PARAMETRIC STUDY
Introduction

➢ Parametric Study Tool is a MASTA Mode which provides functionality to analyse the impact of varying specified properties on entities within a design.

➢ Examples of use of the parametric study tool include:
  ▪ Bearing pre-load study to find optimum pre-loads.
  ▪ Manufacturing tolerance studies where e.g. the effect of the distribution of expected pin position errors on planetary load sharing can be investigated.
Three main study types are available for use:

- **Linear Sweep**
  - Can be performed in either 1 or 2 dimensions.
  - Parameters are varied linearly, with equal steps, within their specified range.

- **Monte Carlo**
  - Performed in $n$ dimensions.
  - Parameters are varied with a Gaussian (Normal) distribution via mean and standard deviation values.

- **Design of Experiments**
  - Performed in $n$ dimensions.
  - Parameters can be varied either linearly or non-linearly and list items can also be used.
  - Parameters can be grouped together to create dependencies, e.g. duration and speed on a load case.
In this tutorial we will be looking to examine the effects of bearing pre-load.

Firstly we need to configure the design so that pre-load can be varied in PST mode.
- Go to “Design” mode
- Select “Intermediate Left Bearing”. This is the bearing we will be changing pre-load on.
- In the properties grid navigate to the “Mounting” subsection and set “Pre-Load” to “Solid Loaded Pre-Load”. Information on the options for pre-load specification can seen in the tooltip when hovering over “Pre-Load”.
Select PST mode which consists of three main areas:

- Assembly Tree and Properties Grid
- Load Cases Control
- Setup and Results Area
Tutorial (1) – Load Case Selection

- Parametric studies can be performed on either single load cases or duty cycles.

- In this example we will examine effects when the design is loaded with “Low Speed Max Power”.

- Select this from the Load Cases Control after choosing “Single Load Case”.

“Compound Load Case” allows for Duty Cycles to be run.
We will be performing a linear sweep with 25 steps on the bearing pre-load.

In the “Editor” tab set “Steps in Dimension 1” to 25. The other options can remain as they are for this initial study.

In the “Setup” tab add in “Axial Displacement Pre-Load” for “Intermediate Left Bearing”.

Set the range to be ±500 μm.
Press the Run button in the Load Cases Control area.

After the analysis is completed, navigate to the “Linear Sweep Charts” tab to view results in graphical form.

With “Intermediate Left Bearing” selected, click “Add New Result”.

Add “Modified Reference Rating Life Time” found in Bearing System Deflection -> Component Detailed Analysis -> ISO/TS 16281:2008\(^1\).

From the plot, an axial displacement pre-load of 400 μm looks promising.

\(^1\)Refer to the standard for information on the calculation of quantities.
Tutorial (1) – View Results Continued

➢ Selecting the “Immediate Shaft Assembly” will show results for each bearing in the assembly.

➢ Intermediate Right Bearing has low life time at high pre-load so an axial displacement pre-load of -50 μm appears to be a good compromise.

Tip: underlaying data can be copied from charts within MASTA by right clicking and selecting copy to clipboard.
➢ Try reproducing the plot on the right for Safety Factor Contact on both gear sets. Hint, start by selecting the “1st Gear Stage” and clicking “Add New Result”. Safety factors are on the “Component Detailed Analysis” item.

➢ Note, the effects on contact safety factor, over bending, are being investigated as contact SF is approx. 35% lower than bending SF.
➢ Try reproducing this plot for misalignment:

➢ Looking at the effects of pre-load on bearing lifetime, contact safety factor and misalignment, how much pre-load would you opt for?
In this tutorial we will be looking to examine the effects of bearing mounting errors.

Select the “Low Speed Max Power” load case.

In the “Editor” tab in PST mode, configure the study to be Monte Carlo with 100 steps.

Note, when running Monte Carlo, “Is Logging Data?” is automatically set to true which means we will need to choose which output properties are of interest to us before running the analysis.

Click the “Changing Design” box to allow bearing design properties to be changed.
For “Intermediate Left Bearing” add the following input properties and set their mean and standard deviation in the “Setup” tab:

- On the “Data Logging Setup” tab, add Safety Factor Contact and Modified Reference Rating Life Time for all gears and bearings in the system. Hint, use the “All Entities of Same Type” options so you don’t need to go through each entity individually.

Note: The specification on the left means that there is a 99.7% probability that parameters will be within ±15 μm.
Press the Run button in the Load Cases Control area.

Results can be seen in the “Reports” tab
- In histogram form by selecting a design entity with inputs/outputs.
- In tabular form by clicking the root assembly, “EV Gearbox Design”.

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Next task...

- You have now completed the structured tasks
  - If you have time, please go back to the various tasks and attempt to work through the ‘Additional Tasks’
- The next slide in this document contains some additional tasks you might want to attempt after completing all the other tutorials
Some Additional Tasks

➢ Investigate the effects of oil sump temperature on efficiency.
➢ Prerequisite: work through the Efficiency tutorial.

➢ Note that in-order to change temperature levels, the load case must be set to override default temperatures.
➢ To do this, go to the “Load Cases and Duty Cycles” mode and select the load case of interest.
➢ In the “Settings” tab, deselect “Use Default Temperatures”.

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