

# ORBIS

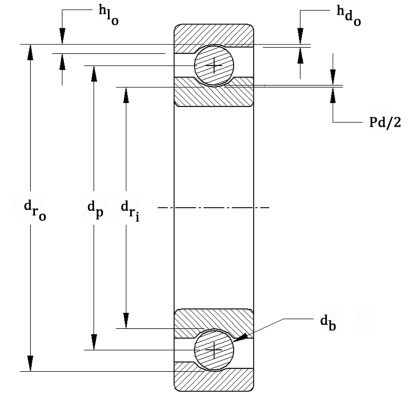
MODERN ROLLING-ELEMENT BEARING ANALYSIS SOFTWARE

# OVERVIEW

## Introduction

ORBIS is a computer program to solve the nonlinear elastic behavior of rolling-element ball bearings. The model considers each ball-to-race contact for all bearing rows defined in the system; resulting in complete knowledge of element load distributions and their raceway attitudes.

The program offers a graphical interface designed by a bearing analyst to be useful and intuitive. Our mission is to make ORBIS the industry standard for rolling-element bearing analysis.



## Program Capabilities

The following tables list key features and analytical outputs of the ORBIS program.

**Table 1.** ORBIS feature list.

Feature List
Angular Contact Ball Bearings
Radial/Conrad Ball Bearings
3 or 4 Point, Gothic Arch Ball Bearings
Cylindrical Roller Bearings
Analyze up to 5 Bearing Rows
Multi-Point 5 DOF Loading
Fitup/Interference Considerations
Direct Temperature Loading
Preload Spring Modeling
Ring Clamping Effects
Truncation Analysis
Fatigue Life w/ adjustment factors
Parameter Sensitivity Studies
Flexible Shaft Modeling
Tolerance Analysis
Lubricant Film Thickness
Dahl Stiffness & Hysteresis Plots
Load Case Batch Processing
Data Plotting
Data Export to Excel®

**Table 2.** Program outputs.

Row & System Level	Result Output	
	Rolling-Element Level	
All input parameters	Normal Ball Loads	
Ball Crossing Angles	Contact Angles	
Internal Clearances	Mean Hertzian Stress	
Ring Distortion Properties	% Truncated Length	
Mounted Preload	Truncated Center & Edge Stresses	
Reaction Forces on Shaft	Ellipse Dimensions (major & minor)	
Inner Ring Displacements	Max Sub-Surface Shear Stress	
Axial Stiffness with Ring Compliance	Depth of Max Sub-Surface Shear Stress	
System Jacobian Matrix (Diagonals)	Upper and Lower Contact Extremities	
Full Row Stiffness Matrices	Contact Normal Approach	
L10 & Adjusted Fatigue Life	Contact Normal Stiffness	
Lubricant & Reliability Adjustment Factors	Element Spinning Velocities	
Coulomb & Viscous Bearing Torques	Element Rolling Velocities	
Maximum Ball Excursion	Spinning Torque	
	Rolling Torque	
	Pitch Orbit Velocity	
	Minimum Film Thickness	
	Minimum Film Lambda Value	
	Centrifugal Forces	
	Gyroscopic Moments	

# WHY CHOOSE ORBIS?

## Capabilities

In addition to analyzing multiple bearings on a common shaft, ORBIS provides many tools and features to aid in the design and optimization of the user defined system. For instance, the sensitivity tool allows almost any input parameter to be independently varied and plotted against one or more output parameters. Other tools include tolerance analysis, flexible shaft modeler, batch processing and Dahl torque hysteresis. See the Key Tools & Features section for further details.

## Accuracy

ORBIS is built on core methods published by A. B. Jones and has become the trusted bearing analysis solution for industries extending from bearing manufacturers to aerospace and defense companies. In addition to verification from our clients, ORBIS accuracy has been validated by comparing numerous test cases with the Jones program.

## Ease of Use

By adhering to clear and instinctive data input, and organizing information in an intuitive manner, we believe you will find the ORBIS interface easy to use. Customizable bearing, material and lubricant databases save time by 'remembering' numerous parameters that are often reused. Databases can also be shared on the same network to reduce analysis inconsistencies.

## Long Term Dependability

Since the first version release in 2009, we have continued developing ORBIS. We believe clients should not have to purchase new versions every time a feature is added. To address this, software licenses are leased and all users receive new version releases. Also, the Java® development platform was specifically chosen due to its robust compatibility with various computer operating systems and machine architectures. Our mission is to make ORBIS the industry standard for rolling-element bearing analysis.

## User Base

The ORBIS user base consist of bearing manufacturers, missile and defense contractors, and the aerospace industry. Please contact us for more user information.

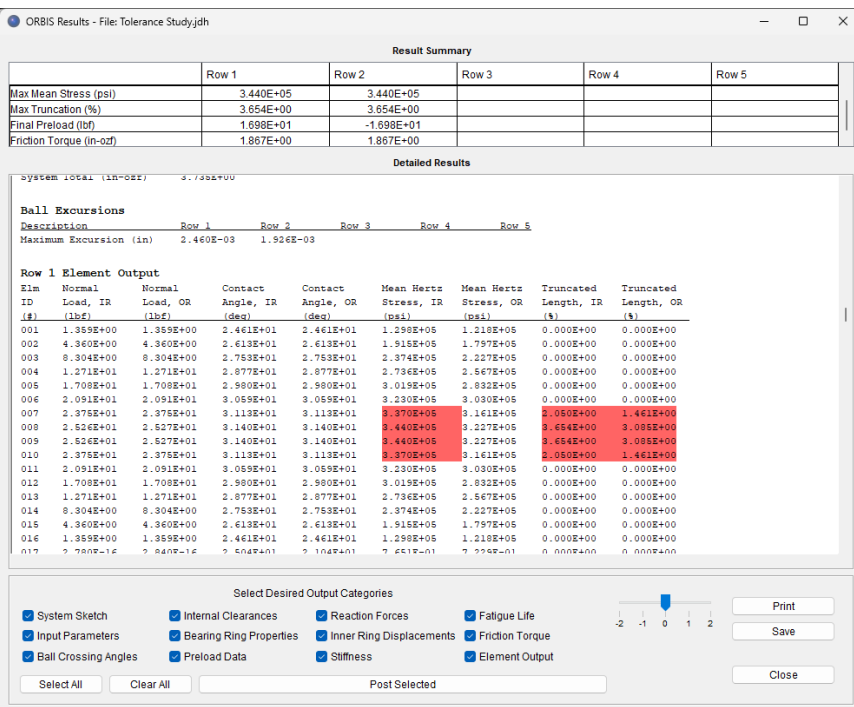
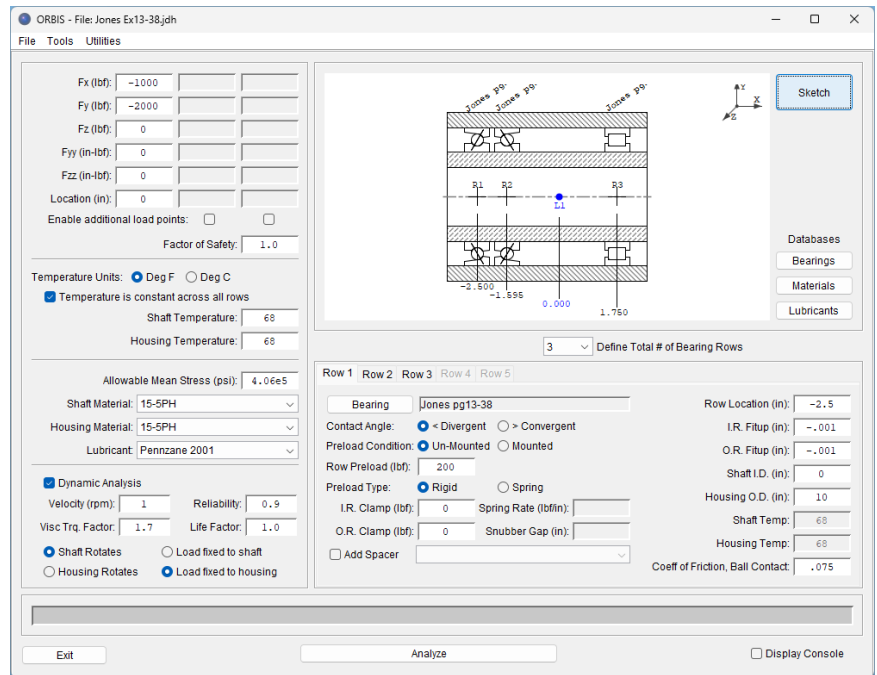


# MAIN INTERFACE & RESULTS WINDOWS

## Main Interface

The main graphical user interface (GUI) is used to setup, review and submit most analyses within ORBIS. Key features include:

- ✦ Engineering sketch of bearing system
- ✦ Drop-down menu assignment for bearings, materials and lubricants
- ✦ Tabbed pane access to parameter definition for each bearing row
- ✦ User input checking for both completeness and valid data types
- ✦ Standard file based configuration management
- ✦ Description bar with pertinent details for the current active input field



## Analysis Results Window

Most output data is presented in results windows; where data is both summarized and provided in full text detail. These windows 'float' so multiple analysis runs can be compared side-by-side. Additional features of the analysis results window include:

- ✦ Quick summary table displaying key result parameters
- ✦ Automatic result highlighting of all over stressed and/or truncated elements
- ✦ Text based results window for easy copy/pasting and annotating
- ✦ Exporting to delimited file that directly imports to Microsoft Excel ®
- ✦ Direct print button

# KEY TOOLS & FEATURES

## Sensitivity Studies

The Sensitivity utility performs parametric studies of various input variables within the user-defined system. It allows perturbations to an input variable, such as contact angle, curvature, preload, shaft temperature, load components, and many others to be plotted against selected output variables, such as maximum stress, preload, stiffness, etcetera. The plot windows allow mouse zooming, formatting, and export to image files. Additionally, all raw plot data can be exported to Excel® for further user analysis.

**Sensitivity Studies**

**Input Parameter (Independent Variable)**

[Loading] Temperature Bearing Params System Params

Vary From: \_\_\_\_\_ To: \_\_\_\_\_

No. Steps: 5

Select Row #: 1 Ref Value: \_\_\_\_\_

**Output Parameters (Dependent Variables)**

Select Output Row: 1

**Internal Play, Ring Expansions & Preload**

Radial Play, Final  I.D. Expan, Final  I.D. Fitup, Final  Preload, Mnt'd

Axial Play, Final  O.D. Expan, Final  O.D. Fitup, Final  Preload, Final

**Row Deflections & Reaction Forces**

dx  dy  dz  dyy  dzz  Fx  Fy  Fz  Fyy  Fzz

**System Stiffness**

Kx  Ky  Kz  Kyy  Kzz

**Fatigue, Torque & Excursions**

Fatigue Life, L10  Total Torque  Max Excursion

**Element Output**

Normal Load  Sub-Surface Shear  Film Height, H-D

Contact Angle  Shear Depth  Film Height, C-Z

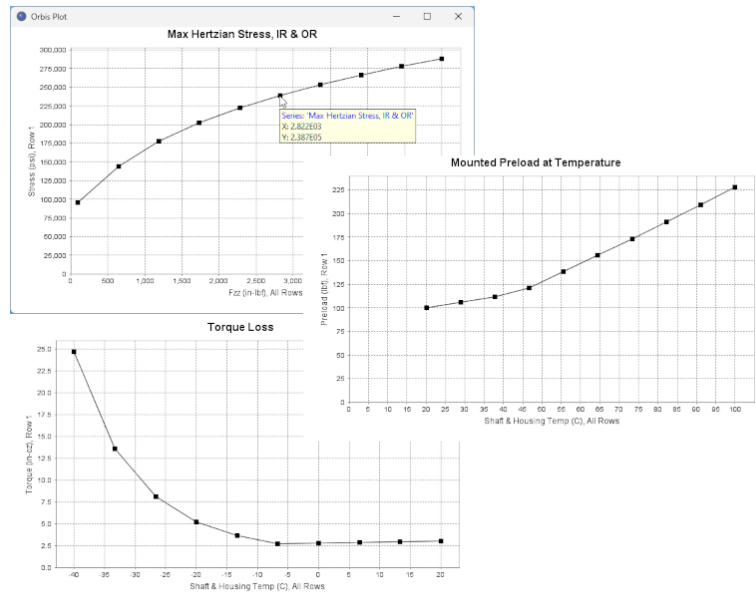
Hertzian Stress  Ellipse Height  Lambda, C-Z

**Criteria:**  Min  Mean  Max

**Raceway:**  I.R.  O.R.  All

Export raw data to file

Plot Results \_\_\_\_\_ Close



## Tolerance Analysis

This utility iteratively solves all permutations of key tolerances. Minimum and maximum values for preload, ID/OD fitups, contact angle or radial play, and curvatures can be assessed. Additionally, the sign convention on each load component can be specified to run through all plus-minus combinations. The tool seeks tolerance combinations to cause maximum contact stress. Additionally, if truncated contacts are found, the tool will find the worst case tolerance conditions to cause the largest percent truncation.

**Tolerance Analysis**

**Tolerances**

Preload	Row 1	Row 2	Row 3	Row 4	Row 5
System Preload (lbf):	170		230		

**Preload Distribution Factors:**

Row 1	Row 2	Row 3	Row 4	Row 5
1	-1	0		

**Permutation Options**

Vary load component sign (load #1 only)

**Result Options**

Find max mean stress condition

Find max % truncation condition

**Notes**

1. This utility evaluates all permutations of min/max tolerances and reports the results specified in Options section. Note: either max mean stress or max % truncation must be selected.

2. Free Contact Angle or Free Radial Play may be selected. However, the bearing type will determine applicability. For instance, if Free Contact Angle is applied but there are cylindrical rollers in the system, then this input will be ignored for all rows with cylindrical roller bearings. For angular contact/radial bearing types, the two parameters are related and either input option is valid.

3. WARNING: Due to the large number of possible permutations, this routine may take several minutes to complete. Performing this procedure on a Static analysis will be notably quicker than on a Dynamic analysis.

Analyze \_\_\_\_\_ Close

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**Tolerance Analysis**

**Tolerances**

	Min	Max	Row Ref
Free Contact Angle (deg):	23	27	25.0
Free Radial Play (in):			5.153E-03
Inner Raceway Curvature:	-.52	-.53	-.52
Outer Raceway Curvature:	-.52	-.53	-.52
I.R. Fitup (in):	-.001	0	-.001
O.R. Fitup (in):	-.001	0	-.001

**Permutation Options**

Vary load component sign (load #1 only)

**Result Options**

Find max mean stress condition

Find max % truncation condition

**Notes**

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Analyze \_\_\_\_\_ Close

# KEY TOOLS & FEATURES

## Load Case Batch Processing

The batch processing utility allows import of a .csv file with multiple load cases defined and will process all cases against the configured bearing system. Main result parameters, such as maximum stress, percent truncation, and resistive torque are tabulated against each load case for quick review. Any case from the result table can be sent to a full result window for detailed inspection. The result table can be exported to a text file for further post processing. Additionally, a full detailed result file can be automatically generated and saved for all load cases.

**Batch Process**

Select \*.csv file with load cases:

Fx (lbf)	Fy (lbf)	Fz (lbf)	Fyy (in-lbf)	Fzz (in-lbf)	Location (in)
0	20	0	0	0	0
0	0	20	0	0	0
0	0	0	20	0	0
100	100	100	100	100	0
200	200	200	200	200	0
300	300	300	300	300	0
400	400	400	400	400	0

Factor of Safety: 1.0

**Run Options**

Save individual result files with name prefix: loadcase

Show warning if loadcase does not converge  
Note: Results will show zeros for all non-converged cases.

**Result Summary**

Case	Max Stress (psi)	Max % Truncation	Fatigue Life (Rev)	Torque (in-ozf)
1	8.001E+04	0.0	6.359E+10	1.385E+01
2	7.994E+04	0.0	6.359E+10	1.385E+01
3	7.780E+04	0.0	6.442E+10	1.383E+01
4	9.502E+04	0.0	2.921E+10	1.560E+01
5	9.942E+04	0.0	1.586E+10	1.893E+01
6	1.067E+05	0.0	1.016E+10	2.199E+01
7	0.000E+00	0.0	0.000E+00	0.000E+00
8	0.000E+00	0.0	0.000E+00	0.000E+00

## Flexible Shaft Analyzer

This utility is used to account for elastic compliance of the bearing shaft, resulting in independent bearing rotation attitudes. The elasticity model uses Timoshenko beam element formulations that account for both bending and shear deflections in the shaft. The user can define up to 25 unique circular beam elements; each of which may contain unique cross section dimensions and/or materials. Deformed shaft shape can also be plotted.

**Flexible Shaft Analyzer**

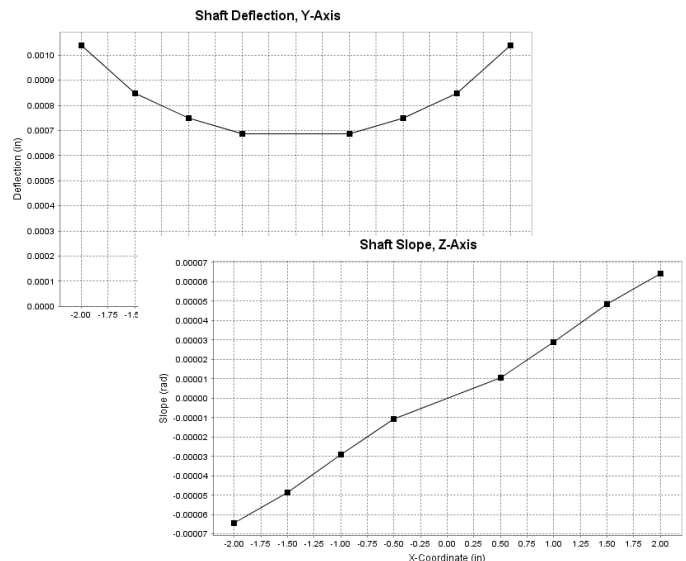
X-Start (in)	X-End (in)	I.D. (in)	O.D. (in)	Material
-2	-1.5	2	2.25	Ti-6Al-4V
-1.5	-1	2	2.5	Ti-6Al-4V
-1	-0.5	2	2.75	Ti-6Al-4V
-0.5	0.5	2	2.75	Ti-6Al-4V
0.5	1	2	2.75	Ti-6Al-4V
1	1.5	2	2.5	Ti-6Al-4V
1.5	2	2	2.25	Ti-6Al-4V

**Solver Convergence**

Max Step Error (lbf): 1.4E01  
Max No. of Solution Attempts: 20000

**Output Options**

Show Rigid Analysis Results  
 Plot Shaft Deflections



# KEY TOOLS & FEATURES (CON'T)

**Dahl Torque Hysteresis**

Step 1: Generate Dahl Parameters

Select Torque Units:

Select Angle Units:

Edit Contact Coefficient of Friction:

Row 1	Row 2	Row 3	Row 4	Row 5
0.075	0.075	0.075		

Generate Dahl Parameters

Torque Stiffness:

Steady State Coulomb Torque:

Step 2: Setup Torque Loop Plotting

No. of Points Per Loop:

Reversal Angles (>0)
0.5
0.6
0.7
0.8
0.9
1.0

Export Plot Data

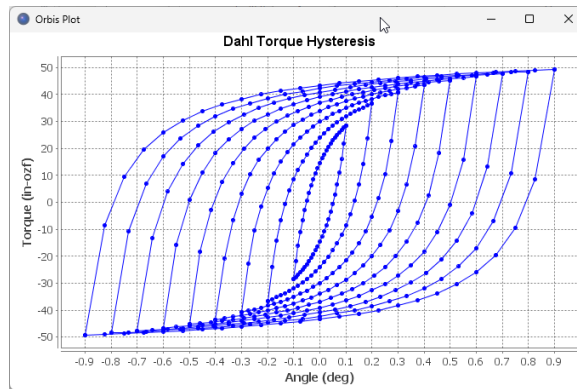
Clear Table

Plot Torque Loops

Close

## Dahl Torque Hysteresis

The Dahl Torque Hysteresis utility is used to analyze the torsional stiffness (torque versus angle) of the bearing system during startup or direction reversal. This phenomenon occurs through small finite angles of rotation, often most apparent when direction of rotation is reversed, at speeds sufficiently slow such that viscous drag is negligible. The utility provides quick inspection of the reversing torque slope and steady state torque. Additionally, the utility can quickly generate small angle hysteresis loops for both graphical plot inspection and data export.



## Hertzian Contact Analysis

The Hertzian Contact tool is a general engineering tool to solve classical Hertzian point and line contact problems. The tool solves arbitrary two body contact problems and provides the resulting contact stress, elliptical contact area, linearized contact stiffness and sub-surface shear stresses. Since the tool uses the main material database, only body radii and the normal load are specified to run the analysis.

**Hertzian Contact**

Contact Parameters

Select type of contact:  Point Contact  Line Contact

Normal Load (lbf):

Body "A"

Radius, Plane 1 (in):   Concave  Flat

Radius, Plane 2 (in):   Concave  Flat

Material:

Body "B"

Radius, Plane 1 (in):   Concave  Flat

Radius, Plane 2 (in):   Concave  Flat

Material:

Illustrative Diagram

Show Diagram

Edit Materials

Analyze

Results

Usage notes:

1. All text inputs must be parseable to a positive numeric data type.
2. Input fields support math expressions and unit conversions.
3. Pressing the "Show Diagram" button will attempt to resolve user selected body conformities and show an illustrative figure. No effort is made to scale bodies based on user defined radii. Also, bodies "A" and "B" are arbitrary in figures.
4. Hertzian contact analysis assumes resolved contact area is small compared to the principal radii of curvature.

Save Results

Print Results

Close

# KEY TOOLS & FEATURES (CON'T)

## Margin of Safety

The Load Margin of Safety tool calculates a true load margin on the defined system of bearings. The reported margin is the percent load increase, expressed as a decimal, that could be applied to the defined load to reach a specified limit criteria. Option for the limiting criteria are maximum mean stress and/or truncation; where the tool reports the margin to the first limit criteria found. Furthermore, truncation limits can be adjusted to a maximum allowable percent truncation (i.e. allow a maximum of 10% truncation).

Enter Design Limit Loads (DLL's)			
Fx (lbf):	-1000	0	0
Fy (lbf):	-2000	0	0
Fz (lbf):	0	0	0
Fyy (in-lbf):	0	0	0
Fzz (in-lbf):	0	0	0
Location (in):	0	0	0

Enable additional load points:

Factor of Safety: 1.25

**Margin Options**

Don't allow truncation

Allowable Truncated Length (%):

Allowable Mean Stress (psi): 4.06e5

Display Results Window

**Results**

```
Limit Criteria.....: TRUNCATION
Margin of Safety.....: 3.399
% Truncation.....: 0.007
Margin load stress (psi): 2.991E+05

WARNING: Solution slightly exceeds
truncation requirement.
```

Analyze Cancel

**Specify Shaft Deflections**

Shaft location for enforced displacements (in.): 0.0

dx (in.): 0.0

dy (in.): 0.0

dz (in.): 0.0

dyy (rad): .001

dzz (rad): .001

**Notes**

This utility enforces a prescribed deflection on the shaft. Deflections are relative to the mounted and preloaded state of the defined bearing system. All system loads from the main window are ignored.

It is recommended to perform a no-load analysis on the system (from the main window) prior to using this utility.

Analyze Cancel

## Enforced Displacements

This tool allows the user to specify an enforced displacement instead of external loads. The displacement can be specified anywhere along the shaft and all 5 degrees of freedom are available.



### **Quotes and/or Additional Information**

Please contact us for a quote or any questions regarding the ORBIS software and its capabilities. We offer multiple license discounts and free trial versions for qualified parties.

Sincerely,

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