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Altair MotionView 2019 Tutorials

MV-1023: Using Python Subroutines in MotionView Model Building

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MV-1023: Using Python Subroutines in MotionView Model Building

The objective of this tutorial is to replace several entities in a MotionView model with Python user subroutines. You will run a model initially, and then edit the file to incorporate Python scripts in place of MotionView entities and compare the results from each simulation.

In this tutorial, you will learn how:

- User subroutines are incorporated into MotionView
- User subroutines are useful in customizing models
- To create Python scripts that can be used to define these subroutines (and how they are called by MotionView).

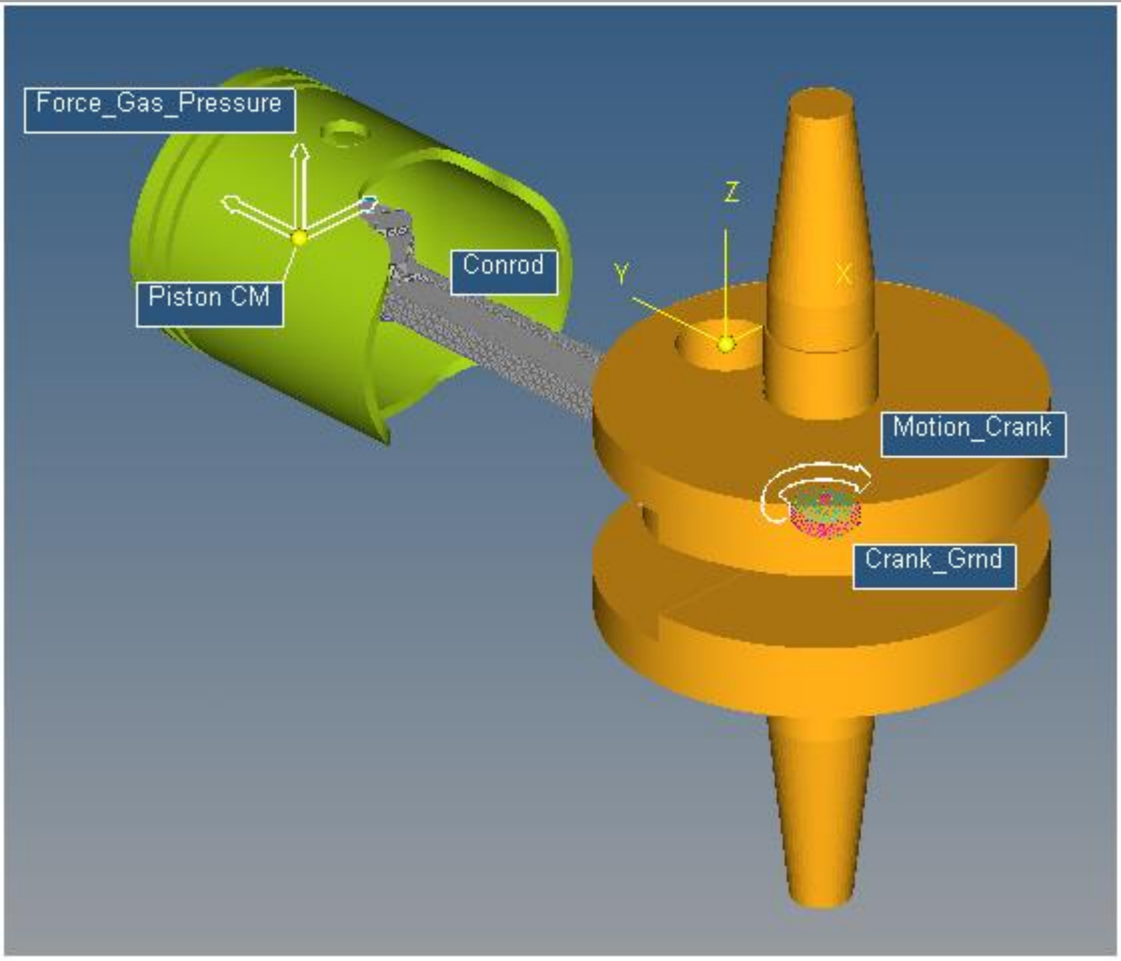
You must be familiar with the MotionView user interface and entities panel, as well as have some experience defining and modifying entities. Some experience with the Python programming language is necessary to fully understand the topics covered.

Exercise One - Introduction to User Subroutines

User subroutines are a useful tool to customize simulations and analyses. These subroutines, or usersubs can be created using variety of programming languages like C, Ruby, TCL, and Python. Subroutines created in programming languages like C, C++ and FORTRAN etc. are compiled to create `*.dll` files using the **MS UserSub Build Tool** (located in the MotionView **Tools** menu). These dlls are then used by the solver. In older versions of MotionView only compiled usersubs (`*.dll`) were supported. Starting with MotionView version 11.0, usersubs are enabled to use Python and Matlab scripts. In this tutorial, we will be using Python to create usersubs. User subroutines can make use of external Python scripts in order to define complex simulations, which cannot be created through the MotionView GUI. With a basic knowledge of the Python programming language, a user can easily generate intricate experiments to simulate any complex mechanism.

This tutorial will show you how to replace five MotionView entities with their corresponding usersubs.

Copy the model file required for this exercise, `engine_baseline.mdl`, along with all of the H3D files located in the `mbd_modeling\motionsolve\python_usersub` folder to your `<working directory>`.



The single cylinder engine model

The model we are using is a single cylinder engine, and uses a curve, an output, a force, and a motion entity. The system also uses default damping.

- The curve is read from a CSV file, and gives a force value based on the angular displacement of the connecting rod.
- The output returns the displacement magnitude of the piston.
- The force entity uses the angle of the connecting rod and the curve to apply a variable pressure force to the piston.
- The motion entity applies an angular motion to the **Crank_Grnd** revolute joint.
- The default damping of the system is 1, however it can be changed in the **Bodies** panel.

The following is a list of the entities and usersubs we will be using in this tutorial, along with a brief description of their usage:

	Entity	**Usrsub**	**Description**
	Curve	SPLINE_READ	Reads the curve data file.
	Request	REQSUB	Outputs the requested values

	Entity	**Usrsub**	**Description**
	Force	GFOSUB	Applies a force on the system.
	Motion	MOTSUB	Applies a motion to the system.
	Damping	DMPSUB	Defines the damping of a flexbody.

Step 1: Running the model.

1. Click the ***Run*** panel icon, , to access the **Run** panel.
2. Click on the folder icon located next to the **Save and run current model** option, and browse to your `<working directory>`. Specify the name as `engine_baseline.xml` for the MotionSolve input XML file.
3. Check your model for errors, and then click the ***Run*** button to run your model.

   This will give you result files to compare with your usrsub results.

Exercise Two - Adding User Subroutines

Notes on using XML syntax in Python

Python can use many MotionSolve functions and inputs when certain syntax rules are followed. When using a MotionSolve function such as `AKISPL` or `SYSFNC`, the string "`py_`" must be added to the beginning. For example, "`py_sysfnc(…`" would be the correct usage of `SYSFNC` in Python. When defining a usersub function in Python, the name of the function and the inputs must match those outlined in the MotionSolve online help pages exactly. When accessing model data in python through a function such as `SYSFNC`, use the exact property name in quotations as the "`id`" input. Model properties that are passed into Python in the function definition can be accessed throughout the script, and do not need additional defining to use. An example of these syntax rules being used is shown below:

```
def REQSUB(id, time, par, npar, iflag):
    [A, errflg] = py_sysfnc("DX",[par[0],par[1]])
return A
```

Step 1: Using SPLINE_READ to Replace the Curve Entity.

The first user-subroutine we will implement uses the `SPLINE_READ` function to return the curve from the included `pressure_curve.csv` file. `SPLINE_READ` is the usersub that corresponds to the curve entity in MotionView. It uses data points in an external file to create a curve, which can then be used by other entities.

Writing the Python script:

1. Open a new Python file, and define a function with the name `SPLINE_READ` using "`def SPLINE_READ():`", giving the appropriate inputs and outputs. The inputs and outputs used are: `id`, `file_name`, and `block_name`.

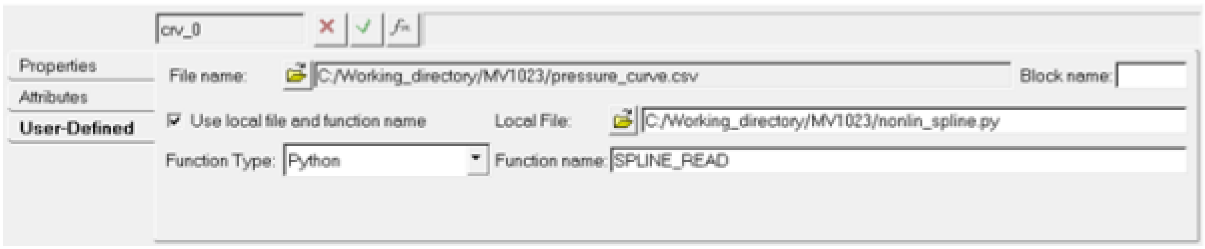
2. Import the Python CSV package by including `import csv` after the function definition.
3. Open `pressure_curve.csv` in the function, and read the file to your Python script as a variable. This can be done with "`variable = open('pressure_curve.csv', 'r')`".
4. Change the format of this variable from csv by defining a new variable, and using `csv.reader()` to read your variable file.
5. Define an empty list, "`L`", to store the `pressure_curve` data values. Iterate through the list using "`for item in curv:`". Append each item as a separate list value with "`L.append(item)`".
6. Remove the headers from the csv file by redefining the list from the second value till the end of the list. This can be done with "`L = L[1:]`".
7. Define a counter variable to be used later. Define two lists that are half the length of "`L`", and set them equal to zero. To do this, use "`x = 16*[0.0]`" twice; once with the x value and once with the y value.
8. Create a while loop dependent on your counter variable being less than the length of your list, minus one.
9. In each iteration of the loop, define your x and y data values for the index "`i`" as a floating value of each half of your "`L`" data sets. This should look like "`x[i] = float(L[i][0])`" and "`y[i] = float(L[i][1])`". Increase your counter variable by 1.
10. Define a z variable with a floating value of 0.0, and close the csv file. Defining a z variable is necessary, as the next function we will use requires an x, y, and z variable.
11. Use the `put_spline` MotionSolve function, and return the "`id`", as well as the lists containing the first and second column of values and the z variable. This should be done with "`errflg = py_put_spline(id,x,y,z)`" followed by "`return errflg`".
12. Save this file to your working directory as `nonlin_spline.py`.

Your `nonlin_spline.py` Python script should resemble the following:

```
def SPLINE_READ(id, file_name, block_name):


    import csv
    ifile= open('pressure_curve.csv','r')  ## opens data file as
    readable variable
    curv = csv.reader(ifile)               ## reads csv data, stores as
    useable var.


    L = []              ## creates empty list
    for item in curv:
    L.append(item)   ## separates file values into list


    L = L[1:]           ## removes block names from list


    i=0                           ## creates counter
    x = 16*[0.0]
    y = 16*[0.0]                ## splits list into x and y lists
    while i < (len(L)-1):
         x[i] = float(L[i][0])  ## changes values from str to float
         y[i] = float(L[i][1])
         i+=1                   ## counter increment

    z = 0.0                             ## defines z value
    ifile.close()                       ## closes data file
    errflg = py_put_spline(id,x,y,z)    ## var to create MotionSolve
    spline

    return errflg                       ## returns var
```

Implementing the Python script:

1. In MotionView, go to the **Curve** panel , and locate the **Force_Pressure** curve in the project directory tree to the left of the MotionView workspace.
2. From the **Properties** tab, check the box marked **User-defined**.
3. From the **Attributes** tab, make sure **Linear extrapolation** is checked.
4. Click on the **User-Defined** tab, and use the **File name** file browser to select the `pressure_curve.csv` file.
5. Change the **Function Type** in the drop-down menu from **DLL** to **Python**, and ensure the function name is **`SPLINE_READ`**. You do not need to enter anything for the **Block name**, as it is not needed in this tutorial.
6. Check the box marked **Use local file and function name**. Use the Local File file browser (the folder button to the right) to locate and select the `nonlin_spline.py` file.


crv_0
Properties
Attributes
User-Defined
File name: C:/Working_directory/MV1023/pressure_curve.csv
Block name:
☑ Use local file and function name
Local File: C:/Working_directory/MV1023/nonlin_spline.py
Function Type: Python
Function name: SPLINE_READ

The curve panel using the `SPLINE_READ` usersub

Step 2: Using REQSUB to Request an Output.

The second user-subroutine will use Python to specify which values to return. In this tutorial, the returned values will be the magnitude of displacement for the piston.

Writing the Python script:

1. Create another Python file, and define a function named `REQSUB` with the appropriate inputs and outputs. The syntax for this is "`def REQSUB(id, time, par, npar, iflag)`".

2. Use the `sysfnc` utility to implement the "`DM`" (or displacement magnitude) function on the first and second input parameters, and define a variable and an error flag by writing "`[D, errflg] = py_sysfnc("DM",[par[0],par[1]])`".
3. Return a list of eight values, where the second value is your variable, and the rest are equal to 0. This will be your result variable, and should look like "`result = [0,D,0,0,0,0,0,0]`".
4. Save this file to your working directory as `req_nonlin.py`.

Your `req_nonlin.py` Python script should resemble the following:

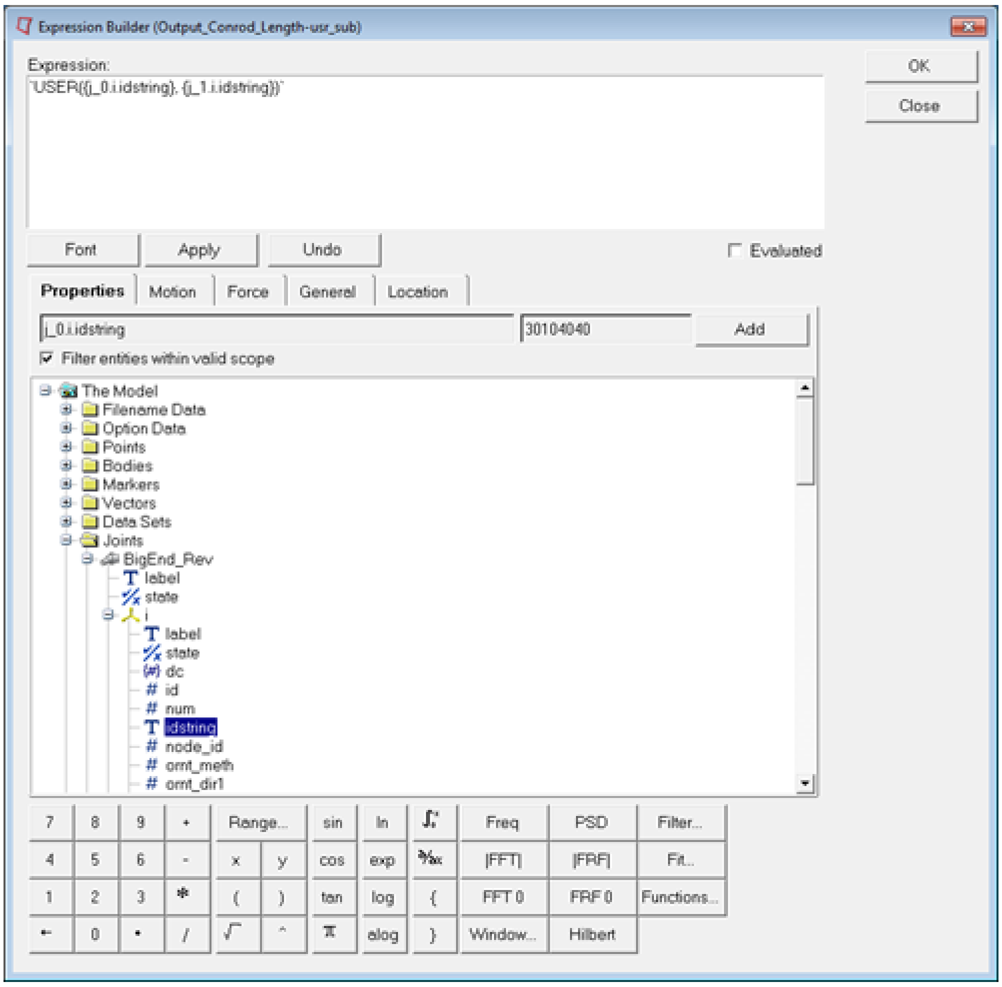
```
def REQSUB(id, time, par, npar, iflag):


    [D, errflg] = py_sysfnc("DM",[par[0],par[1]])  ## sets "D" as piston
    displacement mag
    result = [0,D,0,0,0,0,0,0]         ## lists results for output
    return


    return result         ## sends list with results to motionsolve as
    output
```

Implementing the Python script:

1. In MotionView, go to the **Outputs** panel, and locate the **Output_Conrod_Length** output in the project directory tree to the left of the MotionView workspace.

   The **Outputs** panel is displayed.
2. From the **Properties** tab, select **User Defined** from the first drop-down menu.
3. Click in the text field labeled **Output**, and then click on the button to open the **Expression Builder**.
4. In the text field of the **Expression Builder**, click inside the parentheses and add "`{},{}`".

5. From the **Expression Builder**, locate and select the **j_0.i.idstring** (located in the **Joints** folder in the directory) and insert this id string into the expression by positioning the cursor inside a set of braces and clicking the **Add** button. In addition, add the **j_1.i.idstring** into the expression by repeating this same process.


Expression: `USER({j_0.i.idstring}, {j_1.i.idstring})`

Properties: j_0.i.idstring — 30104040

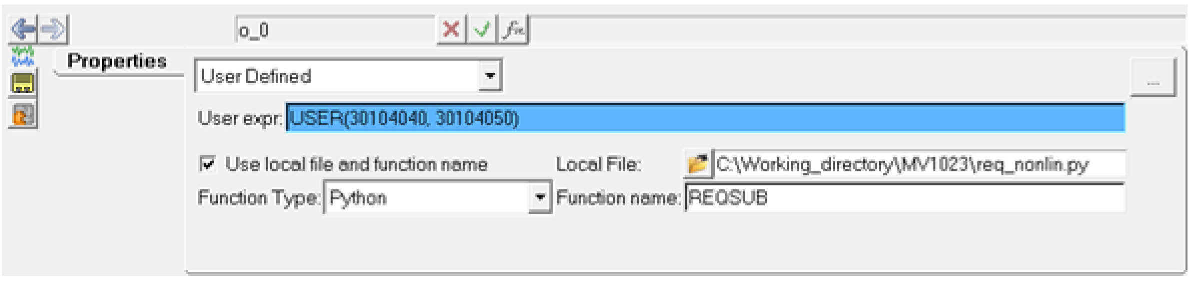
☑ Filter entities within valid scope

Expression Builder dialog

6. Click ***OK*** to close the dialog.

7. Check the **Use local file and function name** box, and select ***Python*** from the **Function Type** drop-down menu.

8. Use the **Local File** file browser to locate and select the `req_nonlin.py` script, and make sure that the **Function name** text field reads **REQSUB**.


o_0

User Defined

User expr: USER(30104040, 30104050)

☑ Use local file and function name

Local File: C:\Working_directory\MV1023\req_nonlin.py

Function Type: Python

Function name: REQSUB

Outputs panel using REQSUB

Step 3: Using GFOSUB to Replace the Force Entity.

The `GFOSUB` user subroutine replaces a force with a user defined Python script. The `GFOSUB` used here will take the curve data defined with `SPLINE_READ`, and change depending on the Conrod angle according to the curve.

Writing the Python script:

1. Open a new Python file, and define the function `GFOSUB` by typing "`def GFOSUB(id, time, par, npar, dflag, iflag):`".
2. Import "`pi`" from the Python "`math`" library using "`from math import pi`".
3. Use the "`AZ`" function for angle in the z direction with the `sysfnc` command, to save it as a variable. To do this, type "`[A, errflg] = py_sysfnc("AZ",[par[1],par[2]])`".
4. The angle will be measured in radians by default, so change the variable defined in the previous step to degrees. As the model extends from the origin into the negative y direction, you will need to multiply by -1. The method used in this tutorial is "`B = ((-1)*A*180)/pi`".
5. Define another variable using the "`akispl`" utility, which interpolates the force values from the curve. You will need input arguments of your angle "`B`", zero to specify a two dimensional curve, and zero for the curve input and the order. This line is written as "`[C, errflg] = py_akispl(B,0,par[0],0)`".
6. Return a list three elements long, where the second element is the variable defined with the Akima interpolation function. The data from interpolation is stored in the first column, so use "`return [0,C[0],0]`".
7. Save this file to your working directory as `gfo_nonlin.py`.

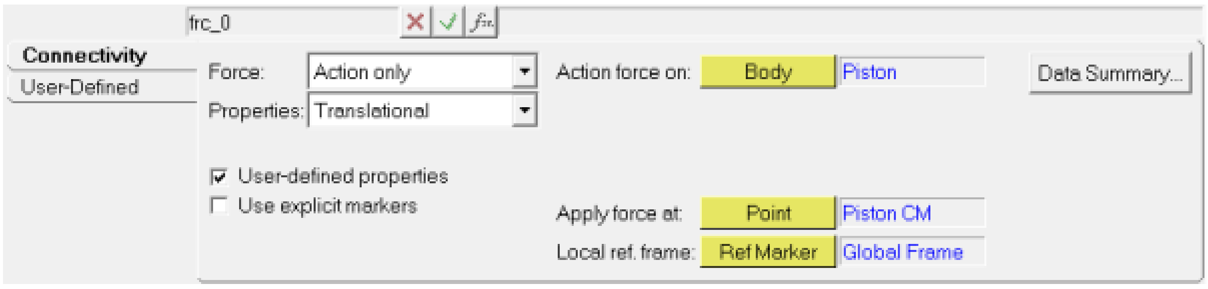
Your `gfo_nonlin.py` Python script should resemble the following:

```
def GFOSUB(id, time, par, npar, dflag, iflag):


    from math import pi


    [A, errflg] = py_sysfnc("AZ",[par[1],par[2]])  ## retreives conrod
    angle
    B = ((-1)*A*180)/pi                            ## converts radians
    to degrees


    [C, errflg] = py_akispl(B,0,par[0],0)  ## interpolates data to fit
    curve


    return [0,C[0],0]  ## returns C data as force values
```

Implementing the Python script:

1. In MotionView, go to the **Forces** panel, and locate the **Force_Gas_Pressure** force in the project directory tree to the left of the MotionView workspace.

2. From the **Connectivity** tab, check the **User-defined properties** box.



frc_0

Connectivity | User-Defined

Force: Action only

Properties: Translational

☑ User-defined properties

☐ Use explicit markers

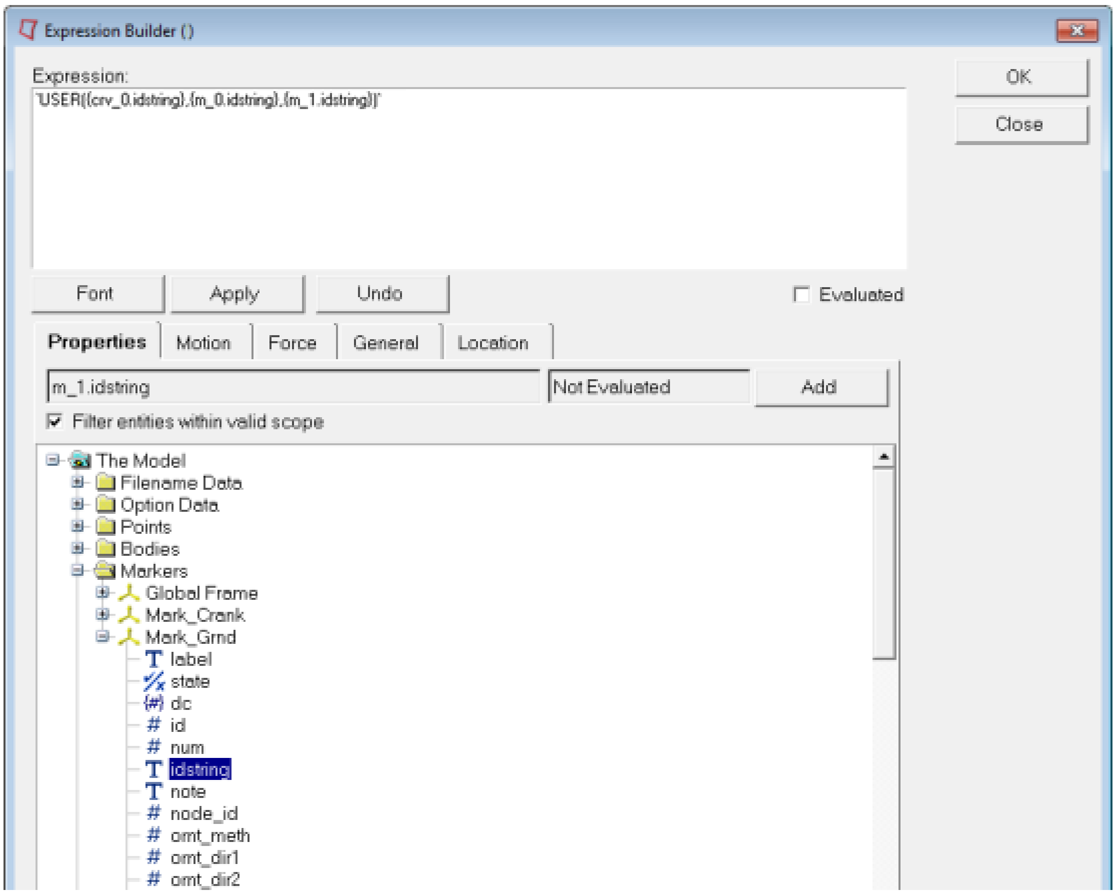
Action force on: Body Piston

Apply force at: Point Piston CM

Local ref. frame: Ref Marker Global Frame

Data Summary...

3. From the **User-Defined** tab, edit the Force value with the **Expression Builder** to include the **curve idstring**, the **ground marker idstring**, and the **crank marker idstring**.



Expression Builder ()

Expression:

```
`USER({crv_0.idstring},{m_0.idstring},{m_1.idstring})`
```

☐ Evaluated

Properties | Motion | Force | General | Location

m_1.idstring   Not Evaluated   Add

☑ Filter entities within valid scope

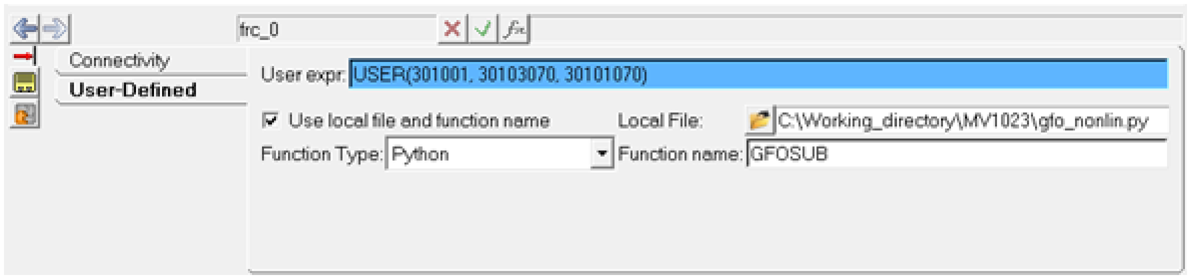
```
The Model
  Filename Data
  Option Data
  Points
  Bodies
  Markers
    Global Frame
    Mark_Crank
    Mark_Grnd
      label
      state
      dc
      id
      num
      idstring
      note
      node_id
      omt_meth
      omt_dir1
      omt_dir2
```

4. Click ***OK*** to close the dialog.

5. Check the **Use local file and function name** box, and select ***Python*** from the **Function Type** drop-down menu.

6. For **Local File**, select `gfo_nonlin.py` from your working directory.

7. Make sure the **Function name** is set to **GFOSUB**.



User expr: USER(301001, 30103070, 30101070)

☑ Use local file and function name

Local File: C:\Working_directory\MV1023\gfo_nonlin.py

Function Type: Python

Function name: GFOSUB

Step 4: Using MOTSUB to Define a Motion.

Writing the Python script:

1. Open a new python file, and define the `MOTSUB` function, including the required inputs. The correct syntax for this is "`def MOTSUB(id, time, par, npar, iord, iflag):`".

2. The `MOTSUB` user subroutine requires a function or expression, and its first and second order derivatives. Create conditional statements using the function order variable "`iord`" to define the function and its first and second derivatives with "`if iord==0:`", "`elif iord==1:`" and "`else:`".

3. The function and its derivatives should be defined with the same variable name. The function used in this tutorial is "`A = 10.0461*time`". This makes the first derivative equal to "`A = 10.0461`", and the second derivative equal to "`A = 0.0`".

4. Return the function variable with "`return A`".

5. Save this file to your working directory as `mot_nonlin.py`.

Your `mot_nonlin.py` Python script should resemble the following:

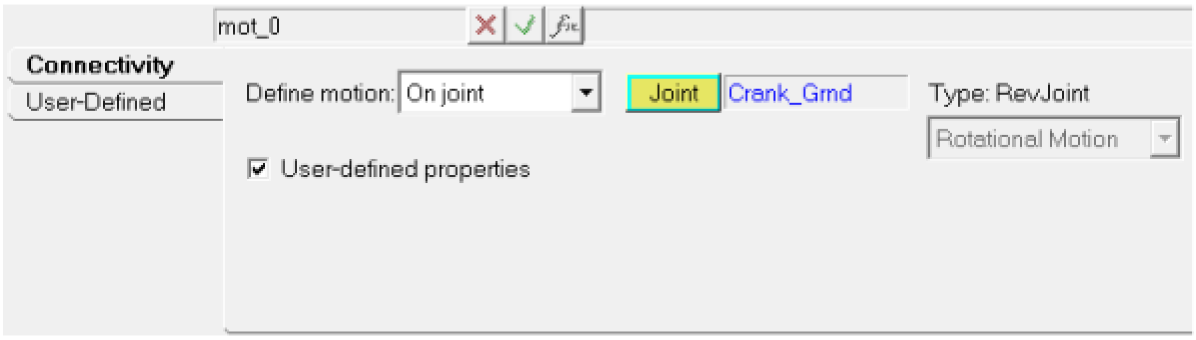
```
def MOTSUB(id, time, par, npar, iord, iflag):

    if iord==0:          ## function
        A = 10.0461*time
    elif iord==1:        ## first derivative
        A = 10.0461
    else:                ## second derivative
        A = 0.0
    return A        ## returns function based on iord input
```

Implementing the Python script:

1. In the directory tree on the left side of the HyperWorks desktop, locate the **Motion_Crank** motion and click on it.

   The **Motions** panel is displayed.

2. In the **Motions** panel, check the **User-defined properties** box.



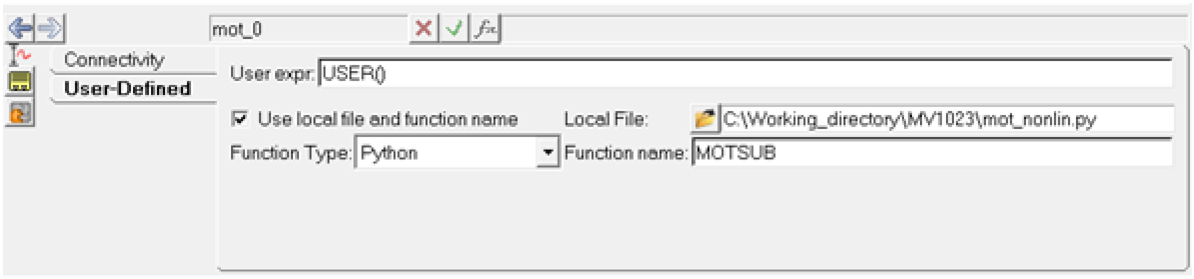
Define motion: On joint
Crank_Grnd
Type: RevJoint
Rotational Motion
☑ User-defined properties

3. Click on the **User-Defined** tab.

   Because we defined the function in the Python script, we do not need to modify **USER()** text field.

4. Check the box labeled **Use local file and function** name, select ***Python*** from the **Function Type** drop-down menu.

5. Use the **Local File** file browser to locate and select the `mot_nonlin.py` file.



User expr: USER()
☑ Use local file and function name
Local File: C:\Working_directory\MV1023\mot_nonlin.py
Function Type: Python
Function name: MOTSUB

Motions panel using MOTSUB

Step 5: Using DMPSUB to Add Custom Flexbody Damping.

Writing the Python script:

1. Open a new Python file and define the `DMPSUB` function with "`def DMPSUB():`", giving it the following inputs: "`id, time, par, npar, freq, nmode, h`".

2. Define a list the length of "`nmode`" using "`cratios = nmode*[0.0]`".

   `nmode` is the number of modes in the flexbody.

3. Create an "`if`" statement to iterate along the list of modes in the flexbody. The "`xrange()`" function can be used here, resulting in "`for I in xrange(nmode):`".

4. In each iteration of the loop, set each index in your variable equal to 1 by adding "`cratios[i] = 1.0`".

5. At the end of your script, return the list variable with "`return cratios`".

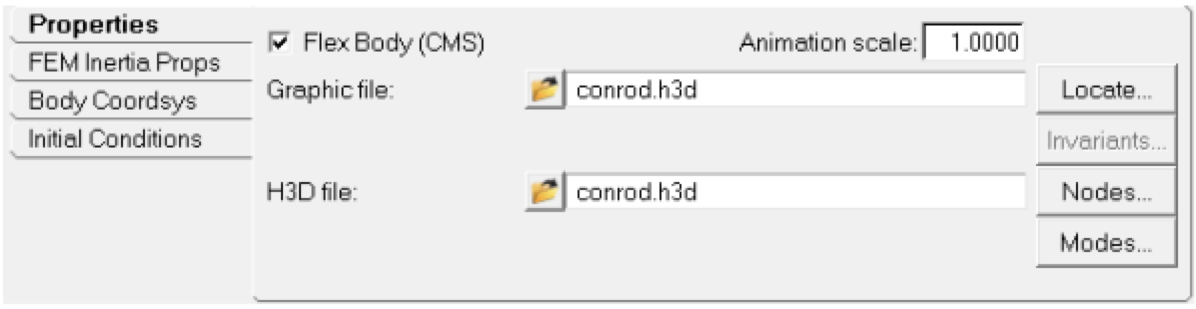
6. Save your script as `dmp_nonlin.py`.

Your `dmp_nonlin.py` Python script should resemble the following:

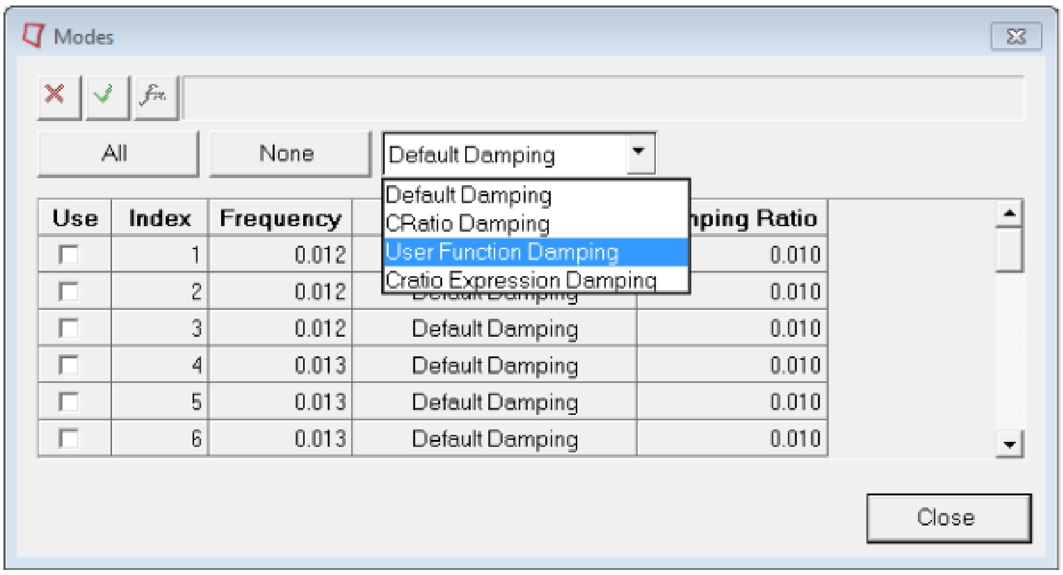
```
def DMPSUB(id, time, par, npar, freq, nmode, h):

    cratios = nmode*[0.0]     ## makes preallocated list for markers

    for i in xrange(nmode):
        cratios[i] = 1.0      ## sets marker damping to 1

    return cratios            ## returns damping values
```

Implementing the Python script:

1. In the directory tree on the left side of the HyperWorks desktop, locate the **Conrod** body and click on it (this is a flexbody in the model).
2. From the **Properties** tab, click on the ***Modes...*** button (located in the lower right corner of the panel) to display the **Modes** dialog.



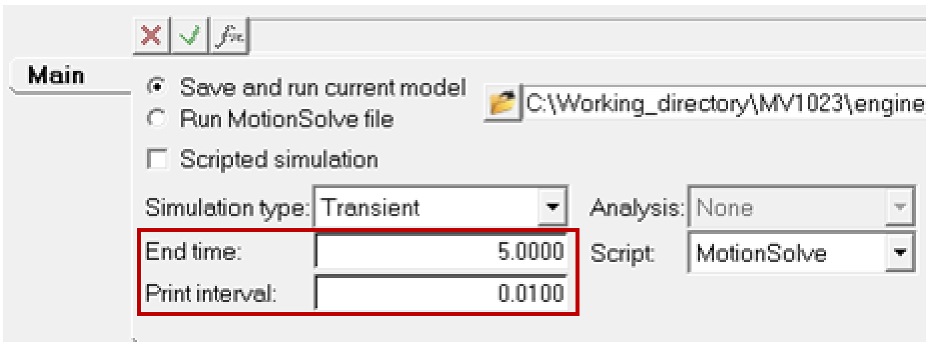
3. Use the drop-down menu to select the **User Function Damping** option.



Use	Index	Frequency		...nping Ratio
☐	1	0.012		0.010
☐	2	0.012	Default Damping	0.010
☐	3	0.012	Default Damping	0.010
☐	4	0.013	Default Damping	0.010
☐	5	0.013	Default Damping	0.010
☐	6	0.013	Default Damping	0.010

Because we defined the damping in our `dmp_nonlin.py script`, we do not need to change the **USER()** expression.

4. Go to the **Run** panel .
5. Change the **End time** to `5.0`, and the **Print interval** to `0.01`.



Simulation type: Transient
End time: 5.0000
Print interval: 0.0100

6. Now, export the MotionSolve file using **File > Export > Solver Deck**.

Note Currently there is no GUI option available to specify the `DAMPSUB` file defining flexbody damping, therefore the `dmp_nonlin.py` must be manually added to the MotionSolve file (`*.xml`) by adding following statements to the flexbody definition:

```
is_user_damp         = "TRUE"
usrsub_param_string = "USER()"
interpreter          = "Python"
script_name          = "dmp_nonlin.py"
usrsub_fnc_name      = "DMPSUB"
```

Your flexbody definition should look like below:

```
<Body_Flexible
    id                  = "30104"
    lprf_id             = "30104002"
    mass                = "7.424574879203591E-02"
    inertia_xx          = "1.471824534365642E+02"
    inertia_yy          = "4.505004745855096E+00"
    inertia_zz          = "1.501914135052064E+02"
    inertia_xy          = "-5.546373592613223E-03"
    inertia_yz          = "-1.984540442733755E-03"
    inertia_xz          = "1.557626595859531E-03"
    cm_x                = "1.191728011928773E-03"
    cm_y                = "-2.225471002399553E+01"
    cm_z                = "5.469513396916666E-05"
    h3d_file            = "conrod.h3d"
    is_user_damp        = "TRUE"
    usrsub_param_string = "USER()"
    interpreter         = "Python"
    script_name         = "dmp_nonlin.py"
```

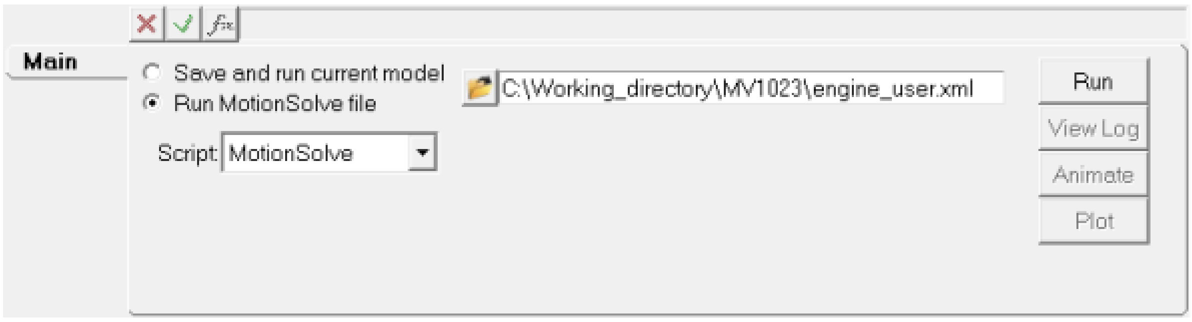
```
        usrsub_fnc_name      = "DMPSUB"
        flexdata_id          = "30104"
        animation_scale      = "1."
    />
```

Exercise Three - Running Your Simulation with Usersubs

Now that all the user subroutines have been implemented, run your model, and compare your results to those from your initial test.

Step 1: Using the Run Solver Panel to Run Your Model.

1. Go to the **Run** panel , click on/activate the **Run MotionSolve file** radio button.
2. Now browse to the `*.xml` file saved in previous step.



Main

( ) Save and run current model

(•) Run MotionSolve file

Script: MotionSolve

C:\Working_directory\MV1023\engine_user.xml

3. Click the ***Run*** button.

Exercise Four - Comparing Your Results

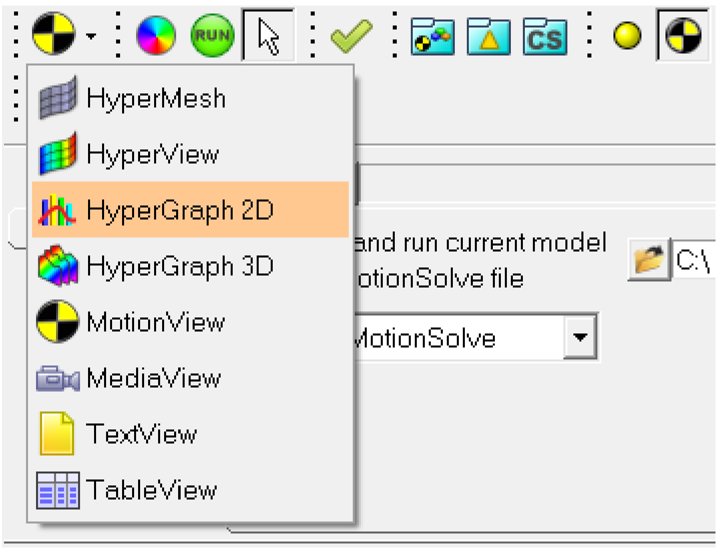
Now that we have results for both the initial model and the model using user subroutines, we will compare the data to ensure accuracy. We will do this using HyperGraph and Hyperview to compare the outputs and deformations of the system.

Step 1: Using HyperGraph to Plot the Displacement Magnitudes.

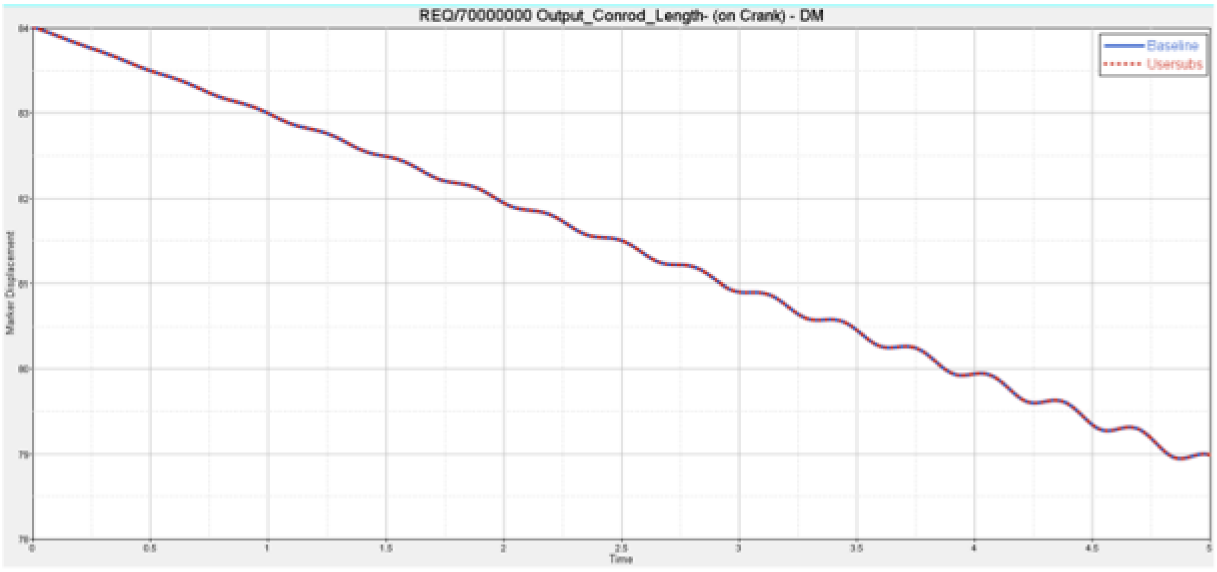
Using the outputs from both simulations, we will compare the displacement magnitude of the piston. A correct result from the usersub run will match the results from the initial run.

1. Begin by opening a new window by clicking the ***Add Page*** button .

2. Switch the application from **MotionView** to **HyperGraph 2D** by selecting it from the **Client Selector** drop-down menu (located on the left-most end of the **Client Selector** toolbar).



3. In HyperGraph, click the **Build Plots** panel button on the **Curves** toolbar.
4. In the **Build Plots** panel, locate your baseline results from your working directory using the **Data file** file browser. Select the file `baseline.abf`, and click ***Open***.
5. The x and y axes options are be shown below. The default x variable is **Time**. For the y variable: select ***Marker Displacement*** for **Y Type**, leave the default for **Y Request**, and select ***DM*** for **Y Component**.
6. Click the **Apply** button (located on the far right side of the panel).
7. For your usersub results, repeat steps 4 through 6, using **REQSUB** and **RESULT(2)** for **Y Type** and **Y Component** respectively.
8. Click **Apply**.

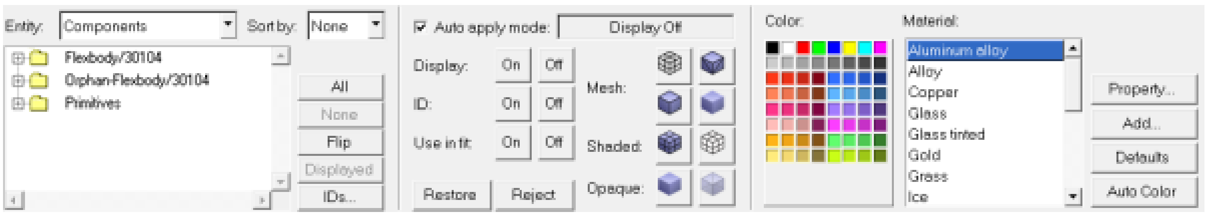


Comparison of output results from both model simulations

Step 2: Using HyperView to Compare Flexbody Stresses.

Using HyperView, you can view the stresses and deformations on the flexbody. The results between the two simulations should be the same.

1. Add a new window by clicking the **Add Page** button .
2. Switch the application from HyperGraph 2D to HyperView using the **Client Selector** drop-down menu.
3. Click the **Load Results** button on the **Standard** toolbar.
4. Locate your `baseline.h3d` results file in your working directory, and click ***Open***.
5. Click ***Apply***.
6. Open the **Entity Attributes** panel , and click the ***Off*** button next to the **Display** option. Make sure that the **Auto apply mode** check box is checked.


Entity: Components
Sort by: None
Flexbody/30104
Orphan-Flexbody/30104
Primitives
Auto apply mode: ✓
Material: Aluminum alloy

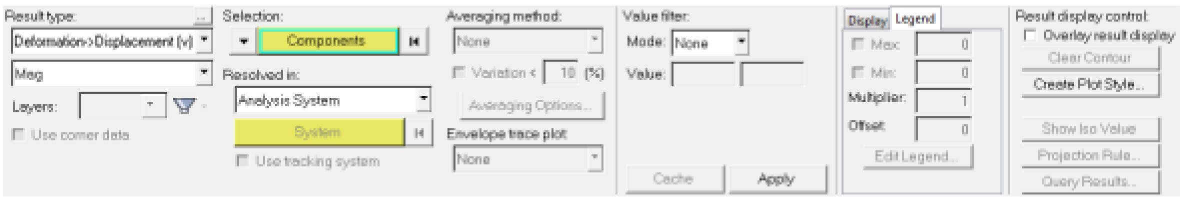
7. In the model window, click on the piston head, and both crank components.

   Only the flexbody component should be displayed.

8. Click the **Contour** panel button located on the **Results** toolbar.

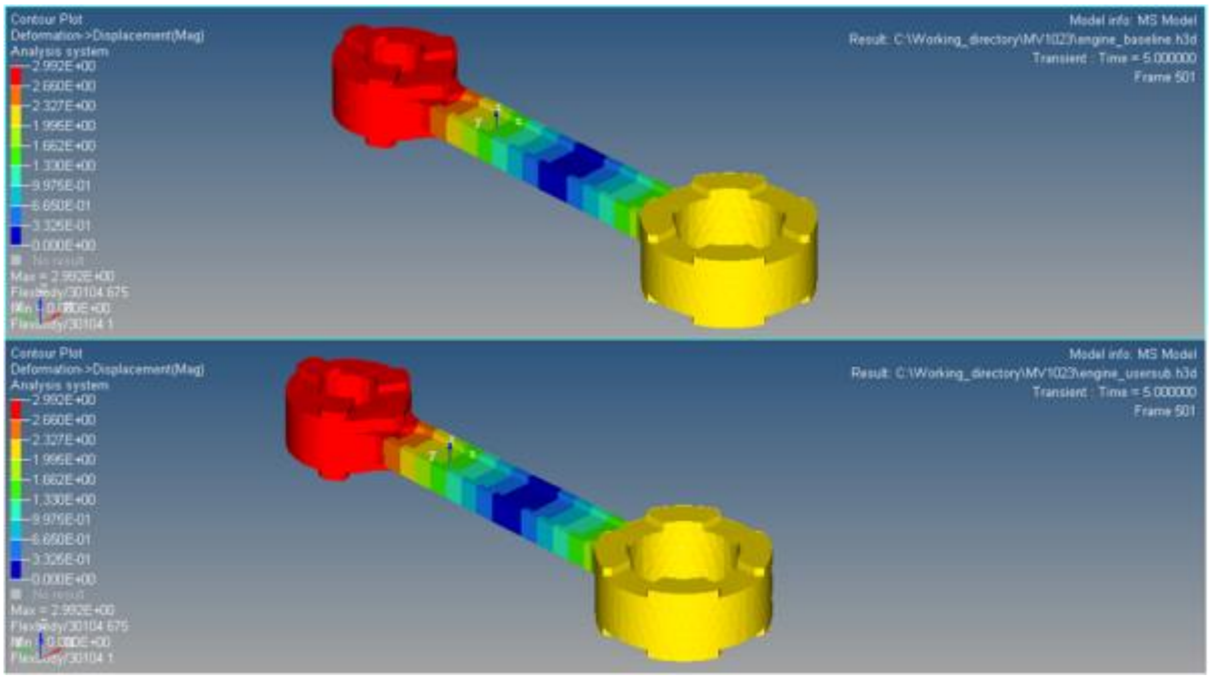
   The **Contour** panel is displayed.

9. Set **Result type** to **Deformation->Displacement (v)**, and click on the flexbody in the model window.


Result type: Deformation->Displacement (v)
Mag
Selection: Components
Resolved in: Analysis System
Averaging method: None
Value filter: Mode: None
Multiplier: 1
Offset: 0

10. Click the ***Apply*** button (located in the lower middle portion of the panel).
11. Next, click on the **Tracking Systems** panel button located on the **Results** toolbar.
12. From the **Track** drop-down menu, select ***Component***, then click on the flexbody in your model window.
13. Separate your model window into two halves using the **Page Window Layout** drop-down menu (located on the **Page Controls** toolbar).
14. In the blank model window, repeat steps 3 through 12 for your usersub h3d file.

15. Click on the **Start/Pause** button on the **Animation** toolbar to animate your models.



Comparison of flexbody deformation in HyperView