

COBRA-AHS (2nd Generation)

COBRA-2G ADVANCED HIGH-SPEED COMPUTER OPTIMIZED BALL & ROLLER BEARING ANALYSIS



COBRA-2G, the 2nd Generation of COBRA-AHS, is a High Speed bearing analysis program that computes the behavior of up to five (5) bearing rows on a flexible or rigid shaft loaded in 5 DOF. COBRA-2G is integrated with ANSYS to perform fit-up and temperature-distribution analyses, including iterative thermal/dimensional interaction and sub-surface stress distribution analysis using ANSYS. Additional features include 6 DOF Ball Kinematics for prediction of Sliding and Skidding as well as the legacy Jones Race Control model and a physics based Non Linear Thermal Viscoelastic (NLTV) mixed film traction model. Stress models include Heat Treat Residual Stress and Hoop Stress from fits and operation speed. COBRA-2G automatically prepares files for input into the Wedeven Associates SCM (Single Contact Model) for rigorous analysis of Mixed EHL loaded contacts.

PROGRAM CAPABILITIES & FEATURES INCLUDE:

Up to 5 Bearings on flexible or rigid shaft	Internal Clearance & End-Play	Interactive Sensitivity Studies
Up to 10 Applied Loads in 5 DOF	STLE Fatigue Life Adjustments	Interactive Duty Cycle Analysis
Up to 20 Shaft Sections	Misalignment, Location Offsets	Up to 2000 Duty Cycle Conditions
Tapered and hollow shaft sections	Hybrid Bearings, Duplex Bearings	Skid Estimates for Ball and
Pre-defined defaults for many inputs	Lubricant Film Thickness	Cylindrical Roller Bearings
Housing and Shaft Distortion inputs	Lubricant Effects on L10 Life	Input in SI or US units
Crowned Rollers w/ Lamina	Library of Lubricants	Results in SI and US units
Preload	Library of Materials	Copy Results & Plots to Clipboard
Bearing heat generation & cage forces	Interactive Roller Edge Stress	Print Results & Plots
Seamless interface to ANSYS	Analysis w/ Contour Plot Outputs	Automatic Update of Results & Plots
ANSYS Race Segment stress models	Under Race Cooling of SIR bearings	Prepares ANSYS COMBI214
Imposition of Residual Stress	In contact Flash Temperature	Elements for Rotordynamic models
	Export of Data files to WAI SCM	LP & IH Life Models

5 BEARING TYPES:

Radial (Conrad) Ball, Angular Contact Ball, Cylindrical Roller (with Under Race Cooling) Tapered Roller (?)
Split Inner Race (3 Point Contact) with Under Race Cooling

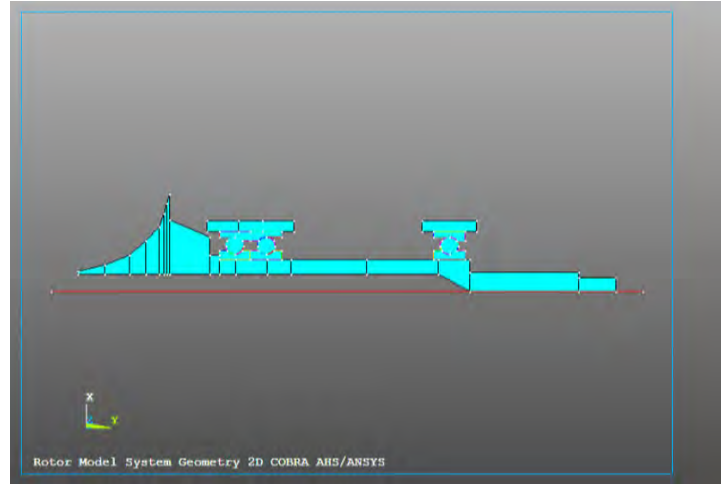
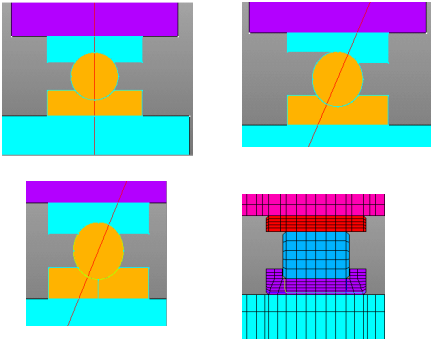
2 EDITIONS AVAILABLE:

Full: All features including ANSYS seamless links for temperature distributions and more rigorous Fit-Up analysis
Plus ANSYS Race Segment Models for sub-surface stress distribution analysis

Reduced: Excludes ANSYS Race Segment Stress Models

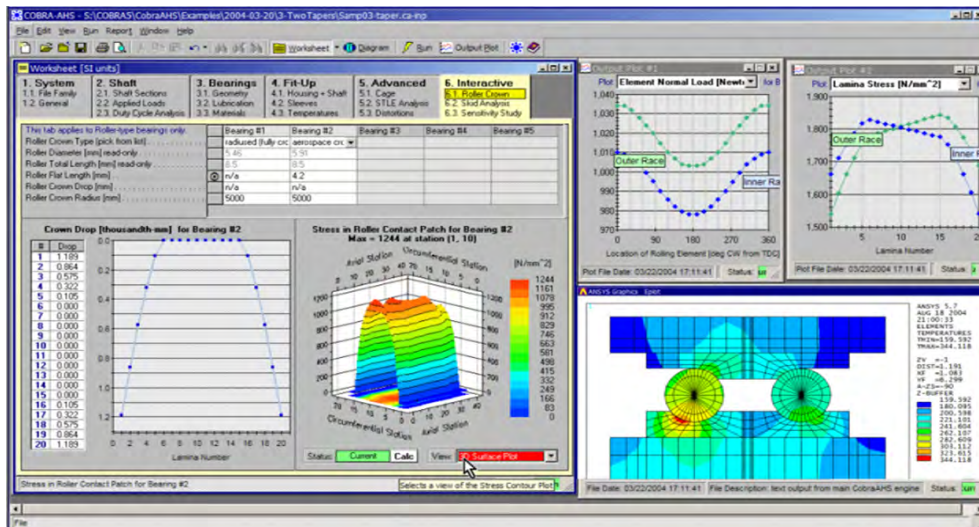
Detailed Bearing System Definition

COBRA-2G can create detailed shaft-bearing systems with mixed bearing types



Detailed Contact Stress & Thermal Analysis

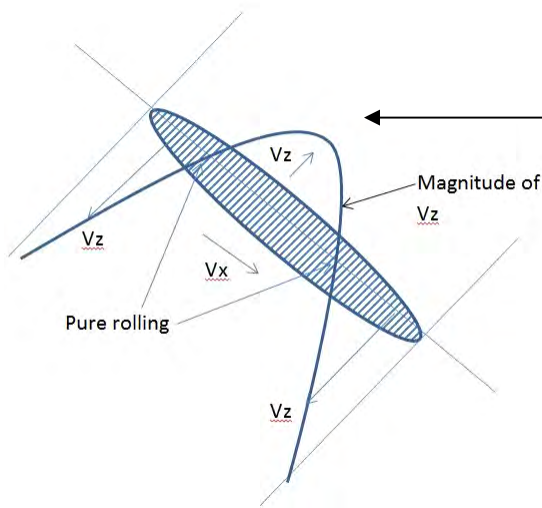
COBRA-2G has a modern menu-driven Windows interface with tabbed worksheet format. Users can interactively change data and quickly generate results. COBRA-2G predicts Edge Stress concentration and contains a library of standard crown profiles. User defined or measured profiles can also be analyzed. The seamless interface with ANSYS allows for steady state thermal analysis and dimensional IDC (Internal Diametral Clearance) change estimates



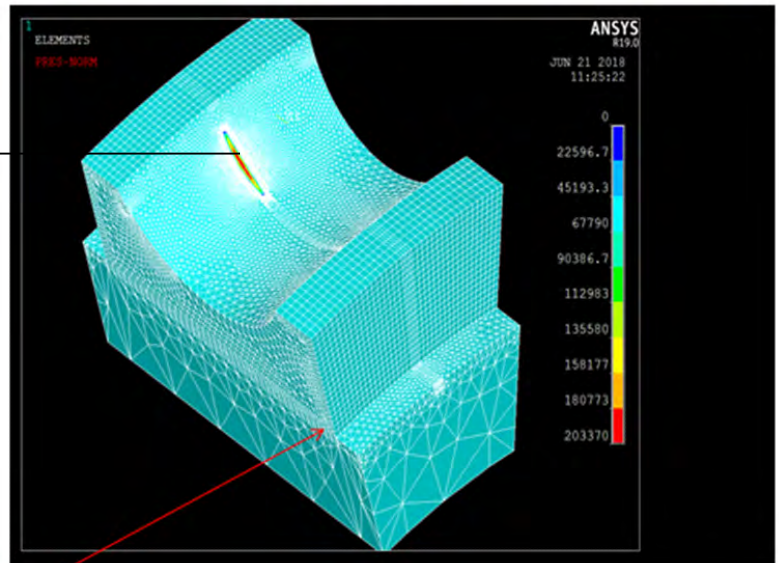
6 DOF Kinematics Skid & Sliding Velocity Profile

The 6 DOF ball kinematics solution gives cage slip (skid) estimates at low thrust load and detailed "in contact" sliding velocity profiles for use in the Non Linear Thermal Viscoelastic Traction (NLTV) model implemented in the analysis of high DN split inner race and angular contact ball bearings. Input files are created for the Wedeven Associates Single Contact Model (SCM) for rigorous analysis of mixed EHL contacts.

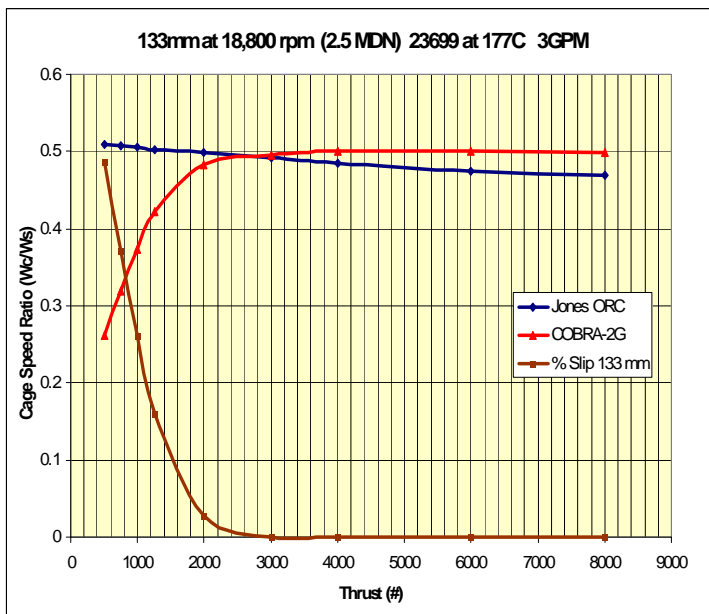
In Contact Sliding Velocity



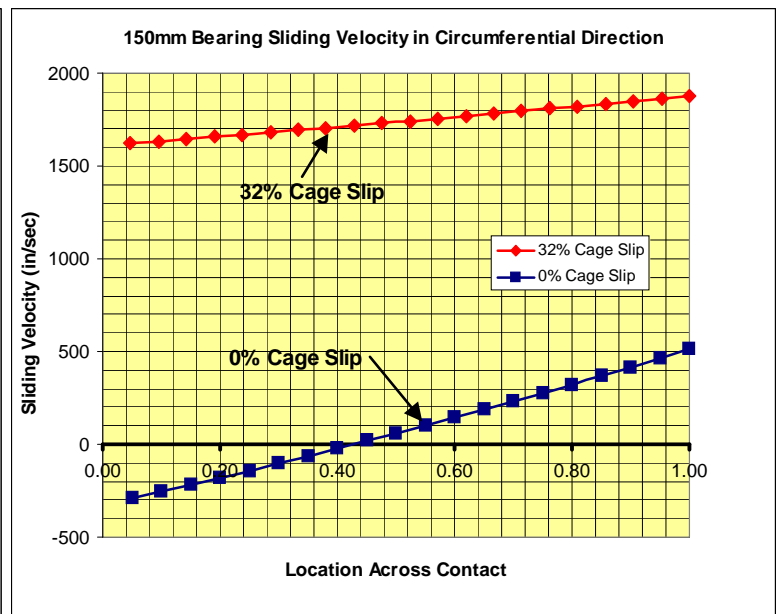
Addition of Hertz Pressure Loading of Race



Cage Slip at 2.5 MDN

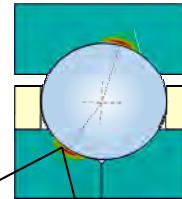
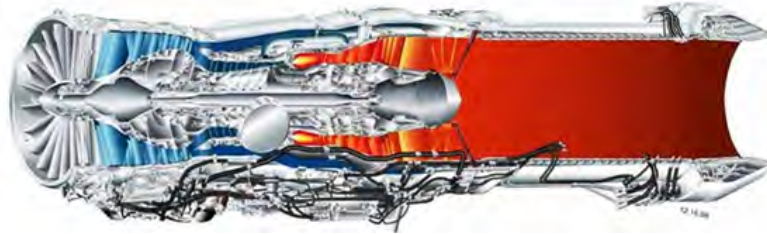


In-Contact Sliding Velocity Profiles



COBRA-2G/WAI Physics Based Traction Model Integrated for Full Component Design/Analysis

COBRA-2G contains the WAI physics based Non Linear Thermal Viscoelastic Traction (NLTV) model incorporating a Maxwell Viscoelastic Fluid and the Johnson-Trevaawerk traction formulation. Physical property data needed for the model is generated using the WAI WAM machine. COBRA-2G applies this formulation to a sliced inner and outer race contact patch for estimating the contribution to Heat Generation from EHL traction and Traction Forces used in Skidding Analysis. Also, input files for the WAI SCM (Single Contact Model) are prepared for detailed Mixed EHL Contact analysis.

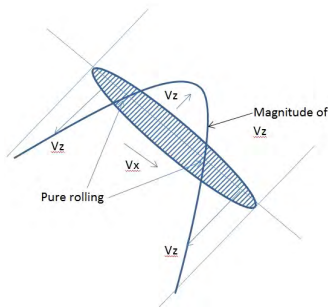


Visco-elastic Maxwell Fluid Model

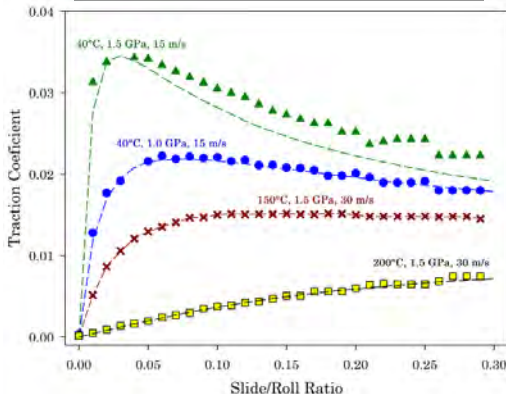


$$\dot{\gamma} = \frac{1}{E} \frac{\partial \sigma}{\partial t} + \frac{\sigma}{\eta}$$

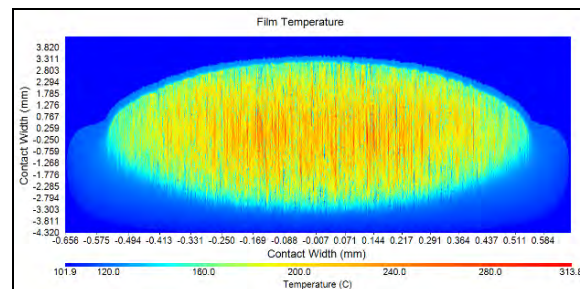
$$\frac{\partial \tau(x,y)}{\partial x} = \frac{GU_z}{U_z h} - \frac{G\tau_c}{U_z \eta(x,y)} \sinh\left(\frac{\tau_c}{\tau}\right)$$



NLTV Traction Model vs Test



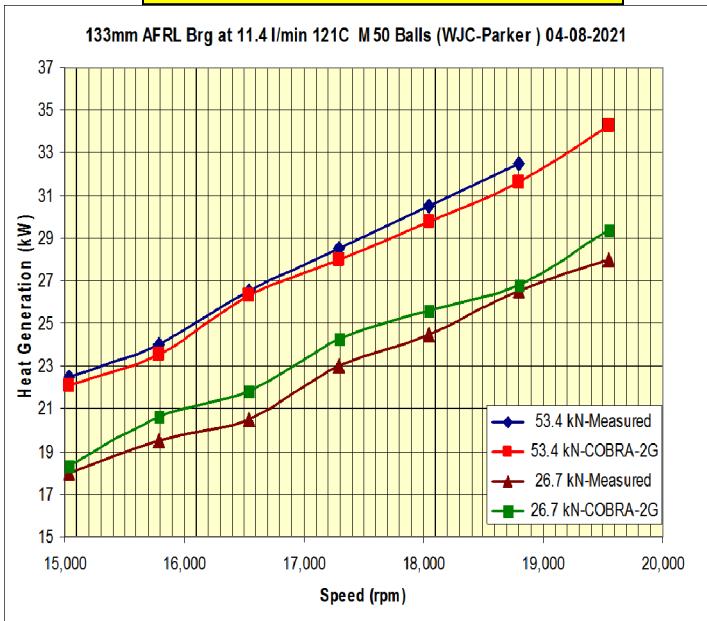
WAI SCM Film Temperature Estimate Example



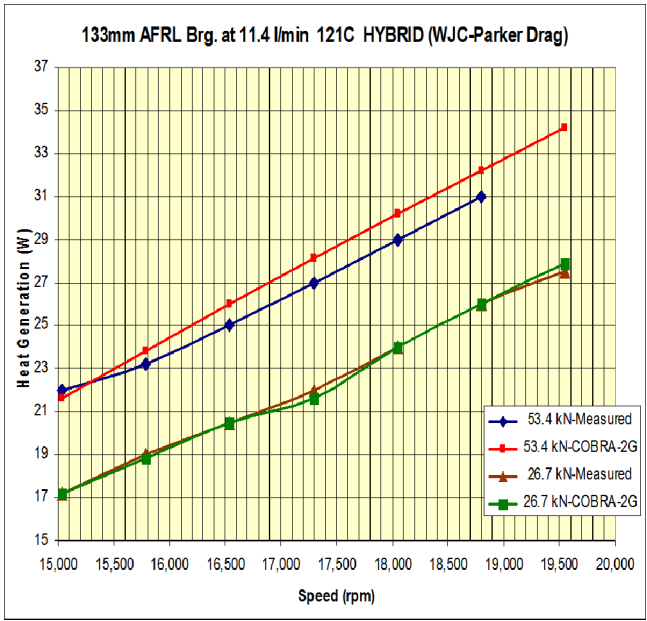
Improved Heat Generation Estimates for High DN

COBRA-2G gives improved heat generation prediction for high speed, high load split inner race angular contact ball bearings as verified by two sets of high speed test rig data to 3 MDN and 16,500 pounds thrust load. COBRA-2G contains physics based heat generation models that quantify heat generated from lubricant drag or churning loss, Inner and Outer race EHL Traction loss, EHL hydrodynamic pumping loss, Hysteresis loss and Lube Inertia. Cage pilot surface and ball pocket friction are also included. Knowing the % contribution of each source enables the bearing designer to focus on the areas of largest generation.

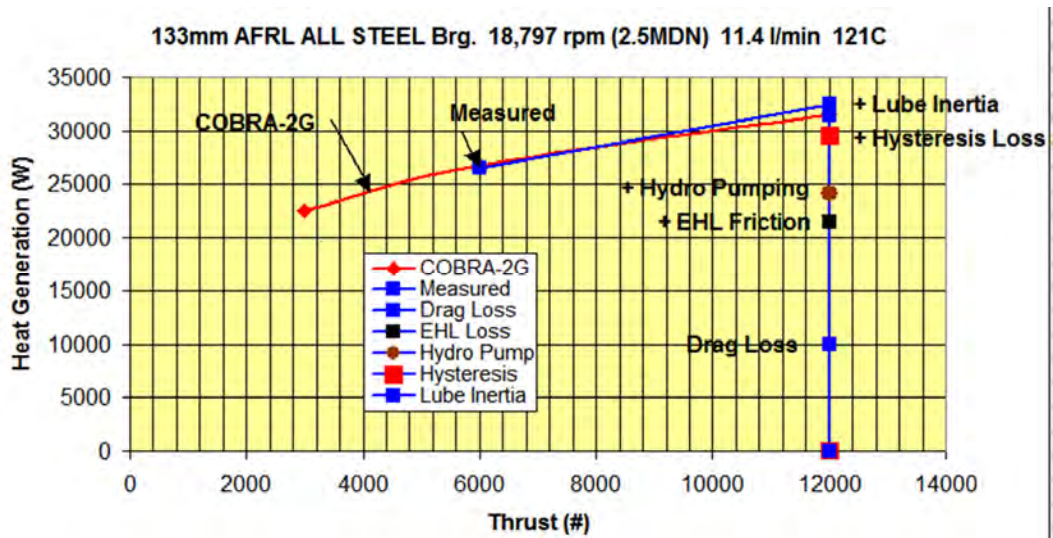
All Steel Bearing to 2.6 MDN



Hybrid Bearing to 2.6 MDN



COBRA-2G Captures Increase in Heat Generation with speed at 26.7 kN & 53.4 kN Thrust

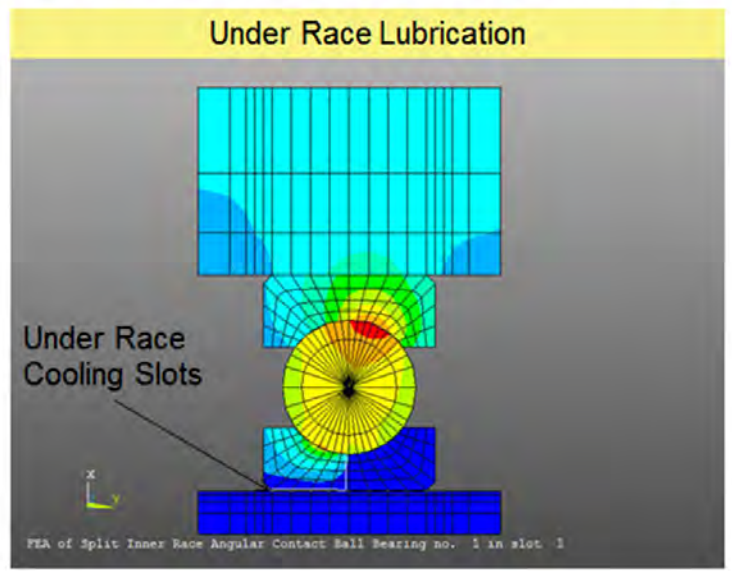
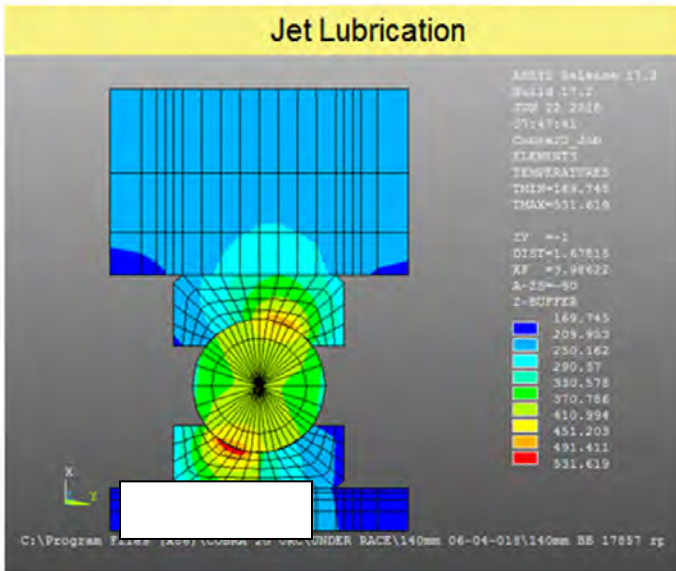


COBRA-2G Captures Increase in Heat Generation with Thrust Load

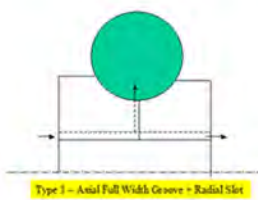
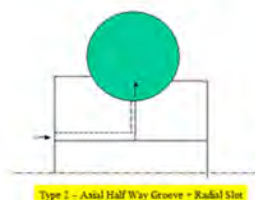
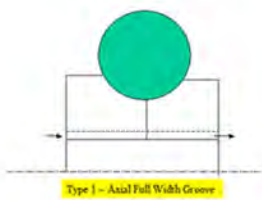
Evaluation of Different Methods for Cooling

COBRA-2G has a seamless interface to ANSYS for steady state thermal analysis of ball and cylindrical roller bearings having Oil Jet or Under Race lubrication/cooling systems. The Under Race cooling models include rectangular and Arcuate (semi-circular) flow passages as well as several lubricant passage arrangements. The image below demonstrates the significant reduction in inner race temperature due to under race cooling. Also notice that COBRA-2G captures the temperature difference between the loaded and unloaded halves of the 2 piece race for the SIR bearing. Such results have been verified by measured data on a 160mm SIR bearing at 2.5 MDN.

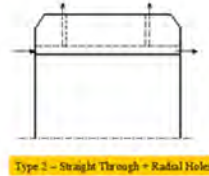
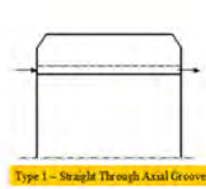
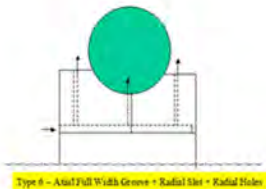
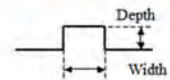
ANSYS FEA Bearing Temperature Model Results for 140mm Brg at 2.5 MDN & 10K lbs. Thrust



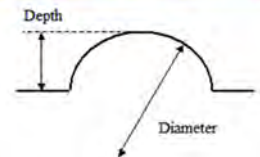
Temperature model shows effective cooling of under race slots



Type 1 - Rectangular



Type 2 - Arcuate (Circular)

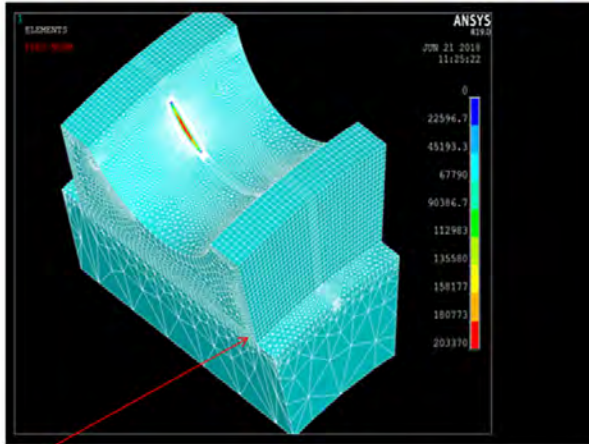


COBRA-2G provides for multiple combinations of coolant delivery and flow passage cross section shape

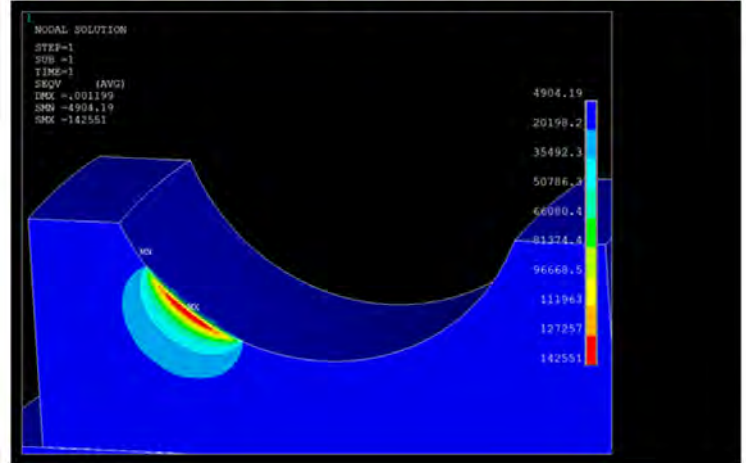
Evaluate Sub-Surface Stresses

COBRA-2G has a seamless interface to generate ANSYS Race Segment Models for analysis of sub-surface stress distribution at the most heavily loaded ball. Such models can be generated for inner and outer race contacts and include loading from the ball load Hertz pressure, traction forces along the contact ellipse, press fits, race speed and “as-manufactured” residual stress.

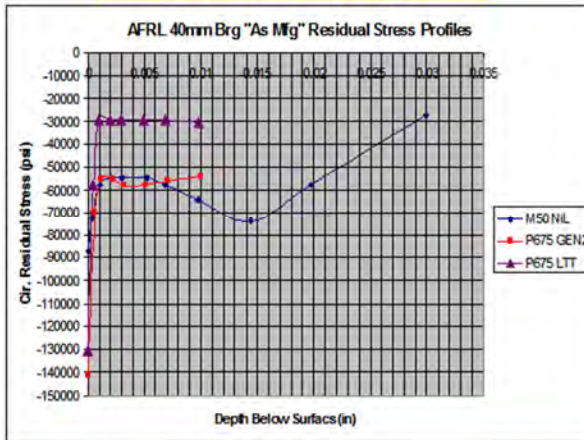
Addition of Hertz Pressure Loading of Race



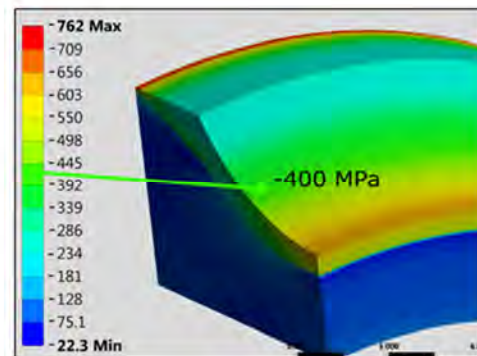
VonMises Stress Plot for Hertz Pressure Loading on Inner Race



Measured Residual Stress Profile
(-400 MPa = -58,000 psi)



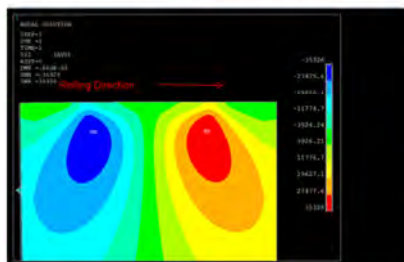
Imposed Residual Stress in COBRA-2G
for M50 NiL



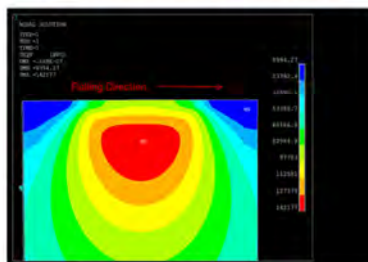
COBRA-2G allows residual stress input as a polynomial fit or table look up for stress vs. depth

Decisive Stresses in Rolling Contact Fatigue

Original Lundberg-Palmgren Orthogonal Shear Stress

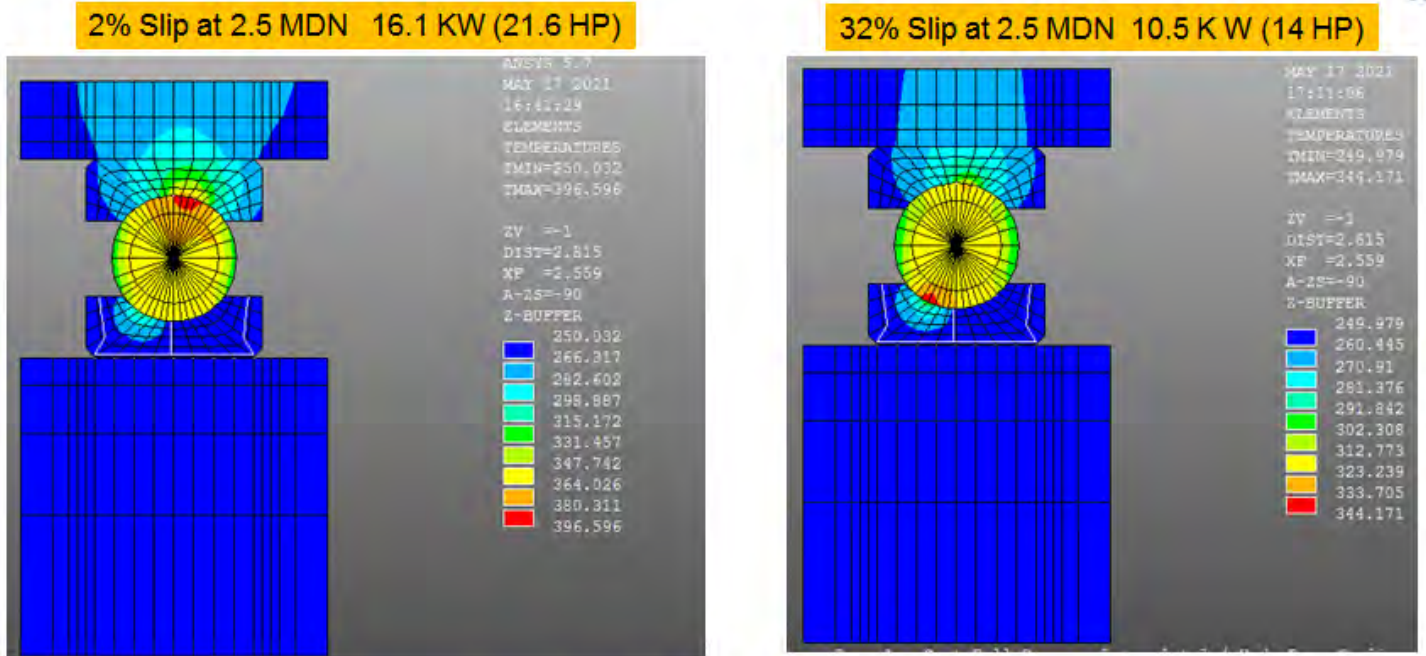


More Recent vonMises Equivalent Stress



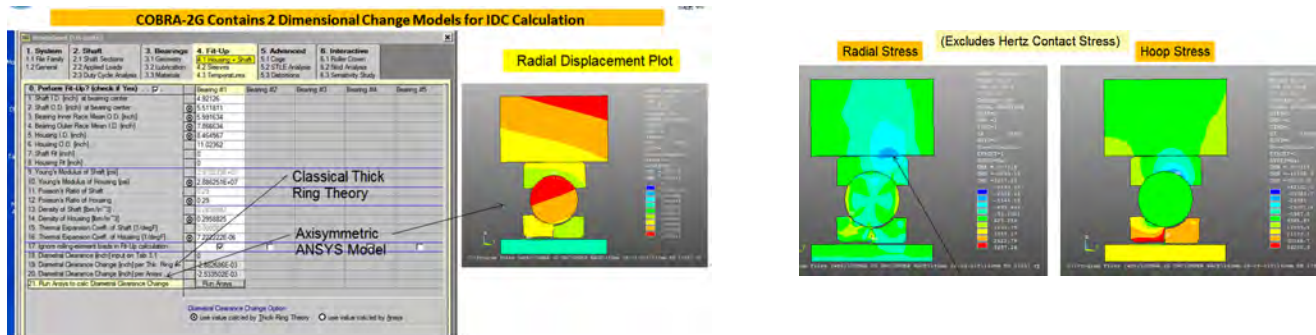
Temperature Distributions with High Cage Slip

COBRA-2G ANSYS Thermal Analysis detects development of “hot spot” within a bearing with high % Cage Slip. Although the bearing heat generation decreased from 16.1 KW for 2% slip to 10.5 KW for the case of 32% cage slip, a high temperature zone is detected at the inner race contact due to the high sliding velocity that developed from cage slip. This will impact the Tribology of that contact and can be evaluated using the Wedeven Associated Single Contact Model (SCM) for mixed EHL analysis.



COBRA-2G Clearance Change Models

COBRA-2G contains the Classical Thick Ring FitUp model and more rigorous ANSYS estimates of Internal Diametral Clearance (IDC) in a bearing. Ball or Roller load effect on IDC can be included in the estimate. This feature is useful for evaluating preload change in thin race bearings or preloaded bearings cooled to cryogenic temperatures.



COBRA-2G Input/Results Form Examples

Lubrication Inputs

Worksheet [SI units]

1. System
1.1. File Family
1.2. General

2. Shaft
2.1. Shaft Sections
2.2. Applied Loads
2.3. Duty Cycle Analysis

3. Bearings
3.1. Geometry
3.2. Lubrication
3.3. Materials

4. Fit-Up
4.1. Housing + Shaft
4.2. Sleeves
4.3. Temperatures

5. Advanced
5.1. Cage
5.2. STLE Analysis
5.3. Distortions

6. Interactive
6.1. Roller Crown
6.2. Skid Analysis
6.3. Sensitivity Study

	Bearing #1	Bearing #2	Bearing #3	Bearing #4	Bearing #5
Lubricant Type [pick from list]	MIL-L 23639	MIL-L 23639	MIL-L 26352		
Lube Density [g/cm ³]	1.0102	1.0102	Mineral Oil (Shell Turbo 33)		
Lube Thermal Expansion Coefficient [1/C]	0.000745	0.000745	MIL-L 7808		
Lube Thermal Conductivity [W/m C]	0.152	0.152	Polyphenyl Ether MCS 293		
Lube Viscosity @40C [cSt]	29	28	MIL-L 23639		
Lube Viscosity @100 C [cSt]	5.1	5.1	user-defined lubricant		
Pressure Coefficient of Viscosity [mm ² /N]	0	0	5.1		
Lube Operating Temperature [C]	65	65	65		
Element CLA Roughness [microns]	0.08	0.08	0.08		
Inner Race CLA Roughness [microns]	0.1	0.1	0.1		
Outer Race CLA Roughness [microns]	0.1	0.1	0.1		
Outer Race Flange CLA Roughness [microns]	n/a	n/a	0.1		
Roller End Face CLA Roughness [microns]	n/a	n/a	0.08		
Element-to-Race Friction Coefficient	0.1	0.1	0.1		
Flange Roller-End Friction Coefficient	n/a	n/a	0.1		
Lube Flow Rate [liters/min]	2	2	2		
Lube Churning Factor [%]	3.4062%	3.4062%	3.8151%		

Notes:
If you select a pre-defined Lubricant Type, then COBRA-AHS will enter default values for lubricant properties. If you select 'user-specified lubricant', then you must specify the lubricant's properties. However, 'Pressure Coefficient' may be left unspecified, in which case the COBRA-AHS engine will calculate it and display on the Results' page.
Click the black dot (or press F5) in the table above to enter COBRA's estimated or default value for these parameters.

Lubricant Type - pick from the list, or enter a name and all properties for your own lubricant
Status: **Open**

STLE Life Factor Inputs

Worksheet [SI units]

1. System
1.1. File Family
1.2. General

2. Shaft
2.1. Shaft Sections
2.2. Applied Loads
2.3. Duty Cycle Analysis

3. Bearings
3.1. Geometry
3.2. Lubrication
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4. Fit-Up
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Perform STLE Analysis?

	Bearing #1	Bearing #2	Bearing #3	Bearing #4	Bearing #5
Reliability [%]	99.00%	99.00%	95.00%		
Inner Race Material [pick from list]	M50 NIL steel	M50 NIL steel	AISI 52100 steel		
Outer Race Material [pick from list]	M50 NIL steel	M50 NIL steel	AISI 52100 steel		
Element Material [pick from list]	M50 NIL steel	M50 NIL steel	AISI 53100 st		
Melting Practice [pick from list]	VIM-VAR	VIM-VAR	AISI 52100 steel		
Metalworking [pick from list]	Forged Rings	Forged Rings	M-1 or M-2 steel		
Inner Race Hardness [Rockwell C]	60	60	M42 or WBA43 steel		
Outer Race Hardness [Rockwell C]	62	62	B6-42 or CRB-7 steel		
Element Hardness [Rockwell C]	58	58	AISI 440C steel		
Rework [pick from list]	Reworked @ L11	Reworked @ L11	M50 NIL steel		
Stressed Volume Removed in Rework [%]	8.00%	8.00%	AISI 4720 steel		
Operating Temperature [degC]	100	100	AISI 8720 steel		
Water Content [ppm]	45000	45000	3310 or CBS 600 steel		
Filter Rating [microns]	4	4	alumina, hot pressed		
Shaft I.D. at bearing location [mm]	0	0	alumina, cold pressed		
Inner Race Mean O.D. [mm]	66.4	66.4	silicon carbide		
Inner Race Tight Fit [mm]	-0.052	-0.052	silicon nitride		
Approximate Maximum Hertz Stress [N/mm ²]	1380	1300	1000		
Residual Shear Stress at Crit. Depth [N/mm ²]	200	200	-200		

Notes on the 'Perform STLE Analysis' box in upper left:
- If checked, then you must specify all STLE parameters (on this Tab) for all Bearings. STLE analysis will be performed when you click 'Run'.
- If not checked, then the table of STLE parameters (on this Tab) is locked (read-only). STLE analysis will not be performed when you click 'Run'.

Element Material [pick from list]
Status: **Open**

Cylindrical Roller Bearing Skid Analysis

Worksheet [SI units]

1. System
1.1. File Family
1.2. General

2. Shaft
2.1. Shaft Sections
2.2. Applied Loads
2.3. Duty Cycle Analysis

3. Bearings
3.1. Geometry
3.2. Lubrication
3.3. Materials

4. Fit-Up
4.1. Housing + Shaft
4.2. Sleeves
4.3. Temperatures

5. Advanced
5.1. Cage
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6.3. Sensitivity Study

	Bearing #1	Bearing #2	Bearing #3	Bearing #4	Bearing #5
Bearing Type (read-only)			Cylindrical Roller		
Number of Elements	18	18	26		
Element Diameter [mm]	11.11	11.11	7		
Contact Angle [deg]	25	-25	n/a		
Roller Length [mm]	n/a	n/a	8.5		
Outer Race Shape [pick from list]	0	0	circular		
Out-Of-Round Magnitude [mm]	0	0	elliptical		
Lube Temperature [degC]	65	65	3-point OOR		
Initial Load Estimate [N]	0	0			
Skid Adjustment Factor [dimensionless]	1	1			

Results for Bearing #3
Status: **Current** Calc

```
# COBRA-AHS 5.0 ROLLER BEARING SKID AN
# InputFileSpec=
# InputFileDate=
# BrgType= 1
ARRAY 4 7 T
# RadialLoad[N]      %Spicy1      %Slip
.1200E+04            .9798E+00    .2018E-
.1050E+04            .9680E+00    .3200E-
.9000E+03            .9479E+00    .6210E-
.7500E+03            .9047E+00    .9531E-
.6000E+03            .8164E+00    .1846E-
.4500E+03            .6490E+00    .9510E-
```

Outer Race Shape (click down-Arrow to pick from list)
Status: **Saved**

Sensitivity Study Results

Worksheet [SI units]

1. System
1.1. File Family
1.2. General

2. Shaft
2.1. Shaft Sections
2.2. Applied Loads
2.3. Duty Cycle Analysis

3. Bearings
3.1. Geometry
3.2. Lubrication
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4. Fit-Up
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6.3. Sensitivity Study

Sensitivity Study 1

Input
Item: Bearing
Bearing #: 1
Parameter: Contact/Cup Angle
Units: [mm]
Number of Steps: 5
Step Size: 2
Nominal Value: 25
Minimum Value: 21
Maximum Value: 29

Results
Plot: Max. Hertz Stress [N/mm²] for Bearing #1

Run Sensitivity Study #1
Status: **Current** Last Run: 2/13/2003 18:04:37

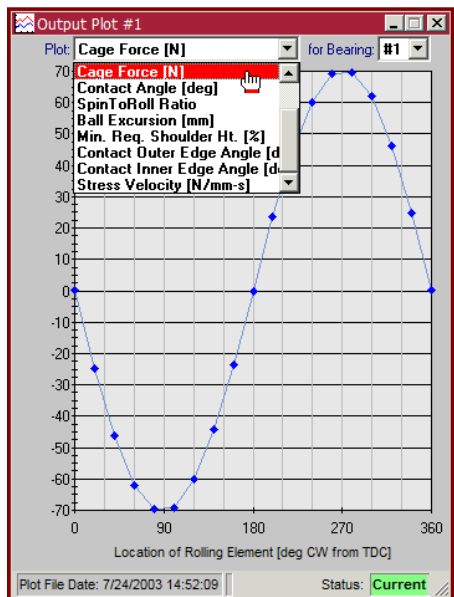
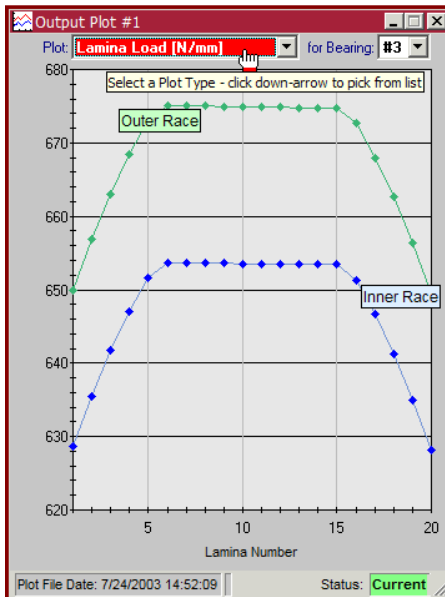
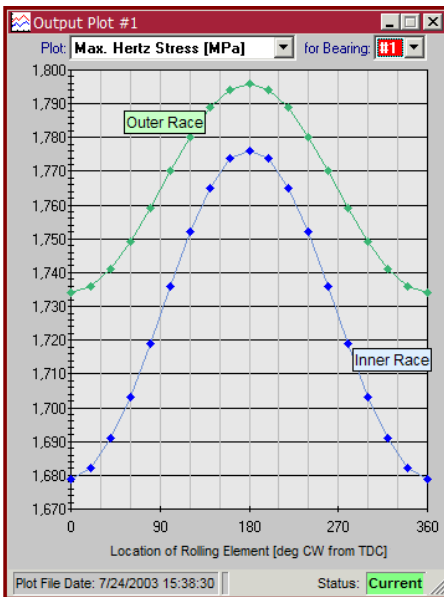
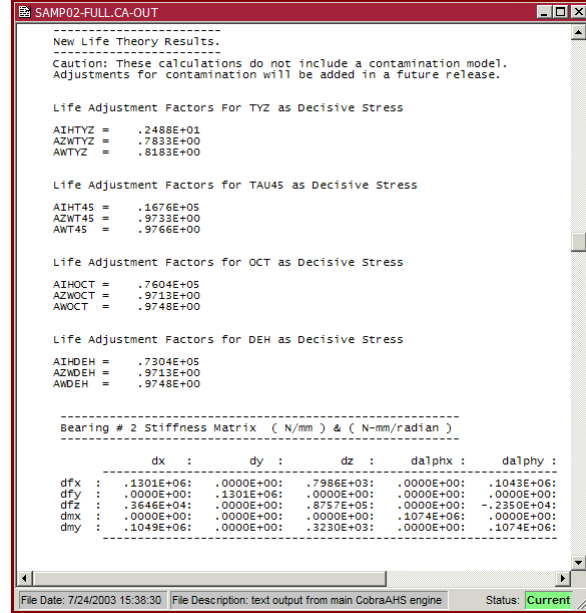
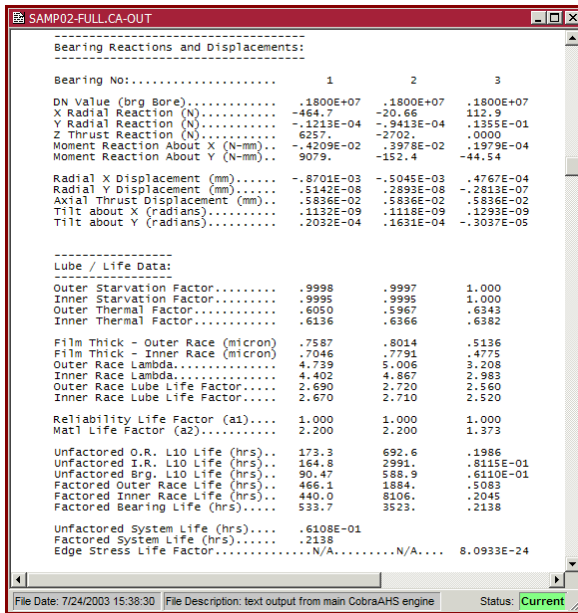
Select data to plot - click down-Arrow to pick from list
Status: **Saved**

PROGRAM RESULTS INCLUDE:

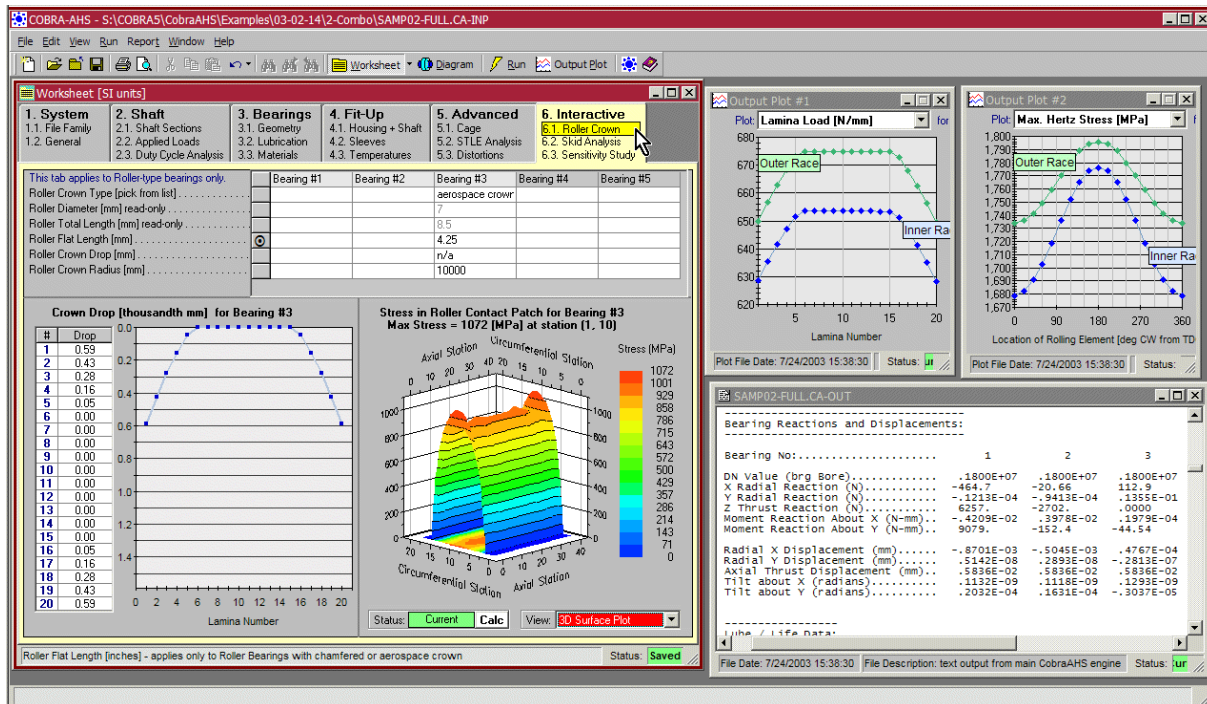
Bearing Reactions & Load Sharing
 Radial & Axial Spring Rates
 Angular Spring Rate
 Dynamic Capacity
 System B10 Life
 Bearing B10 Life
 Load Zones

Hertz Contact Stress
 Sub-Surface Shear Stress
 Operating Contact Angle
 Element Loads
 Contact Ellipse Size
 Min. Required Shoulder Heights
 Lubricant Film Thickness

Life Adjustment Factor-Lubrication
 Individual Element Output
 Contact Flash Temperature
 Contact Sliding Velocity Distribution
 Roller Edge Stress
 Per Bearing Plots of 11 parameters
 And more



COBRA-2G Roller Edge Stress Example



SYSTEM REQUIREMENTS:

IBM-compatible PC; 32-bit or 64-bit Windows Operating System (2000, XP, Vista, Windows 7-10); CD drive 40 MB hard disk space; 192 MB RAM installed (256 MB preferred); 800x600 pixel screen resolution; 16-bit color display

PACKAGE INCLUDES:

Installation CD; End-User License; Example Problems; Printed Manual; Release Notes, USB Hardware Security Key Free Technical Support for 1 year. Fee-based support available thereafter.