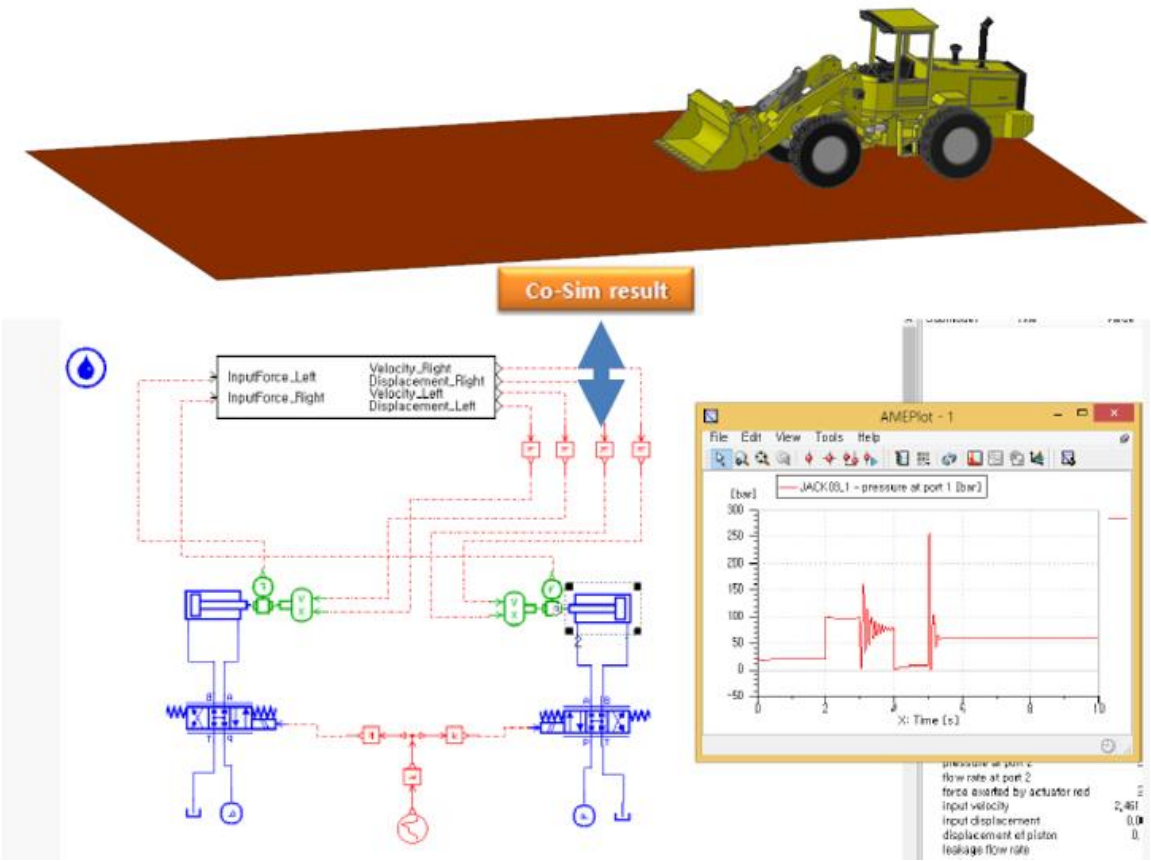
RECURDYN

Wheel Loader
(General CoSim with AMESim by FMI)



FunctionBay

Edition Note

This document describes the release information of **RecurDyn V9R4**.

Table of Contents

Chapter 1

Getting Started

This tutorial describes how co-simulation between RecurDyn and AMESim can be performed using the Functional Mockup Interface (FMI) method. RecurDyn handles kinematic analysis, and AMESim handles hydraulic system analysis, and these two analyses are co-simulated.

The model to be covered in this tutorial is a wheel loader vehicle model, which models the hydraulic actuator using AMESim and performs co-simulation with RecurDyn for steering control of the wheel loader.

Objective

This tutorial covers the following topics:

- How to create General Plant Input and Output in RecurDyn
- How to set up the environment of RecurDyn General CoSim FMI
- How to model AMESim Interface Block
- How to set up the environment of AMESim FMI
- How to perform co-simulation of the General CoSim FMI between RecurDyn and AMESim
- How to review the results with post-processing in RecurDyn

Prerequisites

- This tutorial is intended for users who have completed the basic tutorials provided with RecurDyn. If you have not completed these tutorials, then you should complete them before proceeding with this tutorial.
- The software for AMESim and Compiler must be installed to proceed with this tutorial. This tutorial is based on AMESim 2017 and **Microsoft Visual Studio 2012** is used as a compiler. Specifically, for AMESim 2017, only up to **Microsoft Visual Studio 2012** is supported, and the higher versions are not supported.

Procedures

This tutorial consists of the following tasks. The following table outlines the time required to complete each task.
(* The time required may vary depending on the specifications of the computer and the proficiency of the user.)

Task	Duration (minutes)
Modeling of General Input and Output in RecurDyn	10
Setting General CoSim FMI in Master Mode of RecurDyn	30
Setting General CoSim FMI in Slave Mode of RecurDyn	30
Result Analysis	10
Total	80

Estimated Time to Complete

80 minutes

Chapter

2

Modeling of General Plant Input and Output in RecurDyn

Task Objective

Learn how to create Plant Input and Output in **RecurDyn**.

Estimated Time to Complete

10 minutes

Opening the Model

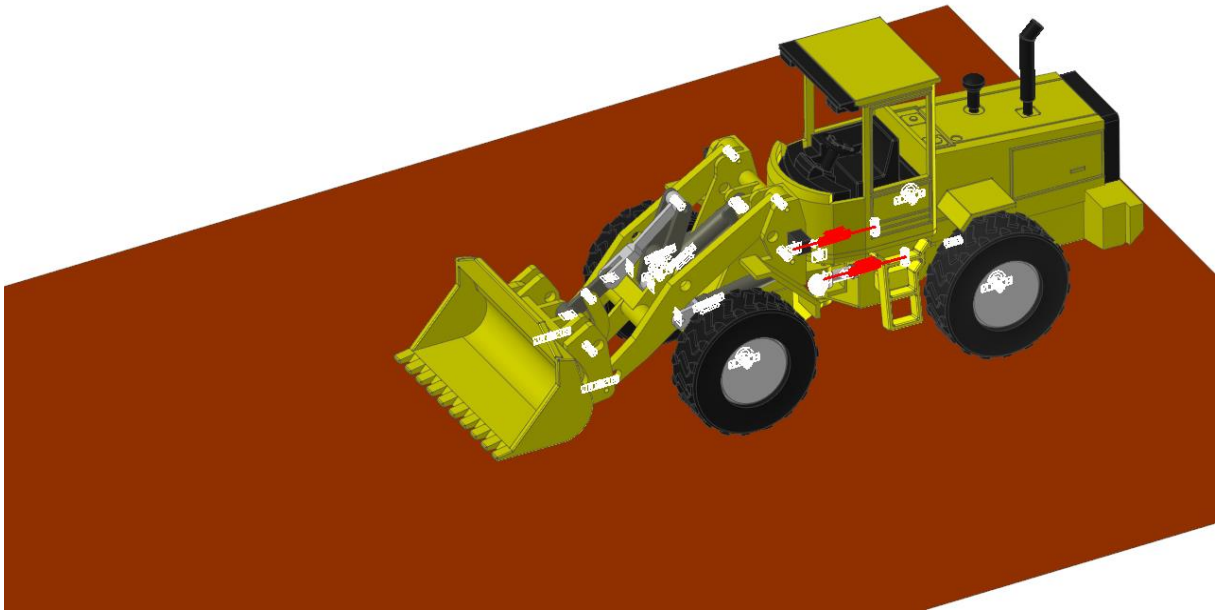
To copy the example model

- Copy the **FMI (AMESim)** tutorial example folder provided by **RecurDyn** to an analyzable location.
  Folder path: <Install Dir>\Help\Tutorial\Control\AMESim\WheelLoader

To run RecurDyn and open the initial model:

1. On the Desktop, double-click the **RecurDyn** icon to run **RecurDyn**. The **Start RecurDyn** dialog window will appear.
2. When the **Start RecurDyn** dialog window appears, close it.
3. In the **File** menu, click **Open**.
4. In the example folder copied above, select **WheelLoader_Start.rdyn**.
5. Click **Open**. The model appears as shown in the following figure.
6. In the **File** menu, click **Save As** and save the file as **WheelLoader_FMI.rdyn.**

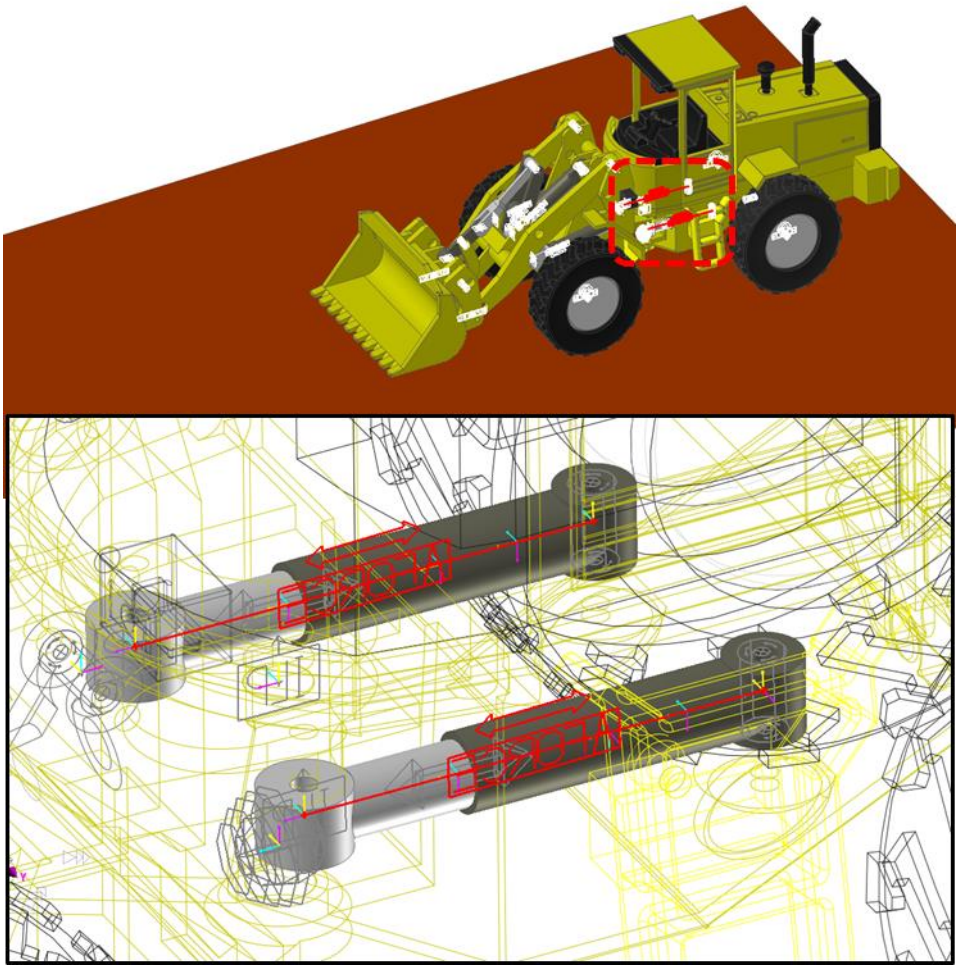
Tip: You need to specify the folder name so that there is no space in the path to save the model, so there is no problem in Co-Simulation process.



To analyze the model configuration:

1. In **Render Toolbar**, select **Each Render**.
2. In the Database window, select **Axial1** and **Axial2**.

Zoom in the two highlighted Axial Force elements. These two Axial Force elements are the actuators for steering the wheel loader.

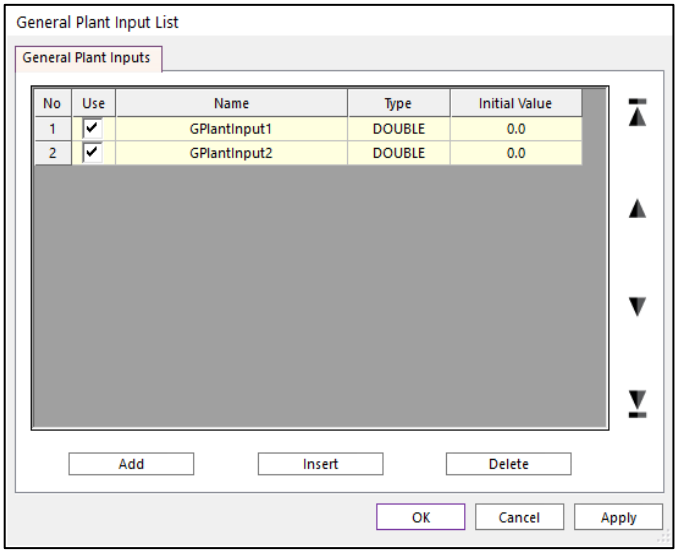


Creating General Plant Input

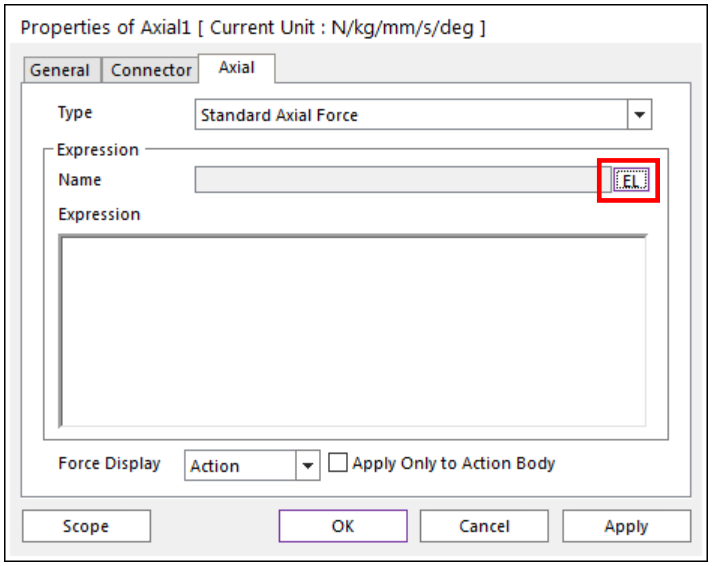
Create a General Plant Input to input the actuator hydraulic pressure generated in AMESim to the axial force.

To creating General Plant Input:

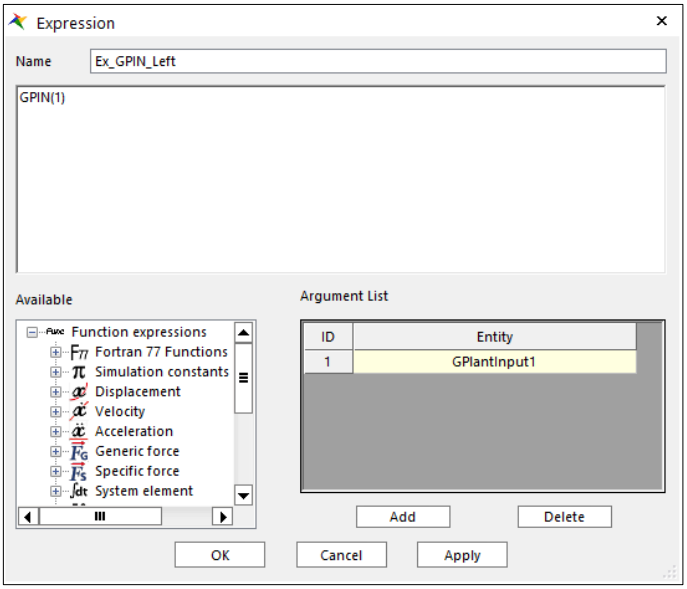
1. On the **Communicator** tab, in the **Control** group, click **GPlant_In (General Plant Input)**.
2. In the **General Plant Input List** window, click **Add** to create **GPlantInput1**. Click **Add** again to create **GPlantInput2**.
3. Click **OK** to close the **General Plant Input List** window.



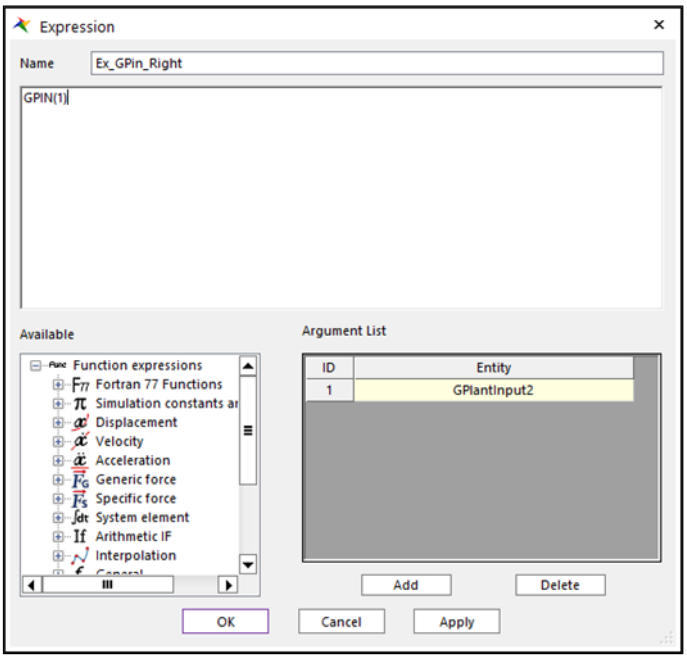
4. In the Database window, among the **Force** elements, right-click **Axial1** and click **Properties**.
5. Click the **EL** button in the **Expression** pane to open the **Expression List**. Then click the **Create** button.



6. As the **Expression Name**, enter "**Ex_GPIN_Left**".
7. For a function, enter **GPIN(1)**.
8. In **Argument List**, click **Add**.
9. From the database, drag & drop **PlantInput1** to the ID 1 of the **Argument List** as shown in the figure on the right.
10. Click the **OK** button to complete the **Expression** setup for **Axial1**.



11. Open the **Properties** dialog window for **Axial2** as well and complete the **Expression** setup for **Axial2** as shown in the figure on the right in the same manner as steps 5 to 10 above.

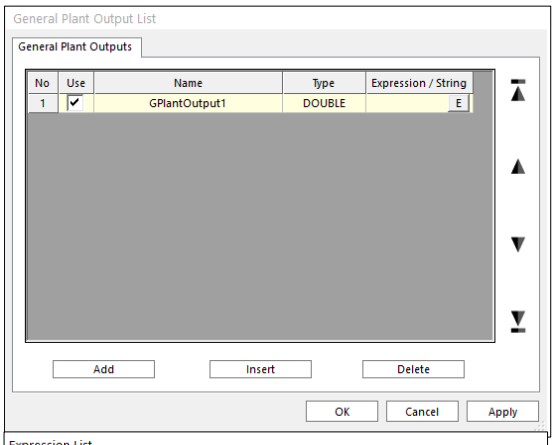


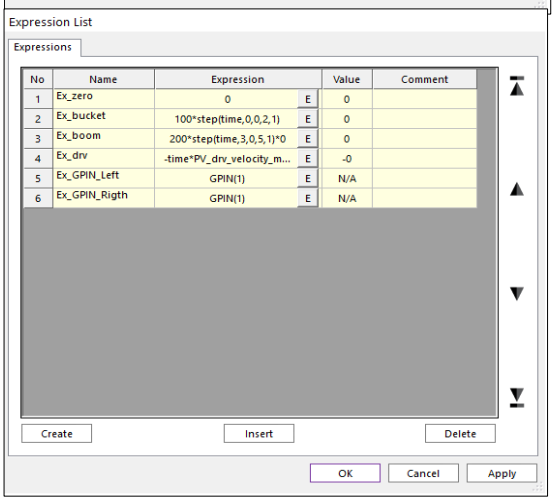
Creating General Plant Output

To transmit the detected values of actuator length and change speed for steering control of wheel loader to **AMESim**, create the **General Plant Output**.

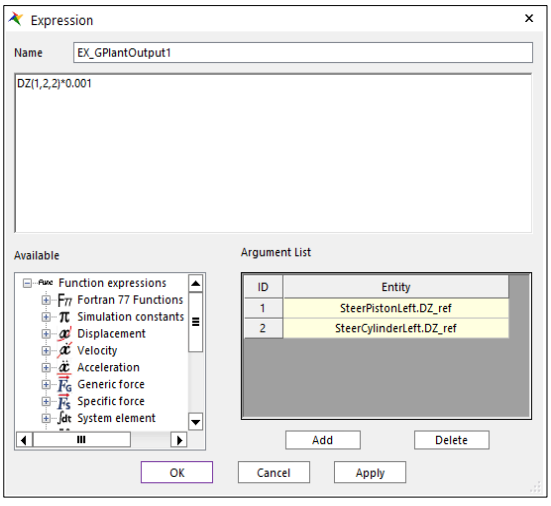
To create Plant Output:

1. On the **Communicator** tab, in the **Control** group, click **GPlant_out (General Plant Output)**.
2. In the **General Plant Output List** window, click **Add**.
3. If **GPlantOutput1** is created, click **E** under **Expression/String**.
4. In the **Expression List** window, click the **Create** button.

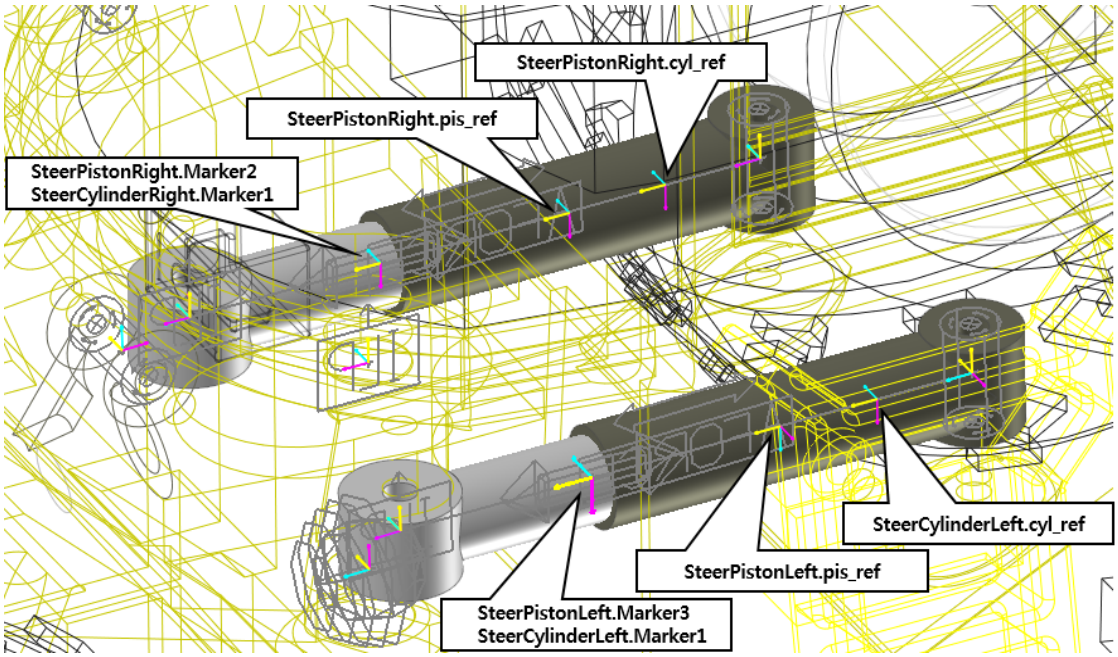




5. Change the **Name** of **Expression** to **Ex_GPlantOutput1**.
6. In the **Expression** window, enter the function **DZ(1,2,2)*0.001**.
7. In **Augment List**, click **Add** to make two **IDs**.
8. In the **Augment List**, enter the following two markers:
   - ID 1: SteerPistonLeft.DZ_ref
   - ID 2: SteerCylinderLeft.DZ_ref
9. Click **OK** to apply the changes.
10. In the **GPlant Output List** window, click **Add** to create **GPlantOutput2**.



11. In the **Expression List** window, click the **Create** button.
12. Change the **Name** of **Expression** to **Ex_GPlantOutput2**.
13. In the **Expression** window, enter the function **VZ(1,2,2)*0.001**.
14. In the Augment List, enter the following two markers:
    - ID 1: SteerPistonLeft.VZ_ref
    - ID 2: SteerCylinderLeft.VZ_ref
15. In the same manner as steps 1 to 14, create **GPlantOutput3** and **GPlantOutput4** by entering the following functions and markers in the **Augment List**.
    - GPlantOutput 3
        - Expression Name: Ex_GPlantOutput3
        - Function: DZ(1,2,2)*0.001
        - Augment List ID1: SteerPistonRight.DZ_ref
        - Augment List ID2: SteerCylinderRight.DZ_ref
    - GPlantOutput 4
        - Expression Name: Ex_GPlantOutput4
        - Function: VZ(1,2,2)*0.001
        - Augment List ID1: SteerPistonRight.VZ_ref
        - Augment List ID2: SteerCylinderRight.VZ_ref



Performing Simulation

Run the simulation to check the initial model status.

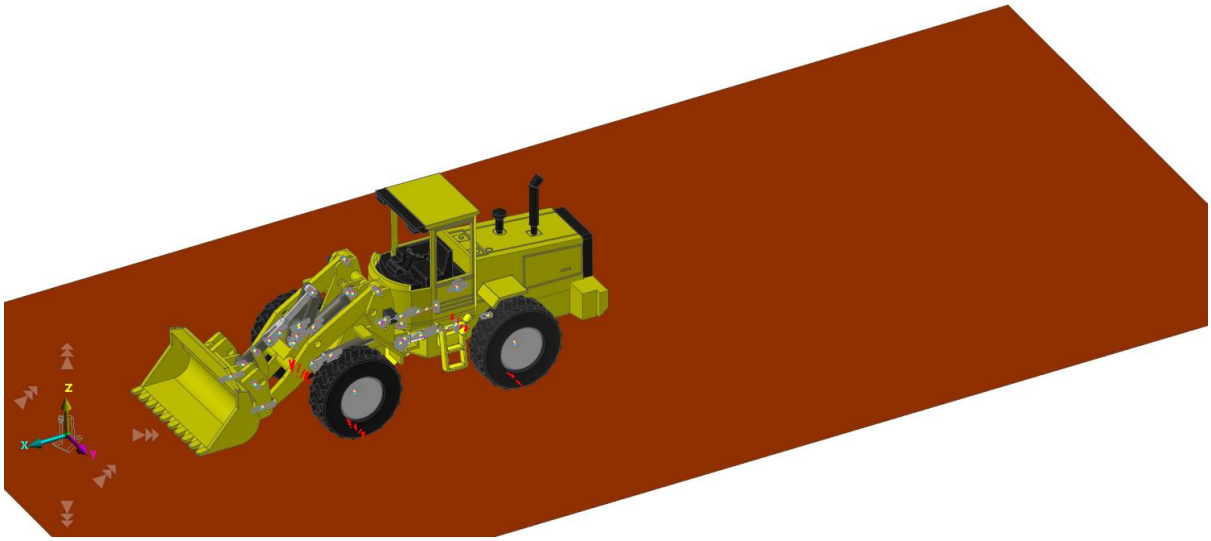
To run the simulation:

1. On the **Analysis Tab**, in the **Simulation Type** group, select **Dyn/Kin**. The **Dynamic/Kinematic Analysis** dialog window appears.
2. After entering parameters as follows, click the **Simulation** button.
   - End Time: 7
   - Step: 700

To view the result:

1. Under the **Analysis Tab**, in the **Animation Control** group, press the **Play** button to check if the wheel loader moves as shown in the figure below.

If the analysis is completed normally and there is no problem with the model, the wheel loader will go straight from the initial state to before the last 7 seconds. This is because the hydraulic pressure was not applied to the actuator for wheel loader steering.



Chapter

3

Setting General CoSim FMI in Master Mode of RecurDyn

Task Objectives

Learn how to perform **Co-simulation** by setting **General CoSim FMI** to **Master Mode** for **RecurDyn** and **Slave Mode** for **AMESim**. At this time, an **Interface Block** is required in the **AMESim** to exchange the detected values of the **RecurDyn** model mechanism and the hydraulic pressure generated in **AMESim**. Learn how to create the **AMESim Interface Block** model and configure FMI settings.

Estimated Time to Complete

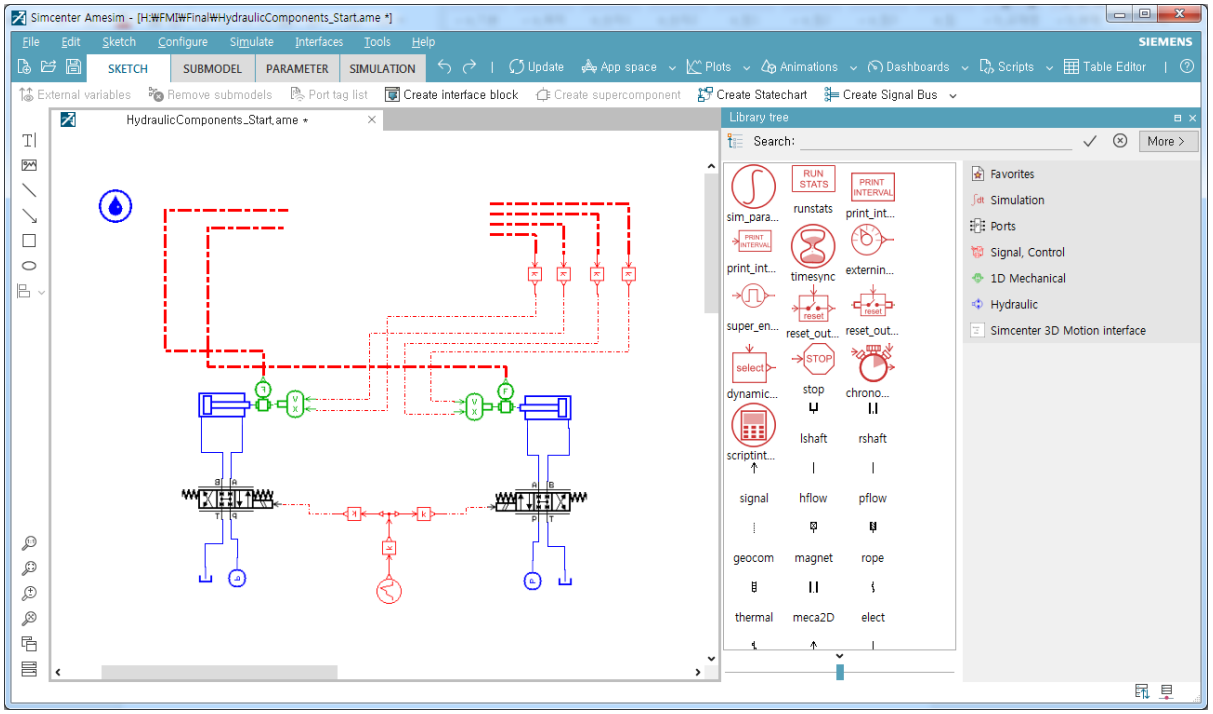
30 minutes

Importing the AMESim Model

AMESim model with an actuator is also available in the tutorial example folder copied in the previous chapter. Perform the **Interface Block** modeling by utilizing the provided model.

To run AMESim and import the initial model:

1. Double-click the **AMESim** icon on the Windows Desktop, etc. to run **AMESim**.
2. In the **File** menu, click **Open**.
3. In the example folder copied above, select **HydraulicComponents_Start.ame**.
4. Click **Open**. The AMESim model with an actuator is displayed as shown in the figure below.
5. Select **File > Save as** to change the name of the model file to **HydraulicComponents_fmu_export.ame**.

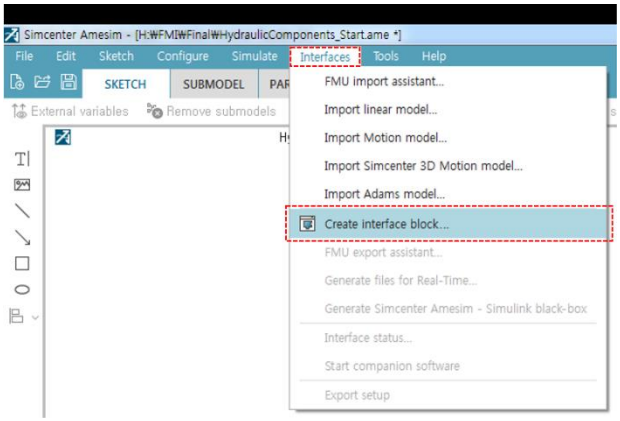


Modeling of AMESim Interface Block

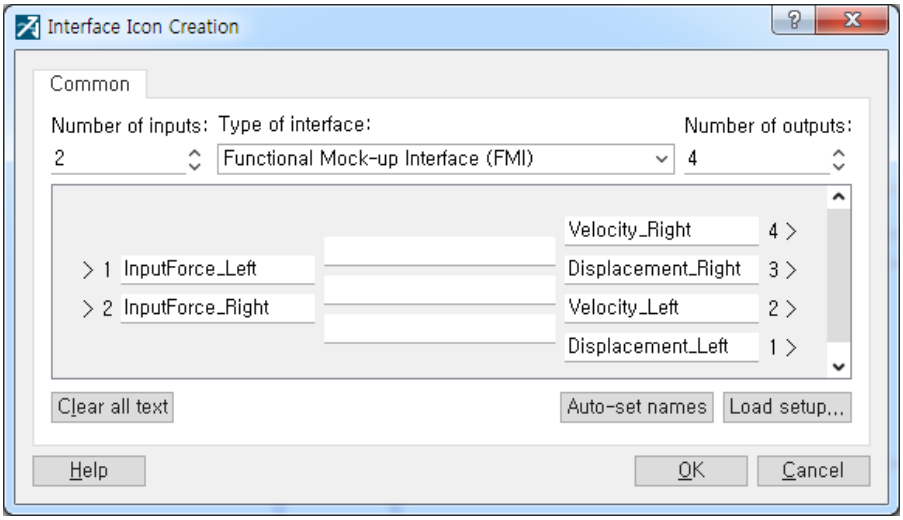
To create AMESim Interface Block:

1. Click **Menu > Interfaces > Create Interface Block** to create an **Interface block**.

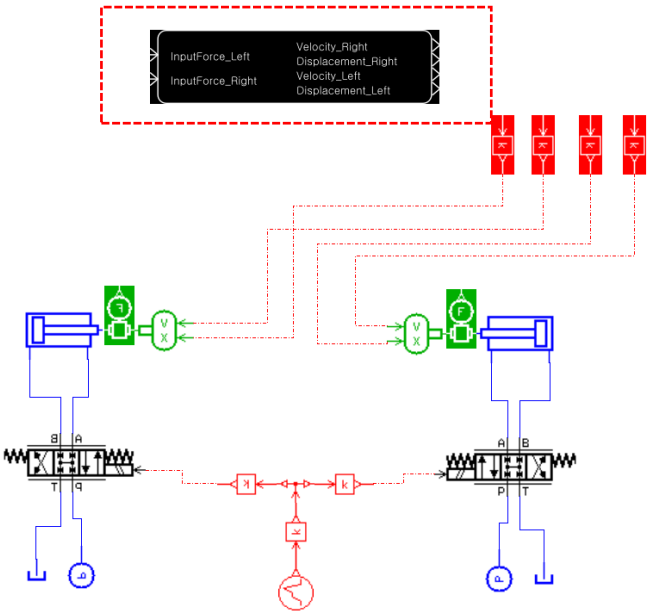
   (Menu positions may vary depending on the **AMESim** version.)



2. In the **Interface Icon Creation** dialog window, set the **Number of inputs** to two.
3. **Change Type of interface** to **Functional Mock-up Interface (FMI)**.
4. Set the **Number of outputs** to four.
5. Enter the names of the **Inputs** in the correct order as follows.
   - >1: InputForce_Left
   - >2: InputForce_Right
6. Enter the names of the **Outputs** in the correct order as follows.
   - 4>: Velocity_Right
   - 3>: Displacement_Right
   - 2>: Velocity_Left
   - 1>: Displacement_Left
7. Click the **OK** button to complete creation.

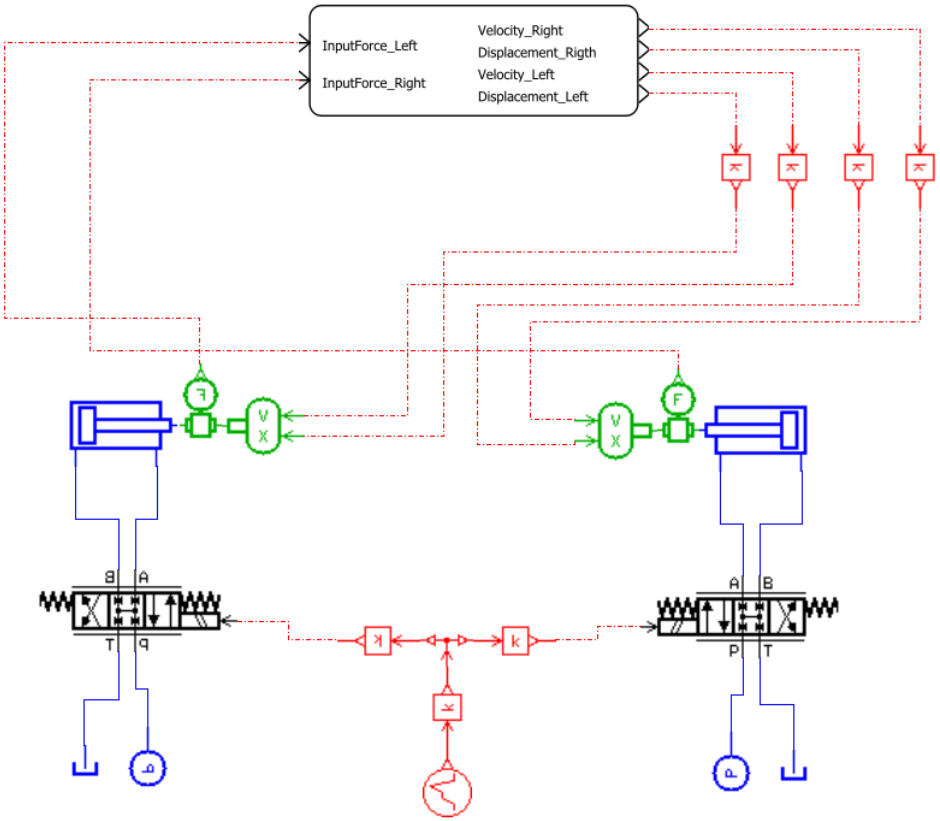


8. When the **Interface block** appears in the modeling window, move the block with the mouse.



To connect the AMESim Interface Block:

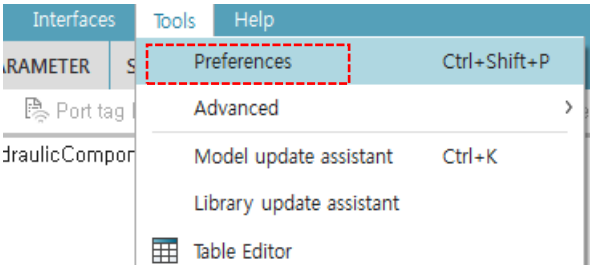
1. Connect the **Interface block** and the actuator elements as shown in the figure below. If the connection is different from the figure, you may get incorrect results. Therefore, it must be correctly connected to the port of the actuator component and the **Input & Output** port of the **Interface block** as shown in the figure below.



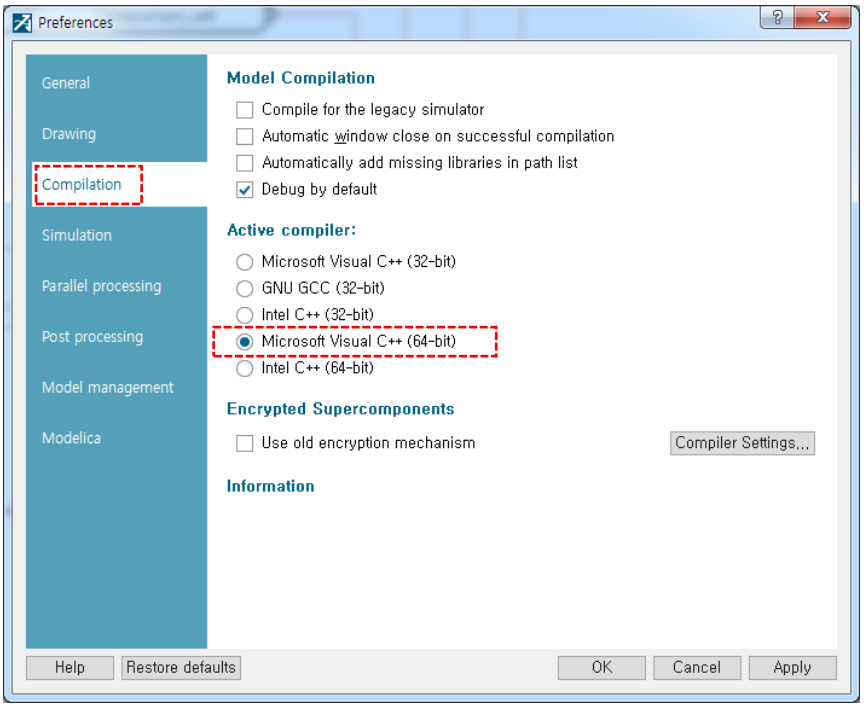
Setting AMESim FMI

To set the environment of AMESim Compiler:

1. Click **Menu > Tool > Preferences** to run it.



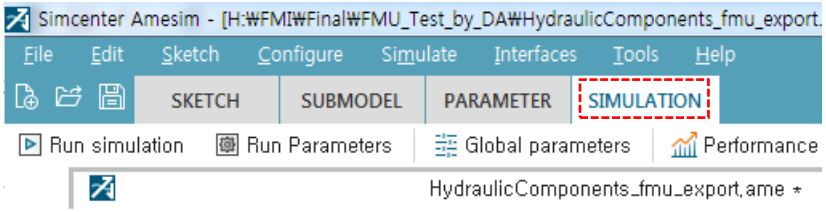
2. In the **Preferences** dialog window, click the **Compilation** tab.
3. Under the **Model Compilation**, check the **Debug by default** option.
4. Under the **Active compiler**, select **Microsoft Visual C++ (64-bit)**.



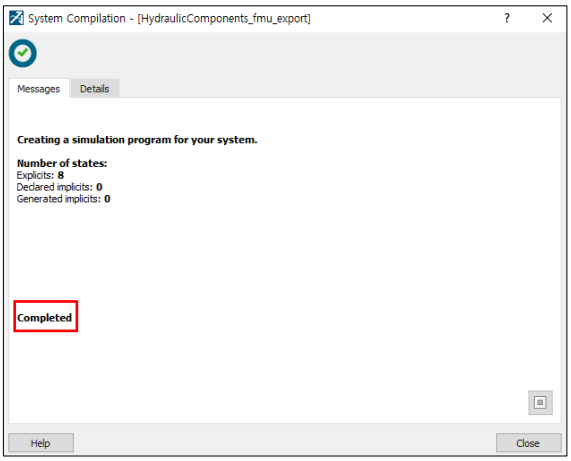
Exporting AMESim FMU

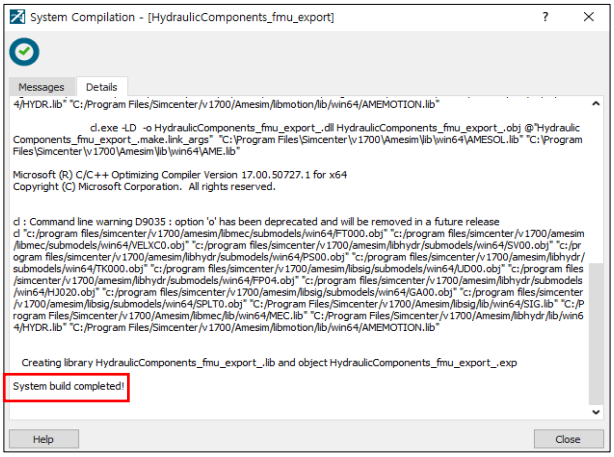
To export *.fmu file in AMESim:

1. Click the **SIMULATION** Tab to change mode.

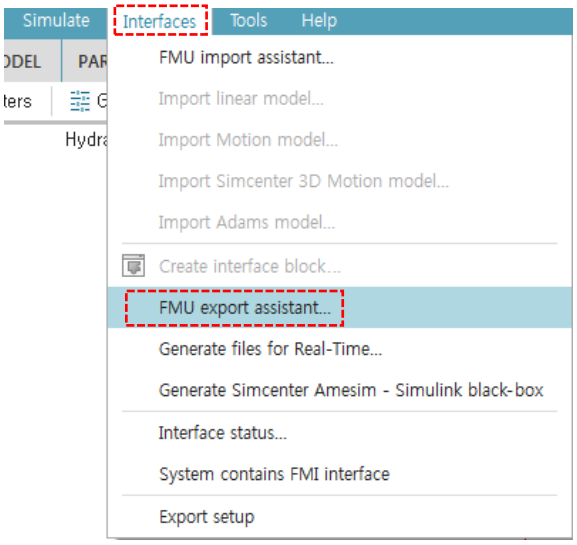


Tip: You can check the **Build** status of the model by checking the **Completed message** on the **Message Tab** and the **System build completed message** on the **Details Tab**.

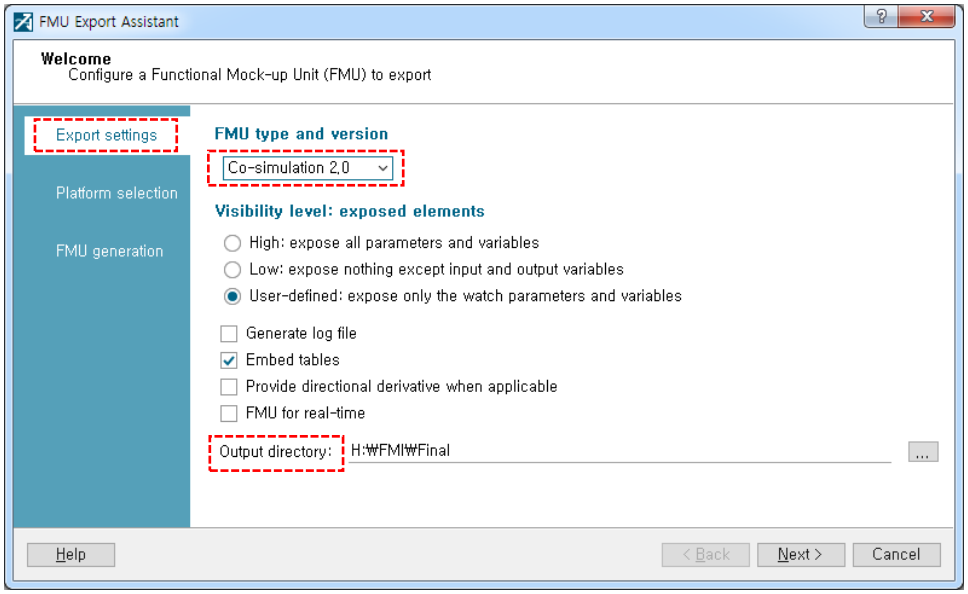




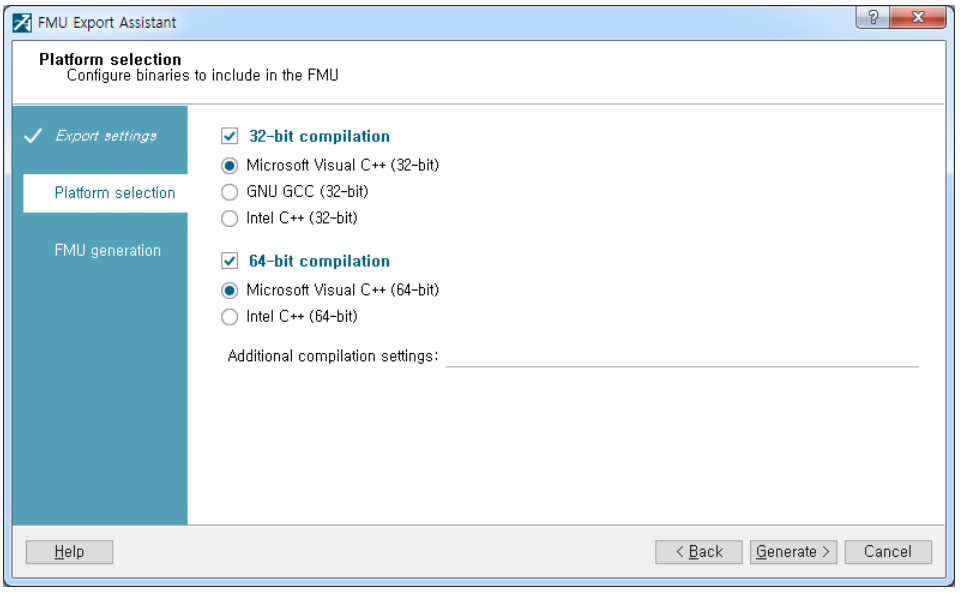
2. Click **Menu > Interfaces > FMU export assistant...**.



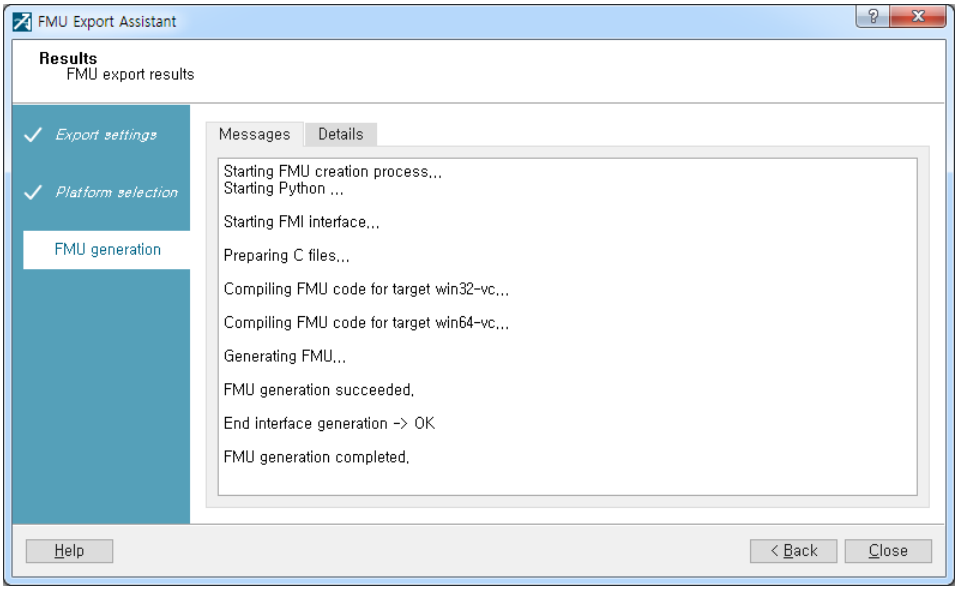
3. In the **Export settings** page, set **FMU type and version** to **Co-simulation 2.0**.
4. Set the **Output directory** to the folder where the **RecurDyn** file of this manual is located.
5. Click the **Next** button.



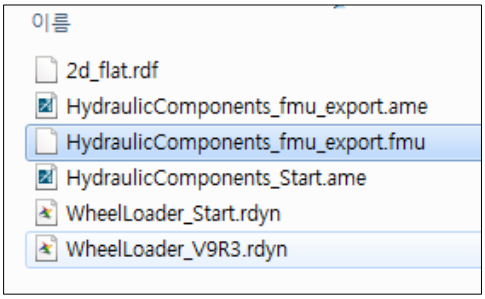
6. On the **Platform selection** tab, verify that the **compiler** is set to **Microsoft Visual C++**.
7. Click the **Generate** button to begin creating the ***.fmu** file and exporting the file.



8. Export the *.fmu file generated by **AMESim** to the location you set.



9. You can see that the *.fmu file is created in the folder as shown on the right:



Setting General CoSim FMI in RecurDyn

To set the environment of FMI Co-Sim in RecurDyn:

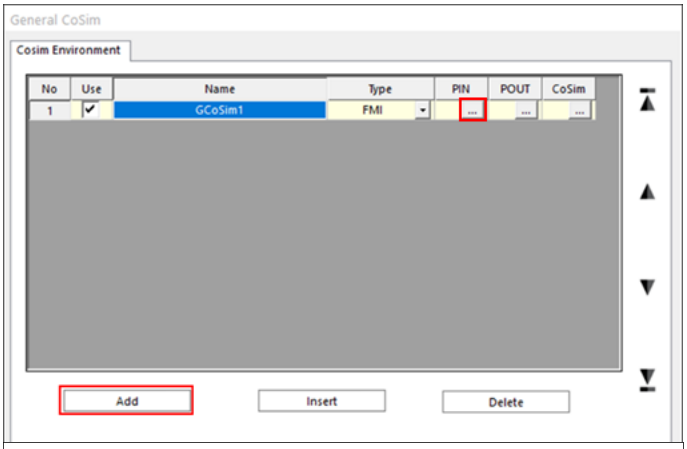
1. On the **Communicator** tab, in the **Control** group, click **GCoSim**.

2. In the **General CoSim window**, on the **CoSim Environment** page, click the **Add** button.

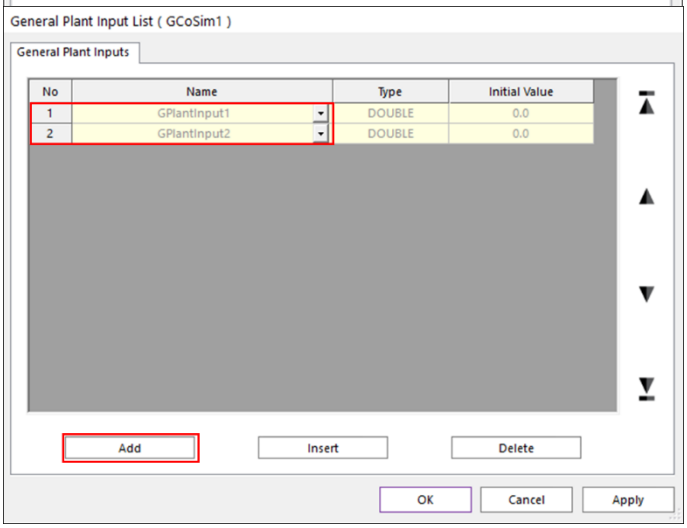
3. Set **Name** to GCoSim1.

4. Select **Type** to **FMI**.

5. Click the ... button under **PIN**.

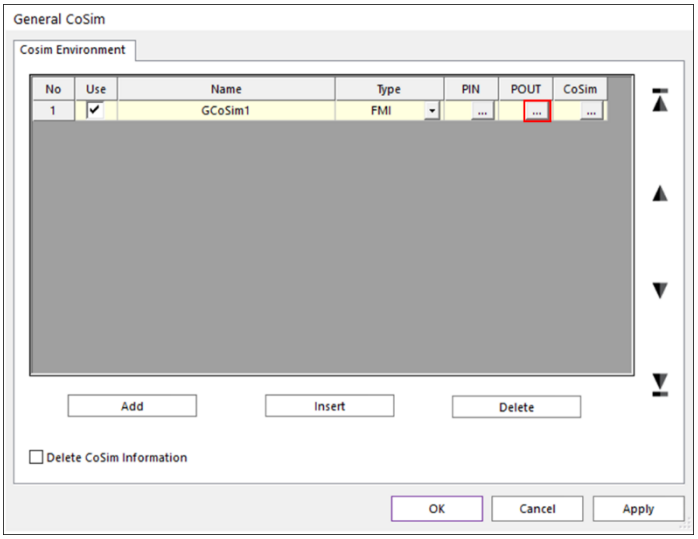


6. In the **General Plant Input List (GCoSim1)** window, click **Add** twice to add **GPlantInput1** and **GPlantInput2**.



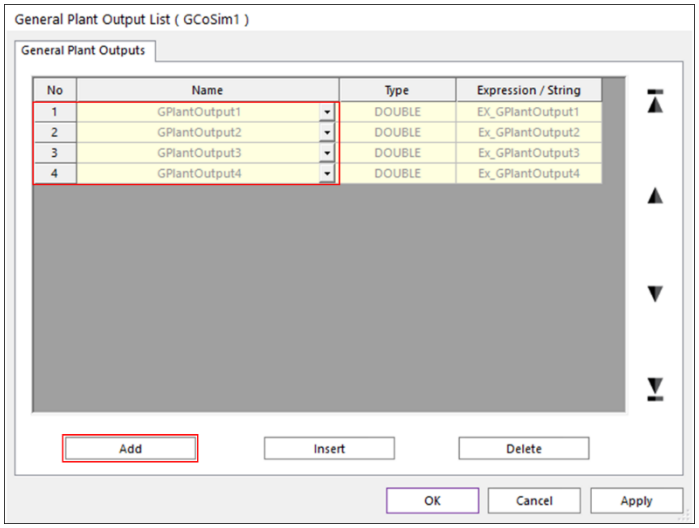
7. Click the **OK** button.

8. In the **General CoSim** window, on the **CoSim Environment** page, click the ... button under POUT.

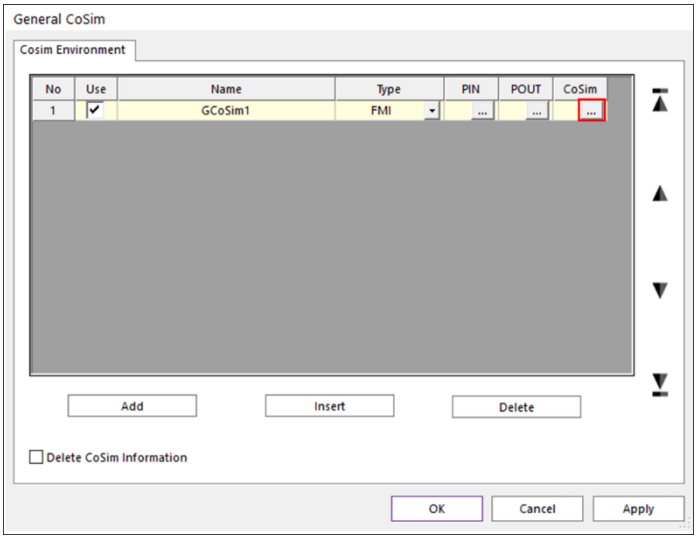


9. In **General Plant Output List (GCoSim1)** window, click the **Add** button four times to add four GPlantOutputs.

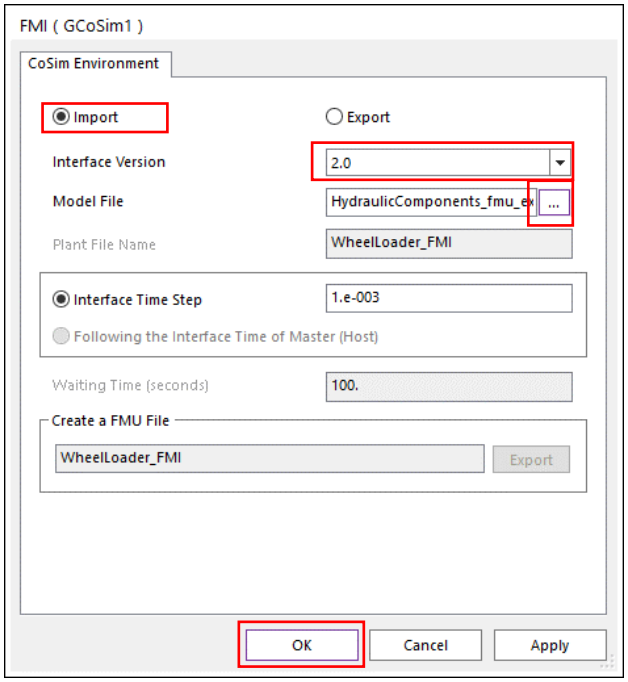
10. Click the **OK** button.



11. In the **General CoSim** window, on the **CoSim Environment** page, click the ... button under CoSim.



12. In the **FMI (GCoSim1)** dialog window, on the **CoSim Environment** page, select the Import option.
13. Set **Interface Version** to 2.0.
14. In Model File, click the ... button, and select **HydraulicComponents _fmu_export.fmu** file created in the Open dialog window.
15. Click the **OK** button in the **FMI (GCoSim1)** dialog window to complete the settings.
16. In the **General CoSim** window, on the **CoSim Environment** page, click the **OK** button to complete the settings.



RecurDyn Master Mode Co-simulation

Performing co-simulation in RecurDyn

Co-simulate the wheel loader model of **RecurDyn** and the actuator model of **AMESim** using **FMI**.

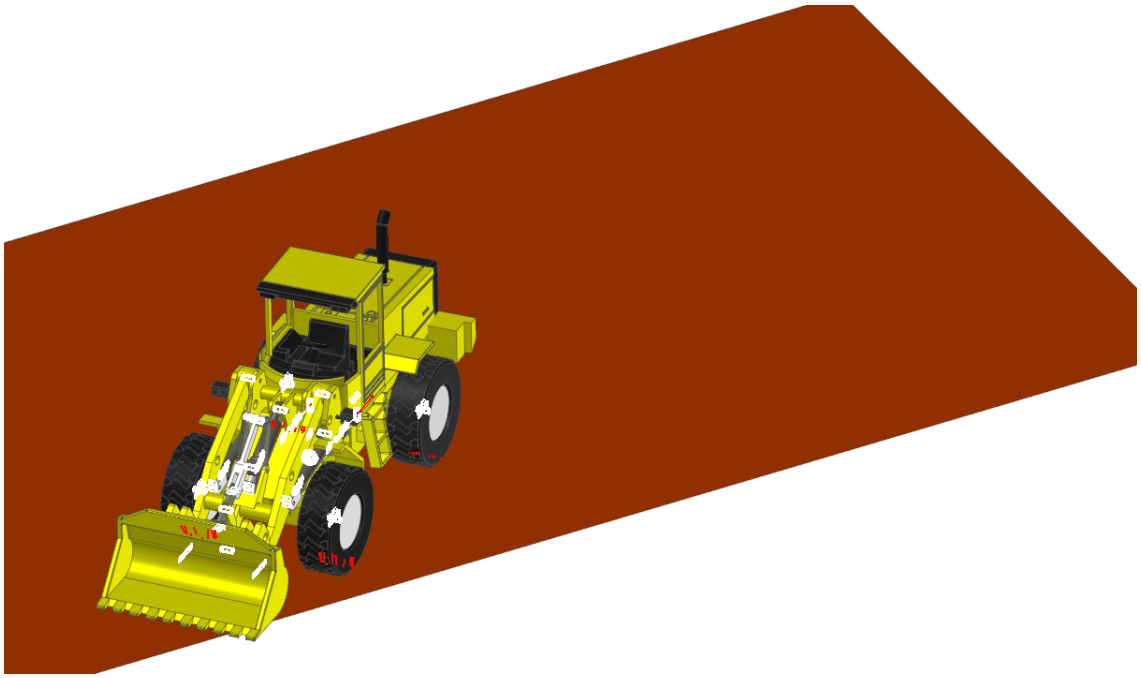
To run the simulation:

1. On the **Analysis Tab**, in the **Simulation Type** group, select **Dyn/Kin**. The **Dynamic/Kinematic Analysis** dialog window appears.
2. After entering parameters as follows, click the **Simulation** button.
   - End Time: 7
   - Step: 700

To view animation result:

1. On the **Analysis Tab**, in the **Animation Control** group, click the **Play** button to check if the wheel loader moves as shown in the figure below.

   ※ If co-simulation is successfully completed between RecurDyn and AMESim, the wheel loader will move to the left. This is because the hydraulic pressure is generated in the actuator in AMESim for wheel loader steering and this hydraulic pressure is applied to the actuator in RecurDyn.



Chapter

4

Setting General CoSim FMI in Slave Mode of RecurDyn

Task Objectives

In this chapter, as opposed to the previous one, you will learn how to perform **FMI Co-simulation** by setting **RecurDyn** to **Slave Mode** and **AMESim** to **Master Mode**.

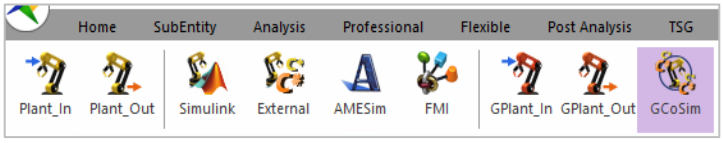
Estimated Time to Complete

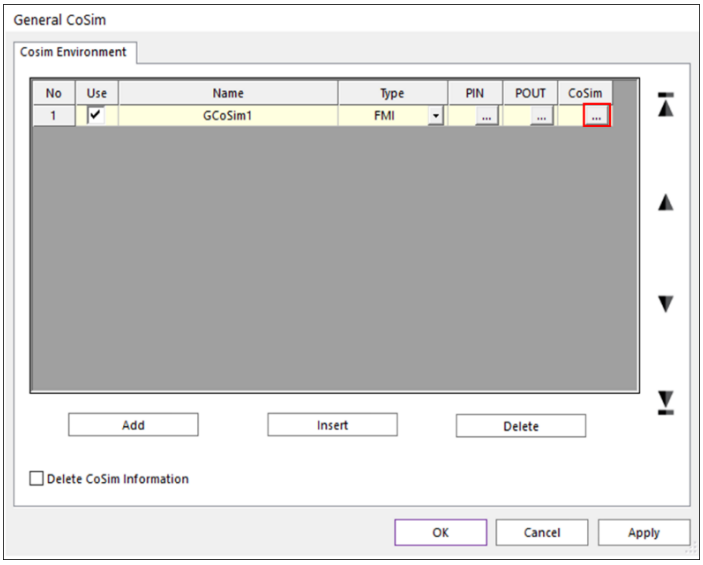
30 minutes

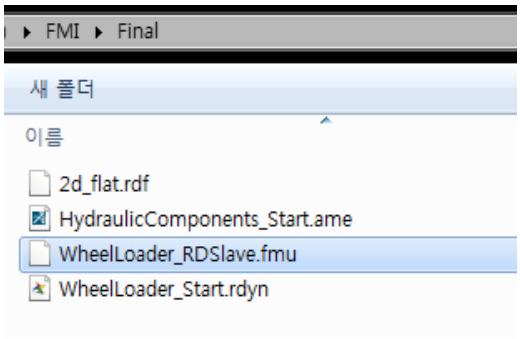
Setting General CoSim FMI in RecurDyn

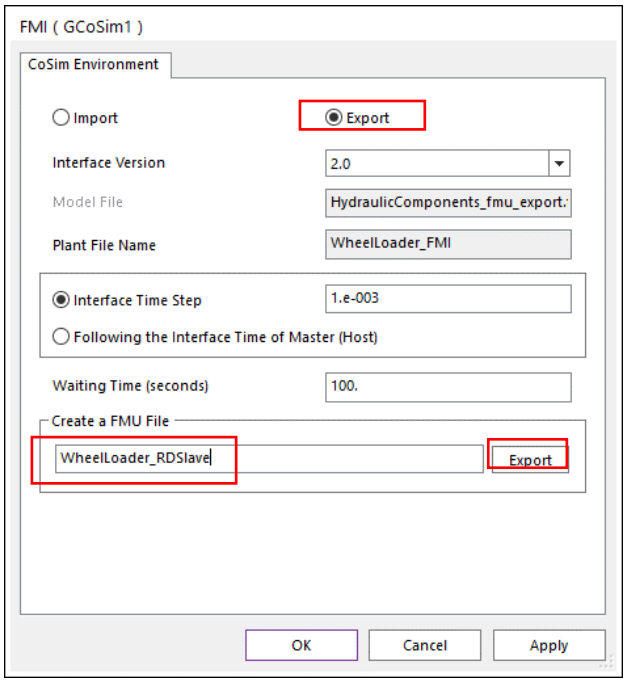
To set the environment of FMI Co-Sim in RecurDyn:

1. On the **Communicator** tab, in the **Control** group, click **GCoSim**.
2. In the **General CoSim** window, on the **CoSim Environment** page, click the ... button under **CoSim**.
3. In the **FMI** dialog window, on the **CoSim Environment** page, select the **Export** option.
4. Set **Interface Version** to **2.0**.
5. In **Create a FMU File**, set the name of the file to **WheelLoader_RDSlave**.
6. Click the **Export** button to export the ***.fmu** file.





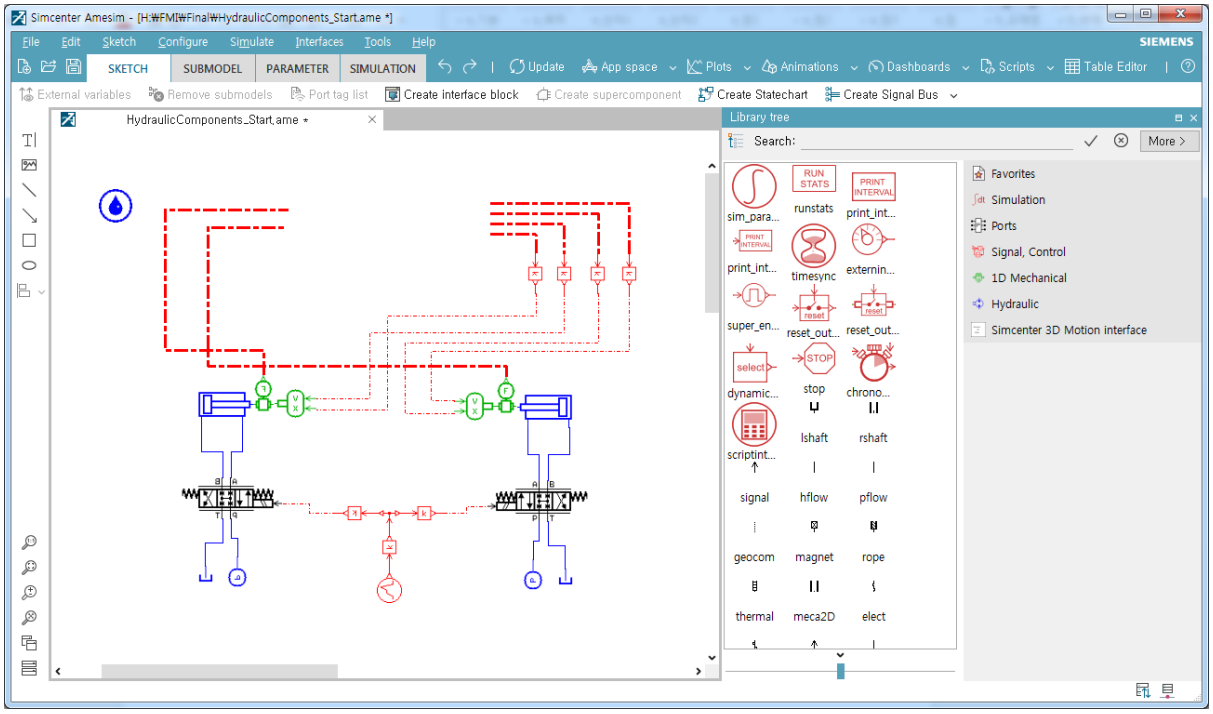




Setting AMESim FMI

To run AMESim and import the initial model:

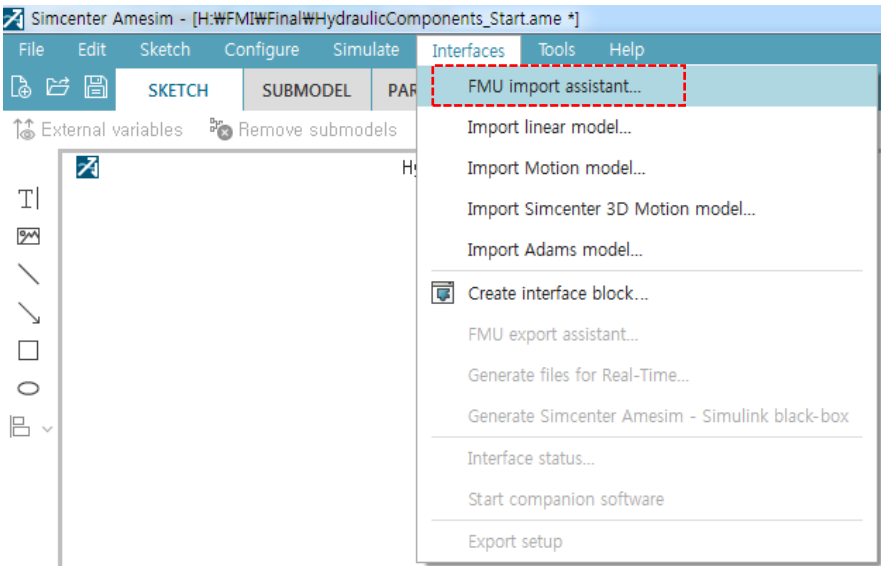
1. Double-click the **AMESim** icon on the Desktop of Windows, and then run **AMESim** again.
   (※ If AMESim is already running, close it and run it again.)
2. In the **File** menu, click **Open**.
3. In the example folder copied above, select **HydraulicComponents_Start.ame**.
4. Click **Open**. The AMESim model with the actuator is displayed as shown in the figure below.
5. Select **File > Save as** to change the name of the model file to **HydraulicComponents_fmu_import.ame**.



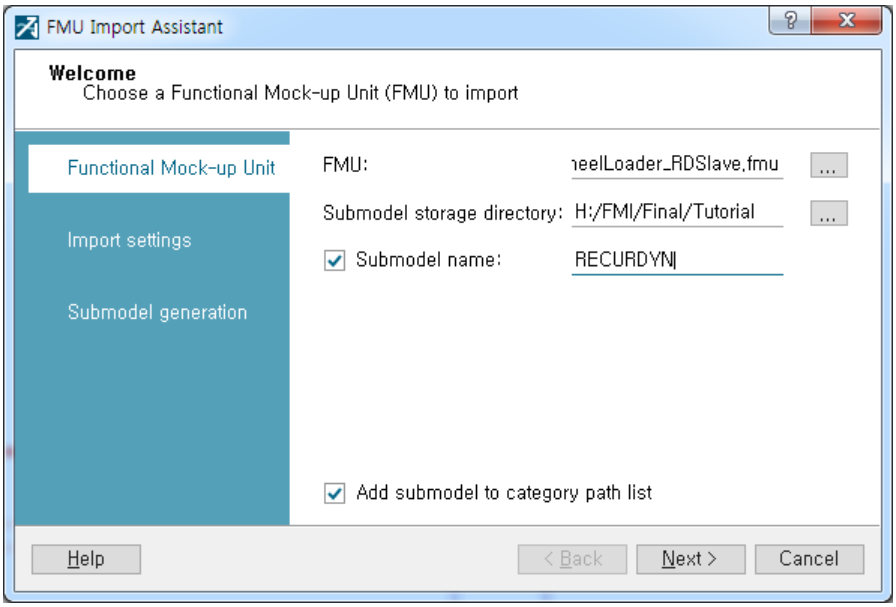
Modeling of AMESim Interface Block

To import FMU Interface Block:

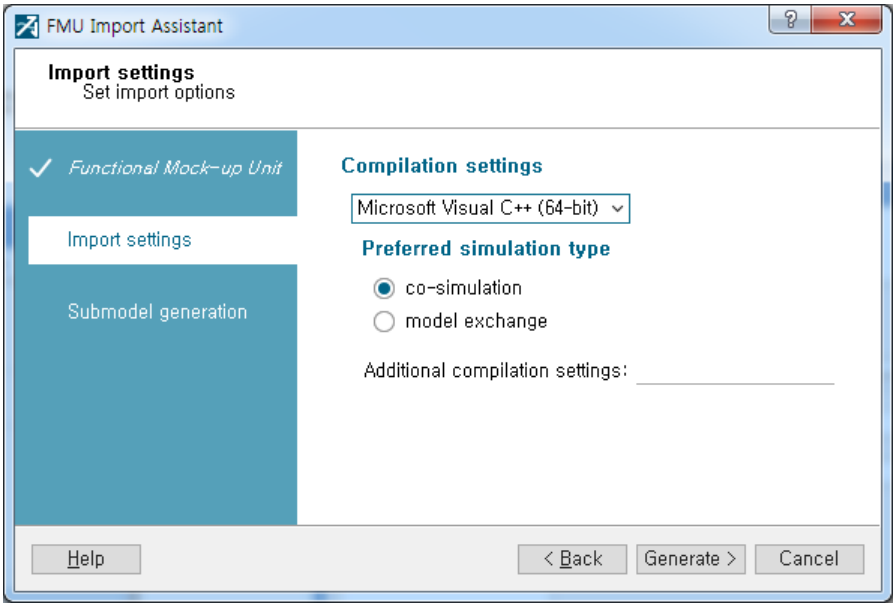
1. Click **Menu > Interfaces > FMU import assistant...**.



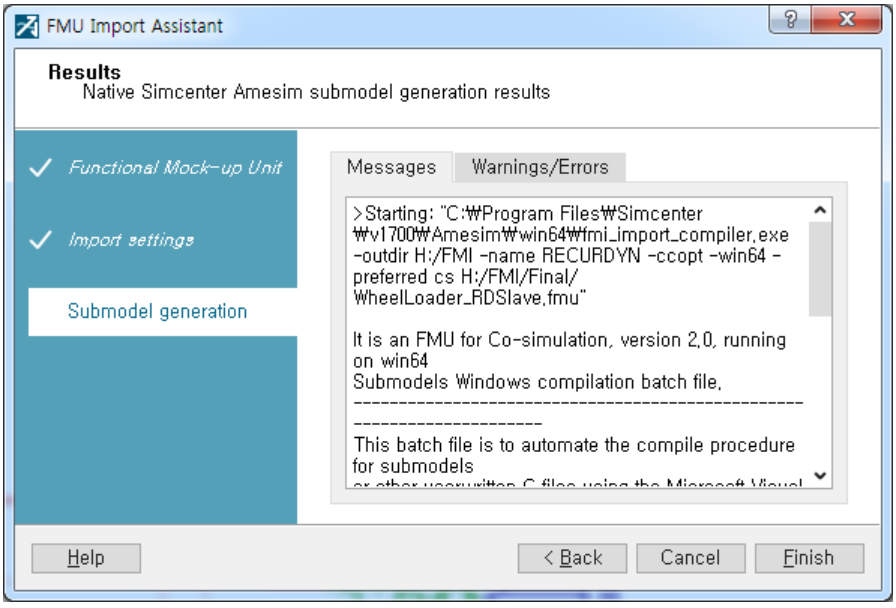
2. On the **Functional Mock-up** page, in the **FMU** setting, connect the **WheelLoader_RDSlave.fmu** file created by **RecurDyn**.
3. Set the **Submodel storage directory** to the folder where the files ***.rdyn** and ***.ame** are located.
4. Set the name of **Submodel** to **RECURDYN**.
5. Click the **Next** button.



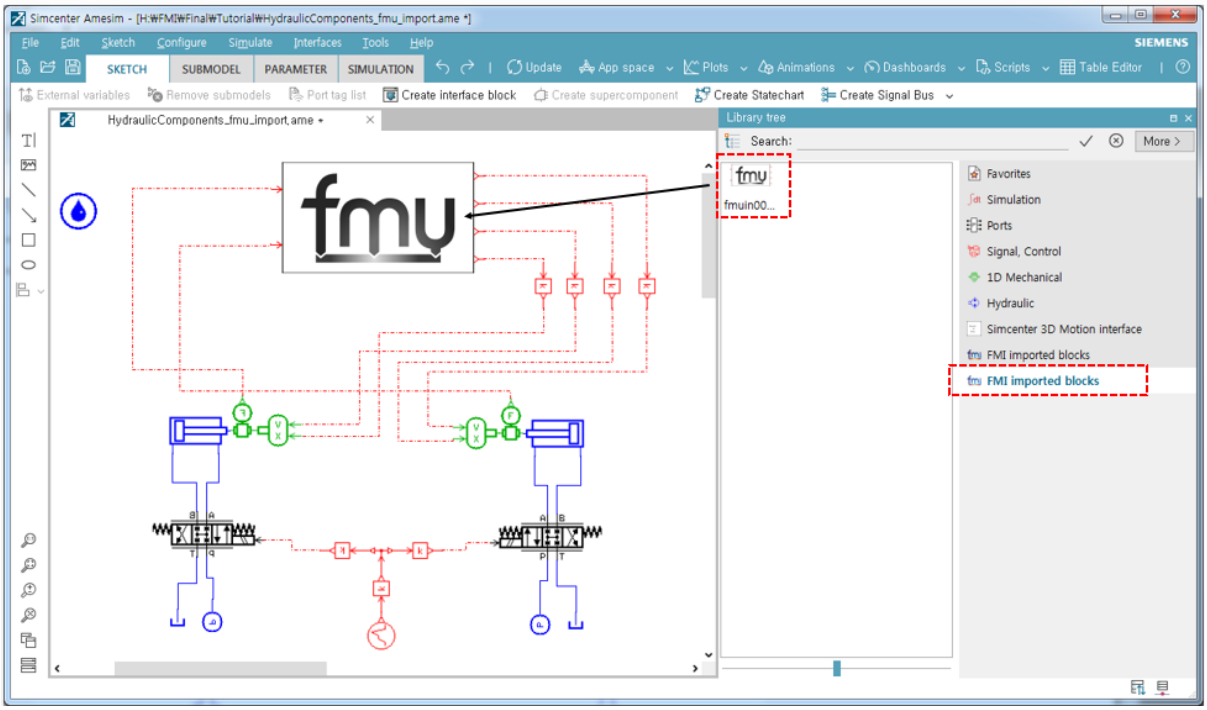
6. On the **Import settings** page, under **Compilation settings**, set the **Compiler** option to **Microsoft Visual C++(64-bit)**.
7. Set the **Preferred simulation type** to **co-simulation**.
8. Click the **Generate** button.



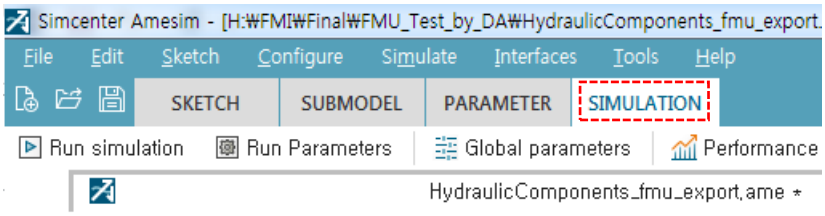
9. Check the **messages** to see whether **Submodel generation is** completed, and click the **Finish** button.



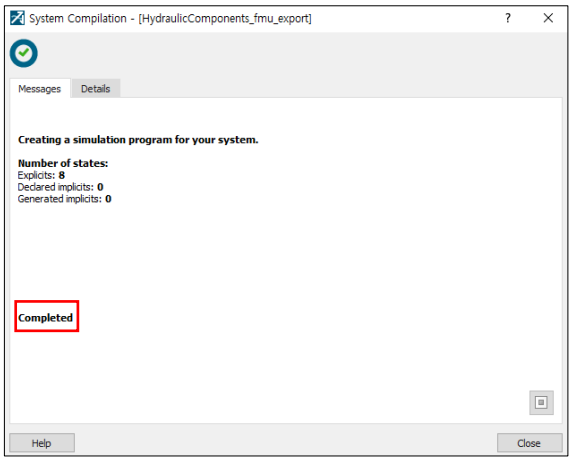
10. In **Library tree**, click **FMI imported blocks** to see the **fmu** block model. Create this **fmu** block in the AMESim model by **dragging & dropping** the block and connect it with other elements as shown in the figure below.

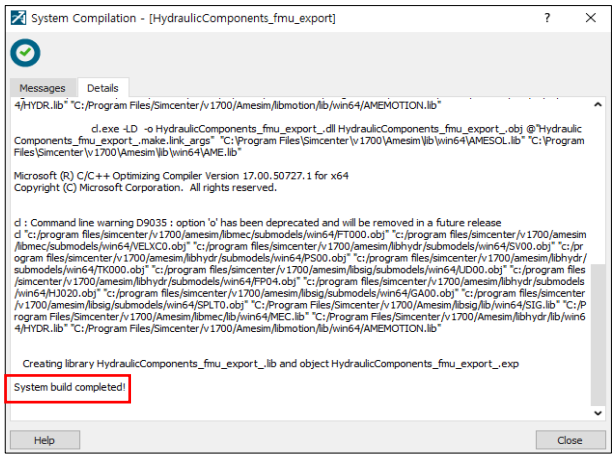


11. Run the **Simulation mode**.

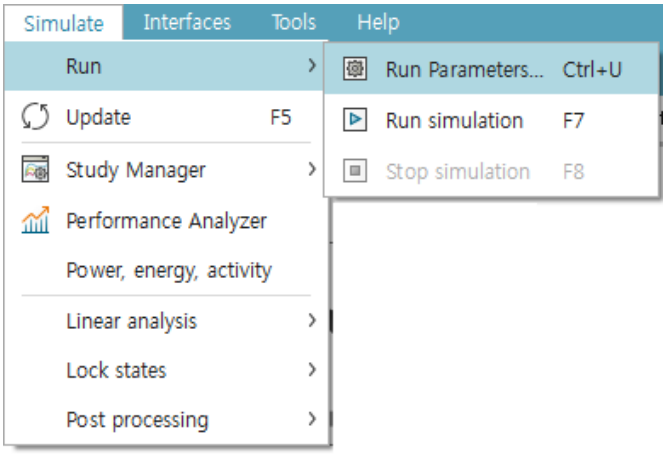


Tip: You can check the **Build** status of the model by checking the **Completed message** on the **Message Tab** and the **System build completed message** on the **Details Tab**.

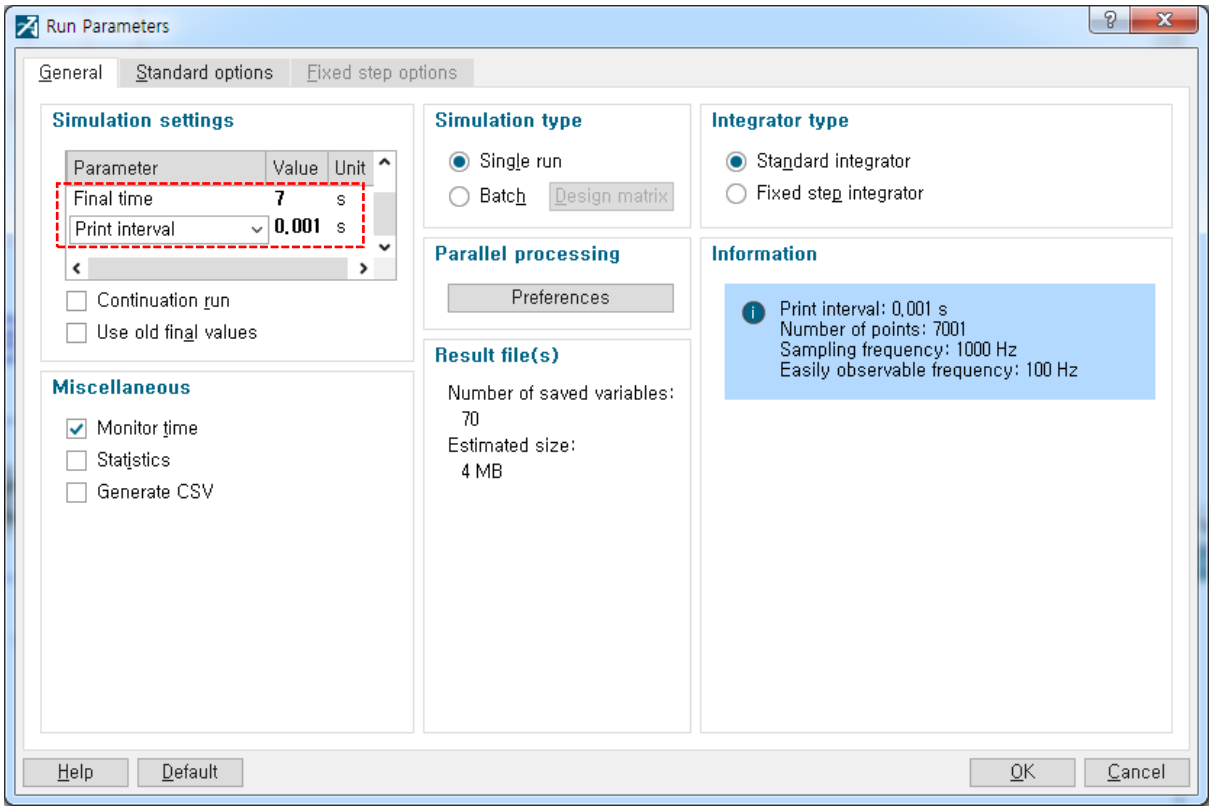




12. Click **Menu > Simulate > Run > Run Parameters** to open the Run Parameters window.



13. Set **Final time** to **7 s** and **Print interval** to **0.001 s**, which are the same values as those set for Interface Time Step in RecurDyn.

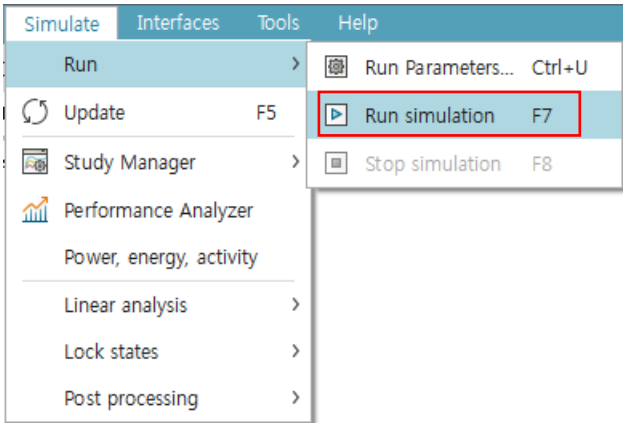


14. Click **OK** to complete the settings.

RecurDyn Slave Mode Co-simulation

Run co-simulation in AMESim.

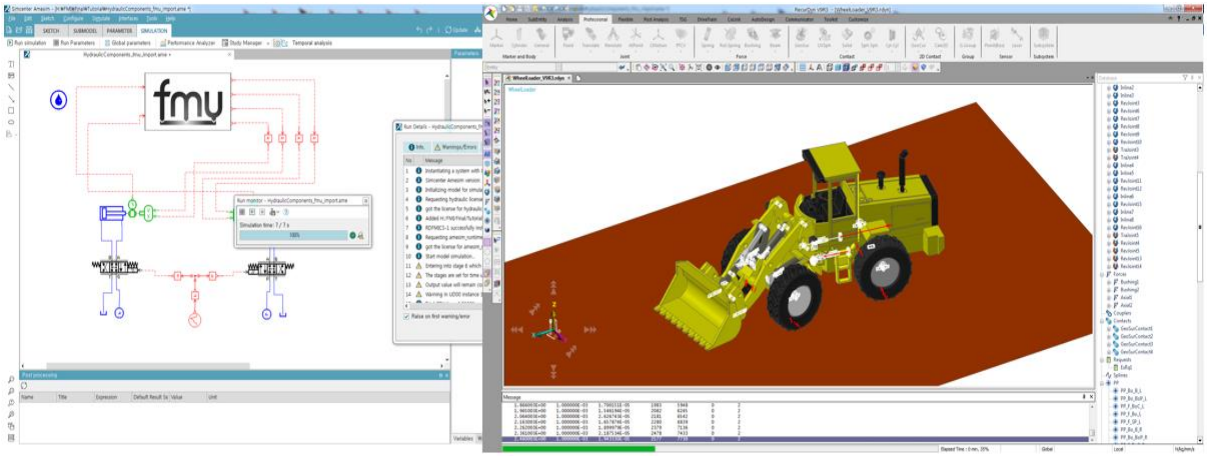
To run the simulation:



1. **Save** and **Close** the **WheelLoader_FMI.rdyn** model of **RecurDyn**, and then exit **RecurDyn**.

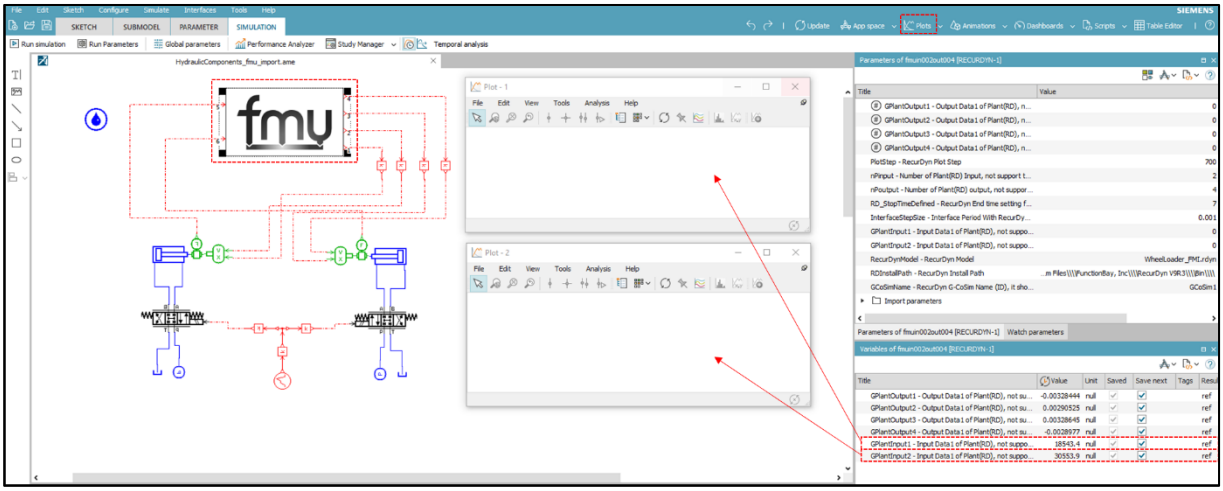
   (If RecurDyn is still running, co-simulation cannot be performed because AMESim cannot run RecurDyn automatically.)

2. Select **Menu > Simulate > Run > Run simulation**.
3. When the simulation starts, **AMESim** runs **RecurDyn**, opens the model, and starts the co-simulation automatically.

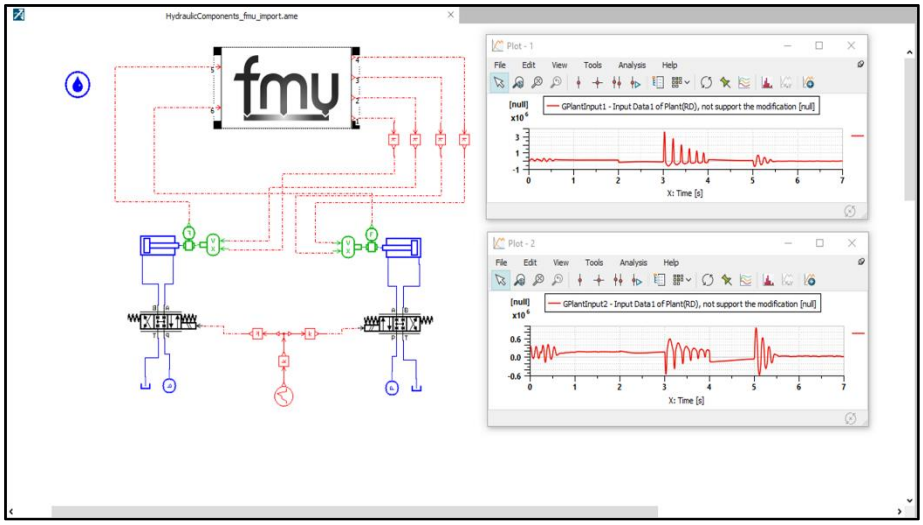


To view analysis results in AMESim:

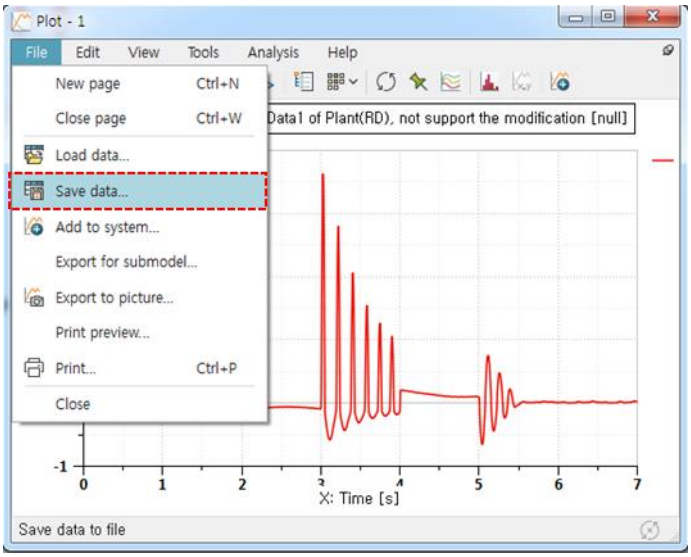
1. After the analysis is complete, double-click the **Plots** button on the ribbon menu in AMESim to create a Plot window.
2. In AMESim, click **FMI Import blocks**.
3. In Variables of fmuin002out004 [RECURDYN-1], **drag & drop GPlantInput1** and **GPlantInput2** to the **Plot** window.

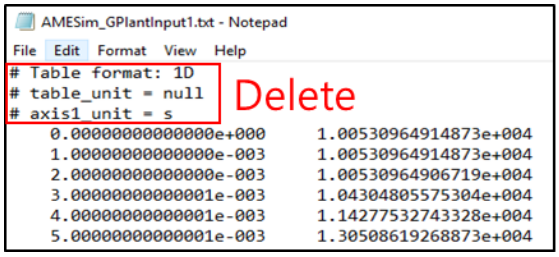


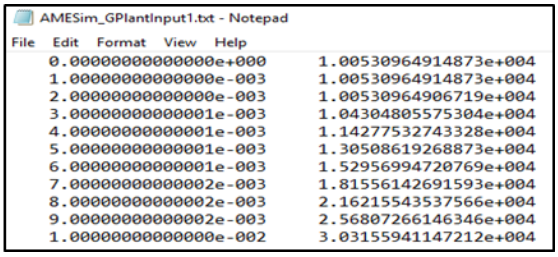
4. Then, in AMESim, you can see the results of **GPlantInput1** and **GPlantInpput2** displayed as a plot.



5. In the Plot window, click **File > Save data**. In the Save window, save the result of **PlantOutput1** as the **AMESim_GPlantInput1.txt** file.
6. Open the **AMESim_GPlantInput1.txt** file using a text editor program. Delete the unnecessary header part in the upper text and save the file.







Chapter

5

Verifying and Analyzing Results

Task Objectives

Use the **General CoSim FMI** method to perform the **Co-simulation** between **RecurDyn** and **AMESim** and check the animation result and numeric data produced.

Estimated Time to Complete

10 minutes

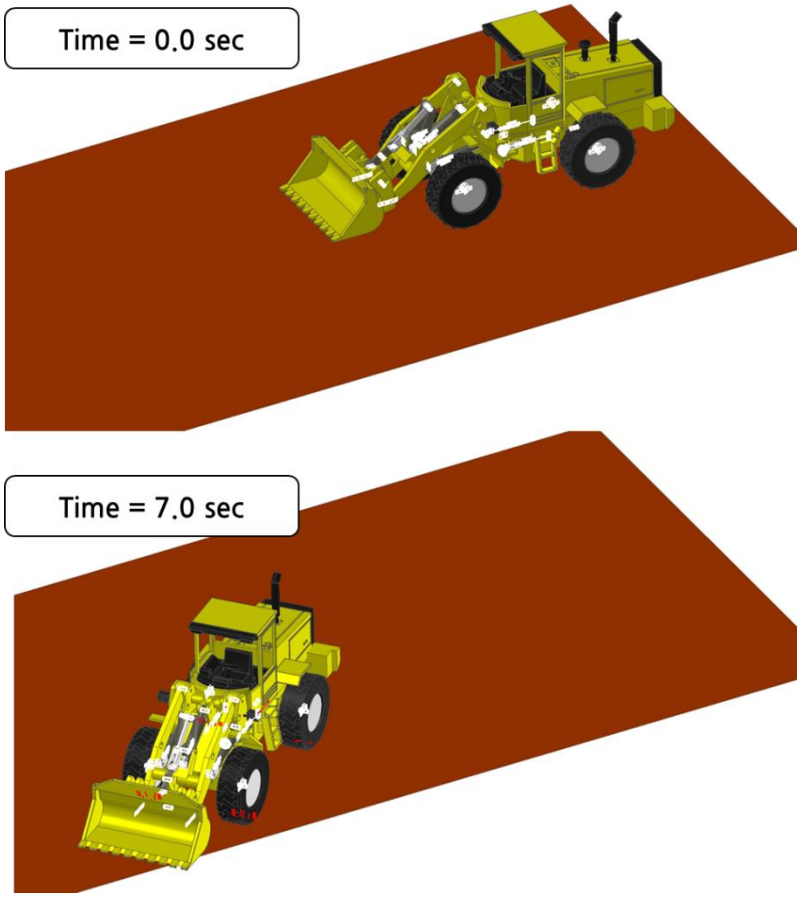
Verifying and Analyzing Results

Make sure that the GPlantInput value in RecurDyn matches the GPlantInput value in AMESim. In the wheel loader model, when steering with the hydraulic pressure generated by the actuator, check the dynamic results such as the reaction force of the joints in each part.

Importing the result of RecurDyn animation and checking the result

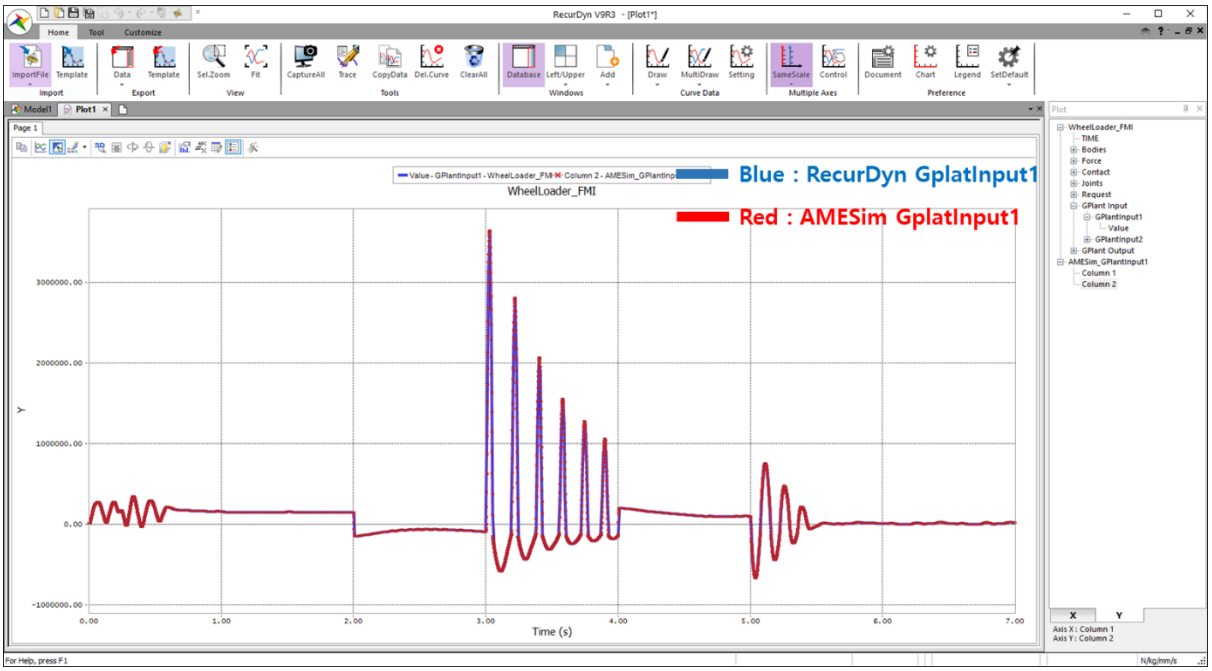
If you perform co-simulation in the master mode of RecurDyn, you can execute Animation Play directly from RecurDyn. If you perform co-simulation in the master mode of AMESim, import the animation result file (*.rad).

1. Go to the **Analysis** tab.
2. In the **Animation Control** group, click the **Play** button to check the result of animation. You can see that the wheel loader moves to the left.



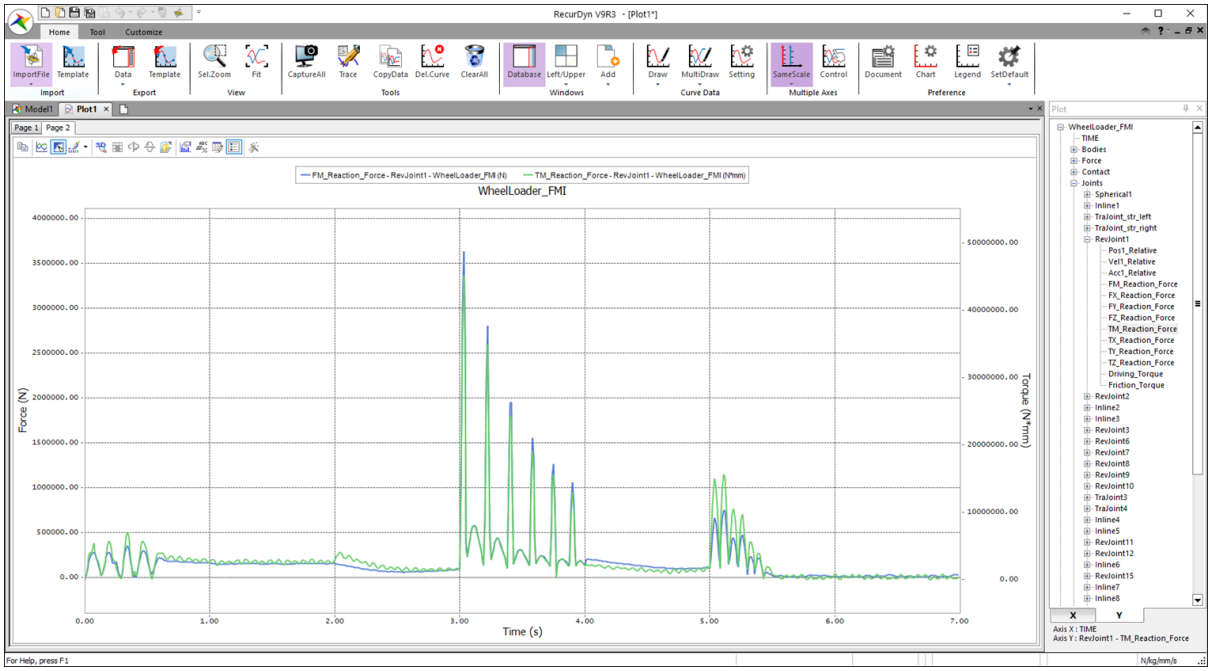
To run RecurDyn Plot and plot the result:

1. Run **RecurDyn/Plot**.
2. **Import** the ***.rplt** file, which is the result of dynamic analysis by **RecurDyn**.
3. Import the **AMESim_GPlantInput1.txt** file, which is the result of **AMESim GPlantInput1** created in the previous chapter.
4. **Draw** the values of **GPlantInput1** in the Plot database window.
5. **Plot** the **Column2** of the result of AMESim. (At this time, the value on the **X** axis must be **Column1**.)



6. You can see that the two results match. From these results, you can see that all the numerical data have been exchanged properly between the two software.

7. Click the **Plot Page Add** button to add a new page.
8. Plot **FM_Reaction_Force** and **TM_Reaction_Force** of **RevJoint1** in the Plot database window. At this time, modify the value of **Axis X** into **Time**.
    - **RevJoint1**is a joint that connects the left cylinder and the vehicle. You can check the reaction force and torque of the joint when hydraulic pressure is generated in the actuator. In this way, you can remodel various operating conditions of the wheel loader and check the reaction force and torque values.



Thanks for participating in this tutorial!