ME360 Mechanisms Tutorial – Mechanism motion and redundancy

Dr. Enrique S. Gutierrez-Wing

This tutorial requires the part files that are located in the following link:

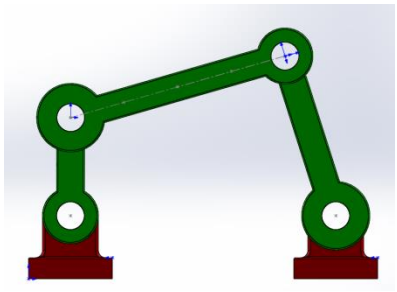
https://drive.google.com/file/d/0Byt6Ja-Dc9x6VFRNYlYzeTBleTA/view?usp=sharing

Download the files and save them to a local directory. Make sure to take note of where you saved them.

1) Start Solidworks
2) Make sure that the Motion Add-in is active (click on Tools>Add-ins, tick Solidworks Motion and click OK)
3) Open a new assembly (File>New>Assembly)
4) Insert the following components into the assembly (the ones you downloaded):
    a. Bearing.SLDPRT
    b. Crank.SLDPRT
    c. Extension.SLDPRT
    d. Rocker.SLDPRT

    Click the Browse button and navigate to the directory where you saved the files. You can do a multiple selection and import them all at once or insert them one by one.
5) Right-click on Bearing in the graphics window and select Float
6) Orient Bearing so that its arched surface is at the top (+Y) and the hole axis is parallel to the Z axis.
7) Mate the bottom, left and front faces of Bearing to the Top, Right and Front planes, respectively (requires 3 mates: Coincident).
8) In the Design Tree (Feature Manager), left click on Bearing, copy with CTRL-C and paste it into the assembly. This will create a copy of Bearing in the assembly, we will call it NewBearing.
9) Mate the front and bottom faces of NewBearing to the Front and Top planes, respectively.
10) Mate Bearing and NewBearing so that they are 130mm apart, with NewBearing on the +X side of Bearing.
11) Create a revolute (Hinge) mate between the hole in Bearing and one of the holes in Crank. Mate faces on the components in such a way that the joint looks realistic.
12) Create a revolute (Hinge) mate between the other hole in Crank and one of the holes in Extension.
13) Create a revolute (Hinge) mate between the other hole in Extension and one of the holes in Rocker.

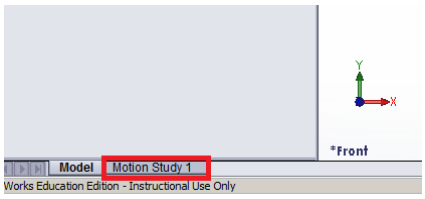
14) Create a revolute (Hinge) mate between the other hole in Rocker and the hole in NewBearing. The assembly should look like this (Front View: CTRL+1):



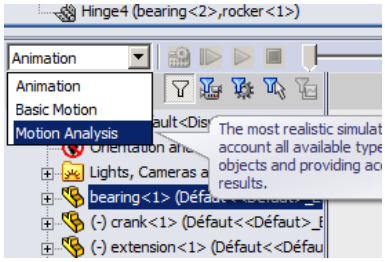
Check that the links can only move in parallel planes. Try to drag them out of their planes to make sure that no joint is missing or wrongly defined.

SAVE YOUR WORK NOW

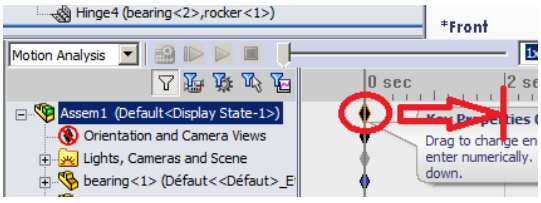
15) Once you are sure that the motion of the mechanism is correct, press the Motion Study tab at the bottom left of the screen to create a new motion study.



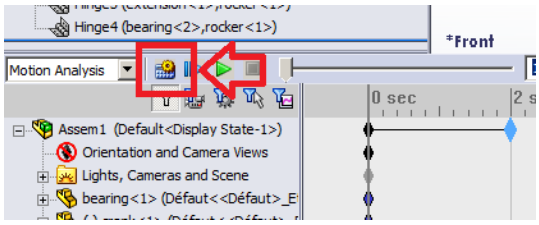
16) Select Motion Analysis from the drop-down menu on the left side of the Motion panel.



17) Click and drag the first Key marker on the Motion timeline to about the 2 sec mark (exact value is not relevant)

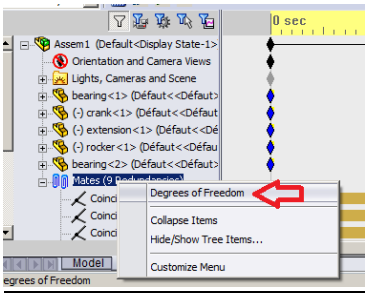


18) Run the analysis by clicking on the button indicated below:

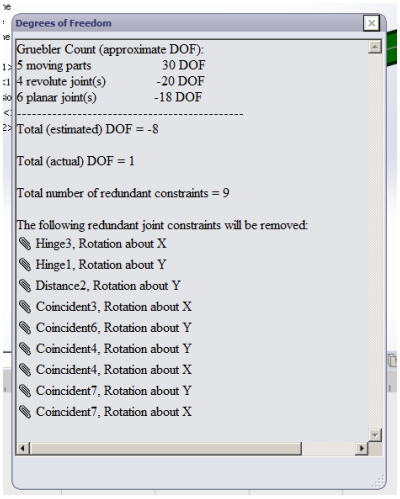


Nothing will happen with the mechanism since we don't have a motion source yet, but the motion solver will check for redundancies.

19) On the Motion panel, right-click on Mates>Degrees of Freedom:

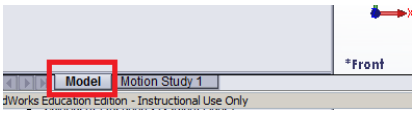


20) A window will pop-up showing the 9 redundant joins in the mechanism and the actions taken by the solver to resolve these:

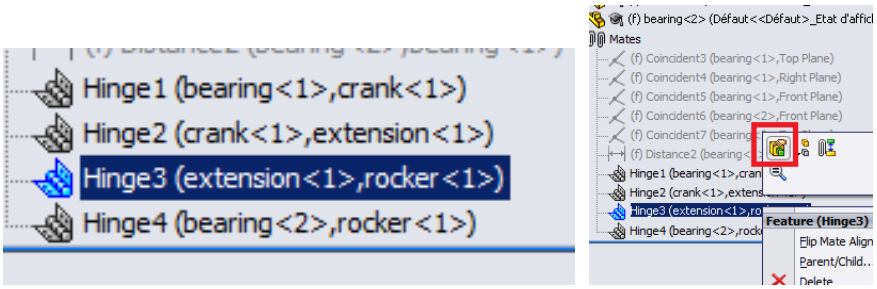


Instead of letting the solver take control of the mechanism, we will resolve the redundancies by choosing appropriate types of joint.

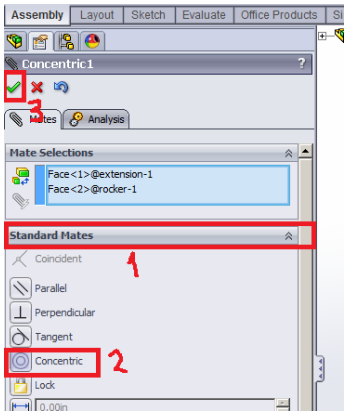
21) Click on the Model tab at the lower left corner of the screen.



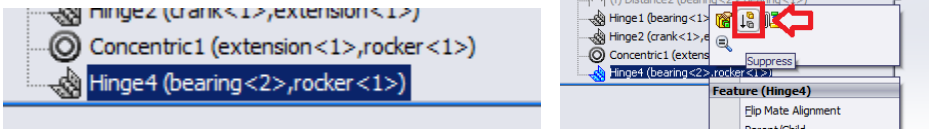
22) Fix Bearing and NewBearing (right-click on them in the Graphics Window and select Fix).
23) In the Design Tree right click on the Hinge joint between Extension and Rocker and select the Edit Feature icon.



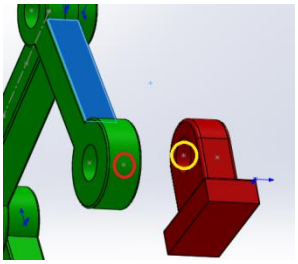
24) Click on the Standard Mates tab, select Concentric and then accept. Close the Mates pane.



25) On the Design Tree right-click on the mate between Rocker and NewBearing and suppress it.



26) Click on the Follower in the graphics window and drag it towards the front to separate it from the NewBearing. This will make it easier to create a new joint bewteen the two components.

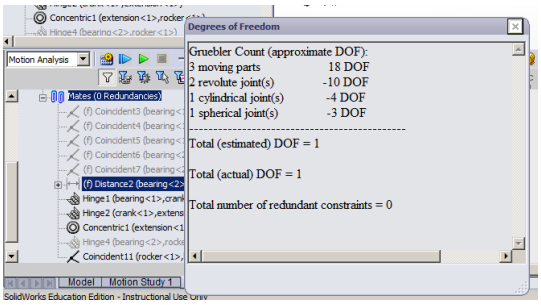


27) Create a spherical joint between the two points encircled in the figure by selecting Mate>Coincident and then selecting the two points.

28) Align the Crank so that its body is horizontal and between the two bearings. You can do this by creating a parallel mate between one of its side faces and the Top Plane. Once you create the mate and the Crank is in a horizontal position suppress the mate to free the Crank.

SAVE YOUR WORK NOW

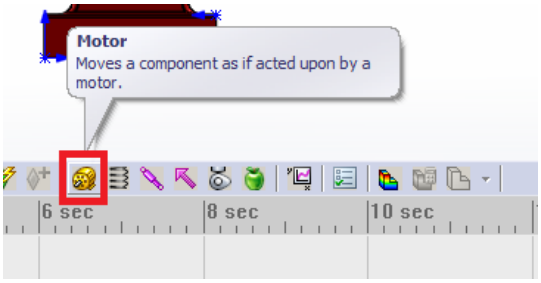
29) Right-click on the Motion Study 1 tab at the bottom left of the screen and select Create a New Motion Study. A new study is created with the new joint configuration.
30) Choose Motion Analysis and drag the Key marker to the right in the timeline.
31) Run the analysis to check for redundancies.
32) Right-click on Mates in the Motion panel and check for joint redundancies.



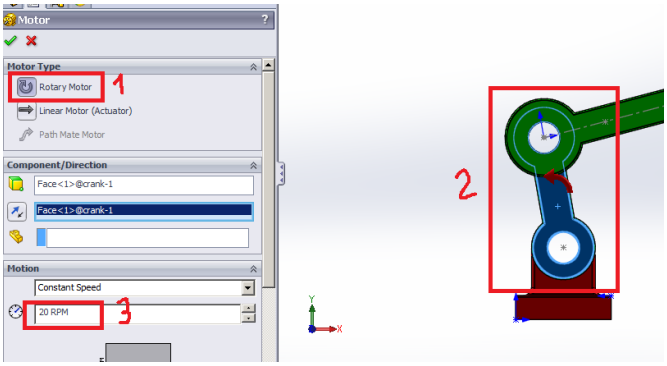
The mechanism should have exactly one Degree of Freedom (DOF), meaning that we only need a single motion source to control its position. In Solidworks this source is called a Motor and we will insert it next.

33) Slide the key marker to 0 seconds. This will make the following changes valid from the start of the simulation. This step is important for any changes you make to the mechanism.

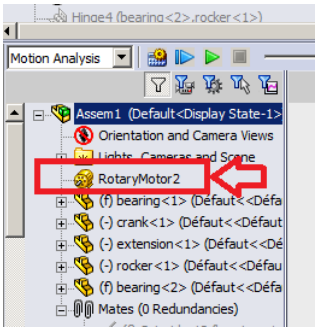
34) On the Motion ribbon, click on the Motor icon



35) Select Rotary Motor, click on the front face of Crank in the graphics window and set the speed of the motor to 20 rpm, then accept by clicking on the green tick mark at the top.



An entry for the motor will be created in the Motion Study tree:



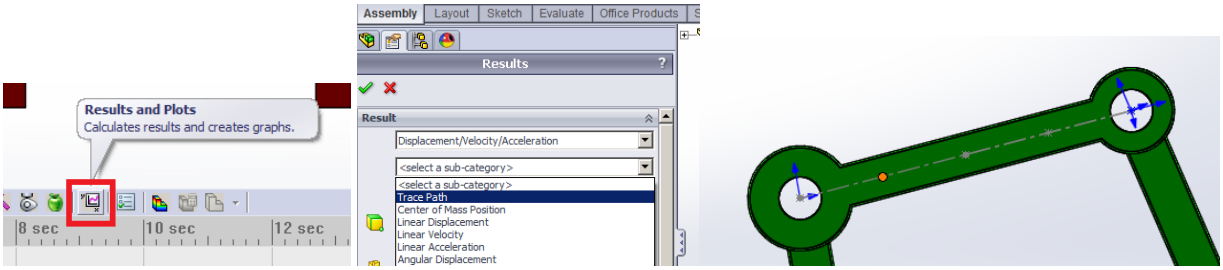
To reconfigure the motor just right-click on it and choose Edit Feature.

36) Move the analysis Key marker in the timeline to 6 seconds. This will allow the Crank to complete two full motion cycles (20rpm -> 3 sec/cycle).
37) Run the analysis by clicking on the Calculate icon in the Motion Panel.

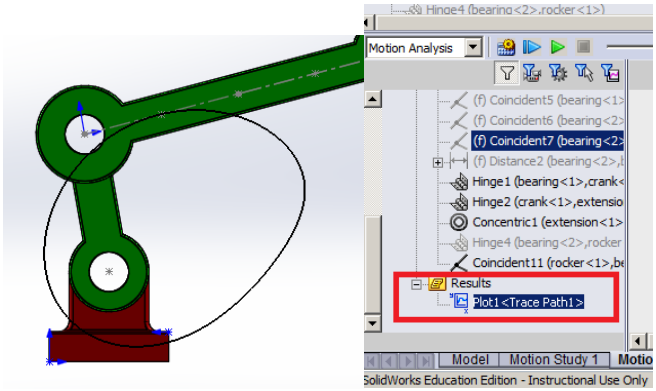
SAVE YOUR WORK NOW

RESULTS

38) Trace the motion paths of the point at ¼, ½ and ¾ length on Extension. Click on the Results and Plots icon in the Motion ribbon, then select category Displacement/Velocity/Acceleration and sub-category Trace Path. Finally, click on one of the points in the graphics window. Repeat these steps for each of the three points.



The motion path will be displayed as in the figure below. You will also see a new entry in the Motion Analysis tree that makes reference to the plot. All plotted results will be referenced below this Results entry and you can Show, Hide and Edit the results from there (right-click the Plot and then select the appropriate option).



ASSIGNMENT

1) Trace the velocities in the X and Y directions for the midpoint of Extension.
2) Save the results to a CSV file (right-click on the plots and choose Export CSV). Open them in Excel
3) Change the materials of all the parts to Plain Carbon Steel
4) Add Gravity to the Motion Study and plot the Motor Torque

Determine:

a) The maximum value of the motor torque
b) The angle of the crank for which the motor torque is maximum in each cycle
c) The maximum vertical force exerted on Bearing and NewBearing
d) The minimum motor power required to have to move the Crank at a constant angular speed of 600 rpm.
e) Explain the meaning of the negative motor torque values and how they are related to the motion of the mechanism links.