RecurDyn/EHD Tutorial

Piston Lubrication

FunctionBay, Inc.

Step 01 – Import RFlex Bodies

Steps

① Open the "**PistonLubricationEHD_Tutorial_Start.rdyn**" model in RecurDyn V9R1

② Select **G-Manager** icon in G-Manager group of Flexible tab

③ Select the **Cylinder** rigid body.

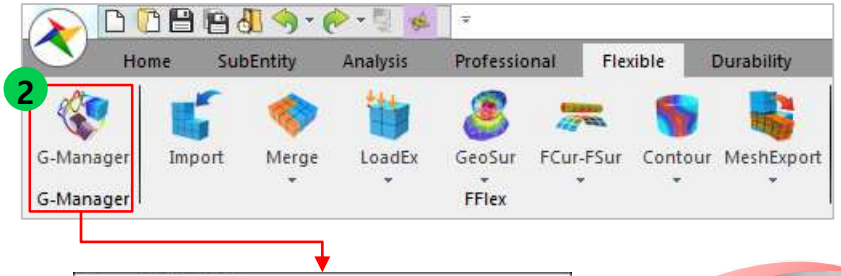
④ In G-Manger dialog, change the "**Target converting body**" to "**RFlex**"

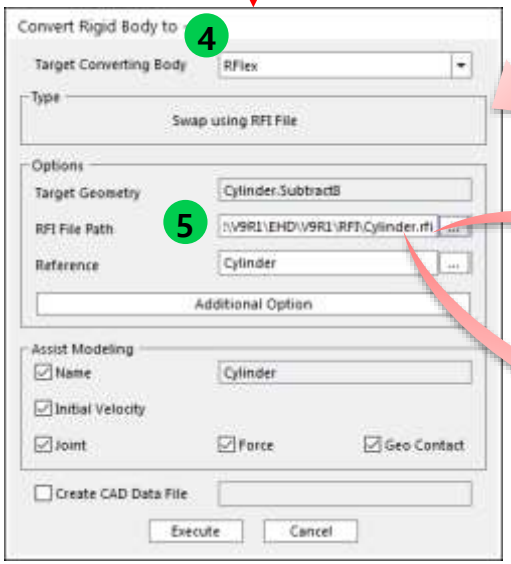
⑤ Specify the RFI file in the "**RFI File Path**" input field using the already provided "**Cylinder.rfi**" and click **Execute**.

⑥ **Swap** the **Piston** body as same as above STEP 2~5, using the provided "**Piston.rfi**" file.

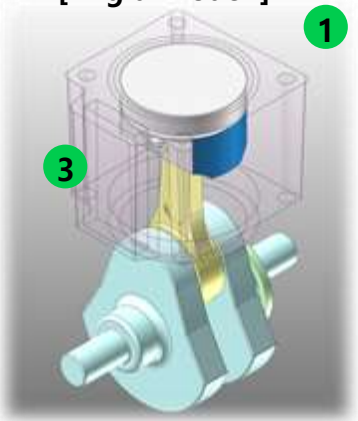
⑦ **Save** the model as "PistonLubricationEHD_Tutorial_Rflex.rdyn"

※ You can simulate and review the result of EHD applied to the rigid bodies.
PistonLubricationEHD_Tutorial_Rigid.rdyn

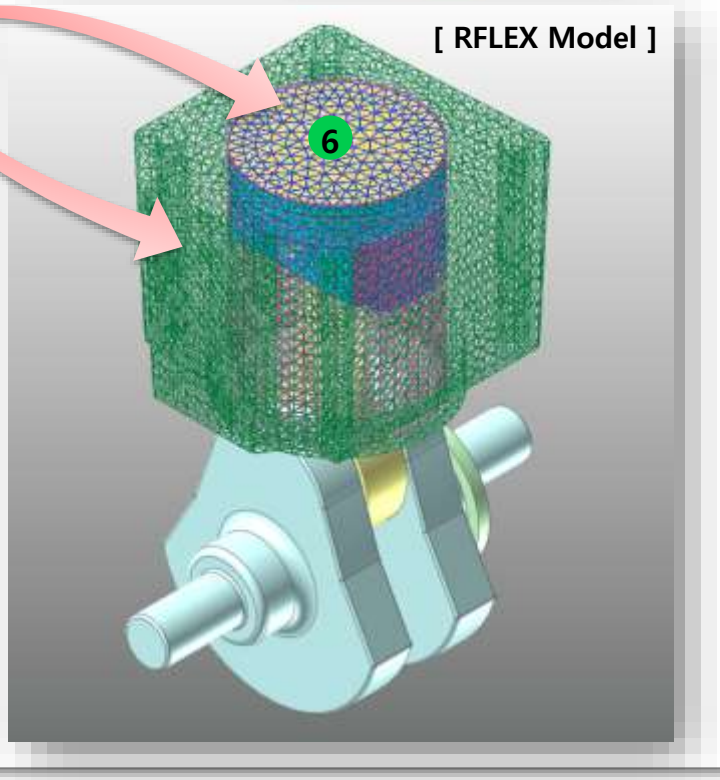




[Rigid Model]



[RFLEX Model]



Step 02 – Make a PatchSet

Steps

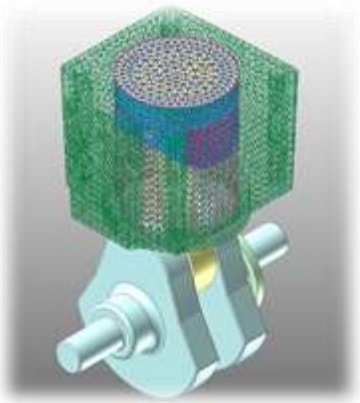
① **Enter** the **edit mode** of the Cylinder Body to create the PatchSet.

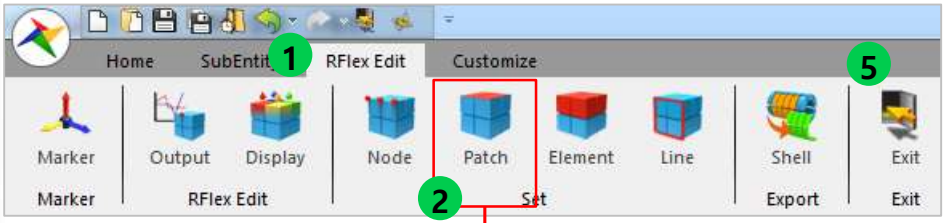
② Create **PatchSet** as an EHD **Cylinder** Wall as shown figure. (Use Add/Remove (Continuous))

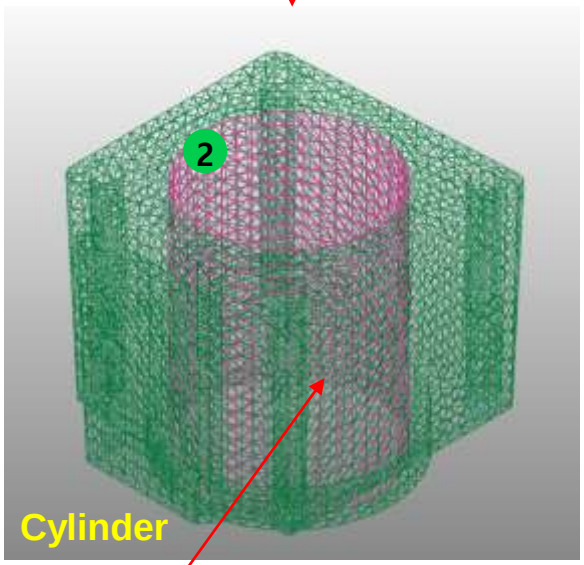
③ **Exit** the **edit-mode**, and **enter** the **Piston** body.

④ Create **2 PatchSets** as for Piston. (**SetPatch1** using both side surfaces to apply EHD and **SetPatch2** using the upper surface to apply Gas-force Pressure) as shown in the figure.

⑤ **Exit** the **edit-mode**.

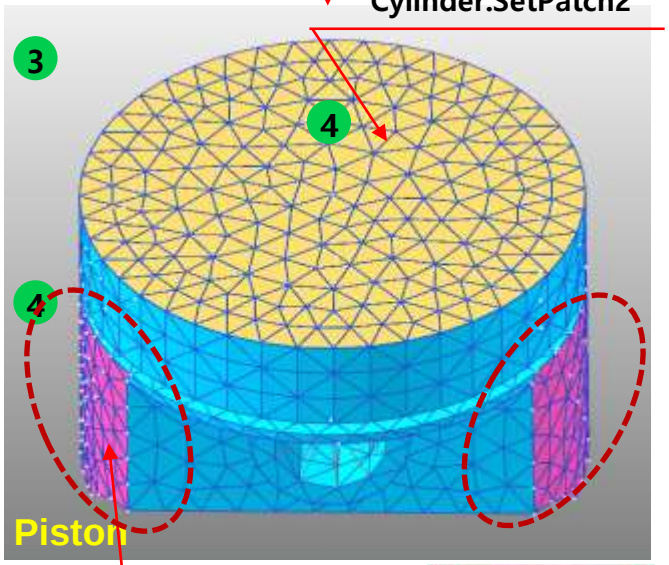




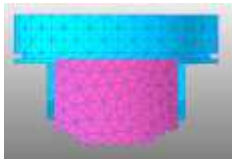


Cylinder.SetPatch1

Cylinder.SetPatch2



Cylinder.SetPatch1



Step 03 – Create the Modal Pressure to the Piston

Steps

① Select "**Pressure"** icon (**Modal Pressure Load)** in **RFlex** Group of **Flexible** tab.

② In a Modal Pressure Load dialog, set **Piston.SetPatch2** as the **Patch Set**

③ Change the **Pressure Direction** from "Up" to "**Down**" direction

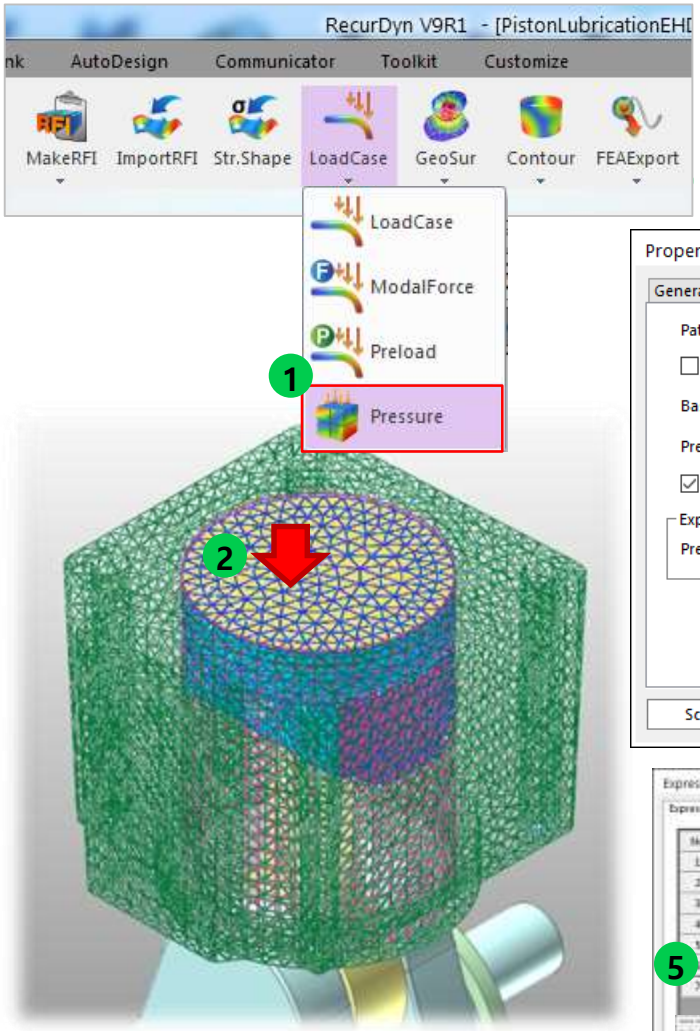
④ Click the **EL button** of **[Expression]-[Pressure]**.

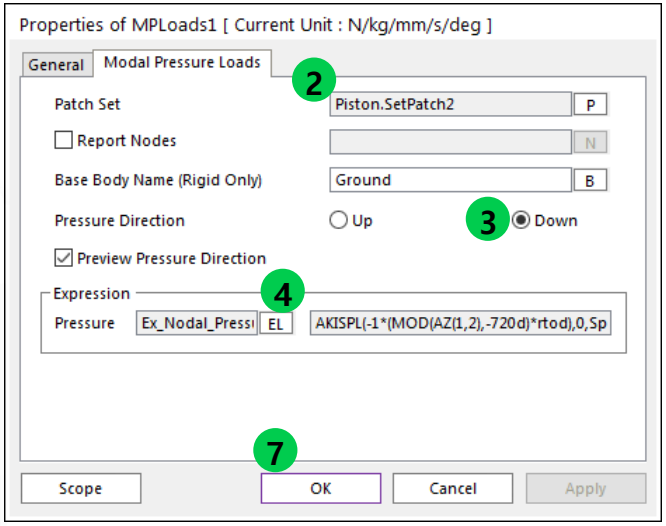
⑤ In the Expression List dialog, **select** the "**Ex_Nodal_Pressure**" expression.

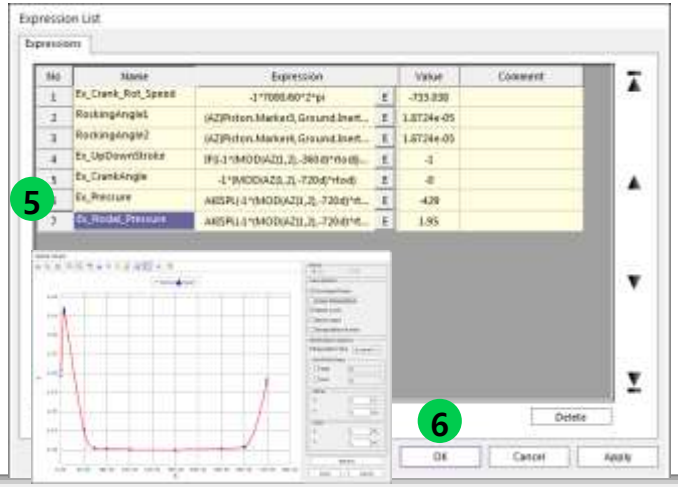
⑥ Close Expression List dialog

⑦ Click the "OK" to close the dialog.

※ The firing gas force is defined by Function Expression. In that expression, the gas force will be generated using a spline curve w.r.t the Crank Angle vs. Gas Force







Step 04 – Create Piston Lubrication EHD Entity

Steps

① Select **PistonLub** icon in the Toolkit group of the Toolkit tab.

② Set the **Creation option** to **"Body,Point,Direction,Direction, Body,Point,Direction,Direction"** (You can define the EHD axis more clearly)

③ Choose the **Cylinder** RFlex Body as Base-body of EHD

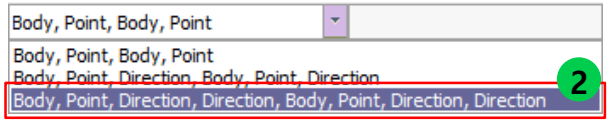
④ Pick the **Center Point of Base Body (Cylinder)**. In this tutorial, it is **"0,-46.5,0"**

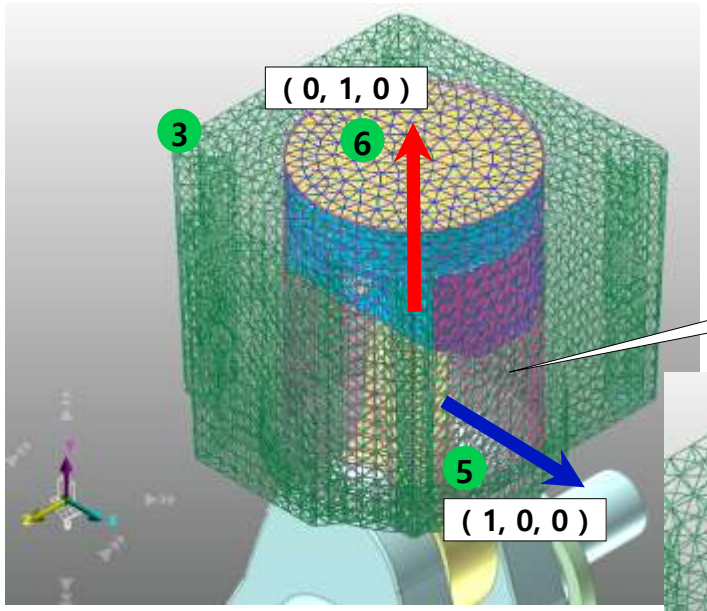
⑤ Set the **direction #1 of Base-Body** to Global Y Axis (0, 1, 0)
→ Y-axis direction of Base Marker

⑥ Set the **direction #2 of Base-Body** to Global X Axis (1, 0, 0)
→ X-axis direction of Base Marker

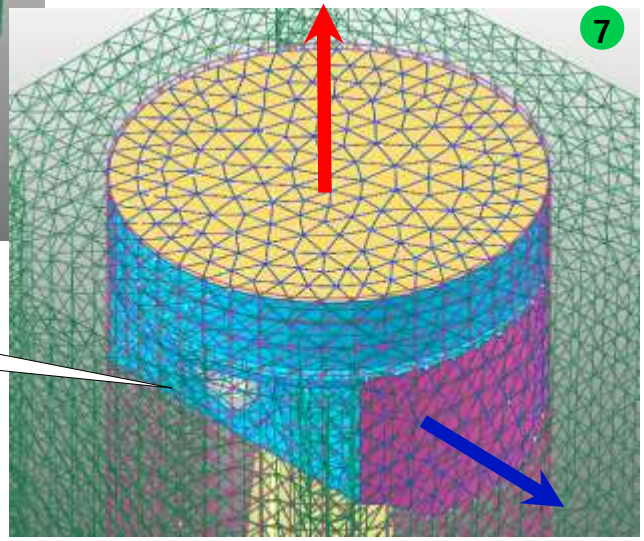
⑦ Define the **Action Body** as same as above steps 3 ~ 6
- **Action Body: Piston**
- **Center Point: 0,-29.5,0**
- **Direction #3: Global Y Axis**
- **Direction #4: Global X Axis**

⑧ **Lubrication1** is created.





4 **Cylinder EHD Position: (0, -46.5, 0)**



Piston EHD Position: (0, -29.5, 0)

X, Y Axis Directions of both bodies MUST BE SAME!

Step 05 – Define the EHD Geometry Properties

Steps

[EHD Geometry Setting]

① **Open** the Properties Dialog of **Lubrication1** (PistonLub EHD)

② **Input** the EHD Geometry **Properties** as below:

- Piston Diameter: 70
- Piston Height: 29
- Cylinder Diameter: 70.045
- Cylinder Height: 95

③ Input "**Piston.SetPatch1**" in the **Piston PatchSet** field.

④ Input "**Cylinder.SetPatch1**" in the **Cylinder PatchSet** field.

[Mesh Grid Setting]

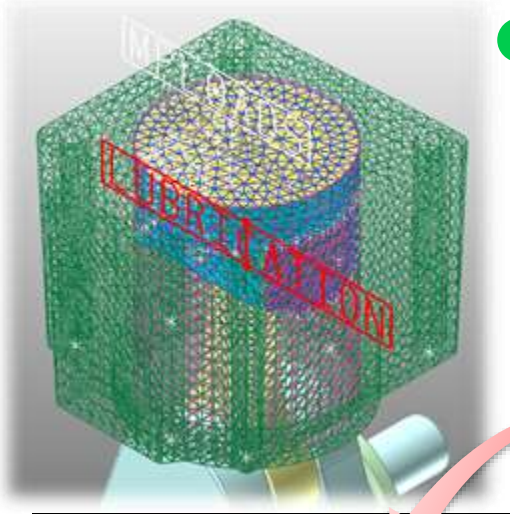
⑤ Click the "**Mesh Grid Setting**" button.

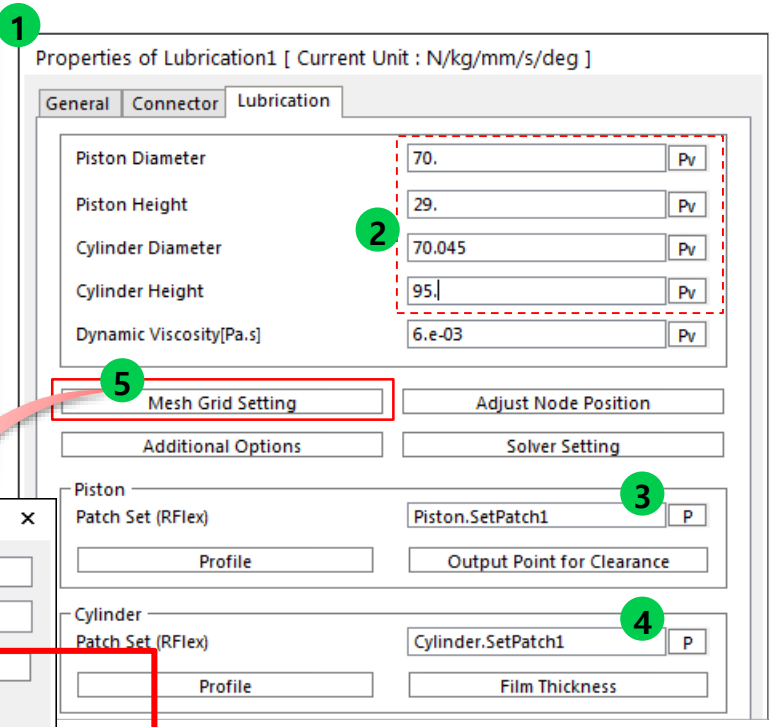
⑥ In the Mesh Grid Setting dialog,

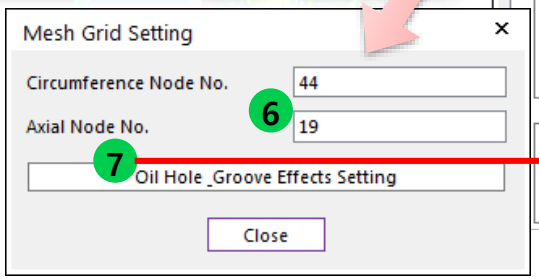
- **Circumference Node No.: 42**
- **Axial Node No.: 21**

⑦ Open the "**Oil Hole_Groove Effect Setting**" dialog, and check on the "**View Nodes**", then you can see the Mesh Grid Display.

⑧ Close the dialog.



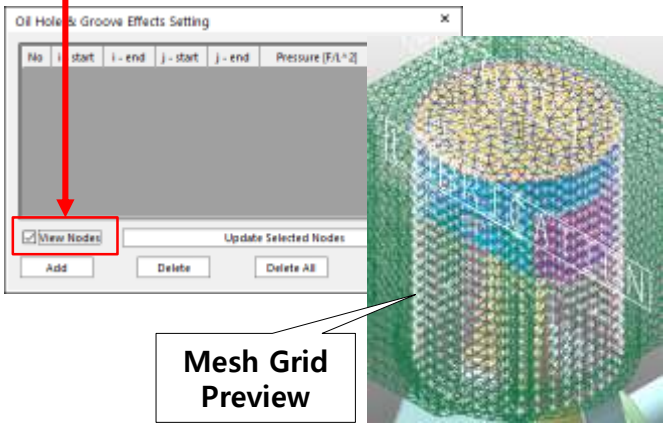




Tips: How to decide the No. of Mesh Grid

To improve the efficiency of the simulation of RecurDyn/EHD Model, make the length of the mesh grid similar to the maximum gap between piston and cylinder.

In the Tutorial, In this tutorial, the maximum gap is about 5 mm.
The circumference length is "π x 70.045 = 220.05" and height is "95"
Therefore, the recommended values are:
- Circumference Node No. is 44 (5x44 = 220)
- Axial Node No. is 19 (5x19 = 95)



Step 06 – Define the EHD Material Properties

Steps

① In the property dialog of **Lubrication1,** Input the **Dynamic Viscosity** as "**6e-3**".

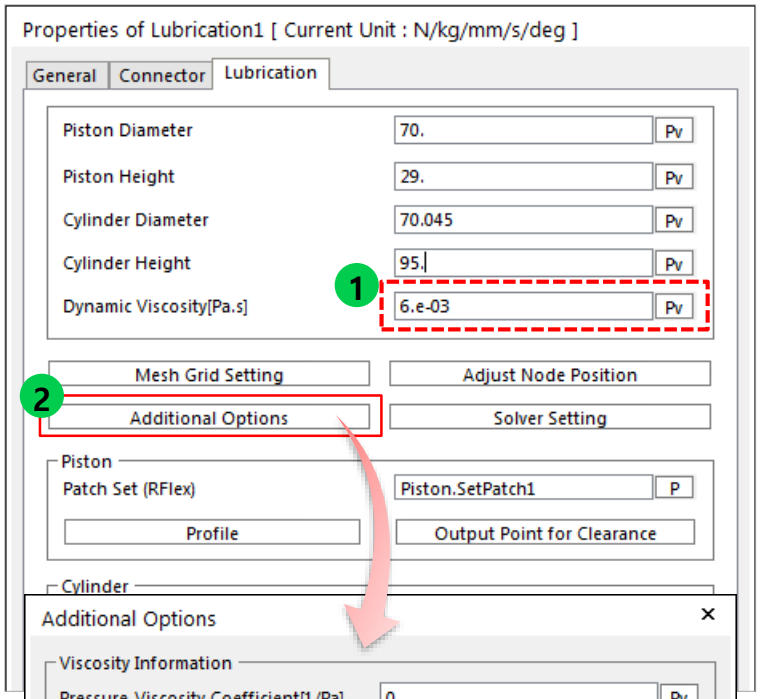
② Click the "**Additional Options**" **button.**

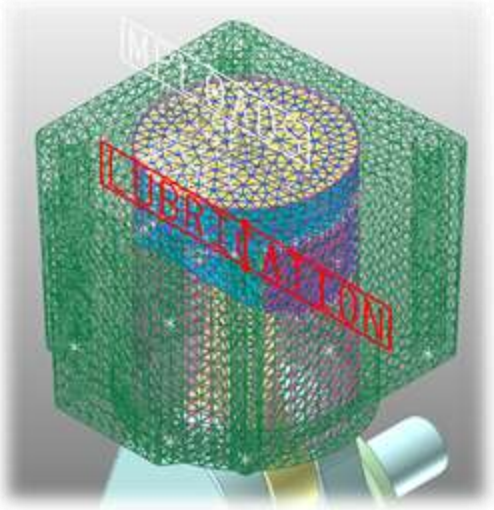
③ Use "**Direct Input**" in Asperity Contact Information.

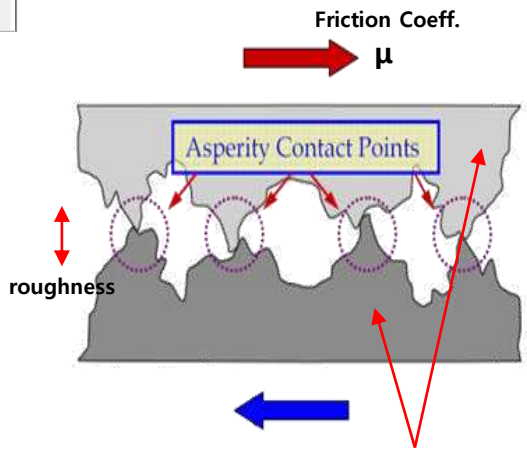
④ Input the values as shown below:

- **Roughness: 0.001**
- **Composite Elastic Modulus: 68000**
- **Elastic Factor: 0.003**
- **Friction Coefficient: 0.5**

⑤ Close the dialog







Step 07 – Set the EHD Solver Settings

Steps

① In the property dialog of **Lubrication1,** click the "**Solver Setting**" button

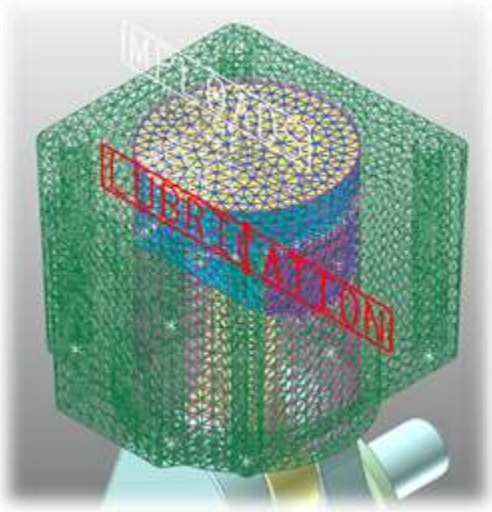
② Set the number of "**Maximum Iteration**" to "**200**"

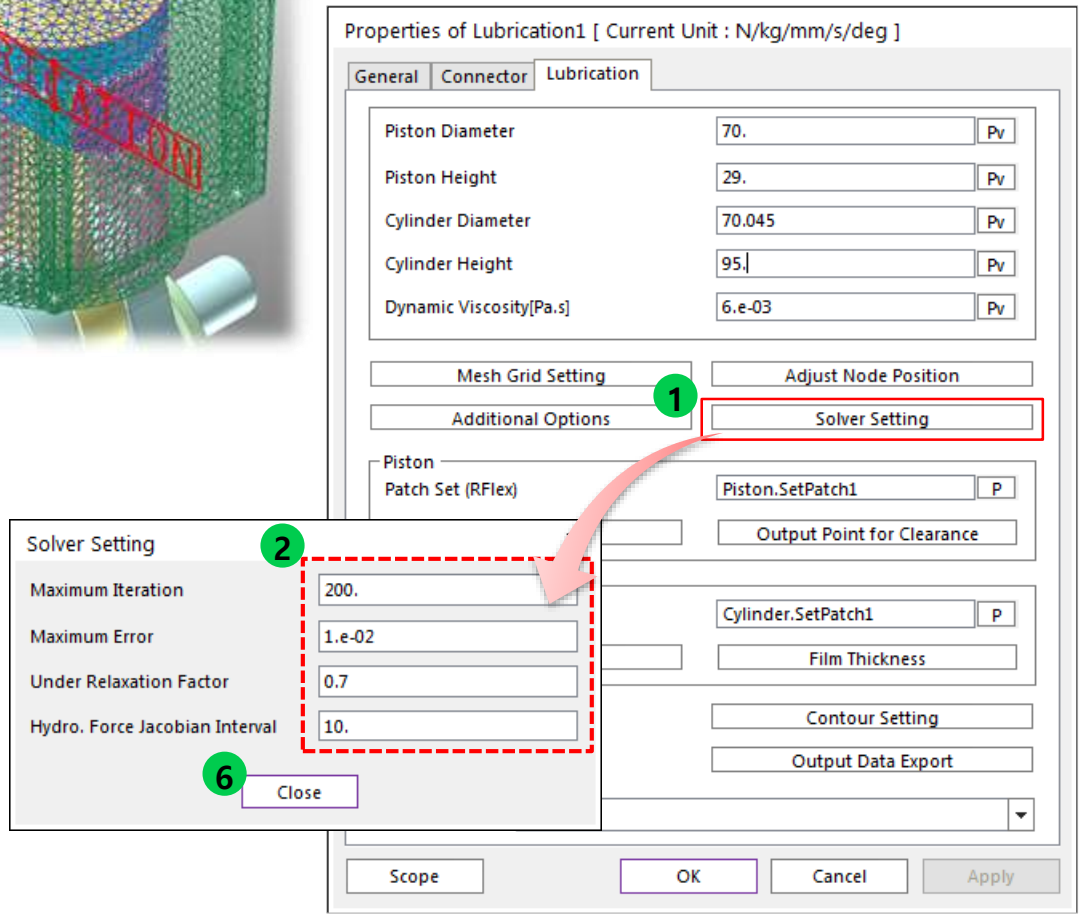
③ Set the "**Maximum Error**" to "**1e-2**"

④ Set the "**Under Relaxation Factor**" to "**0.7**"

⑤ Set the "**Hydro. Force Jacobian Interval**" to "**10**"
(The bigger the value that you use, the faster the solving speed can be. However, increasing this value can reduce the accuracy)

⑥ **Close** the dialog





Step 08 – Run EHD Dynamic Analysis

Steps

① Open the property dialog of **Cylinder** RFlex Body, and select only **5 mode shapes (seq 7~ seq 11)** and close the dialog

② Open the property dialog of **Piston** RFlex Body, and select only **5 mode shapes (seq 7 ~ seq 11)** and close the dialog.

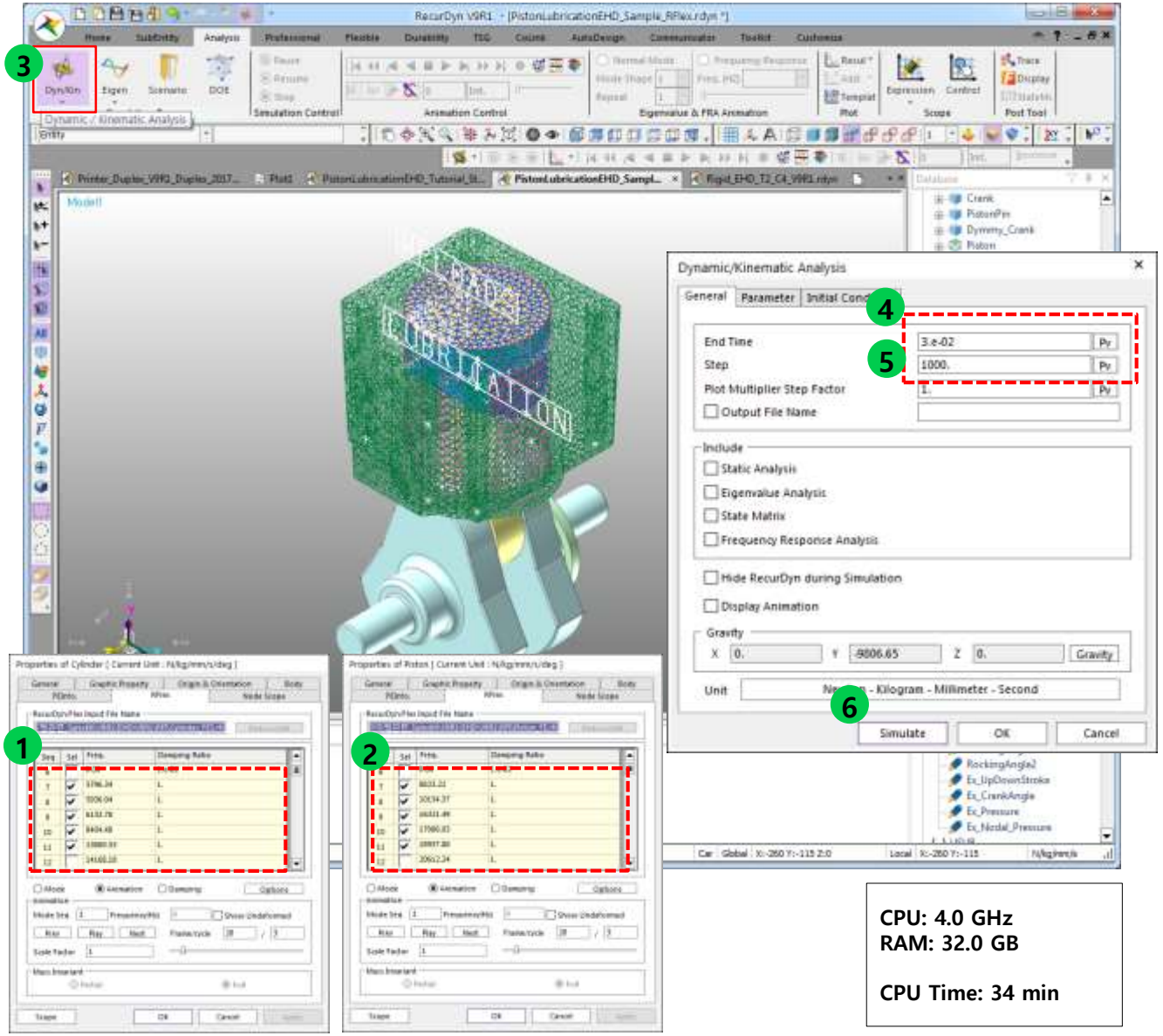
※ The more mode shapes are selected, the longer the solving speed would be.

③ Select **Dyn/Kin** icon in Simulation Type group of Analysis tab.

④ Set the **End Time** to "**3.e-2**"

⑤ Set the **Step to "1000"**

⑥ Click the "**Simulate**" button



CPU: 4.0 GHz
RAM: 32.0 GB

CPU Time: 34 min

Step 09 – Review the EHD Analysis Results (1)

Steps

[EHD Contour Result]

① **Open** property dialog of **Lubrication1** & **check on** the "**Show Pressure Contour**"

② Click the "**Contour Setting**" button

③ Set **Pressure Type** to **"Hydrodynamic + Asperity"**

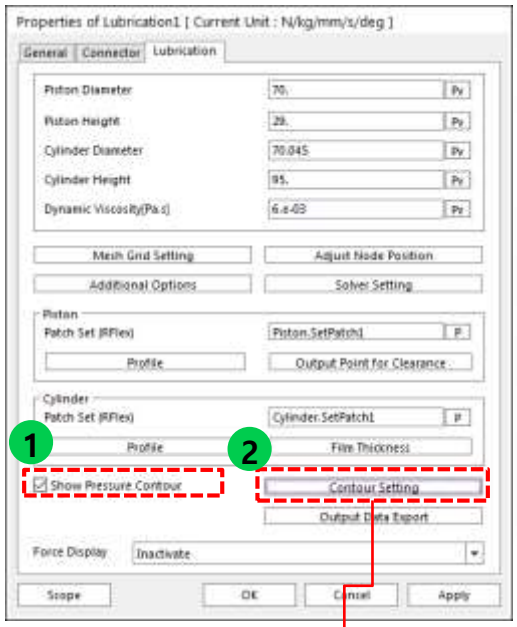
④ Click the **Apply** Button

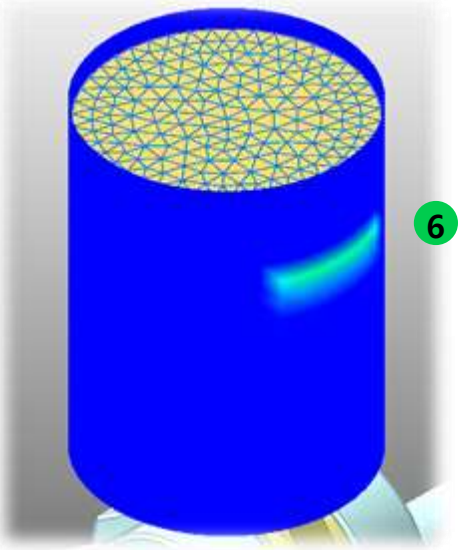
⑤ **Play** the **Animation**

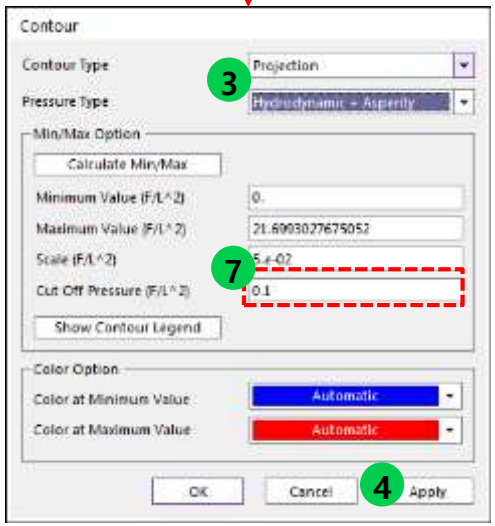
⑥ You can see the contour plot of the **EHD force result** in the working plane

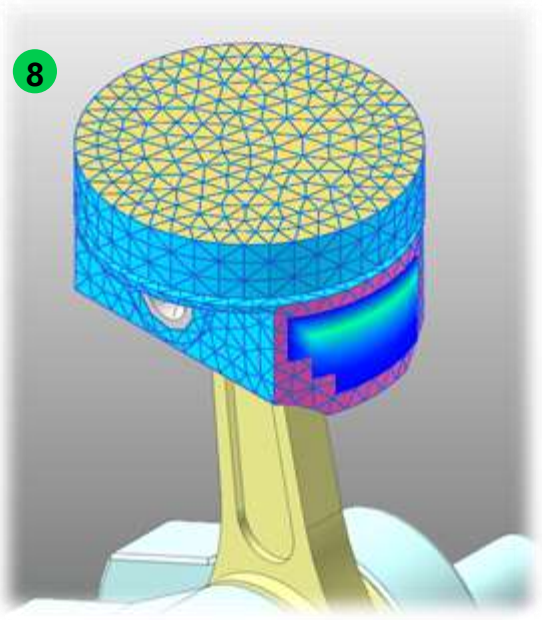
⑦ Set the **Cut Off Pressure** to "**0.1**", then click the **Apply** button.

⑧ **Play** the **Animation**, you can see the contour plot and the values less than the Cut Off value will not be displayed.









Step 10 – Review the EHD Analysis Results (2)

Steps

[EHD Plot Results]

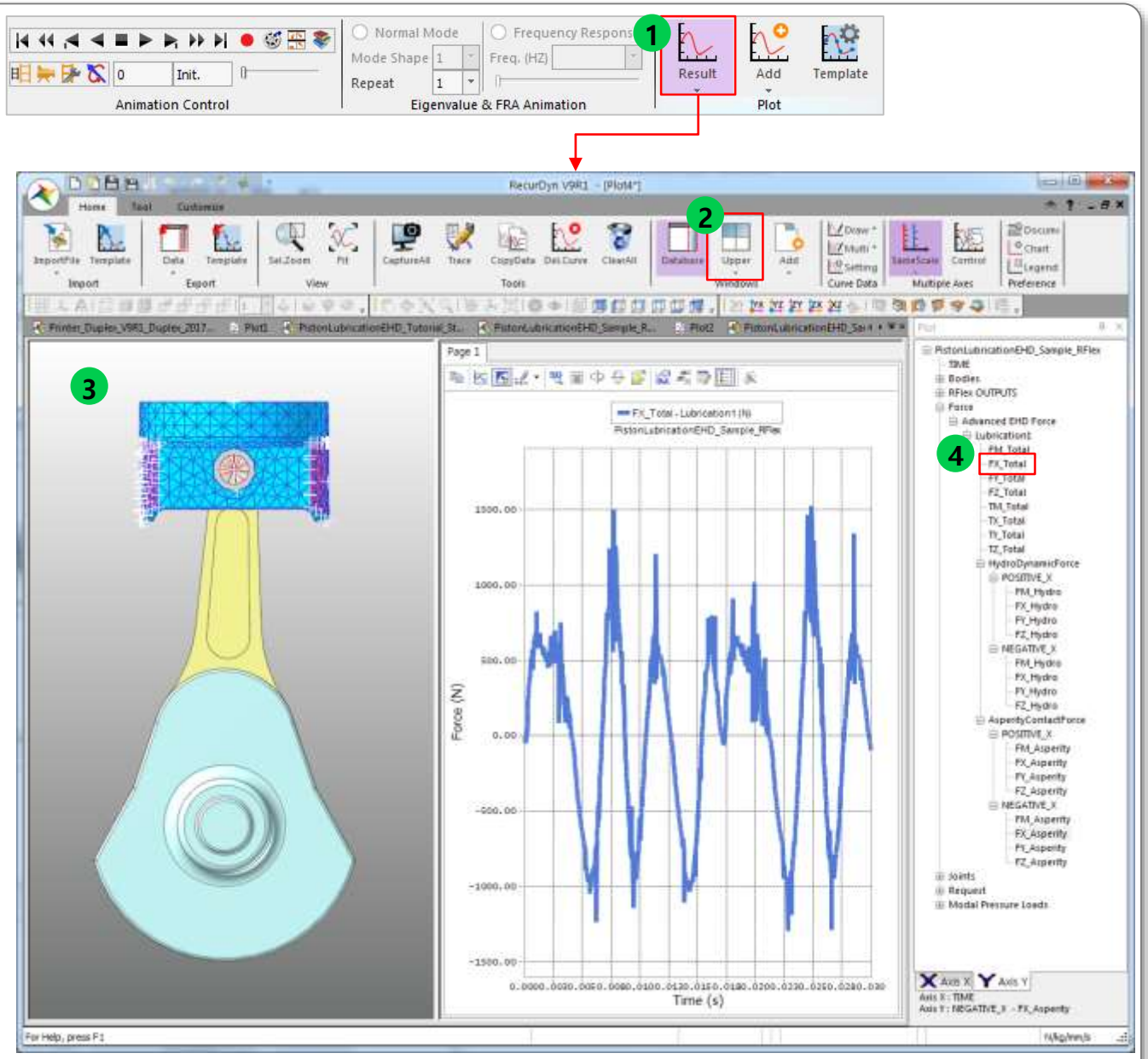
① Select the "**Result**" icon in the Plot group of Analysis Tab.

② Select **Upper** icon in Windows group of Home tab to Split the Plot Window

③ Load animation to the left-side window. ([Tool]-[Animation]-[**LoadAni**])

④ Click the Right-side Plot window, and **draw the curve** from Plot Databse ("**Force/Advanced EHD Force/Lubrication1/FX_Total**")

※ User can see the Hydro+Asperity Total Lubrication Force between Piston and Cylinder. Also, user can see the contact area in the left-side animation result.



Step 11 – Review the EHD Analysis Results (3)

Steps

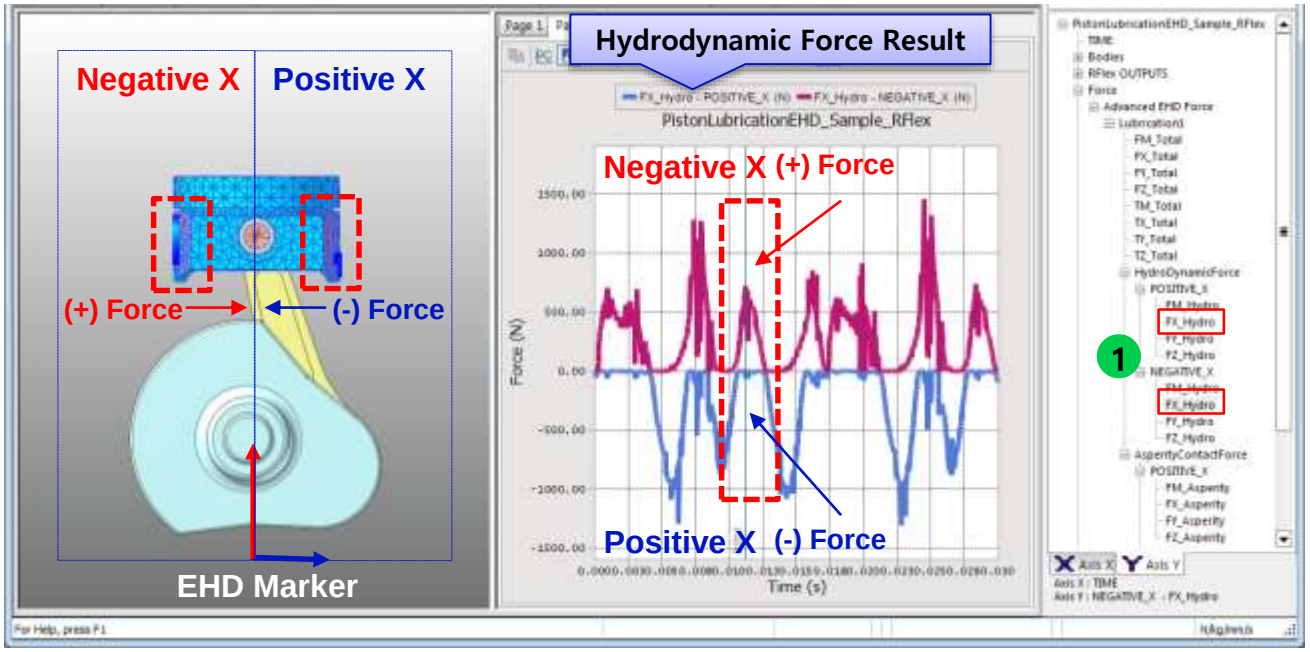
[EHD Plot Results]

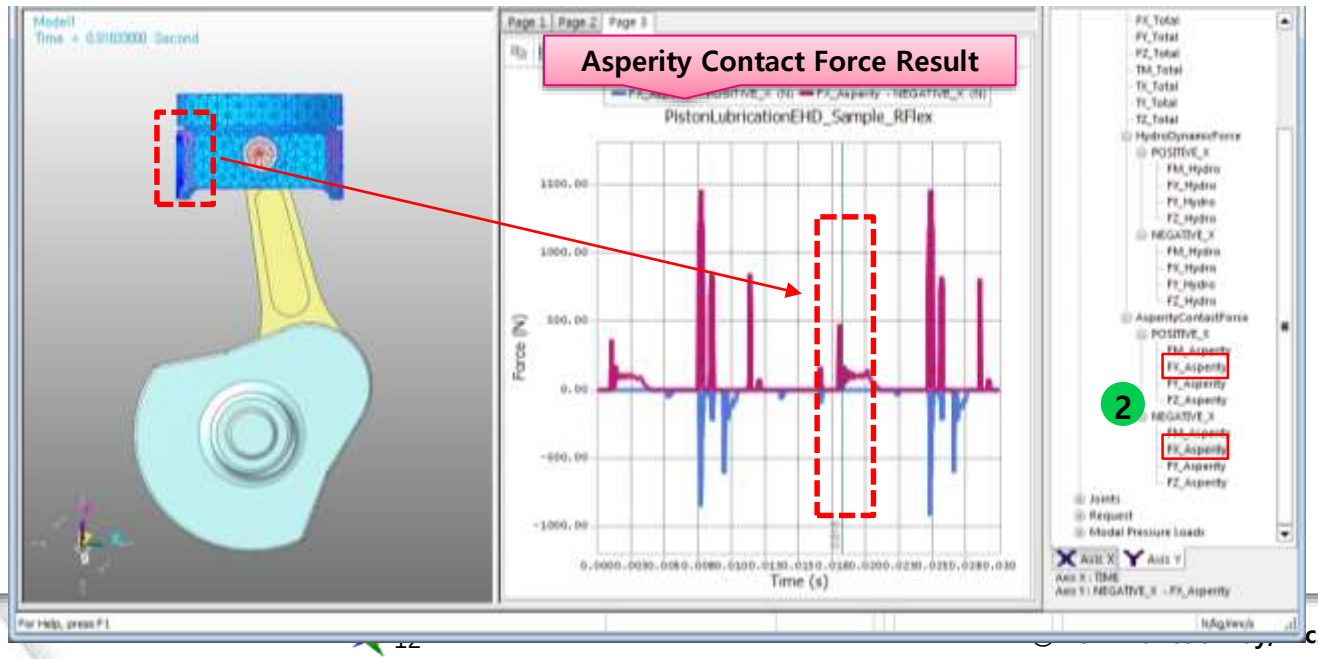
① Draw the curves from Plot Database "…/Lubrication1/HydroDynamicForce/Positive_X/**FX_Hydro**" and "…/Lubrication1/HydroDynamicForce/Negative_X/**FX_Hydro**".

② **Add a New Page ([Home]-[Windows]-[Add])**

③ Then draw the curves in the new page. "…/Lubrication1/AsperityContactForce/Positive_X/**FX_Asperity**" and "…/Lubrication1/AsperityContactForce/Negative_X/**FX_Asperity**".

※ You can see where the contact area is and the magnitude of the contact force.





Step 12 – Create Output Points for Clearance

Steps

① Return to the Working window of RecurDyn, open the property dialog of **Lubrication1** (EHD property)

② Click the "**Output Point for Clearance**" button

③ Set the **reference marker** to "**Piston.Marker1**" (Action Marker of Lubrication1)

④ **Add** 4 **Output Gap points**

⑤ Set the **Height / Angle** as below:

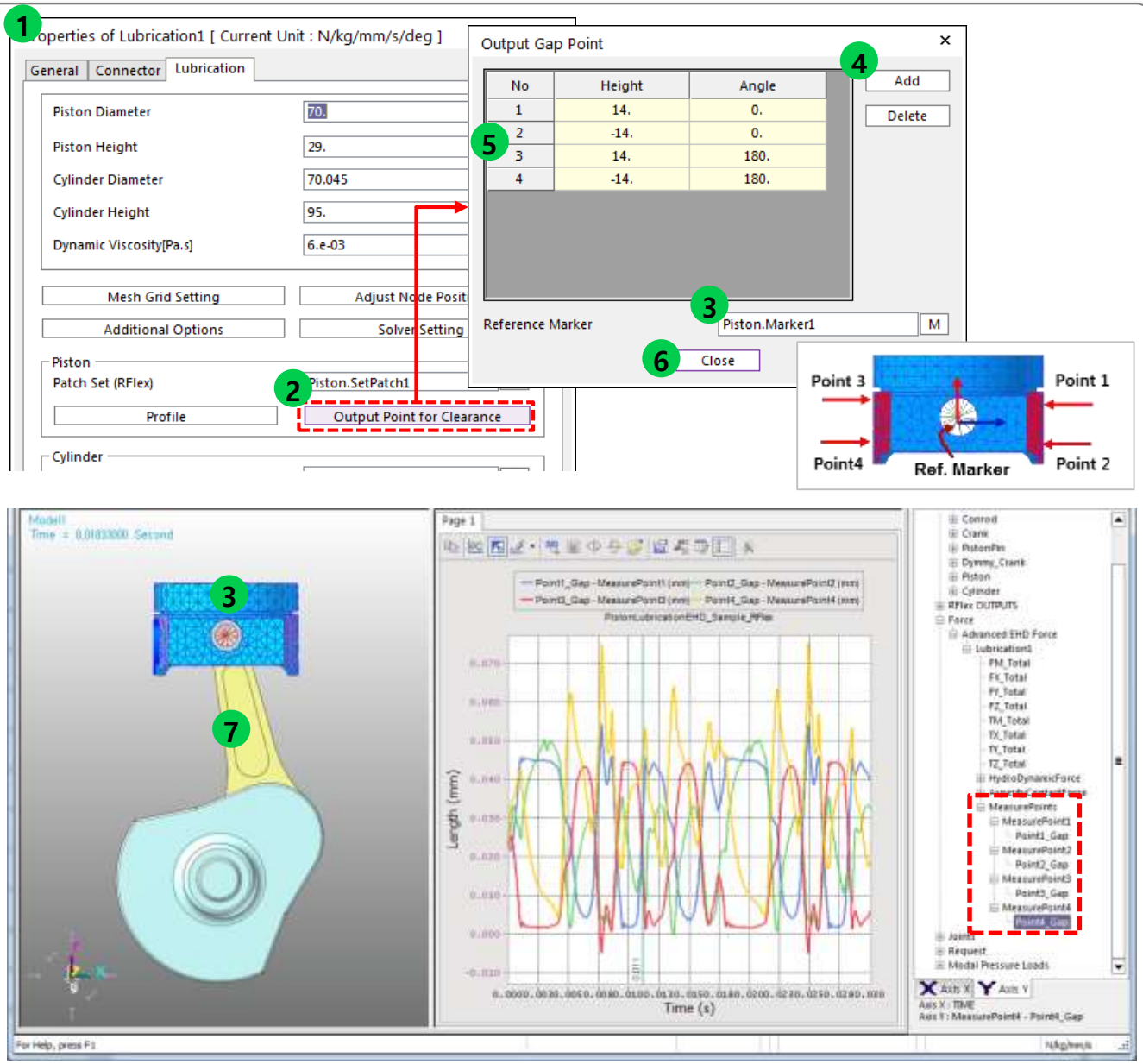
1) 14, 0

2) -14, 0

3) 14, 180

4) -14, 180

⑥ **Close** the dialog



Step 13 – Modify the Piston Profile

Steps

[Piston Profile Modification]

① Click the "**Profile**" button.

② Check on "**Use Profile**" option, in the **Piston Profile** dialog

③ Set the values as below:

1) **Profile Length: 29**

2) **Number of Angle: 44**

3) **Ref. Marker: Piston.Marker1**

4) **No. of Height: 19**

④ Click the "**Create Data Field Uniformly**" button

⑤ The input filed of **Profile** is filled automatically

(You cannot modify the values directly in this dialog)

⑥ **Export** the data as *.csv

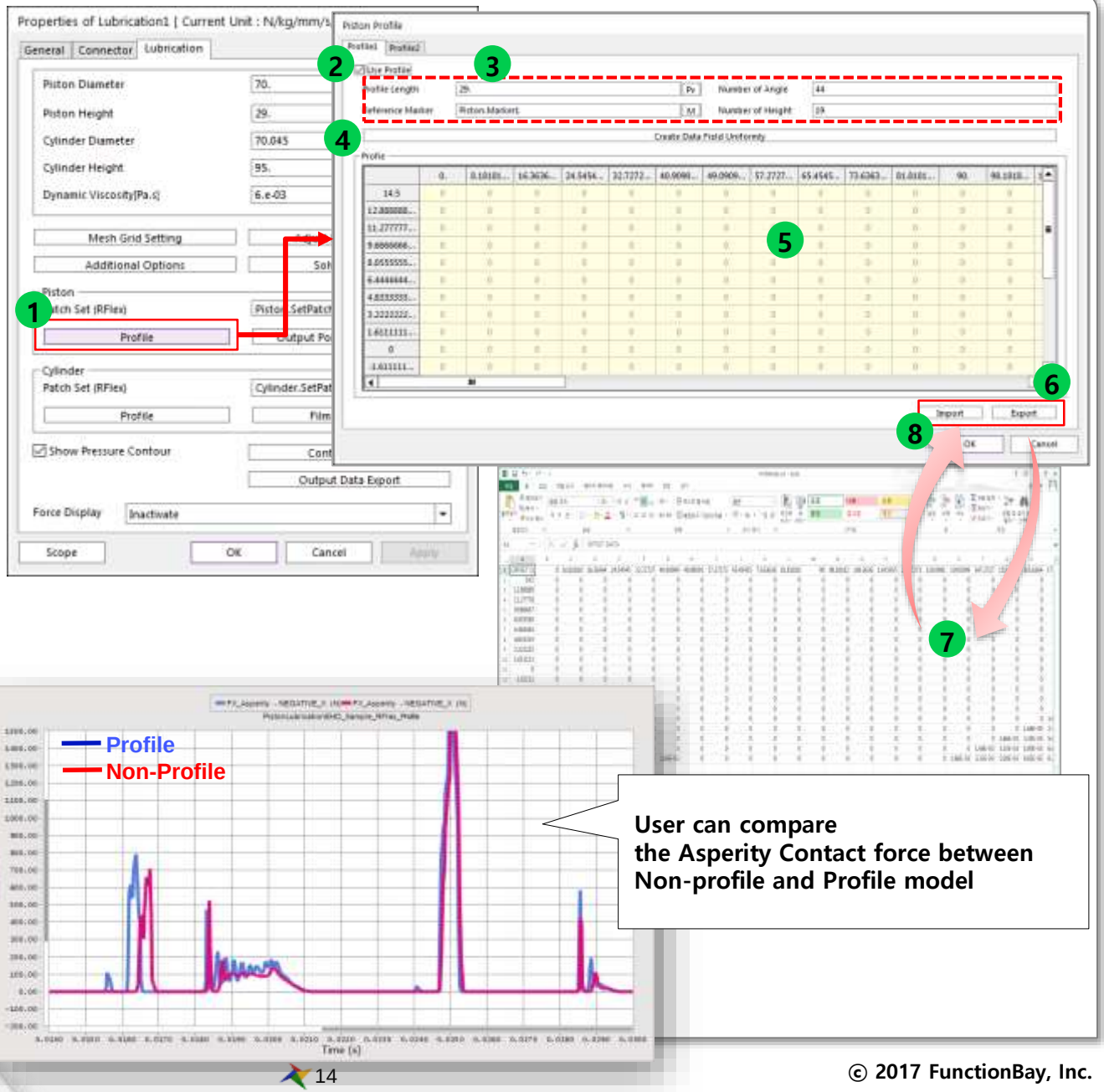
⑦ **Open** the *.csv file by **Excel**, and **modify** the profile data.

⑧ **Import** the modified *.csv in **Piston Profile** dialog.

(In this tutorial, you can use pre-created "**ProfileData.csv**")

⑨ **Close** the Profile dialog

⑩ You can run **simulation** again using the new setting.



Thank you.

5F, Pangyo Seven Venture Valley 1 danji 2dong, 15, Pangyo-ro 228beon-gil,
Bundang-gu, Seongnam-si, Gyeonggi-do, 13487, Korea
Tel: +82-31-622-3700, Fax +82-31-622-3704, http://www.functionbay.co.kr