Power Flow and System Deflection Analysis
Power Flow
For sections 4 onwards, you can use the model you have built in section 3. Alternatively there is a pre-built model ‘EV Gearbox.Masta’ that you can load in order to complete the remaining tasks.
Power Flow - Introduction

- Power flow is mainly used to check your design and load cases since it does not account for misalignments which affect gear ratings.
- Power flow solves the Power = Torque x Speed equation for all components and connections.
Power Flow - Interface

Power Flow Mode

Assembly View

Properties Grid

Load Cases & Duty Cycles

Power Flow Tabs

Results Area
Power Flow - 2D and 3D View

- Click on the 2D View tab, and select and run a load case to see the transmission power through the two gear stages
- Then click on the 3D View tab and click animate to see your drive train operate
- You can see which gear flank is loaded by checking the “Colour Loaded Flanks?” box
  - The assignment of the left and right gear flanks are dependent on the positive Z direction of the global coordinate system
Click on the Reports tab to see the results of the load case you ran.

The report gives rating results including damage and safety factors for the Gear Pairs according to ISO 6336, DIN 3990 or AGMA 2101-D04 standards, not including any misalignment.
Power Flow - Reports

Select the top level of the assembly view and the load case you just ran to generate a power flow analysis summary report.

- A more detailed report of individual gear sets can be generated by selecting a gear set in the assembly tree but for now, stick to the top level.
Scroll down or click on “Rating For All Gear Sets” to see the fatigue and static safety factors of the two gear pairs.

Each safety factor is associated with bending and contact durability.

Bending failure is characterised by shearing at the gear root.

Contact failure is characterised by surface damage on the gear face width.

Click on the copy symbol above the tables and create a spreadsheet to your safety factors each load case into. You will need this spreadsheet later.
The safety factor indicates how far away the applied stress is from the maximum stress.

Fatigue safety factors are calculated from the fatigue strength and the stress amplitude.

Static safety factors are based on the tensile yield strength of the material.
Power Flow - Duty Cycle Analysis

- Select the top level in the assembly tree, select the duty cycle tab, select the top level of the duty cycle and run the duty cycle
- Then copy the fatigue and static safety factors into your spreadsheet
System Deflection
System Deflection - Introduction

- System deflection takes misalignment into account and solves Force = Stiffness x Deflection equation for all components and connections
- Misalignment in MASTA is defined in the transverse plane as a displacement along the line of action (where the gears are in mesh during rotation)
- Main outputs include: component deflections and reaction loads, shaft stress; gear misalignments and rating (to ISO 6336, AGMA 2101 - D04 or DIN 3990 standards for cylindrical gears) and bearing loads, misalignments, lifetimes and ratings (to ISO 76, ISO 281 and ISO/TS 16281 standards)

Line of action
System Deflection - Interface

- System Deflection Mode
- Assembly View
- Properties Grid
- Load Cases & Duty Cycles
- System Deflection Tabs
- Results Area
System Deflection – 2D View

- Select the 2D View tab and run a load case
- Click on the display drop-down box to view different types of visual results
- Power flow, system axial loads and bearing elements that are closest to truncation may be useful to see when potential problems arise in your drive train
  - Truncation = when the theoretical Hertzian contact area of the element goes beyond the bearing race groove
System Deflection – 3D View

- Select the 3D View tab to view the system deflections.

You can select/deselect which components you are interested in here.

You can exaggerate the system deflections, increase force arrow size, and adjust model transparency here.
System Deflection – 3D View

- Switch on “Solid Shafts”, “Solid Components” and “Transparent Model”
- The greyed out “no contour” drop-down menu is now selectable
  - Select “Displacement-Linear Magnitude” to view the magnitude of the deflections of each shaft
- Adjust the displacement scale to see the directions of the displacement in relation to original position shown by the transparent model
- To view a sub-assembly or individual components, double-click on the sub-assembly or component, respectively, in the component tree in the assembly view
System Deflection - Reports

- Select the reports tab, the top level of the assembly tree and the load case you ran to generate a summary report of the system
- Reports for the shafts and bearings are now available
System Deflection – Gear Mesh Misalignment

- Clicking on “Cylindrical Gear Mesh Misalignments” will show you the misalignments of the individual gears for each gear set, and the total equivalent misalignment.
System Deflection – Gear Ratings

- Click on “Ratings For All Gear Sets” to see the fatigue and static gear ratings
- Run the duty cycle and copy the gear ratings into your spreadsheet for each load case and the duty cycle
- Task: Now compare your power flow and system deflection gear ratings in your spreadsheet. What effect did misalignment have on the gear ratings?
System Deflection – Shaft Rating

- Select the top level of the duty cycle and click on “Shaft Fatigue Safety Factor Summary Table” in the Reports tab to see the fatigue and static safety factors of all shafts.

- The Shaft Results tab provides a more detailed analysis of individual shafts:
  - Select the input shaft and select “Fatigue safety Factor” in the drop-down menu.
  - This display shows the position of the lowest safety factor along the shaft profile.
Select the top level of the duty cycle and click on “Bearing Summary Table” in the Reports tab to see the fatigue and static safety factors of all bearings:

- Static: ISO 76
- Fatigue: ISO 281 and ISO 16281

Select the “Bearing Results” tab and select a bearing for more detailed results:

- Change the plot display to “Maximum Normal Stress” to see how the stress is distributed among the bearing elements
- Scroll down to see the contact patterns on the inner and outer bearing races
Next task...

- Please now work through the document:

  5. Gear Macro Geometry

- The next slide in this document contains some additional tasks you might want to attempt after completing all the other tutorials.
Additional Tasks

- By only considering the gears, how can gear ratings be improved?
  - Hint: Think about ways to improve allowable bending and contact stresses

- For the next tasks:
  - Any changes to the model will need to be done in the design mode
  - Make a note of the parameters and their values you change so that you can change them back afterwards

- Reduce the axial displacement of the intermediate shaft
  - Hint: Consider changing the gear hands and the helix angle

- In system deflection mode, run the duty cycle and look at the shaft ratings in the Reports tab.
  Are there any shaft safety factors below 1?
  - If so:
    - Which shaft?
    - Find where the safety factor falls below 1 in Shaft Results
    - Try to increase the safety factor ≥1