Lab 12: Joint Driver and Force Creation Lab

Objective

This lab will continue to introduce the definition of Joint Drivers. These drivers will prescribe the motion in the three translational degrees of freedom of the backhoe model. Forces will also be added to the model for damping effects during operation of the system. You will become more familiar with utilizing geometry features, and inserting points to define the forces necessary to raise the bucket of the backhoe, swivel the backhoe about the base, and then lower the bucket back to the initial starting position.

Lab 12 Agenda

1. Edit the joint driver on Translational Joint.1.
2. Define a joint driver on Translational Joint.2.
3. Define a joint driver on Translational Joint.3.
4. Define a joint driver on Revolute Joint.5.
5. Define a TSDA with a damping coefficient between the dump_piston and dump_cyl bodies.
6. Define a TSDA with a damping coefficient between the stick_piston and stick_cyl bodies.
7. Define a TSDA with a damping coefficient between the boom_piston and boom_cyl bodies.
8. Define a Three-Point force acting on the swing2 body to represent a load being lifted by the backhoe.
9. Run a dynamic analysis.
10. Animate the results.

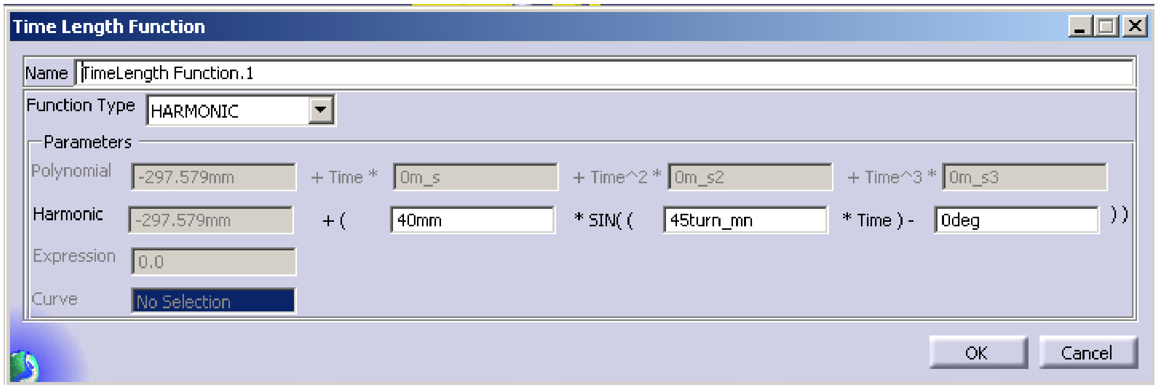
Edit the Joint Driver on Translational Joint.1

There is already a driver applied to the translation joint defined between the dump_cyl and dump_piston bodies from Lab 10. The formula to this driver will be edited. This driver will define the translation motion of the two bodies connected by Translational Joint.1 relative to one another.

A Joint Driver requires that a Joint and a Function be specified in the definition dialog. Once a joint has been specified, the driver Types list will update to show only those types applicable to the specified joint.

Editing Function.1

1. Double-click on the **TimeLength Function.1** branch of the Specification Tree. This will bring up the Function definition dialog.



2. Set the *Function Type* to be **SPLINE.CURVE**.
3. Once a *Function Type* has been selected, the TimeLength Function.1 field entry *Curve* will highlight. To complete the definition of the function, a curve of time vs. displacement must be defined. The first point of the curve will represent the initial offset of the connecting points on the two bodies specified in Translational Joint.1.
4. To specify further separation of these connection points, the subsequent terms of the function must be increasing in value.
5. Right-click in the box to the right of the *Curve* field entry, and select **New** from the contextual menu.
6. To easily define the driving curve, we will import predefined curve data from an external file. This external data has been stored in an Excel spreadsheet. Open the file dump_curve_data.xls (from the C:\Training folder) in Microsoft Excel.
7. In the box shaded green under the column labeled “First Term,” enter the value shown in the *Polynomial* first term field of the Virtual.Lab Motion TimeLength Function.1 definition dialog (-151). The remaining data in the spreadsheet will automatically update. Save and Close the Excel spreadsheet.
8. Within the Virtual.Lab Motion Spline Curve.1 definition dialog, mark the *Reference external data file* check box and click on the **Open a text or Excel file** button to the right of the *External Data* field entry.
9. From the File Selection Menu select the file **dump_curve_data.xls**. This file should be available in the Training folder. Click **Open** to close the File Selection dialog.
10. Within the Spline Curve.1 definition dialog the selected file name should now appear. Below this field entry specify Column X as 1 and Column Z as 2.
11. Click **OK** to close the Spline Curve dialog box.
12. Click **OK** to close the TimeLength Function.1 definition dialog.

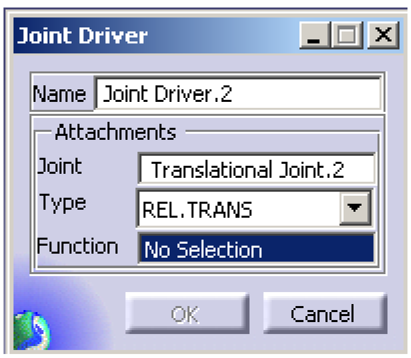
Define a Joint Driver on Translational Joint.2

The second driver will be added to the translation joint defined between the stick_cyl and stick_piston bodies. This driver will define the translation motion of the two bodies connected by Translational Joint.2 relative to one another.

Defining a Joint Driver

1. Expand the Constraint definition toolbar by selecting once on the **black arrow** to the right of the Constraint button shown on the Mechanism Design workbench.

2. Select the **Joint Driver**  button. This will bring up the Joint Driver definition dialog.



3. Select on the Tranlational Joint.2 icon in the Model Display window, or select on the **Translational Joint.2** branch of the Specification Tree. This will become the *Joint* field entry in the Joint definition dialog.

4. Right-click in the *Function* Field of the Joint definition dialog. Select **New** from the contextual menu. This will place a new branch in the Specification Tree under the Analysis Model → Data branch. This new branch will be labeled TimeLength Function.2. This element will become the *Function* setting in the Joint Driver definition dialog.

5. Set the *Function Type* to be **SPLINE.CURVE**.

6. Once a *Function Type* has been selected, the TimeLength Function.2 field entry *Curve* will highlight. To complete the definition of the function, a curve of time vs. displacement must be defined. The first point of the curve will represent the initial offset of the connecting points on the two bodies specified in Translational Joint.2.

7. To specify further separation of these connection points, the subsequent terms of the function must be increasing in value.

8. Right-click in the box to the right of the *Curve* field entry, and Select **New** from the contextual menu.

9. To easily define the driving curve, we will import predefined curve data from an external file. This external data has been stored in an Excel spreadsheet. Open the file stick_curve_data.xls (from the C:\Training folder) in Microsoft Excel.
10. In the box shaded green under the column labeled "First Term," enter the value shown in the *Polynomial* first parameter field of the Virtual.Lab Motion TimeLength Function.2 definition dialog (-290). The remaining data in the spreadsheet will automatically update, Save and Close the Excel spreadsheet.
11. Within the Virtual.Lab Motion Spline Curve.2 definition dialog, mark the *Reference external data file* check box and click on the **Open a text or Excel file** button to the right of the *External Data* field entry.
12. From the File Selection Menu select the file **stick_curve_data.xls**. This file should be available in the Training folder. Select **Open** to close the File Selection dialog.
13. Within the Spline Curve.2 definition dialog the selected file name should now appear. Below this field entry specify Column X as 1 and Column Z as 2.
14. Click **OK** to close the dialog box.
15. Click **OK** to close the TimeLength Function.2 definition dialog.
16. Click **OK** to close the Joint Driver.2 definition dialog.

Define a Joint Driver on Translational Joint.3

The third driver will be added to the translation joint defined between the boom_cyl and boom_piston bodies. This driver will define the translation motion of the two bodies connected by Translational Joint.3 relative to one another.

Defining a Joint Driver

1. Expand the Constraint definition toolbar by selecting once on the black arrow to the right of the Constraint button shown on the Mechanism Design workbench.
2. Select the **Joint Driver** button. This will bring up the Joint Driver definition dialog.
3. Select on the Translational Joint.3 icon in the Model Display window, or select on the **Translational Joint.3** Branch of the Specification Tree. This will become the *Joint* field entry setting in the Joint Driver definition dialog.
4. Right-click in the *Function* Field of the Joint definition dialog. Select **New** from the contextual menu. This will place a new branch in the Specification Tree under the Analysis Model → Data branch. This new branch will be labeled TimeLength Function.3. This element will become the *Function* setting in the Joint Driver definition dialog.

5. Set the *Function Type* to be **SPLINE.CURVE**.
6. Once a *Function Type* has been selected, the TimeLength Function.3 field entry *Curve* will highlight. To complete the definition of the function, a curve of time vs. displacement must be defined. The first point of the curve will represent the initial offset of the connecting points on the two bodies specified in Translational Joint.3.
7. To specify further separation of these connection points, the subsequent terms of the function must be increasing in value.
8. Right-click in the box to the right of the *Curve* field entry, and Select **New** from the contextual menu.
9. To easily define the driving curve, we will import predefined curve data from an external file. This external data has been stored in and Excel spreadsheet. Open the file boom_curve_data.xls (from the C:\Training folder) in Microsoft Excel.
10. In the box shaded green under the column labeled “First Term,” enter the value shown in the *Polynomial* first parameter field of the Virtual.Lab Motion TimeLength Function.3 definition dialog (-265). The remaining data in the spreadsheet will automatically update, Save and Close the Excel spreadsheet.
11. Within the Virtual.Lab Motion Spline Curve.3 definition dialog, mark the *Reference external data file* check box and click on the **Open a text or Excel file** button to the right of the *External Data* field entry.
12. From the File Selection Menu select the file **boom_curve_data.xls**. This file should be available in the Training folder. Select **Open** to close the File Selection dialog.
13. Within the Spline Curve.3 definition dialog, the selected file name should now appear. Below this field entry specify Column X as 1 and Column Z as 2.
14. Click **OK** to close the dialog box.
15. Click **OK** to close the TimeLength Function.3 definition dialog.
16. Click **OK** to close the Joint Driver.3 definition dialog.

Define a Joint Driver on Revolute Joint.5

Defining a Joint Driver

1. Expand the Constraint definition toolbar by selecting once on the black arrow to the right of the Constraint button shown on the Mechanism Design workbench.
2. Select the **Joint Driver** button. This will bring up the Joint Driver definition dialog.
3. Select on the Revolute Joint.5 icon in the Model Display window, or select on the **Revolute Joint.5** branch of the Specification Tree. This will become the *Joint* field entry of the Joint Driver definition dialog.

4. Right-click in the *Function* field of the Joint definition dialog. Select **New** from the contextual menu. This will place a new branch in the Specification Tree under the Analysis Model → Data branch. This new branch will be labeled TimeAngle Function.1. This element will become the *Function* setting in the Joint Driver definition dialog.
5. Set the *Function Type* to be **SPLINE.CURVE**.
6. Once a *Function Type* has been selected, the TimeAngle Function.1 field entry *Curve* will highlight. To complete the definition of the function, a curve of time vs. degrees must be defined. The first point of the curve will represent the initial rotation of the connecting points on the two bodies specified in Revolute Joint.5.
7. To specify further rotation of these connection points, the subsequent terms of the function must be increasing in value.
8. Right-click in the *Curve* field entry, and select **New** from the contextual menu.
9. To easily define the driving curve, we will import predefined curve data from an external file. This external data has been stored in and Excel spreadsheet. Open the file boom_rotation_data.xls (out of the C:\Training folder) in Microsoft Excel.
10. In the box shaded green under the column labeled “First Term,” enter the value shown in the *Polynomial* first term field of the Virtual.Lab Motion TimeAngle Function.1 definition dialog (0). The remaining data in the spreadsheet will automatically update. Save and Close the Excel spreadsheet.
11. Within the Virtual.Lab Motion Spline Curve.4 definition dialog, mark the *Reference external data file* check box and click on the **Open a text or Excel file** button to the right of the *External Data* field entry.
12. From the File Selection Menu select the file **boom_rotation_curve.xls**. This file should be available in the Training folder. Select **Open** to close the File Selection dialog box.
13. Within the Spline Curve.4 definition dialog the selected file name should now appear. Below this field entry specify Column X as 1 and Column Z as 2.
14. Click **OK** to close the dialog box.
15. Click **OK** to close the TimeAngle Function.1 definition dialog.
16. Click **OK** to close the Joint Driver.4 definition dialog.

Define a TSDA with a Damping Coefficient Between the dump_piston and dump_cyl Bodies

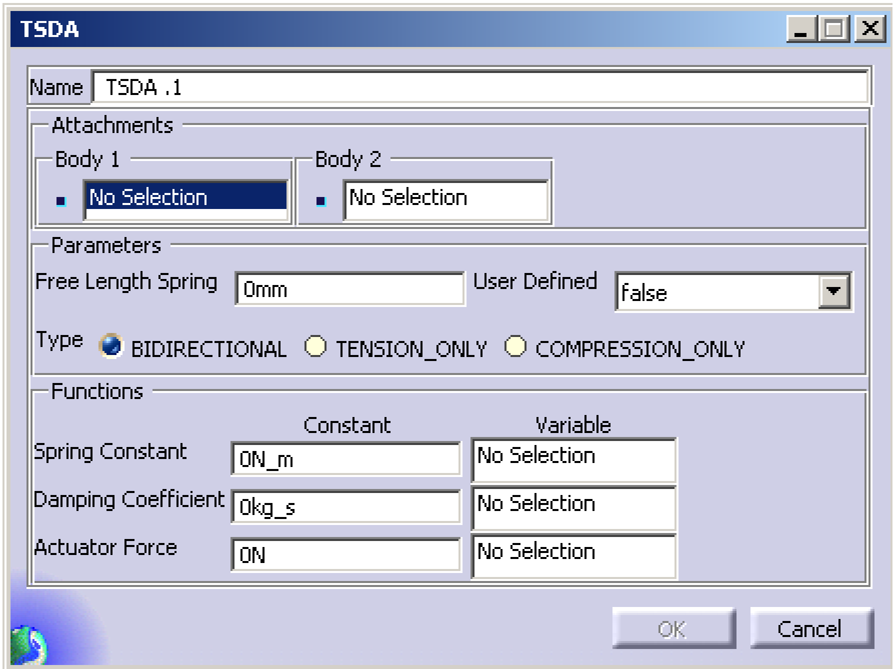
A Translational Spring Damper Actuator (TSDA) force element will be added to the connection between the dump_piston and dump_cyl bodies. This element will serve as a viscous damper in the system to minimize undesirable vibrations in the system due to the motion of the backhoe. The force created in this element acts along the translational degree of freedom between the piston and cylinder bodies.

Defining a TSDA force

The TSDA definition dialog shows that there are two points required to define the connection points of the TSDA. There should be a point on each of the connecting bodies. While the dump_piston body already has a point of connection defined, the dump_cyl body does not. First we will insert a connection point on the dump_cyl body, then define the TSDA element.

1. Under the Product1_ROOT → dump_cyl (dump_cyl.1) branch of the Specification Tree, double-click the dump_cyl part document to activate the Part Design workbench. To insert a point, it is necessary to activate the Wireframe and Surface Design workbench. This can be activated from the Virtual.Lab Motion Main Menu by selecting **Start → Mechanical Design → Wireframe and Surface Design**.
2. Click the Point Button from the Wireframe and Surface Design workbench, this will bring up the Point Definition dialog. Click **OK** to place the point at the body origin and to close the dialog box.
3. Double-click the Analysis Model branch of the Specification Tree to activate the Mechanism Design workbench.
4. Expand the Force definition toolbar by selecting on the **black arrow** to the right of the Bushing  button.

5. Click the **TSDA** Button . This will bring up the TSDA definition dialog.



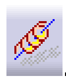
6. Select the first of the two points required to define the TSDA element. Under the Product1_ROOT → dump_piston (dump_piston.1) → dump_piston part document branch of the Specification Tree, select the **Point.3** branch.
7. Select the second of the points. Under the Product1_ROOT → dump_cyl (dump_cyl.1) → dump_cyl part document branch of the Specification Tree, select the **Point.1** branch.

   There are several Parameters utilized in calculating the force exerted between connecting points by the TSDA element. Check the Online Reference Manual for the complete TSDA element mathematical formulation. In this case we will only define the damping coefficient. The Damping Force = damping coefficient * velocity

8. Set the *Damping Coefficient* field entry to `10 kg_s`.
9. Click **OK** to close the dialog box.

Define a TSDA with a Damping Coefficient Between the stick_piston and stick_cyl Bodies

Defining a TSDA force

1. Expand the Force definition toolbar by selecting on the **black arrow** to the right of the Bushing Button .
2. Click the **TSDA** Button . This will bring up the TSDA definition dialog.

The TSDA definition dialog shows that there are two points required to define the connection points of the TSDA. There should be a point on each of the connecting bodies. Both the stick_piston and stick_cyl bodies already have the connection points defined.

3. Under the Product1_ROOT → stick_piston (stick_piston.1) → stick_piston branch of the Specification Tree, select the **Point.3** branch.
4. Under the Product1_ROOT → stick_cyl (stick_cyl.1) → stick_cyl branch of the Specification Tree, select the **Point.1** branch.
5. Set the *Damping Coefficient* to `10 kg_s`.
6. Click **OK** to close the dialog box.

Define a TSDA with a Damping Coefficient Between the boom_piston and boom_cyl Bodies

Defining a TSDA force

1. Click the **TSDA** Button. This will bring up the TSDA definition dialog.
2. Under the Product1_ROOT → boom_piston (boom_piston.1) → boom_piston branch of the Specification Tree, select the **Point.3** branch.
3. Under the Product1_ROOT → boom_cyl (boom_cyl.1) → boom_cyl branch of the Specification Tree, select the **Point.1** branch.
4. Set the *Damping Coefficient* to `10 kg_s`.
5. Click **OK** to close the dialog box.

Define a Three-Point Force Acting on the Swing2 Body

A three-point force element is used to define a force or torque, which acts at a point on a body. The direction of the force, or axis of the torque, is determined by two additional points. These directional points can be on the same body to which the force or torque is applied, or on different bodies. If the three points are all on the same body, the direction of the force or torque will remain constant relative to that body. If the points are on different bodies, the direction and axis will change as the bodies move relative to each other. The magnitude of the force or torque can be defined with a constant value, or a time-varying curve.

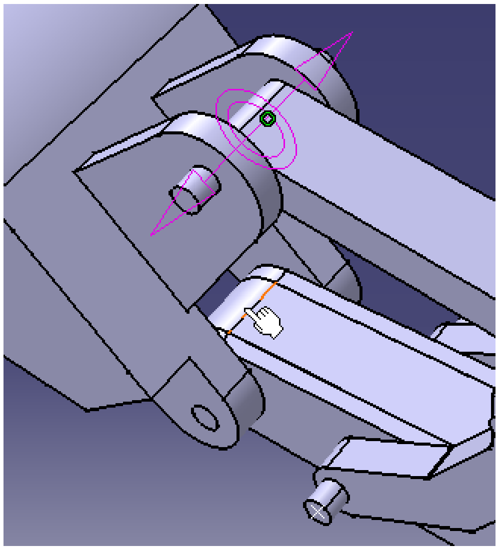
In this Analysis case the direction of the force will remain the same regardless of the motion of the swing2 body relative to the swing body that rotates relative to ground. Two points will be defined on the swing body, and one point will be defined on the swing2 body.

The point that will be added to the swing2 body will later be defined as the point of application. The force is meant to serve as an example of the backhoe lifting a heavy object.

Inserting a Point

1. Double-click the swing2 part document to activate the Wireframe and Surface Design workbench.
2. Click the **Point** Button. This will bring up the Point Definition dialog.

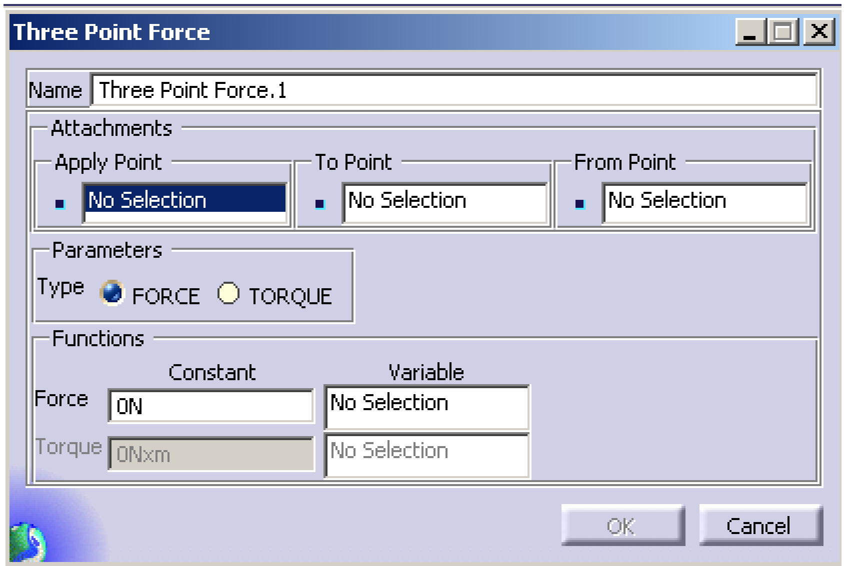
3. Set *Point Type* to **On Curve**. Select the curve on the swing2 body as shown in the figure below (If this line is not shown in the Model Display, the Rendering Style of the Model Display may have to be adjusted before defining the point). Click the **Middle Point** button within the Point Definition dialog. Click **OK** to close the dialog box. There should now be an X indicating the location of Point.7 at the center of the selected line.



The order in which these points are selected while defining a three-point force is important. The first point specifies the location at which the force will be “applied”. The second point specifies the direction the force vector should be pointing “to”. The third point selected specifies the direction the force vector should be pointing “from”.

Defining a Three-Point force:

1. Double-click on the Analysis Model branch of the Specification Tree to activate the Mechanism Design workbench.
2. Expand the Force definition toolbar by selecting on the black arrow to the right of the TSDA Button displayed on the Mechanism Design Workbench.
3. Click the **Three Point Force** Button . This will bring up the Three-Point Force definition dialog.



4. Select **Point.7** from the swing2 body. This will become point set under the *Apply Point* Field Entry. This point indicates the point at which the force will be applied.
5. Select **Point.2** from the swing body. This will become the point set under the *To Point* Field Entry. This point indicates the direction the force vector will be pointing to.
6. Select **Point.1** from the swing body. This will become the point set under the *From Point* Field Entry. This point indicates the direction the force vector will be starting from.
7. In the Parameter section of the dialog set the *Force* value to `100 N`. Click **OK** to close the dialog box.

Congratulations! This completes Lab Session 12. Analyzing the model will be covered in the next lab.