Bearing Equivalent Load

Combining Axial and Radial Forces Applied to a Bearing

Background

Bearing life calculation is based on a single direction load. Calculating life for a bearing with both radial and axial forces applied requires combining them into a single equivalent load. These calculations seem complex reading manufacturers' catalogs. Each manufacturer presents their equations in differently. An individual manufacturer will present equations for each type of bearing they make differently. In reality the equivalent load equation (Equation 1) is the same. It can be generalized by always showing the factors (X_n, Y_n) weighting the radial (F_r) and axial (F_a) forces.

Equation 1	$P = X_n \times F_r + Y_n \times F_a$

Depending on the manufacturer, bearing type and loading condition the weighting factors can be constants, or variable equations (Table 1). In many cases the constants can be one or zero. In these cases manufacturers show the simplified equation (example Equation 2).

Equation 2	$X_n = 1 \; \& \; Y_n = 0 \xrightarrow{yields} P = F_r$

Understanding that the multitude of equations presented by manufacturers is actually one equation makes programming the calculation much simpler (see Excel Functions in Visual Basic).

Nomenclature

e = Load Ratio Threshold for Equation Use
P = Equivalent load used in life calculation of combined radial and axial loads applied to the bearing
F_a = Axial Force
F_r = Radial Force
X_n = Factor for weighting radial force.
Y_n = Factor for weighting axial force. Timken calls this K in their catalog

Dynamic Calculation

Equivalent load (P) is used to combine axial load (F_a) and radial load (F_r) to use in the bearing life equation.

If **Equation 3** $\frac{F_a}{F_r} \le e$ Then **Equation 4** $P = X_1 \times F_r + Y_1 \times F_a$	Else →	If **Equation 5** $\frac{F_a}{F_r} > e$ Then **Equation 6** $P = X_2 \times F_r + Y_2 \times F_a$

e determines which equation to use to find P

Table 1	e	Y_1	X_1	Y_2	X_2
Deep Row Ball	Equation 7	0	1	Equation 8	Table 2
Angular Contact Ball Single	1.14	0	1	0.57	0.35
Angular Contact Ball Tandem Pair	1.14	0	1	0.57	0.35
Angular Contact Ball Pair X or O	1.14	0.55	1	0.93	0.57
Cylindrical Roller**	Catalog*	0	1	Catalog*	0.92
Taper Roller Timken	Equation 9	0	1	Catalog*	0.40
Taper Roller SKF	Catalog*	0	1	Catalog*	0.40
Spherical Roller	Catalog*	Catalog*	1	Catalog*	0.67

*Catalog= See Manufacturer's catalog to find factor for the exact bearing being used. Note that Y_2 will probably simply be called Y cases where $Y_1 = 0$ or any other fixed value

**Cylindrical Roller Bearings with axial should to take thrust load should only be used for light loads. See the manufacturer's catalog for details on limitations due to heat generation.

Equation 7	$e = 10^{\left[e_{B1} \times \log\left(\frac{F_a}{C_0}\right) - e_{B2}\right]}$	1. For Deep Row Ball Bearings 2. Derived from Tables in FAG & SKF Catalogs 3. See Table 2 for factors to use by fit class
Equation 8	$Y_2 = 10^{\left[Y_{B1} \times log\left(\frac{F_a}{C_0}\right) + Y_{B2}\right]}$	

Table 2	Deep Row Ball Bearing Factors by Class of Fit Derived from Tables in FAG & SKF Catalogs					
	Fit	e_{B1}	e_{B2}	Y_{B1}	Y_{B2}	X_2
	Normal	0.235	0.290	0.235	0.070	0.560
	C3	0.190	0.220	0.190	0.057	0.460
	C4	0.117	0.220	0.117	0.035	0.440

Equation 9	$e = \frac{R}{Y_2} \xrightarrow{yields} e = \frac{0.40}{Y_2}$	e for dynamic calculations on Timken Taper Roller Bearings

Static Calculation

Equivalent load (P_0) is used to combine axial load (F_a) and radial load (F_r) to compare to the static load rating (C_0). If the static load rating is exceed a single application will cause failure. Therefore the life calculation does not apply. These are the same equations as for dynamic except 0 notation is used denoting to use static factors to get static results.

If
Equation 10

$$\frac{F_a}{F_r} \leq e_0$$

Then
Equation 11

$$P_0 = X_{10} \times F_r + Y_{10} \times F_a$$

Else →

If
Equation 12

$$\frac{F_a}{F_r} > e_0$$

Then
Equation 13

$$P_0 = X_{20} \times F_r + Y_{20} \times F_a$$

e_0 determines which equation to use to find P_0

Table 3	e_0	Y_{10}	X_{10}	Y_{20}	X_{20}
Deep Row Ball	Equation 14	0	1	0.50	0.60
Angular Contact Ball Single	Equation 14	0	1	0.26	0.50
Angular Contact Ball Tandem Pair	Equation 14	0	1	0.26	0.50
Angular Contact Ball Pair X or O	Equation 14	0	1	0.52	1
Cylindrical Roller	0	0	1	0	1
Taper Roller Timken	Equation 15	Equation 16	1.6	Equation 17	0.50
Taper Roller SKF	Equation 14	0	1	Catalog*	0.50
Spherical Roller	0	Catalog*	1	Catalog*	1

*Catalog= See Manufacturer's catalog to find factor for the exact bearing being used

Equation 14	$e_0 = \frac{1 - X_{20}}{Y_{20}}$	*e* for static calculations
Equation 15	$e_0 = 0.6 \times e \xrightarrow{\text{yields}} e_0 = \frac{0.24}{Y_2}$	*e* for static calculations on Timken Taper Roller Bearings
Equation 16	$Y_{10} = 1.269 \times Y_2$	Y_1 for static calculations on Timken Taper Roller Bearings
Equation 17	$Y_{20} = 0.564 \times Y_2$	Y_2 for static calculations on Timken Taper Roller Bearings

Excel Functions in Visual Basic

```
Public Function EqLoad(X1, Y1, X2, Y2, e, Fr, Fa)
   ' Generalized Equivalent load Equation
   If Fr = 0 Then Fr = 0.0000001 'Stops error if Fr or Fa are zero
   If Fa = 0 Then Fa = 0.0000001
   Fa = Abs(Fa)
   If Fa / Fr > e Then
      EqLoad = X2 * Fr + Y2 * Fa
   Else
      EqLoad = X1 * Fr + Y1 * Fa
   End If
End Function

Public Function DpRwBall_Y2(Y_1, Y_2, C0, Fa)
   ' Deep Row Ball Brg Equations to find Y2
   DpRwBall_Y2 = 10 ^ (-(Y_1 * Log10(Fa / C0) + Y_2))
End Function

Public Function DpRwBall_e(e_1, e_2, C0, Fa)
   ' Deep Row Ball Brg Equation to find e
   DpRwBall_e = 10 ^ (e_1 * Log10(Fa / C0) - e_2)
End Function

Public Function Log10(x)
  ' Needed sub function for Deep Row e Calculation
   Log10 = Log(x) / Log(10)
End Function
```

About the author:

James K. Simonelli is a Licensed Professional Engineer with 30 years experience designing and troubleshooting machine automation, heavy duty equipment and industrial products. He has a broad background with department head roles in engineering, quality and business development in companies varying from startups, turnarounds to Fortune 100 corporations. Mr. Simonelli has served on committees developing industrial standards for the American Gear Manufacturers Association and the Hydraulics Institute.

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