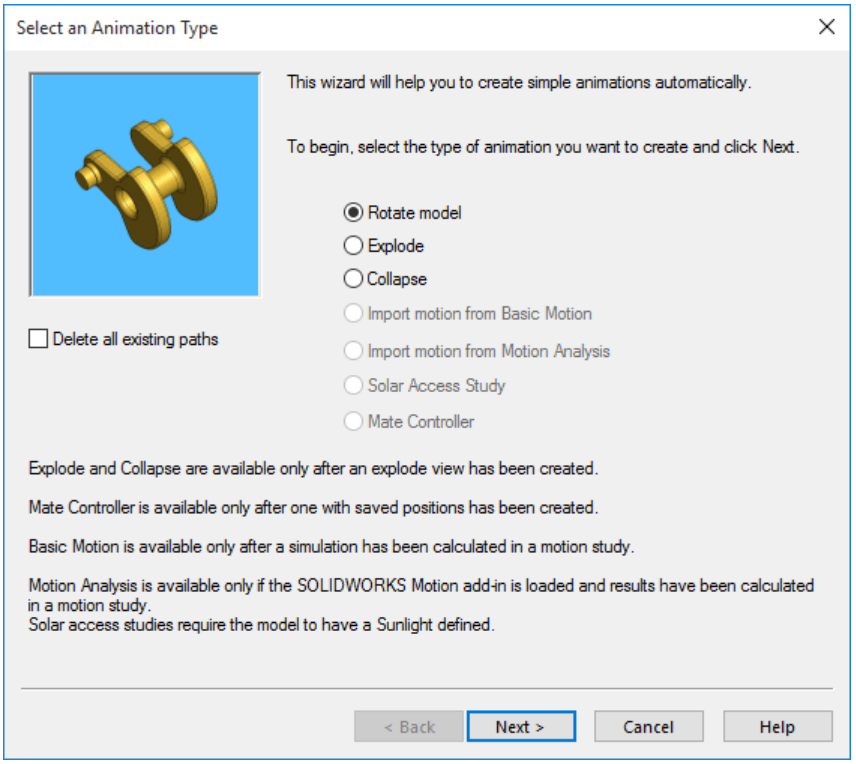


Figure 20-6 *The* ***Select an Animation Type*** *dialog box*

Using the radio buttons available in the **Select an Animation Type** dialog box, an assembly can be rotated, exploded, collapsed, and so on. You can select the required radio button from the dialog box. By default, the **Rotate model** radio button is selected in the dialog box. Therefore, when you choose the **Next** button, the **Select an Axis of Rotation** page of the dialog box will be displayed, as shown in Figure 20-7. In the dialog box, you can specify the axis of rotation, the number of rotations, and the direction of rotation. Specify the required parameters and choose the **Next** button; the **Animation Control Options** page will be displayed, as shown in Figure 20-8. You can set the duration of entire animation and the start time of the animation in this page. After specifying the required parameters, choose the **Finish** button; the animation will be applied to the setup.

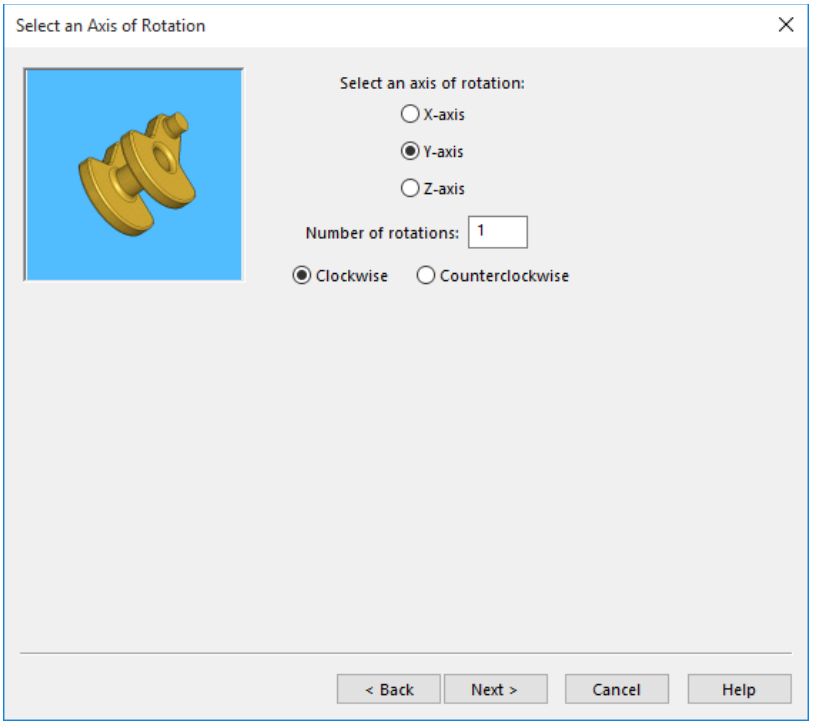


Figure 20-7 *The* ***Select an Axis of Rotation*** *page*

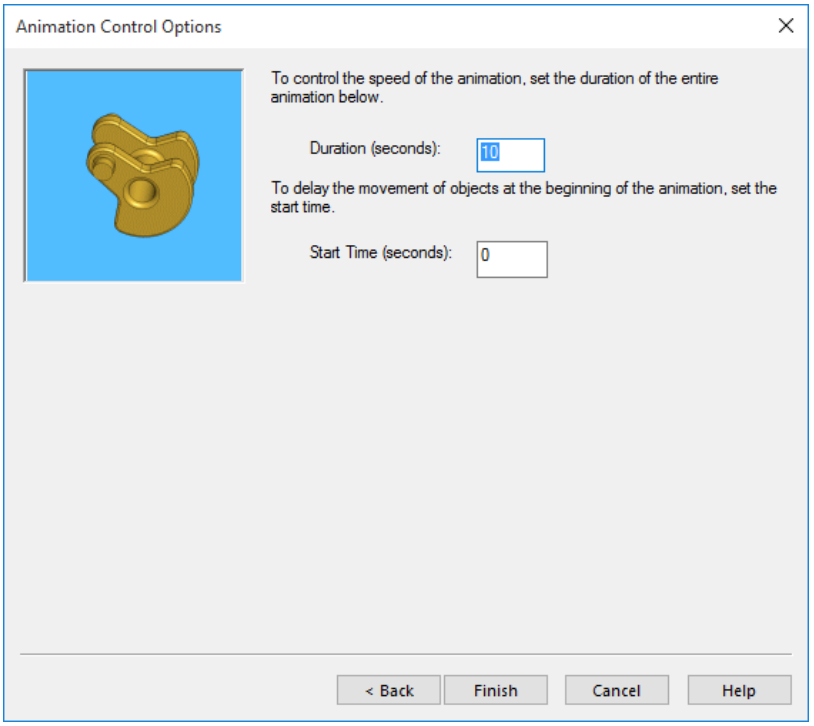


Figure 20-8 *The* ***Animation Control Options*** *page*

Autokey



This button is used to automatically create key points on the time line, based on the operations performed in order to animate the assembly.

Add/Update Key



This button will be activated after selecting the respective part. You can choose this button to add a new keypoint to the time line or update a keypoint that was created earlier. To add a keypoint, right-click on the time line at the desired location; a shortcut menu will be displayed, refer to Figure 20-9.

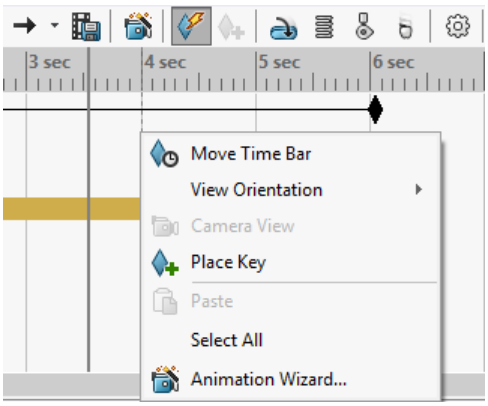


Figure 20-9 *Shortcut menu for placing key points*

Choose the **Place Key** option from the shortcut menu; the key point will be placed at the desired location.

Motor



This button is used to add rotary or linear motor to a component to set up a motion between different components of an assembly. On choosing this button; the **Motor PropertyManager** will be displayed, as shown in Figure 20-10.

The options in this PropertyManager are discussed next.

Motor Type

The buttons available in the **Motor Type** rollout are used to specify the type of motor to be applied. There are three buttons available in this rollout: **Rotary Motor**, **Linear Motor (Actuator),** and **Path Mate Motor**. Using the **Rotary Motor** button, you can apply a rotary motor that helps the object to get rotated along its axis. Using the **Linear Motor (Actuator)** button, you can create an actuator that helps an object to get translated along the linear direction. Using the **Path Mate Motor** button, you can apply a motion along a path.

Component/Direction

There are three selection boxes in this rollout: **Motor Location**, **Motor Direction**, and **Component to Move Relative to**. The **Motor Location** selection box is used to specify the

body on which you are applying the motor. The **Motor Direction** selection box is used to specify the direction in which the motor will rotate or move the selected object. The **Component to Move Relative to** selection box is used to specify the object relative to which the component will move.

Motion

The options available in this rollout are used to specify the speed of the motor. The options available in the **Function** drop-down list of this rollout are discussed next.

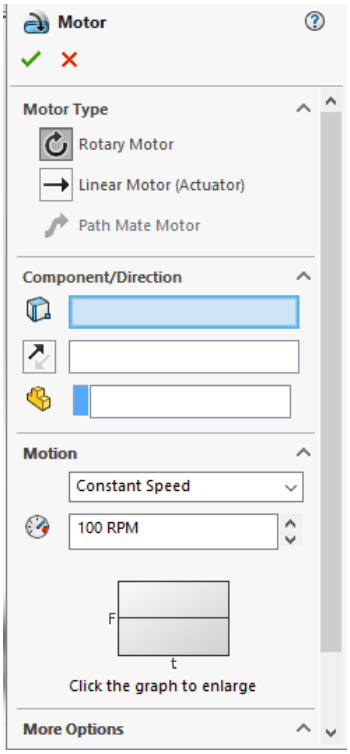


***Figure 20-10** The **Motor** PropertyManager*

Constant Speed

Using this option, you can specify a constant speed (in RPM) for the motor. On selecting this option, the **Speed** edit box below the **Function** drop-down list will be displayed. In the **Speed** spinner box, you can specify the speed of the motion.

Distance

Using this option, you can specify the displacement being covered by the motor. You can also specify the starting time of the motor and the total time in which the displacement will be covered.

Oscillating

Using this option, you can specify the motion of motor as oscillating. On selecting this option, the edit boxes for specifying displacement, frequency, and phase shift become available. You can specify the desired values in these edit boxes.

Segments

Using this option, you can specify the rotational speed of motor into various segments. On selecting this option, the **Function Builder** dialog box will be displayed with the **Segments** button chosen, refer to Figure 20-11. Using the options in this dialog box, you can set variable speed for the motor.

Data Points

Using this option, you can specify data points for the motor speed. Based on these data points, speed of the motor is calculated with respect to time. On selecting the **Data Points** option, the **Function Builder** dialog box will be displayed with the **Data Points** button chosen, refer to Figure 20-12.

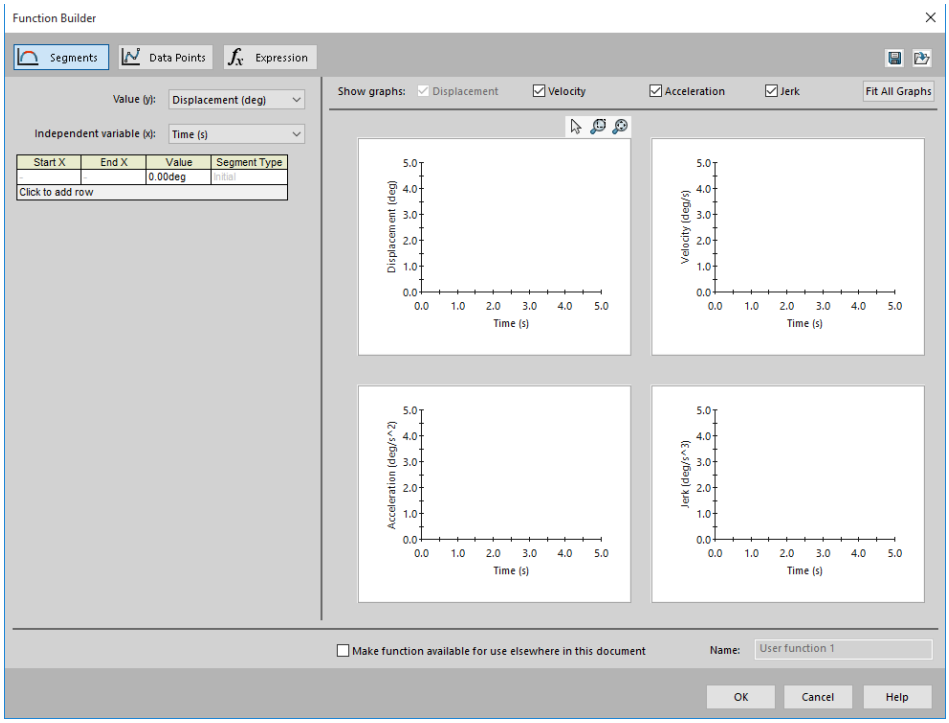


Figure 20-11 *The* ***Function Builder*** *dialog box with the* ***Segments*** *button chosen*

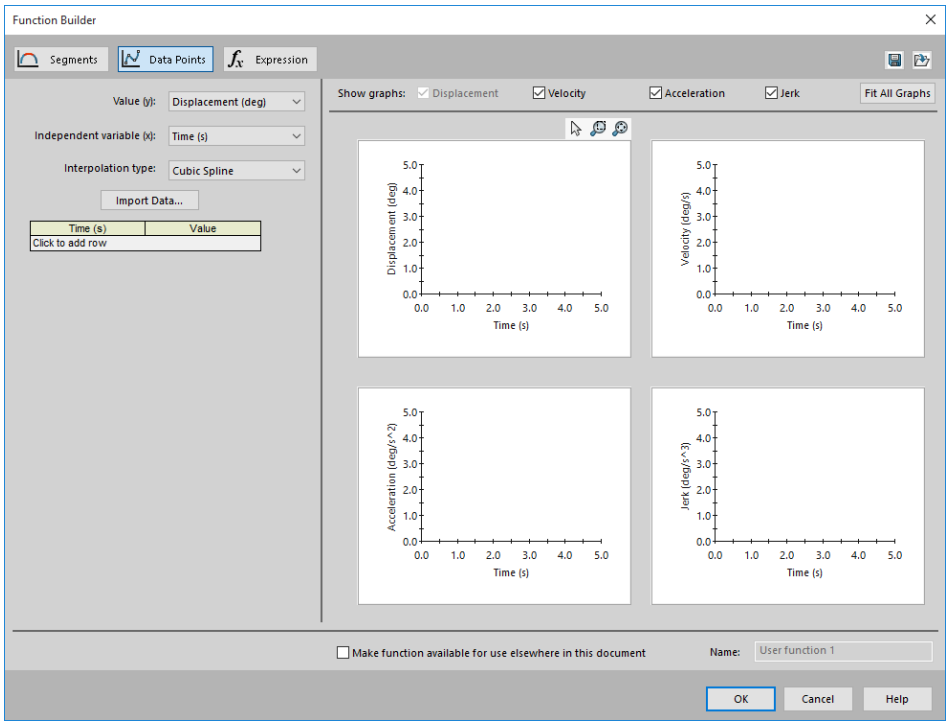


Figure 20-12 *The* ***Function Builder*** *dialog box with the* ***Data Points*** *button chosen*

Expression: Using this option, you can create a mathematical function for specifying the motor speed. On selecting this option, the **Function Builder** dialog box will be displayed with the **Expression** button chosen, refer to Figure 20-13.

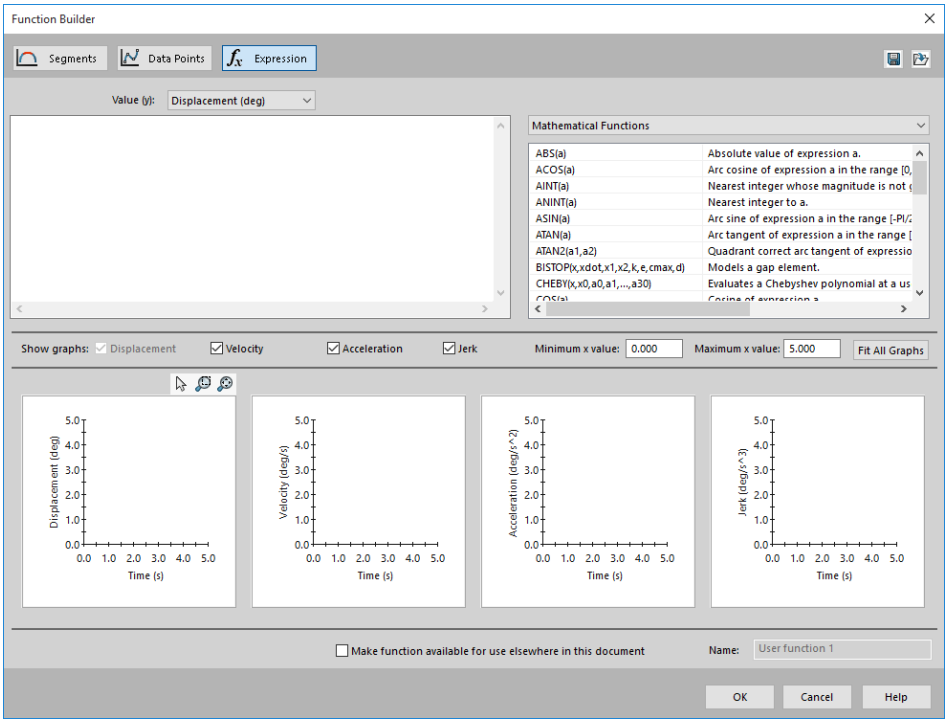


Figure 20-13 *The* ***Function Builder*** *dialog box with the* ***Expression*** *button chosen*

Load Function from File: Using this option, you can use a SOLIDWORKS function file to load mathematical function. Based on that function, the speed of the motor with respect to time will be calculated. On selecting this option, the **Open** dialog box will be displayed. Using the options in this dialog box, you can load function from a file.

Delete Functions: Using this option, you can delete a motion function of the motor. On selecting this option, the **Delete Motion Functions** dialog box will be displayed, refer to Figure 20-14. Using the options in this dialog box, you can delete the selected functions.

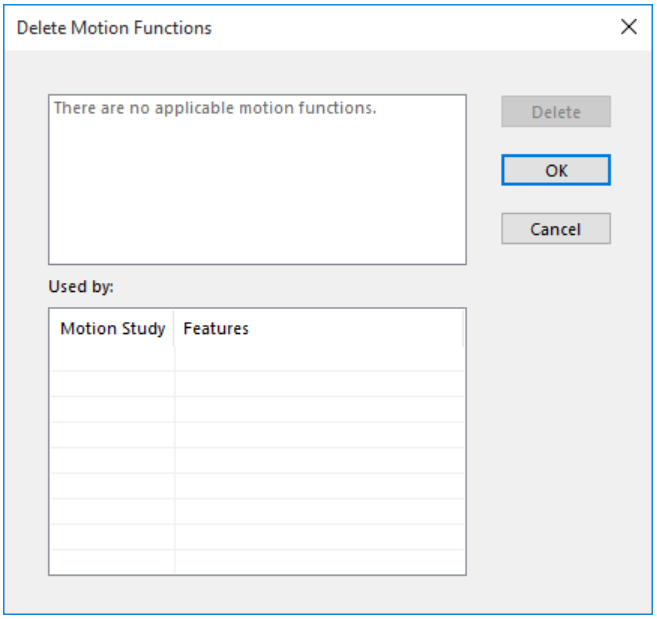


***Figure 20-14** The **Delete Motion Functions** dialog box*

More Options

The option in this rollout is used to specify load-bearing faces for the assembly component.

After specifying the desired options, choose the **OK** button from the PropertyManager to add the motor.

Spring

This button is used to add a torsional or linear spring to the assembly. On choosing this button, the **Spring PropertyManager** will be displayed, as shown in Figure 20-15. The options in this PropertyManager are discussed next.

Spring Type

There are two buttons available in this rollout: **Linear Spring** and **Torsional Spring**. The **Linear Spring** button is used to create a linear spring. Similarly, the **Torsional Spring** button is used to create a torsional spring.

Spring Parameters

The options in this rollout are used to specify parameters of the spring. The **Spring Endpoints** selection box in this rollout is used to specify the end points of the spring. The options in the **Exponent of Spring Force Expression** drop-down list are used to specify the exponential value. The **Spring Constant** spinner is used to specify the value of spring constant (k). The **Free Length** spinner is used to specify the free length of the spring. This edit box is available for linear spring. In case of a torsional spring, the **Free Angle** spinner will be displayed. Select the **Update to model changes** check box to update the model while changing the parameters. If you are using the torsional spring, you can also specify the base component by using the **Base Component** selection box.

Damper

The options in this rollout are used to specify the parameters related to dampers. The **Exponent of Damper Force Expression** is used to specify the exponential value for the damper force expression. The **Damping Constant** spinner box is used to specify the value of damping constant.

Display

The options in this rollout are used to specify the display style of the spring model. The **Coil Diameter** spinner box in this rollout is used to specify the diameter of the coil of spring. The **Number of Coils** spinner box is used to specify the number of coils displayed in the spring model. The **Wire Diameter** spinner box in this rollout is used to specify the diameter of the wire used for spring.

Load Bearing Faces

The option in this rollout is used to specify the faces/edges for bearing/load that can be used in simulation.

After specifying all parameters, choose the **OK** button from the PropertyManager to create the spring motion.

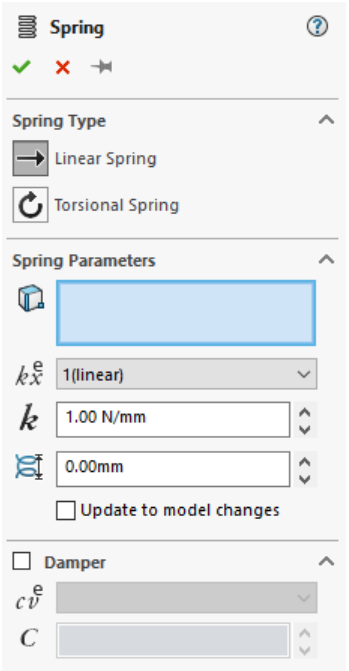


Figure 20-15 *Partial view of the* ***Spring PropertyManager***

Contact

This button is used to add a contact in the motion study so that the assembly components do not penetrate into each other. To add a contact in the assembly, choose the **Contact** button from the **MotionManager** toolbar; the **Contact PropertyManager** will be displayed, refer to Figure 20-16.

Now, select the components between which you want to add the contact; the selected components will be added to the **Components** selection box in the **Selections** rollout. Next, choose the **OK** button from the PropertyManager; the contact will be created.

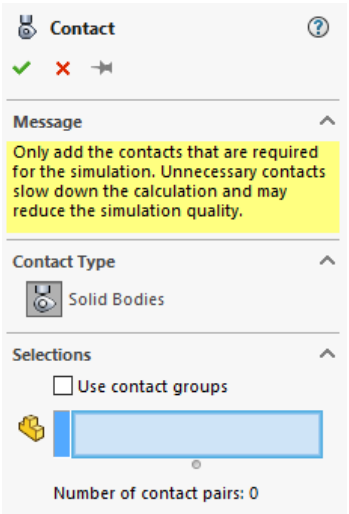


Figure 20-16 *The* ***Contact PropertyManager***

Gravity

This button is used to add gravity to the motion study. On choosing this button, the **Gravity PropertyManager** will be displayed, as shown in Figure 20-17.

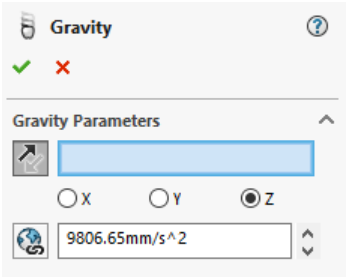


Figure 20-17 The Gravity PropertyManager

Select the **X**, **Y**, or **Z** radio button to specify the direction of gravity. You can also select an entity of the model in the **Direction Reference** selection box to specify the direction vector for gravity. To specify the value of gravity, click on the **Numeric gravity value** edit box and enter the desired value.

Motion Study Properties

This button is used to specify the properties of the motion study being performed. To specify the properties, choose the **Motion Study Properties** button; the **Motion Study Properties PropertyManager** will be displayed, as shown in Figure 20-18.

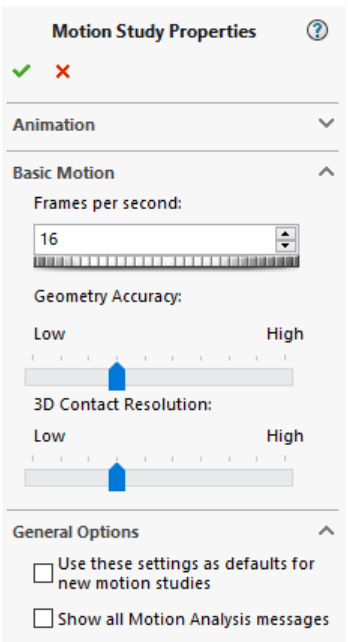


Figure 20-18 The Motion Study Properties PropertyManager

The options in the PropertyManager are discussed next.

Animation

The option in this rollout is used to specify the quality of animation in frames per second.

Basic Motion

The options in this rollout are used to specify the parameters for the basic motion. The **Frames per second** spinner is used to set the number of frames per second for the basic motion. The **Geometry Accuracy** slider is used to increase or decrease accuracy of geometrical mesh. The **3D Contact Resolution** slider is used to increase or decrease the quality of contact between two or more meshing components.

General Options

The options in this rollout are used to specify general settings for the animation. There are two check boxes available in this rollout. The **Use these settings as defaults for new motion studies** check box is used to set the current settings for all the new motion studies. The **Show all Motion Analysis messages** check box is used to display all the messages related to computation of motion study.

TUTORIALS

Tutorial 1

In this tutorial, first you will open the assembly file created in Tutorial 1 of Chapter 12, refer to Figure 20-19 and then you will do motion study of the assembly. **(Expected time: 30 min)**

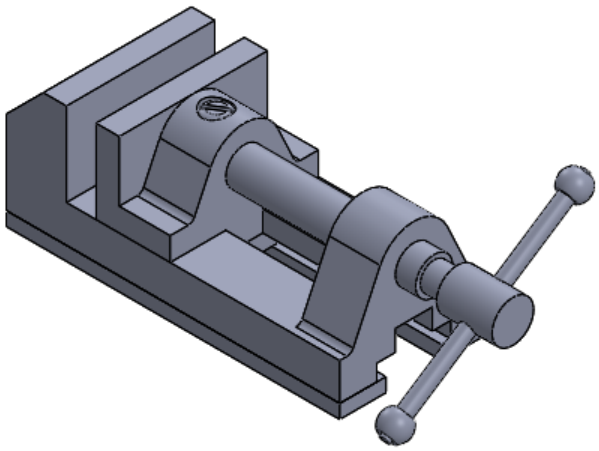


Figure 20-19 *Assembly model for motion study*

The following steps are required to complete this tutorial:

a. Copy the Bench Vice folder from Chapter 12 to the folder of the current chapter.
b. Open the Bench Vice assembly document from the Bench Vice folder.
c. Add motor in the assembly.
d. Simulate motion of the assembly.

Copying the Documents in the Folder of the Current Chapter

Before proceeding further, you need to create the folder of the current chapter and then copy the model and the drawing document in the folder created.

1. Create a folder with the name *c20* in the *SOLIDWORKS* folder. Next, copy the *Bench Vice* folder from *\Documents\SOLIDWORKS\c12* and paste it in the *c20* folder.

Opening the Assembly Document

Next, you need to open the assembly document in the SOLIDWORKS window.

1. Invoke the **Open** dialog box and open the *Bench Vice.SLDASM* document from it; the assembly document for which you want to perform the motion analysis is displayed in the assembly window.

2. Click on the **Motion Study 1** tab displayed at the bottom; the **MotionManager** interface is displayed, as shown in Figure 20-20.

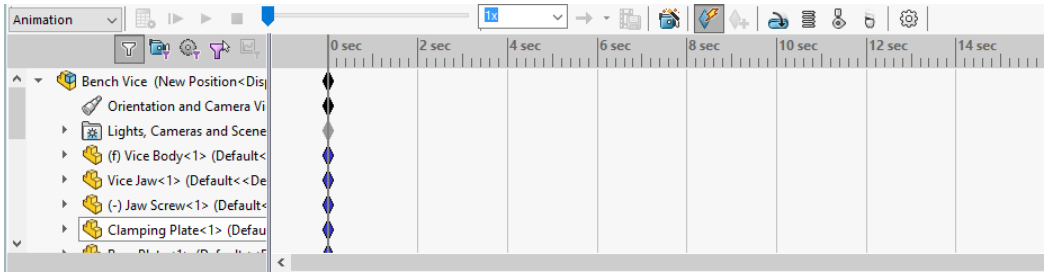


Figure 20-20 *The* ***MotionManager*** *interface*

Adding Motor to the Assembly

Before performing the motion analysis, you need to add motion between the components by adding a motor.

1. Choose the **Motor** button from the **MotionManager** toolbar; the **Motor PropertyManager** is displayed, as shown in Figure 20-21.



2. Choose the **Rotary Motor** button from the **Motor Type** rollout, if it is not chosen by default.

3. Click in the **Motor Location** selection box of the **Component/Direction** rollout and select the cylindrical face of the Jaw Screw, refer to Figure 20-22. The name of the selected face is displayed in the **Motor Direction** selection box.

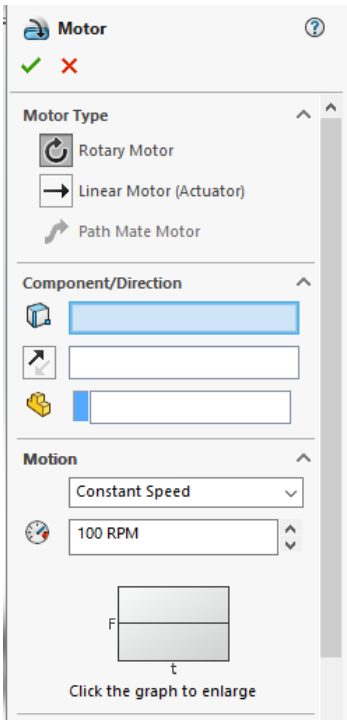


Figure 20-21 *Partial view of the* ***Motor PropertyManager***

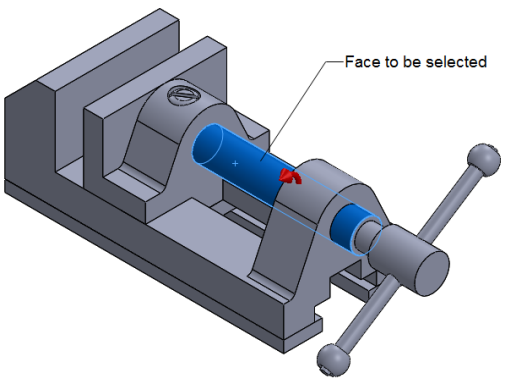


Figure 20-22 *The face to be selected*

4. Make sure that the **Constant Speed** option is selected in the **Function** drop-down list of the **Motion** rollout. Set the value **150** in the **Speed** spinner of the **Motion** rollout.

5. Choose the **OK** button in the **Motor PropertyManager** to add the motor.

Simulating the Motion Study

1. Choose the **Calculate** button from the **MotionManager** toolbar; the motion of the assembly components is displayed in the assembly window. 

2. Choose the **Stop** button from the **MotionManager** toolbar to stop the animation and then to increase the play time of animation, select the key point of first row and drag it to the desired time point, refer to Figures 20-23 and 20-24.

3. Choose the **Calculate** button again to play the animation till the specified time point.

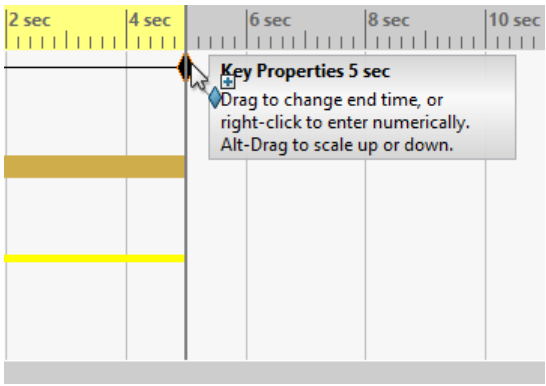


Figure 20-23 *Timeline before moving the key point*

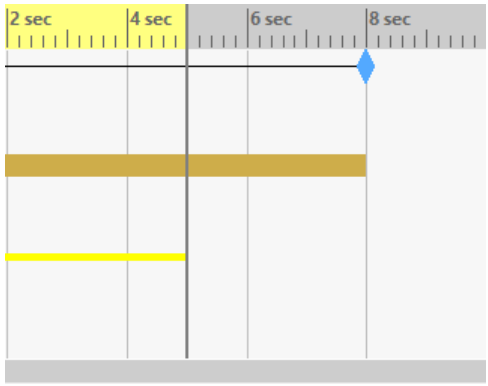


Figure 20-24 *Timeline after moving the key point*



Tip

*The motion of the assembly can be made continuous by selecting the **Playback Mode: Loop** option from the **MotionManager** toolbar. On selecting this option, the motion will start from the beginning after one cycle of motion has ended.*

Tutorial 2

In this tutorial, you will study the motion of a cam spring assembly. The assembly files for this tutorial can be downloaded from *www.cadcim.com*. **(Expected time: 30 min)**

The following steps are required to complete this tutorial:

a. Download the assembly files from *www.cadcim.com*.
b. Assemble the downloaded components.
c. Apply rotary motor to the cam.
d. Simulate the motion of the assembly.

Downloading the Cam Spring Tutorial Files

Before starting the tutorial, you need to download the tutorial file. After downloading the file, extract it to the desired location.

1. Download the *c20_sw_2021_tut.zip* file from *www.cadcim.com*. The path of the files is as follows:

   Textbooks > CAD/CAM > SOLIDWORKS > SOLIDWORKS 2021 for Designers > Tutorial files

Assembling the Components

After extracting the file, you need to assemble the components in the Assembly environment.

1. Start a new SOLIDWORKS assembly document; the **Begin Assembly PropertyManager** along with the **Open** dialog box is displayed.

2. Browse to the Pin part and choose the **Open** button from the dialog box; the model of the Pin is attached to the cursor.

3. Choose the **OK** button from the **Begin Assembly PropertyManager**; the Pin is placed coincident to the origin.

4. Similarly, insert the Cam component and place it at an arbitrary location in the graphics area.

5. Choose the **Mate** button from the **Assembly CommandManager**; the **Mate PropertyManager** is displayed.

6. Select the cylindrical face of the Pin and inner circular face of the Cam; the concentric mate is applied between the cylindrical faces of the Pin and Cam. Also, a pop-up toolbar is displayed.

7. Choose the **Add/Finish Mate** button from the pop-up toolbar; you are prompted to select other references to apply a mate.

8. Choose the **Distance** button from the **Standard Mates** rollout of the PropertyManager; the **Distance** edit box is activated.

9. Specify the value of distance as **4** in the edit box and press ENTER. Next, select the planar faces of the Pin and Cam, refer to Figure 20-25; the distance mate is applied between the planar faces. Also, a pop-up toolbar is displayed.

10. Choose the **Add/Finish Mate** button from the pop-up toolbar; the mate is applied.

11. Follow the above steps and assemble the other components of the assembly. Figure 20-26 shows the assembly after assembling all the components.

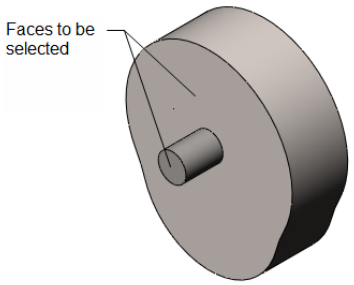


Figure 20-25 *Faces to be selected*

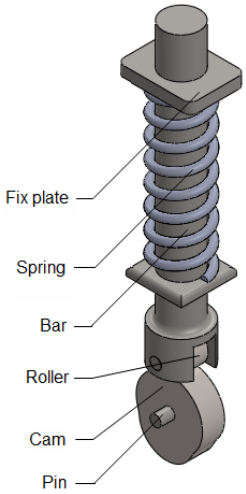


Figure 20-26 *Assembly for performing motion study*

Adding Motor to the Assembly

Before performing the motion analysis, you need to add motion between the components by adding motor.

1. Click on the **Motion Study 1** tab displayed at the bottom left of the window; the **MotionManager** interface is displayed.

2. Choose the **Motor** button from the **MotionManager** toolbar; the **Motor PropertyManager** is displayed.

3. Select the round face of the cam; a motor is applied. Also, the direction of rotation is indicated by a red arrow, refer to Figure 20-27.

4. Accept the other default settings and choose the **OK** button from the PropertyManager; the rotational motion is added to the component.

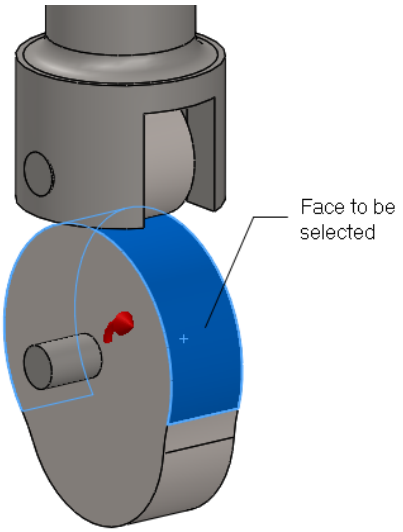


Figure 20-27 *Face to be selected for specifying direction of rotation*

Simulating the Motion Study

1. Choose the **Calculate** button from the **MotionManager** toolbar; the motion of assembly components is displayed in the assembly window.

   You can increase or decrease the play time of motion, as discussed in Tutorial 1 of this chapter.

   Figure 20-28 shows the annotated time line for the motion study.

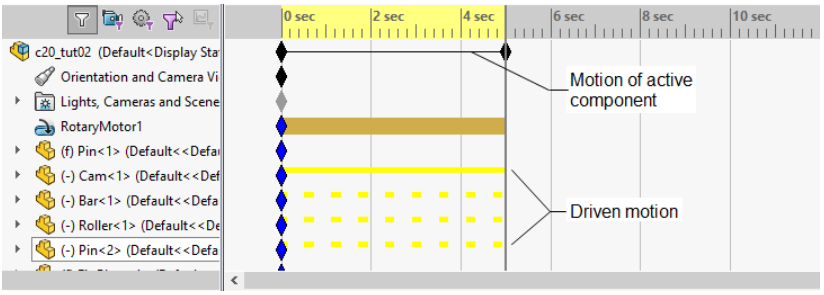


Figure 20-28 *Annotated time line for the motion study*

Self-Evaluation Test

Answer the following questions and then compare them to those given at the end of this chapter:

1. The **Animation** and _____ options are available in the **Type of Study** drop-down list.

2. The Timeline is used to display the position of components at a specific point of time. (T/F)

3. The Time Bar is used to display the scale of time. (T/F)

4. The **Calculate** button is used to calculate the force applied on the component. (T/F)

5. Using the **Motor** button, you can provide the linear motion to the assembly. (T/F)

Review Questions

Answer the following questions:

1. Which of the following is used to represent the current position of components on the time scale?

   (a) Timeline (b) Timebar
   (c) Time slider (d) None of the these

2. Which of the following rollouts in the **Motor PropertyManager** is used to specify the motion type of the motor?

   (a) **Component/Direction** (b) **Motion**
   (c) **More Options** (d) None of the these

3. The _____ tool is used to add actuator to the motion study.

4. You can save the animation clip of current motion study by using the _____ tool.

5. The options in the _____ drop-down list are used to increase or decrease the playback speed of motion study.

EXERCISES

Exercise 1

Simulate the motion of Blower assembly created in Exercise 2 of Chapter 12, refer to Figure 20-29. **(Expected time: 30 min)**

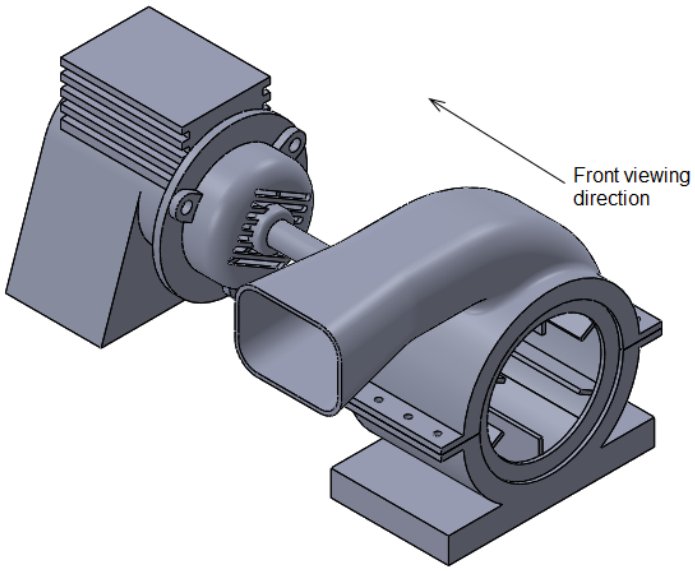


Figure 20-29 *Blower assembly*

Exercise 2

Simulate the motion of Pipe Vice assembly created in Tutorial 2 of Chapter 12, refer to Figure 20-30. **(Expected time: 30 min)**

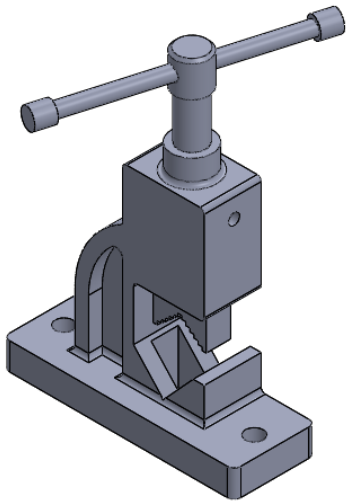


Figure 20-30 *Pipe Vice assembly*

Answers to Self-Evaluation Test

1. Basic Motion, 2. F, **3.** F, **4.** F, **5.** T