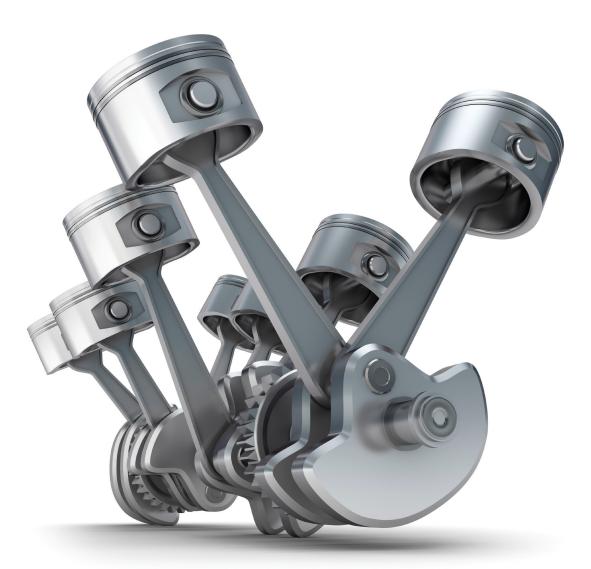
CATIA[®] V5 Tutorials Mechanism Design & Animation Release 21

Nader G. Zamani Jonathan M. Weaver

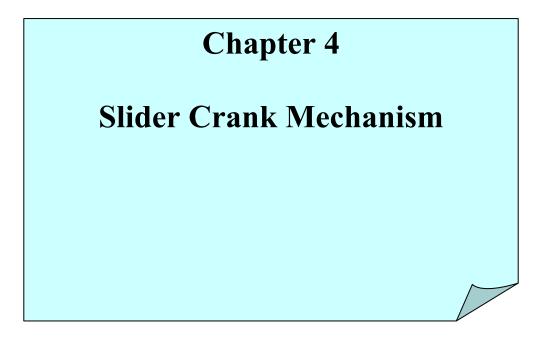




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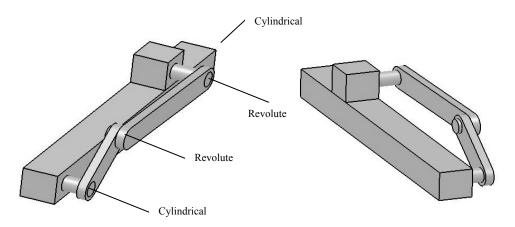
Introduction

In this tutorial you create a slider crank mechanism using a combination of revolute and cylindrical joints. You will also experiment with additional plotting utilities in CATIA.

1 Problem Statement

A slider crank mechanism, sometimes referred to as a three-bar-linkage, can be thought of as a four bar linkage where one of the links is made infinite in length. The piston based internal combustion is based off of this mechanism. The analytical solution to the kinematics of a slider crank can be found in elementary dynamics textbooks.

In this tutorial, we aim to simulate the slider crank mechanism shown below for constant crank rotation and to generate plots of some of the results, including position, velocity, and acceleration of the slider. The mechanism is constructed by assembling four parts as described later in the tutorial. In CATIA, the number and type of mechanism joints will be determined by the nature of the assembly constraints applied. There are several valid combinations of joints which would produce a kinematically correct simulation of the slider crank mechanism. The most intuitive combination would be three revolute joints and a prismatic joint. From a degrees of freedom standpoint, using three revolute joints and a prismatic joint redundantly constrains the system, although the redundancy does not create a problem unless it is geometrically infeasible, in this tutorial we will choose an alternate combination of joints both to illustrate cylindrical joints and to illustrate that any set of joint which removes the appropriate degrees of freedom while providing the capability to drive the desired motions can be applied. In the approach suggested by this tutorial, the assembly constraints will be applied in such a way that two revolute joints and two cylindrical joints are created reducing the degrees of freedom are reduced to one. This remaining degree of freedom is then removed by declaring the crank joint (one of the cylindrical joints in our approach) as being angle driven. An exercise left to the reader is to create the same mechanism using three revolute joints and one prismatic joint or some other suitable combination of joints. We will use the Multiplot feature available in CATIA is used to create plots of the simulation results where the abscissa is not necessarily the time variable.



2 Overview of this Tutorial

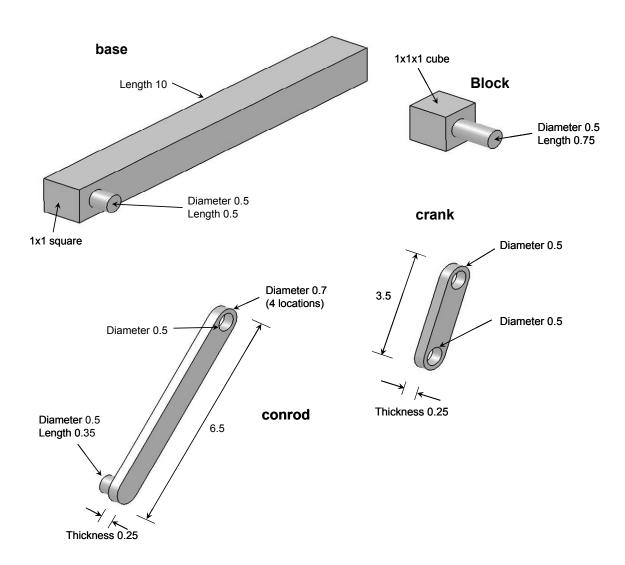
In this tutorial you will:

- 1. Model the four CATIA parts required.
- 2. Create an assembly (CATIA Product) containing the parts.
- 3. Constrain the assembly in such a way that only one degree of freedom is unconstrained. This remaining degree of freedom can be thought of as rotation of the crank.
- 4. Enter the **Digital Mockup** workbench and convert the assembly constraints into two revolute and two cylindrical joints.
- 5. Simulate the relative motion of the arm base without consideration to time (in other words, without implementing the time based angular velocity given in the problem statement).
- 6. Add a formula to implement the time based kinematics associated with constant angular velocity of the crank.
- 7. Simulate the desired constant angular velocity motion and generate plots of the kinematic results.

3 Creation of the Assembly in Mechanical Design Solutions

Although the dimensions of the components are irrelevant to the process (but not to the kinematic results), the tutorial details provide some specific dimensions making it easier for the reader to model the appropriate parts and to obtain results similar to those herein. Where specific dimensions are given, it is recommended that you use the indicated values (in inches). Some dimensions of lesser importance are not given; simply estimate those dimensions from the drawing.

In CATIA, model four parts named **base**, **crank**, **conrod**, and **block** as shown below.



Enter the **Assembly Design** workbench which can be achieved by different means depending on your CATIA customization. For example, from the standard

Windows toolbar, select **File > New** . From the box shown on the right, select **Product**. This moves you to the **Assembly Design** workbench and creates an assembly with the default name **Product.1**.

In order to change the default name, move the curser to **Product.1** in the tree, right click and select **Properties** from the menu list.

From the **Properties** box, select the **Product** tab and in **Part Number** type **slider_crank**.

This will be the new product name throughout the chapter. The tree on the top left corner of your computer screen should look as displayed below.

5	slider_	_crank
Ľ۵	pplica	tions

crank (crank.1) base (base.1) block (block.1) conrod (conrod

Applications

List of Types	:	
FunctionalS Part		^
Process ProcessLibra Product	ary	
Shape		~
Selection:		
Product		

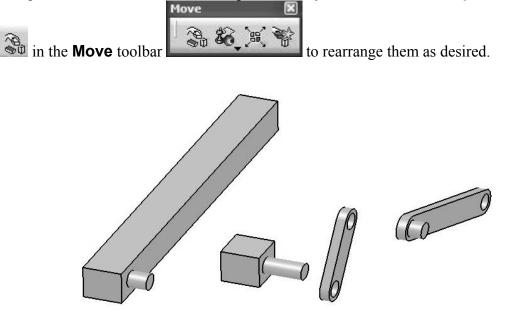
Properties		?×
Current selection	r: Product1	*
Product G	raphic Mechanical Drafting	
Product Part Number Revision Definition Nomendature Source Description	slider_crank	
Define other	properties	
<	- ULF))
		More
1	🎱 ок	Apply Close

The next step is to insert the existing parts in the assembly just created. From the standard Windows toolbar, select **Insert > Existing Component**.

From the **File Selection** pop up box choose all four parts. Remember that in CATIA multiple selections are made with the **Ctrl** key. The tree is modified to indicate that the parts have been inserted.

File Selection			_	_	_	(?)
Look in	CAT_chap	oter_4_DMU_	•	+€		
My Recent Documents	췖base 췖block 췖conrod 췖crank					
My Documents						
My Computer	File name:	I			•	Open
My Network Places	Files of type:	All Files (*.*) □ Open as read-only			•	Cancel
		Show Preview				

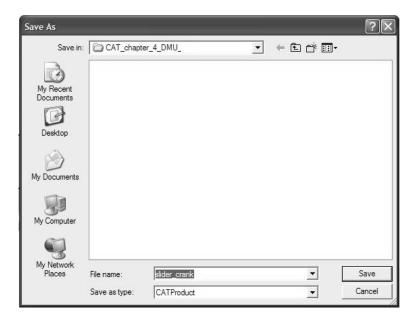
Note that the part names and their instance names were purposely made the same. This practice makes the identification of the assembly constraints a lot easier down the road. Depending on how your parts were created earlier, on the computer screen you have the four parts all clustered around the origin. You may have to use the **Manipulation** icon



The best way of saving your work is to save the entire assembly.

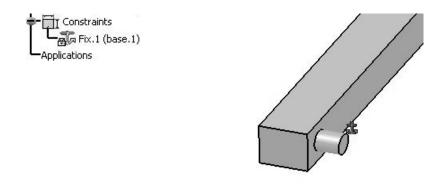
Double click on the top branch of the tree. This is to ensure that you are in the **Assembly Design** workbench.

Select the **Save** icon **I**. The **Save As** pop up box allows you to rename if desired. The default name is the **slider_crank**.



Your next task is to impose assembly constraints.

Pick the **Anchor** icon **the** from the **Constraints** toolbar and select the **base** from the tree or from the screen. This removes all six degrees of freedom for the base.



Next, we will create a coincident edge constraint between the base and the block. This removes all dof except for translation along the edge of coincidence and rotation about the edge of coincidence. The two remaining dof are consistent with our desire to create a cylindrical joint between the block and the base. To make the constraint, pick the

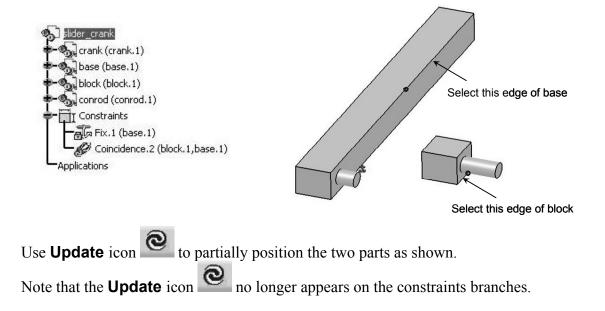




Select the two edges of the **base** and the

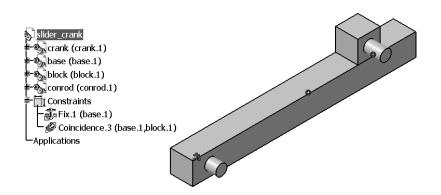
block as shown below.

This constraint is reflected in the appropriate branch of the tree.



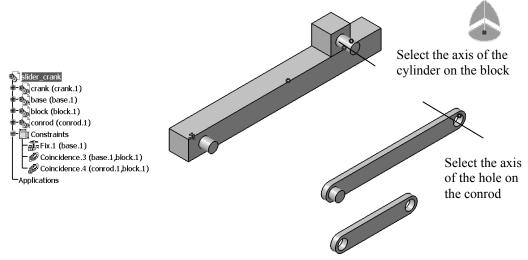
Depending on how your parts were constructed the block may end up in a position quite

different from what is shown below. You can always use the **Manipulation** icon to position it where desired followed by **Update** if necessary.



You will now impose assembly constraints between the conrod and the block. Recall that we ultimately wish to create a revolute joint between these two parts, so our assembly constraints need to remove all the dof except for rotation about the axis.

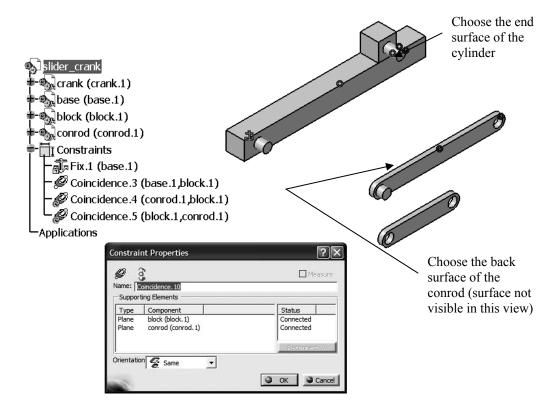
Pick the **Coincidence** icon *from* **Constraints** toolbar. Select the axes of the two cylindrical surfaces as shown below. Keep in mind that the easy way to locate the axis is to point the cursor to the curved surfaces.



The coincidence constraint just created removes all but two dof between the conrod and the base. The two remaining dof are rotation about the axis (a desired dof) and translation along the axis (a dof we wish to remove in order to produce the desired

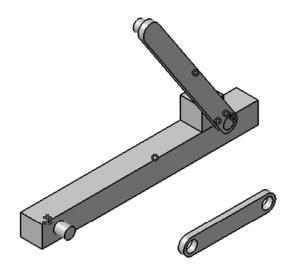
revolute joint). To remove the translation, pick the **Coincidence** icon \mathscr{D} from the **Constraints** toolbar and select the surfaces shown on the next page. If your parts are

originally oriented similar to what is shown, you will need to choose **Same** for the **Orientation** in the **Constraints Definition** box so that the conrod will flip to the desired orientation upon an update. The tree is modified to reflect this constraint.



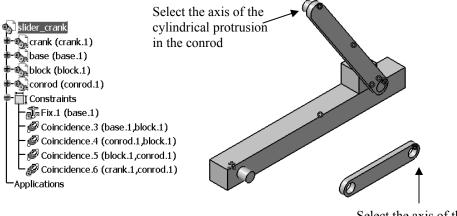
Use **Update** icon to partially position the two parts as shown below. Note that upon updating, the conrod may end up in a location which is not convenient for

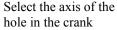
the rest of the assembly. In this situation the **Manipulation** icon can be used to conveniently rearrange the conrod orientation.



So far, we have created assembly constraints which leave degrees of freedom consistent with a cylindrical joint between the block and the base and a revolute joint between the block and the conrod. Next we will apply assembly constraints consistent with a revolute joint between the conrod and the crank. This will be done with a coincidence constraint between the centerlines of the protrusion on the conrod and the upper hole of the base and a surface contact constraint to position the parts along the axis of the coincidence

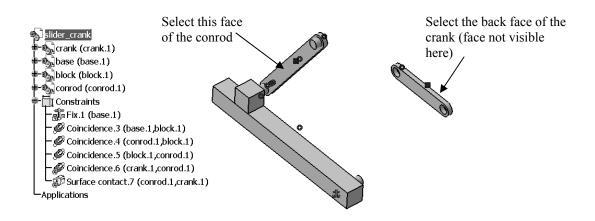
constraint. To begin this process, pick the **Coincidence** icon \swarrow from **Constraints** toolbar. Select the axis of the cylindrical surface and the hole as shown below.



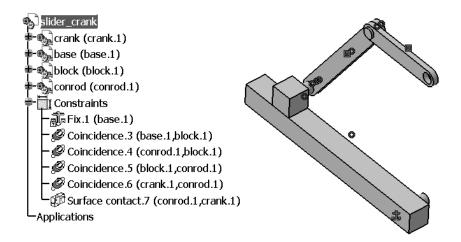


The coincidence constraint just applied removes all dof between the conrod and the crank except for rotation along the axis of coincidence and translation along that axis. To remove the unwanted translational dof, we will use a surface contact constraint (a coincidence constraint could also be applied, but we have chosen to illustrate a contact

constraint here). To create the constraint, Pick the **Contact** icon from **Constraints** toolbar and select the surfaces shown in the next page. The tree is modified to reflect this constraint.

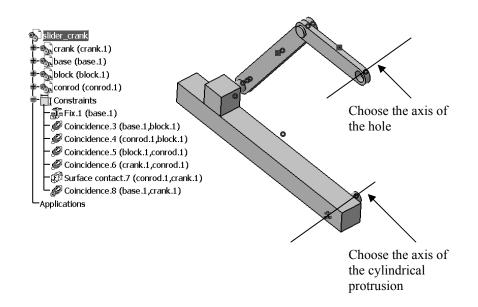


Use **Update** icon to partially position the two parts as shown.

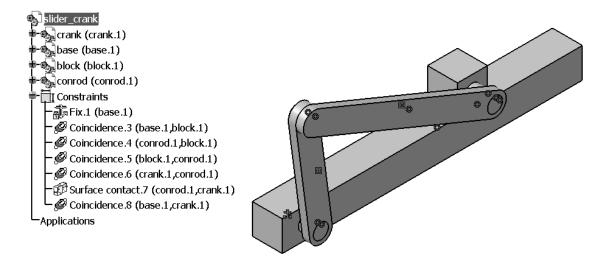


We need to apply one final constraint to locate the lower end of the crank onto the

cylindrical protrusion on the base. Pick the **Coincidence** icon from **Constraints** toolbar. Select the axis of the cylindrical surface and the hole as shown below.



Use **Update** icon to get the final position of all parts as shown. Note that since we have chosen to create a cylindrical joint between the base and the crank, we do not need to specify a constraint to remove the translation along the axis of coincidence; that translation is effectively removed by the remainder of the assembly constraints.



The assembly is complete and we can proceed to the **Digital Mockup** workbench. As you proceed in the tutorial, keep in mind that we have created the assembly constraints with attention to the relative degrees of freedom between the parts in a manner consistent with having a cylindrical joint between the base and the crank, a revolute joint between the crank and the lower end of the conrod, a revolute joint between the upper end of the conrod and the block, and a cylindrical joint between the block and the base.

4 Creating Joints in the Digital Mockup Workbench

The **Digital Mockup** workbench is quite extensive but we will only deal with the **DMU Kinematics module**. To get there you can use the standard Windows toolbar as shown below: **Start > Digital Mockup > DMU Kinematics**.

<u>S</u> tart	Eile	<u>E</u> dit	<u>V</u> iew	<u>I</u> nsert	Tools	<u>A</u> nalyze	<u>W</u> indow	Help
Inf	frastruc	ture			•			
Me	chanica	al Desigr	1		•			
Sh	ape				•			
An	alysis 8	k Simulat	tion		•			
AE	<u>C</u> Plant				•			
Ма	ic <u>h</u> ining				•			
	jital Mo	ckup			• X	DMU Navi	gator	
Eg	uipmen	t & Syst	ems		• 2	DMU Space	ce Analysis	
Dig	ital Pro	cess for	Manufa	icturing	. 5	DM <u>U</u> Kine	matics	
Erg	gonomia	s Desig	n & Anal	ysis	• 🖄	DMU <u>F</u> ittir	ng	
Kn	owledg	eware			• Ko	DMU <u>2</u> D V	liewer	
1	accelera	atiProd	uct		Ğ	DMU F <u>a</u> st	ening Revie	w
		watered the	- 14			DMU Opti	mizer	
<u>1</u> a	accelera	atiProd	uct			DMU <u>T</u> ole	rancing Rev	iew
<u>2</u> a	assembl	y_1.CA	TProduct	t	T			
<u>3</u> s	liding_t	olProd	uct					
<u>4</u> t	esting_	JawsP	roduct					
<u>5</u> T	Transier	ntAna	alysis					
Exi	it				3			



This icon allows you to

create most common joints automatically from the existing assembly constraints. The pop up box below appears.

Assembly Constraints Conve	rsion	?×
Mechanism:		New Mechanism
Auto Greate	Ur	More >>
1	-	OK Cancel

Select the **New Mechanism** button <u>New Mechanism</u>. This leads to another pop up box which allows you to name your mechanism. The default name is **Mechanism.1**. Accept the default name by pressing **OK**.

that the box indicates Unresolved pairs: 4/4	Mechanism Creation
Assembly Constraints Conversion	?×
Mechanism: Mechanism. 1 Auto Create	New Mechanism More >> Unresolved pairs: 4 / 4 OK Cancel

Select the **Auto Create** button **Auto Create**. Then if the **Unresolved pairs** becomes **0/4**, things are moving in the right direction.

Assembly Constraints Conversion		?×
Mechanism: Mechanism. 1	▼ New Mecha	nism
Auto Create	Unresolved pairs:	More >>
	ок ок	Cancel

Note that the tree becomes longer by having an **Application** Branch. The expanded tree is displayed below.

```
🔊 slider_crank
  🍓 crank (crank.1)
  🎭 base (base.1)
  🎭 block (block.1)
 🔩 conrod (conrod.1)
Constraints
 -Applications
  -Mechanisms
     Joints
          Event Strategy (c) (base 1, block 1)
          🖶 🎉 Cylindrical.2 (base.1,crank.1)

    Revolute.3 (block.1,conrod.1)
    Revolute.4 (conrod.1,crank.1)

          -Commands
         ⊢Fix Part ( base.1 )
         Laws
          Speeds-Accelerations
```

Note

The **DOF** is 1 (if you have dof other than 1, revisit your assembly constraints to make sure they are consistent with those herein, delete your mechanism, then begin this chapter again). This remaining dof can be thought of as the position of the block along the base, or the rotation of the crank about the base. Since we want to drive the crank at constant angular speed, the latter interpretation is appropriate.

Note that because we were careful in creating our assembly constraints consistent with the desired kinematic joints, the desired joints were created based on the assembly

constraints created earlier and the Assembly Constraints Conversion icon

All of these joints could also be created directly using the icons in the **Kinematics Joints** toolbar

Kinematics Joints			×
2629	金色图 计卡	华路的会	,部圈把上

In order to animate the mechanism, you need to remove the one degree of freedom present. This will be achieved by turning **Cylindrical.2** (the joint between the base and the crank) into an **Angle driven** joint.

Note that naming the instances of parts to be the same as the part name makes it easy to identify the joint between any two parts.

Double click on **Cylindrical.2** in the tree. The pop up box below appears.

Joint name: Cylindrical.2		
	Joint geometry:	
Line 1: crank. 1/Pad. 1	Line 2: base, 1	/Solid, 1
Angle driven	Length driven	
- Joint Limits		
1st lower limit: Unset	🚔 🗌 1st upper limit:	Unset 🔄
2nd Lower Limit: Unse	🔄 🗌 2nd upper limit:	Unset 🚔

Check the Angle driven box. This allows you to change the limits.

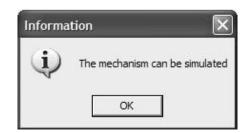
Joint Edition: Cylindrica	z (cymoneur)	
bointendiner je yindrical. 2	Joint geometry:	
Line 1: crank. 1/Pad. 1	Line 2: base.1/Solid.1	
Angle driven	Length driven	
- Joint Limits		
1st lower limit: Unset	🔄 🗆 1st upper limit: Unset	É
2nd Lower Limit: -360d	2nd upper limit: 360deg	•
		Cancel

Change the value of **2nd Lower Limit** to be 0.

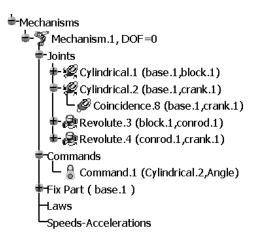
Joint name: Cylindrical.2			
	Joint geometry:		
Line 1: crank. 1/Pad. 1	Line 2: base. 1	/Solid, 1	
Angle driven	Length driven		
Joint Limits			
☐ 1st lower limit: Unset	🖆 🗌 1st upper limit:	Unset	É
2nd Lower Limit: 0deg	📮 🗖 2nd upper limit:	360deg	\$

Upon closing the above box and assuming that everything else was done correctly, the following message appears on the screen.

This indeed is good news.



According to CATIA V5 terminology, specifying **Cylindrical.2** as an **Angle driven** joint is synonymous to defining a command. This is observed by the creation of **Command.1** line in the tree.



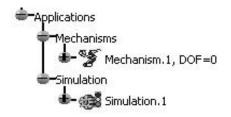
We will now simulate the motion without regard to time based angular velocity. Select



the Simulation icon *from the DMU Generic Animation toolbar*

This enables you to choose the mechanism to be animated if there are several present. In this case, select **Mechanism.1** and close the window.

As soon as the window is closed, a Simulation branch is added to the tree.



Select	
You can select your simula	tion objects
Mechanism. 1	
	OK Cancel

Kinematics Simulation	- Mechanism.1	?×
Command.1 0	360 0.0000	.
Check joint limits		
Reset	🗌 Keep posit	ion on exit

As you scroll the bar in this toolbar from left to right, the crank begins to turn and makes a full 360 degree revolution. Notice that the zero position is simply the initial position of the assembly when the joint was created. Thus, if a particular zero position had been desired, a temporary assembly constraint could have been created earlier to locate the

dit Simula			
Name: Simula	ition. 1		
Animate v			
Insert	Modify	Delete	Skip
Automatic	c insert		
Automatic Interference		Distance	
		Distance Off	<u>*</u>
Interferenc	e 👘		 objects

mechanism to the desired zero position. This temporary constraint would need to be deleted before conversion to mechanism joints.

When the scroll bar in the **Kinematics Simulation** pop up box reaches the right extreme end, select the **Insert** button **Insert** in the **Edit Simulation** pop up box shown above. This activates the video player buttons shown

		11	M			
--	--	----	---	--	--	--

Return the block to its original position by picking the **Jump to Start** button



Note that the **Change Loop Mode** button **is also active now**.

Upon selecting the **Play Forward** button **b**, the crank makes fast jump completing its revolution.

In order to slow down the motion of the crank, select a different **interpolation step**, such as 0.04.

Upon changing the interpolation step to 0 0.04, return the crank to its original position by picking

the **Jump to Start** button **K**. Apply **Play**

Forward button **I** and observe the slow and smooth rotation of the crank. It is likely that your slider will proceed beyond the end of the block; the entities involved in the joints are treated as infinite. If you wish, you may alter your block dimensions so the slider remains on the block.

dit Simulation	
K 4 H II	
1.00	1
Animate viewpoint	1 0.2
Insert Modify	0.1
Automatic insert	0.02 0.01
Interference	Distance
Off 🔄	Off
Edit analysis	Edit simulation objects
Edit se	ensors
	OK Can

Select the **Compile Simulation** icon **H** from the **Generic Animation** toolbar



and activate the option Generate an animation file. Now, pressing the File name button File name ... allows you to set the location and name of the animation file to be generated as displayed below.

Select a suitable path and file name and change the **Time step** to be 0.04 to produce a slow moving rotation in an AVI file.

Save As			?×		
Save in: CAT	_chapter_4_DMU_R14	• E 💣 🗉 •		Compile Simulation	?×
My Recent Documents Desktop My Documents My Computer				Generate a replay Name: Replay.1 Generate an animation file Microsoft AVI Control of the Microsoft AVI	▼ Setup File name ▼
My Network Places File name Save as to	-	<u> </u>	Save Cancel		OK Cancel

The completed pop up box is displayed for your reference.

As the file is being generated, the crank slowly rotates. The resulting AVI file can be viewed with the Windows Media Player.



Compile Simulation

In the event that an AVI file is not

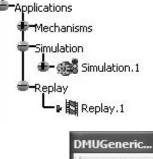
needed, but one wishes to play the animation, repeatedly, a **Replay** need be generated. Therefore, in the **Compile Simulation**

box, check the **Generate a replay** button.

Note that in this case most of the previously available options are dimmed out.

Generate a		n salan salan sa
Name: Replay.	1	
🗌 Generate a	n animation file Microsoft AVI	💌 Setup
		File name
Definition		
Simulation name	Simulation.1	
Time step:	0.04	
🗌 Animate vie	wpoint	

A **Replay.1** branch has also been added to the tree.





Select the **Replay** icon from the **Generic Animation** toolbar Double clock on **Replay.1** in the tree and the **Replay** pop up box appears. Experiment with the different choices of the **Change**

Loop Mode buttons **[]**, **[]**, **[]**.

The block can be returned to the original position by

picking the Jump to Start button

The **skip ratio** (which is chosen to be x1 in the right box) controls the speed of the **Replay**.

lame: Re	play.1			
	.00	-	x 1	
	e viewpoin analysis	t	8	

DMUPla..

Once a **Replay** is generated such as **Replay.1** in the tree above, it can also be played with a different icon.

Select the **Simulation Player** icon **the DMUPlayer** toolbar



The outcome is the pop up box above. Use the cursor to pick **Replay.1** from the tree.



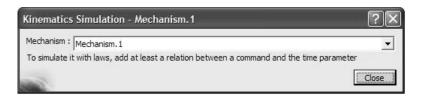
The player keys are no longer dimmed out. Use the **Play Forward (Right)** button **b** to begin the replay.

5 Creating Laws in the Motion

You will now introduce some time based physics into the problem by specifying the crank angular velocity. The objective is to specify the angular position versus time function as a constant 1 revolution/sec (360 degrees/sec).



Click on **Simulation with Laws** icon in the **Simulation** toolbar . You will get the following pop up box indication that you need to add at least a relation between a command and the time parameter.



To create the required relation, select the **Formula** icon $f \otimes$ from the **Knowledge**

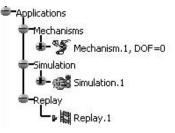


The pop up box below appears on the screen.

ormulas: slider_crank					? [×
				Impo	rt
Filter On slider crank					
Filter Name :					
Filter Type : All					
Double dick on a parameter to edit it	1	1 .	1 200011 2000 10		1.00
Parameter	Value	Formula		Active	^
crank\PartBody\Pad.1\FirstLimit\Length crank\PartBody\Pad.1\SecondLimit\Length	0.25in Oin				
crank/PartBody/Pad. 1/SecondLinit/Length	true				
crank/PartBody/Pad. 1/Sketch. 1/AbsoluteAxis/Activity	true				
crank\PartBody\Pad. 1\Sketch. 1\Tangency. 1\Activity	true				
crank\PartBody\Pad. 1\Sketch. 1\Tangency. 1\mode	Constrained				
crank\PartBody\Pad.1\Sketch.1\Tangency.1\display_parame	false				~
Edit name or value of the current parameter					
crank\PartBody\Pad.1\FirstLimit\Length	0.	25in	-		
New Parameter of type Real Vith Since	le Value	•	_	Add Form	ula
		_			
Delete Parameter				Delete For	nula
		9	OK	Apply	ancel

Point the cursor to the **Mechanism.1, DOF=0** branch in the tree and click. The consequence is that only parameters associated with the mechanism are displayed in the **Formulas** box.

The long list is now reduced to two parameters as indicated in the box.



ormulas: Mechanism.1			?
Incremental			Import
Filter On Mechanism. 1			
ilter Name :	-		
ilter Type : All	-		
ouble click on a parameter to edit it			
Parameter	Value	Formula	Active
Mechanism.1\KINTime	Os		
Mechanism.1\Commands\Command.1\Angle	Odeg		
dit name or value of the current parameter			
Edit name or value of the current parameter Mechanism.1\Commands\Command.1\Angle	[Odeg	4
Mechanism.1\Commands\Command.1\Angle	/ith Single Value	Odeg	
			Add Formula

Select the entry Mechanism.1\Commands\Command.1\Angle and press the Add Formula button Add Formula. This action kicks you to the Formula Editor box.

Incremental Mechanism. 1\Comman	ds\Con	nmand.1\Angle			=
Dictionary		Members of Parameters		Members of All	
Parameters Design Table Operators Point Constructors Law Line Constructors Circle Constructors String	~	All Renamed parameters Length Boolean CstAttr_Mode String Time Angle	*	crank\PartBody\Pad.1\F crank\PartBody\Pad.1\S crank\PartBody\Pad.1\S crank\PartBody\Pad.1\S crank\PartBody\Pad.1\S crank\PartBody\Pad.1\S crank\PartBody\Pad.1\S crank\PartBody\Pad.1\S crank\PartBody\Pad.1\S crank\PartBody\Pad.1\S	econdLimit\Lengt ketch. 1\Activity ketch. 1\Absolute ketch. 1\Tangenc

Pick the **Time** entry from the middle column (i.e., **Members of Parameters**) then double click on **Mechanism.1\KINTime** in the **Members of Time** column.

لیے۔ Mechanism. 1\Command	ds\Cor	nmand.1\Angle			=	
Dictionary		Members of Parameters		Members of Time		
Parameters Design Table Operators Point Constructors Law Line Constructors Circle Constructors String	< >	All Renamed parameters Length Boolean CstAttr_Mode String Time Angle	<	Mechanism. 1 (KINTime		

Since angle can be computed as the product of angular velocity (360deg)/(1s) in our case and time, edit the box containing the right hand side of the equality such that the formula becomes:

 $Mechanism.1 \setminus Commands \setminus Command.1 \setminus Angle =$ (360 deg)/(1s)*($Mechnism.1 \setminus KINTime$)

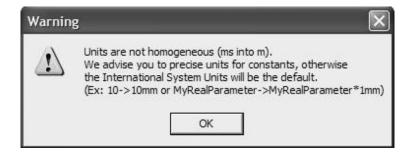
The completed **Formula Editor** box should look as shown below.

Formula Editor:Me	chanism.1\Commands\Command.1\/	Angle	?×
🗆 Incremental 🔎			0
Mechanism.1\Comman	ds\Command.1\Angle	=	
(360deg)/(1s)*/Mechan	ism.1\KINTime		
Dictionary	Members of Parameters Members	of Time	
Parameters Design Table Operators Point Constructors Law Line Constructors Circle Constructors String	All Mechanis Boolean CstAttr_Mode Length String Time Angle	sm. 1\KINTime	
Mechanism.1\KINTime		Os	۲
-		ОК	Cancel

Upon accepting **OK**, the formula is recorded in the **Formulas** pop up box as shown below.

ormulas: Mechanism.1			?
Incremental			Import
Filter On Mechanism.1			
Filter Name : *			
Filter Type : All	•		
Double click on a parameter to edit it			
Parameter	Value	Formula	Active
Mechanism.1\KINTime	Os		
Mechanism.1\Commands\Command.1\Angle	Odeg	= (360deg)/(1s)*Me	echanism yes
idit name or value of the current parameter Mechanism.1\Commands\Command.1\Angle		Ddeg	
,	,		
New Parameter of type Real	With Single Value	•	Add Formula
Delete Parameter			Delete Formula
		🕥 ок 🛛 🕯	Apply

Careful attention must be given to the units when writing formulas involving the kinematic parameters. In the event that the formula has different units at the different sides of the equality you will get **Warning** messages such as the one shown below.

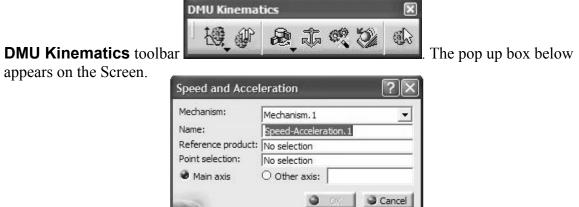


We are spared the warning message because the formula has been properly inputted. Note that the introduced law has appeared in **Law** branch of the tree.

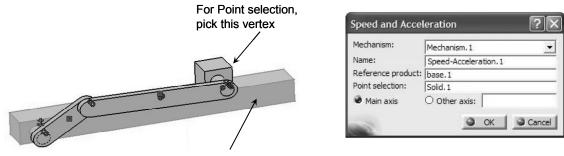


Keep in mind that our interest is to plot the position, velocity and accelerations generated

by this motion. To set this up, select the **Speed and Acceleration** icon **W** from the

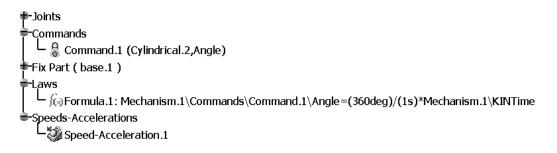


For the **Reference product**, select the **base** from the screen or the tree. For the **Point selection**, pick the vertex of the **block** as shown in the sketch below. This will set up the sensor to record the movement of the chosen point relative to the base (which is fixed).



For Reference product, pick the base

Note that the **Speed and Acceleration.1** has appeared in the tree.



Having entered the required kinematic relation and designated the vertex on the block as the point to collect data on, we will simulate the mechanism. Click on Simulation with





Laws icon 🔯 in the Simulation toolbar This results in the **Kinematics Simulation** pop up box shown below.

Note that the default time duration is 10 seconds.

To change this value, click on the button

. In the resulting pop up box, 0.000 change the time duration to 1s. This is the time duration for the crank to make one full revolution.

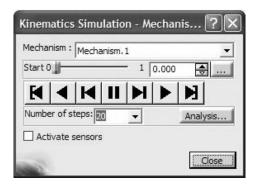
Simulation Duration	×
Maximum time bound: 1	
1	OK OK

Start 0 10 0.000	
Number of steps: 30 - Analys	sis

The scroll bar now moves up to 1s.

Check the **Activate sensors** box, at the bottom left corner. (Note: CATIA V5R15 users will also see a **Plot vectors** box in this window).

You will next have to make certain selections from the accompanying **Sensors** box.



	Values History				
Sensor			Unit	Observed	1
Mechanism. 1\Joints\Revolute	e.4\Angle	520	Degree	No	
Speed-Acceleration.1VX_Ve			Inch	No	
Speed-Acceleration.1\Y_Ve			Inch	No	
`Speed-Acceleration.1\Z_Ve			Inch	No	
`Speed-Acceleration.1\X_Lin			Inch per second	No	÷.
Speed-Acceleration.1\Y_Lin			Inch per second	No	
`Speed-Acceleration.1\Z_Lin			Inch per second	No	
Speed-Acceleration. 1\Linea			Inch per second	No	
`Speed-Acceleration.1\X_Lin			Inch per square s	No	
Speed-Acceleration. 1\Y_Lin			Inch per square s	No	*
Deselect	t All	1	Select All		
Display Options					-
All			O Limited 1		Li
Detect Clashes	Check Limits				
Automatic O Interference	es 🔮 Off	\bigcirc On	⊖ Sto	p	
6 6 8	Outputs				

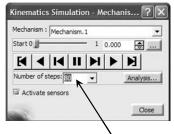
Observing that the coordinate direction of interest is X, click on the following items to record position, velocity, and acceleration of the block:

Mechanism.1\Joints\Cylindrical.1\Length Speed-Acceleration.1\X_LinearSpeed Speed-Acceleration.1\X_LinearAcceleration

As you make selections in this window, the last column in the **Sensors** box, changes to **Yes** for the corresponding items. This is shown on the next page. Do not close the **Sensors** box after you have made your selection (leave it open to generate results).

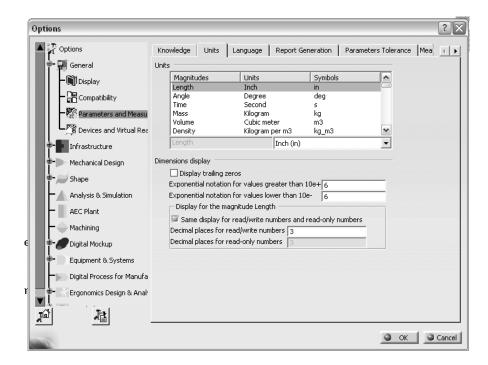
		ues History		
Sensor			Unit	Observed 🗸
Mechanism.1\J	ioints\Cylindrical.1	\Length	Inch	Yes
Mechanism.1\J	ioints\Cylindrical.1	\Angle	Degree	No
Mechanism.1\J	ioints\Cylindrical.2	2\Length	Inch	No
Mechanism.1\J	ioints\Cylindrical.2	?\Angle	Degree	No
	ioints\Revolute.3		Degree	No
Mechanism.1\J	loints\Revolute.4	Angle,	Degree	No
	ration.1\X_Verte:		Inch	No
	ration.1\Y_Verte:		Inch	No
	ration.1\Z_Verte:		Inch	No
	ration.1\X_Linear		Inch per second	
Course Accele		~J ^v	TL	
	Deselect All		Select .	All
-Display Options	;			
Display Options			O Limited	Li
-				
		Check Limits		
 All Detect Clashes 		Check Limits	O On (O Stop
II N		_	O On (O Stop

Also, change the **Number of steps to 80**. The larger this number, the smoother the velocity and acceleration plots will be.

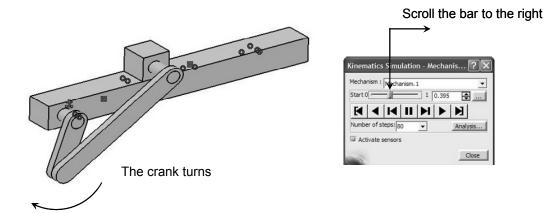


The larger this number, The smoother the plots

Note: If you haven't already done so, change the default units on position, velocity and acceleration to in, in/s and in/s^2 , respectively. This is done in the **Tools**, **Options**, **Parameters and Measures** menu shown on the next page.

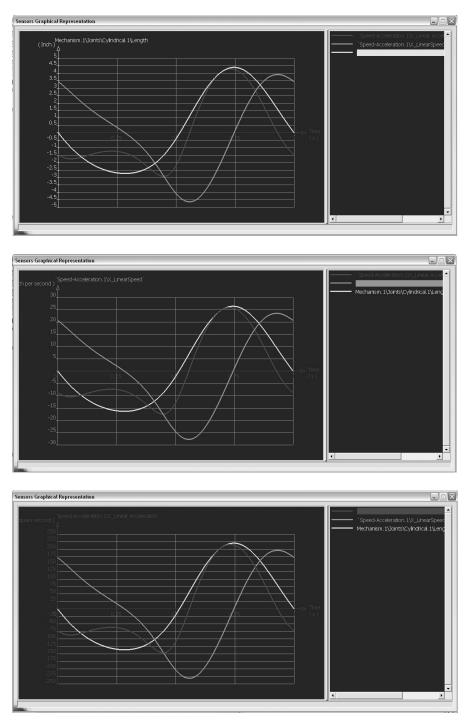


Finally, drag the scroll bar in the **Kinematics Simulation** box. As you do this, the crank rotates and the block travels along the base. Once the bar reaches its right extreme point, the crank has made one full revolution. This corresponds to 1s.



Outputs

Once the crank reaches the end, click on the **Graphics** button **Graphics** ... **Options** in the **Sensor** box. The result is the plot of the position, velocity and acceleration all on the same axis (but with the vertical axis units corresponding to whichever one of the three outputs is highlighted in the right side of the window). Click on each of the three outputs to see the corresponding axis units for each output. The three plots for position (corresponding to cylindrical joint Length), velocity (X_LinearSpeed), and acceleration (X_Linear_Acceleration) are shown below.



It is not uncommon that you may develop a variety of simulation results before determining exactly how to achieve the desired results. In this case, prior results stored need to be erased. To do this, click on the **History** tab

Time	Commands Value	Sensors	Value	Unit	Comment			~
0.0	0	`Spe	7	I				
0.0	4.5	'Spe	6	I				
0.0	9	`Spe	5	I				
0.0	13.5	`Spe	3	I				
0.0	18	`Spe	2	I				
0.0	22.5	'Spe	1	I				
0.0	27	`Spe	0	I				
0.0	31.5	`Spe	1	I				
0.1	36	`Spe	2	I				
0.1	40.5	'Spe	4	I				
0.1	45	`Spe	5	I				\mathbf{v}
				C	lear			
Display	Options							
All						🔿 Limite	d 1	Line
Detect	Clashes	C	heck Lin	nits				
Autor	matic 🔿 Interfere	nces 🗶	Off		⊖ On		○ Stop	
	<u> </u>	~ 1 -0	utputs					
160					ptions		File	

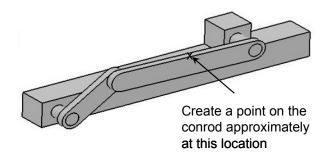
Use the **Clear** key

<u>Clear</u> to erase the values generated.

Selection Instantaneous Va	lues History				
Time Commands Value Sens	ors Value Unit C	Comment			
	Œet	ar			
Display Options	det	ar			
Display Options	Clei	ar	O Limited		Line
Display Options All Detect Clashes	Check Limits	ar		[1	
Display Options	Clei	ar O On			

Next, we will create a plot which is not simply versus time. As an illustrative example, we will place a point somewhere along the conrod. For this point, we will plot its linear speed and linear acceleration versus crank angle. It is important to note that DMU computes positive scalars for linear speeds and linear accelerations since it simply computes the magnitude based on the three rectangular components.

First, return to **Part Design** and create a reference point on the conrod at the approximate location as shown below. Return to **DMU**.



The plan is to generate two plots. The first plot is the speed of the created point against the angular position of the crank. The second plot is the acceleration of the created point against the angular position of the crank.

In order to generate the speed and acceleration data, you need to use the Speed and

Acceleration icon **Mathematics** toolbar

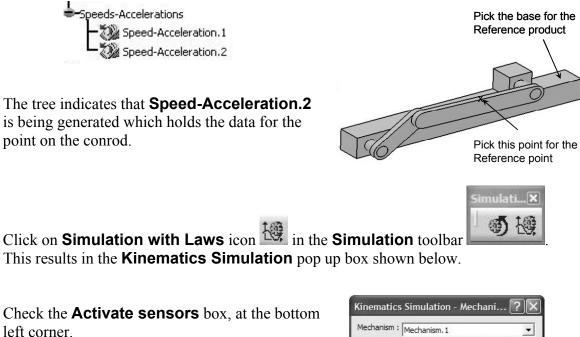


Click on

the icon and in the resulting pop up box make the following selections.

For **Reference product**, pick the base from the screen. For **Reference point**, pick the point that was created earlier on the conrod.

Mechanism:	Mechanism.1
Name:	Speed-Acceleration.2
Reference product:	base.1
Point selection:	Point.1
Main axis	O Other axis:



You will have to make the following selections from the accompanying **Sensors** box.

itart 0 📗 —		1 0.0	00 🍨	
[4 ◀	II №			
Number of ste	ps: 30	•	Analys	

ensors				?
Selection Instantaneous Va	alues History			
Sensor		Unit	Observe	ed 🔺
Mechanism. 1\Joints\Cylindrical. Mechanism. 1\Joints\Cylindrical. Mechanism. 1\Joints\Cylindrical. Mechanism. 1\Joints\Cylindrical. Mechanism. 1\Joints\Revolute. 3 Mechanism. 1\Joints\Revolute. 4 Speed-Acceleration. 1\Y_Verte Speed-Acceleration. 1\Y_Verte	1\LengthAngle 2\Length 2\LengthAngle \Angle x` x` x`	Inch Degree Inch Degree Degree Degree Inch Inch Inch	No No Yes No No No No No	
Speed-Acceleration. 1\X_Linea		Inch per		~
Display Options		O Lim	ited 1	Line
Detect Clashes Automatic O Interferences	Check Limits Off	O On	O Stop	
16 16 8	Outputs Graphics Op	tions	File	
				Close

If you scroll down the list, you will notice that the data from **Speed-Acceleration.1** and **Speed-Acceleration.2** are both available.

Click on the **History** tab History of the **Sensors** box and make sure that no data is present. Of course the data can be cleared using the Clear button.

In the **Sensors** box, click on the following line items; be careful as many entries look alike with minor differences.

Mechanism.1\Joints\Cylindrical.2\LengthAngle Speed-Acceleration.2\LinearSpeed Speed-Acceleration.2\Linear Acceleration

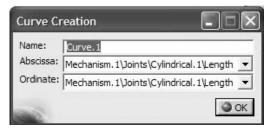
Note: Depending upon your installation, you may see Angle instead of LengthAngle.

As you make these selections, the last column in the **Sensors** box, changes to **Yes** for the corresponding items. Be sure you have picked Cylindrical.2 for the angle since this is the cylindrical joint at the crank connection to the base.

Pick the **Options** button **Options** in the Sensors box. The pop up box shown below appears. Check the **Customized** radio button.



Pick the **Add** button Add. The **Curve Creation** pop up box appears.



Use the pull down menu to make the following selections.

For Abscissa, select Mechanism.1\Joints\Cylindrical.2\LengthAngle For Ordinate, select Speed-Acceleration.2\LinearSpeed.

Name: Abscissa: Ordinate:	Curve.1
	Mechanism. 1\Joints\Cylindrical. 2\Length 4
	`Speed-Acceleration.2\LinearSpeed` 🔹

🔿 Versus time	Customized
Customized Cur	ves
Add Edit	Remove

Press **OK** to close the box. Note that **Curve.1** is now setup.

Pick the **Add** button Add once again.

The **Curve Creation** pop up box appears.

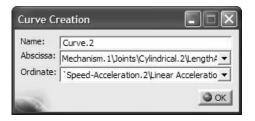
Use the pull down menu to make the following selections.

urve.2	_
echanism. 1\Joints\Cylindrical. 1\Length	-
echanism. 1\Joints\Cylindrical. 1\Length	•
	echanism. 1\Joints\Cylindrical. 1\Length

For Abscissa, select Mechanism.1\Joints\Cylindrical.2\LengthAngle For Ordinate, select Speed-Acceleration.2\Linear Acceleration

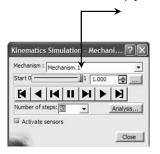
Press **OK** to close the box. Note that **Curve.2** is now setup.

O Versus time	Customized
Customized Cur	ves
Curve.1 Curve.2	
(Add) Edit	Remove



Close the Graphical Representation box.

Drag the scroll bar in the Kinematics Simulation box all the way to the right or simply click on Drag the scroll bar all the way to the right or simply click on



Outputs Once the crank reaches the end, click on **Graphics** button Graphics ... Options in the Sensor box. The **Multiplot** window appears and allows you to pick either **Curve.1**, or **Curve.2**.

The plots for **Curve.1** and **Curve.2** are shown on the next page.

