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R 281

ROLLING BEARINGS
METHODS OF EVALUATING DYNAMIC LOAD RATINGS

1st EDITION

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BRIEF HISTORY

The ISO Recommendation R 281, *Rolling Bearings—Methods of Evaluating Dynamic Load Ratings*, was drawn up by Technical Committee ISO/TC 4, *Ball and Roller Bearings*, the Secretariat of which is held by the Sveriges Standardiseringskommission (SIS).

Work, on this question by the Technical Committee began in 1952 and led, in 1959, to the adoption of a Draft ISO Recommendation.

In December 1959, this Draft ISO Recommendation (No. 278) was circulated to all the ISO Member Bodies for enquiry. It was approved by the following Member Bodies:

Austria	France	Poland
Belgium	India	Portugal
Burma	Italy	Romania
Chile	Japan	Spain
Colombia	Netherlands	Sweden
Czechoslovakia	New Zealand	Switzerland
Finland	Pakistan	U.S.A.
		Yugoslavia

Four Member Bodies opposed the approval of the Draft:

Germany, Hungary, United Kingdom, U.S.S.R.

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in November 1962, to accept it as an ISO RECOMMENDATION.

ISO Recommendation | R 281 | November 1962

ROLLING BEARINGS

METHODS OF EVALUATING DYNAMIC LOAD RATINGS

INTRODUCTORY NOTE

This ISO Recommendation covers methods of evaluating dynamic load ratings for

giving for each part the following items:

Definitions,
Calculation of basic load rating,
Calculation of rating life,
Calculation of equivalent load.

It is recognized that revisions of the calculations may be required from time to time as the result of improvements or new developments.

1. METHOD OF EVALUATING DYNAMIC LOAD RATINGS OF RADIAL BALL BEARINGS

1.1 Definitions

1.1.1 The *life* of an individual ball bearing is defined as the number of revolutions (or hours at some given constant speed) which the bearing runs before the first evidence of fatigue develops in the material of one of the rings or any of the rolling elements.

1.1.2 The *rating life* of a group of apparently identical ball bearings is defined as the number of revolutions (or hours at some given constant speed) that 90 per cent of that group of bearings will complete or exceed before the first evidence of fatigue develops.

1.1.3 The *basic load rating* is that constant stationary radial load which a group of apparently identical ball bearings with stationary outer ring can endure for a rating life of one million revolutions of the inner ring. In single-row angular-contact ball bearings, the basic load rating relates to the radial component of that load, which causes a purely radial displacement of the bearing rings in relation to each other.

1.1.3.1 Load ratings, if given for specific speeds, should be based on a rating life of 500 hours.

1.1.4 The *equivalent load* is defined as that constant stationary radial load which, if applied to a bearing with rotating inner ring and stationary outer ring, would give the same life as that which the bearing will attain under the actual conditions of load and rotation.

1.2 Calculation of basic load rating

The magnitude of the basic load rating C for radial- and angular-contact ball bearings, except filling-slot bearings, is given by the following formulae:

(*a*) with balls of diameter not larger than 25.4 mm or 1 in:

$$C = f_c\ (i \cos \alpha)^{0.7}\ Z^{2/3}\ D^{1.8}$$

(*b*) with balls of diameter larger than 25.4 mm, when kilogramme and millimetre units are used:

$$C = f_c\ (i \cos \alpha)^{0.7}\ Z^{2/3} \times 3.647\ D^{1.4}$$

(*c*) with balls of diameter larger than 1 in, when pound and inch units are used:

$$C = f_c\ (i \cos \alpha)^{0.7}\ Z^{2/3}\ D^{1.4}$$

where i = number of rows of balls in any one bearing,

α = nominal angle of contact = nominal angle between the line of action of the ball load and a plane perpendicular to the bearing axis,

Z = number of balls per row,

D = ball diameter,

f_c = factor which depends on the units used, the geometry of the bearing components, the accuracy to which the various bearing parts are made and the material.

Values of f_c are obtained by multiplying

the values of $\frac{f_c}{f}$, from the appropriate column of Table 1,

by a factor f, covered in the note below.

NOTE. – Current tests of ball bearings of good quality, hardened ball-bearing steel, indicate that the value of the factor f is:

f = 10 when kilogramme and millimetre units are used,

f = 7450 when pound and inch units are used.

TABLE 1. — Factor $\frac{f_c}{f}$

$\frac{D\cos\alpha}{d_m}$ *	$\frac{f_c}{f}$			
	for single-row, radial-contact, groove ball bearings and single- and double-row, angular-contact, groove ball bearings**	for double-row, radial-contact, groove ball bearings**	for self-aligning ball bearings	for single-row, radial-contact, separable ball bearings (magneto bearings)
0.05	0.476	0.451	0.176	0.165
0.06	0.500	0.474	0.190	0.177
0.07	0.521	0.494	0.203	0.189
0.08	0.539	0.511	0.215	0.199
0.09	0.554	0.524	0.227	0.210
0.10	0.566	0.537	0.238	0.219
0.12	0.586	0.555	0.261	0.239
0.14	0.600	0.568	0.282	0.258
0.16	0.608	0.576	0.303	0.276
0.18	0.611	0.579	0.323	0.294
0.20	0.611	0.579	0.342	0.311
0.22	0.608	0.576	0.359	0.327
0.24	0.601	0.570	0.375	0.343
0.26	0.593	0.562	0.390	0.358
0.28	0.583	0.552	0.402	0.372
0.30	0.571	0.541	0.411	0.386
0.32	0.558	0.530	0.418	0.397
0.34	0.543	0.515	0.420	0.406
0.36	0.527	0.500	0.421	0.412
0.38	0.510	0.484	0.418	0.415
0.40	0.492	0.467	0.412	0.417

* d_m = pitch diameter of the ball set.

For values of $\frac{D\cos\alpha}{d_m}$, other than given in Table 1, $\frac{f_c}{f}$ is obtained by linear interpolation.

** (a) When calculating the basic load rating for a unit consisting of two similar single-row radial-contact ball bearings in a duplex mounting, the unit is considered as one double-row radial-contact ball bearing.

(b) When calculating the basic load rating for a unit consisting of two similar single-row angular-contact ball bearings in a duplex mounting, "face-to-face" or "back-to-back", the unit is considered as one double-row angular-contact ball bearing.

(c) When calculating the basic load rating for a unit consisting of two or more similar single-row angular-contact ball bearings mounted "in tandem", properly manufactured and mounted for equal load distribution, the rating of the unit is the number of bearings to the 0.7 power times the load rating of a single-row ball bearing.

If for some technical reason the unit may be treated as a number of individually interchangeable single-row bearings, this paragraph (c) does not apply.

The values of factor $\frac{f_c}{f}$ given in Table 1 apply to bearings whose ring raceways have a cross-sectional radius not larger than,

in radial contact and angular contact groove ball bearing inner rings,	52 per cent of the ball diameter
in radial contact and angular contact groove ball bearing outer rings,	53 per cent of the ball diameter
in self-aligning ball bearing inner rings,	53 per cent of the ball diameter.

The basic load rating is not necessarily increased by the use of smaller groove radii, but is reduced by the use of larger radii than those given above.

1.3 Calculation of rating life

The approximate magnitude of the rating life L for ball bearings, except filling-slot bearings, is given by the formula:

$$L = \left(\frac{C}{P}\right)^3 \text{ million revolutions}$$

where P = equivalent load.

1.4 Calculation of equivalent load

The magnitude of the equivalent load P for radial- and angular-contact ball bearings of conventional type, except filling-slot bearings, under combined constant radial and constant thrust loads, is given by the formula:

$$P = XVF_r + YF_a$$

where X = radial factor,
V = rotation factor,
Y = thrust factor,
F_r = radial load,
F_a = thrust load.

Values of factors V, X and Y are given in Table 2, page 7.

FOOT-NOTES OF TABLE 2 (PAGE 7):

(1) C_o is the static basic load rating.

(2) Values of X, Y and e for a load or a contact angle, other than shown in Table 2, are obtained by linear interpolation.

(3) For single-row bearings, when $\frac{F_a}{VF_r} \leqq e$, use $X = 1$ and $Y = 0$.

(*a*) When calculating the equivalent load for a unit consisting of two similar single-row angular-contact ball bearings in a duplex mounting, "face-to-face" or "back-to-back", the unit is considered as one double-row angular-contact ball bearing.

(*b*) When calculating the equivalent load for a unit consisting of two or more single-row radial- or angular-contact ball bearings mounted "in tandem", the X and Y values for single-row ball bearings are used. Attention is called to footnote ** (c) under Table 1.

(4) Double-row bearings are presumed to be symmetrical.

(5) Permissible maximum value of $\frac{F_a}{C_o}$ depends on the bearing design.

(6) Because experimental data are incomplete, no correct value of factor V for radial and angular contact groove ball bearings with inner ring stationary in relation to the load can be stated. The values shown in the Table are, however, well on the safe side.

TABLE 2. — Factors V, X and Y

Bearing type		$\frac{iF_a}{C_o}$ (1)	$\frac{F_a}{Z D^2}$ units used: pounds and inches	$\frac{F_a}{C_o}$ (1)	$\frac{F_a}{iZ D^2}$ units used: pounds and inches	V — if, in relation to the load, the inner ring is: rotating	V — stationary	X(2) — for single-row bearings(3), when $\frac{F_a}{VF_r} > e$	X(2) — for double-row bearings(4), when $\frac{F_a}{VF_r} \leqq e$	X(2) — for double-row bearings(4), when $\frac{F_a}{VF_r} > e$	Y(2) — for single-row bearings(3), when $\frac{F_a}{VF_r} > e$	Y(2) — for double-row bearings(4), when $\frac{F_a}{VF_r} \leqq e$	Y(2) — for double-row bearings(4), when $\frac{F_a}{VF_r} > e$	e (2)
Non-filling-slot assembly, radial-contact, groove ball bearings(5)				0.014 0.028 0.056 0.084 0.11 0.17 0.28 0.42 0.56	25 50 100 150 200 300 500 750 1 000	1	1.2 (6)	0.56	1	0.56	2.30 1.99 1.71 1.55 1.45 1.31 1.15 1.04 1.00	0	2.30 1.99 1.71 1.55 1.45 1.31 1.15 1.04 1.00	0.19 0.22 0.26 0.28 0.30 0.34 0.38 0.42 0.44
Angular-contact groove ball bearings (5)	$\alpha = 5°$	0.014 0.028 0.056 0.085 0.11 0.17 0.28 0.42 0.56	25 50 100 150 200 300 500 750 1 000			1	1.2 (6)	For this type, use the X, Y and e values applicable to single-row, non-filling-slot assembly, radial-contact, groove ball bearings	1	0.78	For this type, use the X, Y and e values applicable to single-row, non-filling-slot assembly, radial-contact, groove ball bearings	2.78 2.40 2.07 1.87 1.75 1.58 1.39 1.26 1.21	3.74 3.23 2.78 2.52 2.36 2.13 1.87 1.69 1.63	0.23 0.26 0.30 0.34 0.36 0.40 0.45 0.50 0.52
	$\alpha = 10°$	0.014 0.029 0.057 0.086 0.11 0.17 0.29 0.43 0.57	25 50 100 150 200 300 500 750 1 000			1	1.2 (6)	0.46	1	0.75	1.88 1.71 1.52 1.41 1.34 1.23 1.10 1.01 1.00	2.18 1.98 1.76 1.63 1.55 1.42 1.27 1.17 1.16	3.06 2.78 2.47 2.29 2.18 2.00 1.79 1.64 1.63	0.29 0.32 0.36 0.38 0.40 0.44 0.49 0.54 0.54
	$\alpha = 15°$	0.015 0.029 0.058 0.087 0.12 0.17 0.29 0.44 0.58	25 50 100 150 200 300 500 750 1 000			1	1.2 (6)	0.44	1	0.72	1.47 1.40 1.30 1.23 1.19 1.12 1.02 1.00 1.00	1.65 1.57 1.46 1.38 1.34 1.26 1.14 1.12 1.12	2.39 2.28 2.11 2.00 1.93 1.82 1.66 1.63 1.63	0.38 0.40 0.43 0.46 0.47 0.50 0.55 0.56 0.56
	$\alpha = 20°$ $\alpha = 25°$ $\alpha = 30°$ $\alpha = 35°$ $\alpha = 40°$	—	—			1 1 1 1 1	1.2 1.2 1.2 1.2 1.2 (6)	0.43 0.41 0.39 0.37 0.35	1 1 1 1 1	0.70 0.67 0.63 0.60 0.57	1.00 0.87 0.76 0.66 0.57	1.09 0.92 0.78 0.66 0.55	1.63 1.41 1.24 1.07 0.93	0.57 0.68 0.80 0.95 1.14
Self-aligning ball bearings						1	1	0.40	1	0.65	0.4 cot α	0.42 cot α	0.65 cot α	1.5 tg α
Single-row radial-contact separable ball bearings (magneto bearings)						1	1	0.5	—	—	2.5	—	—	0.2

2. METHOD OF EVALUATING DYNAMIC LOAD RATINGS OF RADIAL ROLLER BEARINGS

2.1 Definitions

2.1.1 The *life* of an individual roller bearing is defined as the number of revolutions (or hours at some given constant speed) which the bearing runs before the first evidence of fatigue develops in the material of one of the rings or any of the rolling elements.

2.1.2 The *rating life* of a group of apparently identical roller bearings is defined as the number of revolutions (or hours at some given constant speed) that 90 per cent of that group of bearings will complete or exceed before the first evidence of fatigue develops.

2.1.3 The *basic load rating* is that constant stationary radial load which a group of apparently identical roller bearings with stationary outer ring can endure for a rating life of one million revolutions of the inner ring. In single-row angular-contact roller bearings the basic load rating relates to the radial component of that load, which causes a purely radial displacement of the bearing rings in relation to each other.

2.1.3.1 Load ratings, if given for specific speeds, should be based on a rating life of 500 hours.

2.1.4 The *equivalent* load is defined as that constant stationary radial load which, if applied to a bearing with rotating inner ring and stationary outer ring, would give the same life as that which the bearing will attain under the actual conditions of load and rotation.

2.2 Calculation of basic load rating

The magnitude of the basic load rating C for radial roller bearings is given by the formula:

$$C = f_c\,(i\,l_{eff}\cos\alpha)^{7/9}\,Z^{3/4}\,D^{29/27}$$

where i = number of rows of rollers in any one bearing,

α = nominal angle of contact = nominal angle between the line of action of the roller resultant load and a plane perpendicular to the bearing axis,

Z = number of rollers per row,

D = roller diameter (mean diameter of tapered rollers),

l_{eff} = effective length of contact between one roller and that ring where the contact is the shortest (overall roller length minus roller chamfers, or minus grinding undercuts),

f_c = factor which depends on the units used, the exact geometrical shape of the load-carrying surfaces of the rollers and rings, the accuracy to which the various bearing parts are made and the material.

Values of f_c are obtained by multiplying

the values of $\frac{f_c}{f}$, from the appropriate column of Table 3,

by a factor f, covered in the note below.

NOTE. – Current tests of roller bearings of good quality, hardened roller-bearing steel, indicate that the value of the factor f is:

f = 56.2 when kilogramme and millimetre units are used,
f = 49 500 when pound and inch units are used.

Roller bearings vary considerably in design and execution. Small differences in the relative shape of contacting surfaces may account for distinct differences in load-carrying capacity. It is therefore not possible to give detailed information about the exact basic load rating of a certain general type of roller bearing.

The approximate basic load rating of a roller bearing of good design in all details and made by a reputable roller bearing manufacturer, may be obtained by the use of the $\frac{f_c}{f}$ values given in Table 3.

Actual basic load rating bearings of different type and workmanship may differ from the value indicated. A bearing should be expected to have a lower carrying capacity when, under load, more or less accentuated stress concentrations in the roller contacts are present (point contact) or are not effectively prevented (sharp corners or rigid bearing design). The basic load rating may be increased over the value indicated, when even stress distribution over the whole roller length is automatically assured. For no variant will the factor $\frac{f_c}{f}$ exceed the value indicated by more than 14 per cent.

TABLE 3. — **Factor** $\frac{f_c}{f}$

$\frac{D \cos \alpha}{d_m}$ *	$\frac{f_c}{f}$
0.01	0.083
0.02	0.097
0.03	0.106
0.04	0.113
0.05	0.118
0.06	0.123
0.07	0.126
0.08	0.130
0.09	0.132
0.10	0.134
0.12	0.138
0.14	0.140
0.16	0.141
0.18	0.142
0.20	0.142
0.22	0.141
0.24	0.140
0.26	0.138
0.28	0.136
0.30	0.134

* d_m = pitch diameter of the roller set.

2.3 Calculation of rating life

The approximate magnitude of the rating life L for radial roller bearings is given by the formula:

$$L = \left(\frac{C}{P}\right)^{10/3} \text{ million revolutions}$$

where P = equivalent load.

2.4 Calculation of equivalent load

The magnitude of the equivalent load P for self-aligning and tapered roller bearings of conventional types, under combined constant radial and constant thrust loads, is given by the formula:

$$P = XVF_r + YF_a$$

where X = radial factor,
V = rotation factor,
Y = thrust factor,
F_r = radial load,
F_a = thrust load.

Values of factors V, X and Y are given in Table 4.

TABLE 4. — Factors V, X and Y

Bearing type	V		X				Y				e
	if, in relation to the load, the inner ring is		for single-row roller bearings		for double-row roller bearings***		for single-row roller bearings		for double-row roller bearings***		for single- and double-row roller bearings ***
	rotating	stationary**	when $\frac{F_a}{VF_r} \leq e$	when $\frac{F_a}{VF_r} > e$	when $\frac{F_a}{VF_r} \leq e$	when $\frac{F_a}{VF_r} > e$	when $\frac{F_a}{VF_r} \leq e$	when $\frac{F_a}{VF_r} > e$	when $\frac{F_a}{VF_r} \leq e$	when $\frac{F_a}{VF_r} > e$	
Self-aligning roller bearings and tapered roller bearings $\alpha \neq 0°$ *	1	1.2	1	0.4	1	0.67	0	0.4 cot α	0.45 cot α	0.67 cot α	1.5 tg α

* For $\alpha = 0°$: $F_a = 0$ and $X = 1$.

** Because experimental data are incomplete, no correct value of factor V for roller bearings with inner ring stationary in relation to the load can be stated. The value $V = 1.2$ is, however, well on the safe side.

*** Double-row bearings are presumed to be symmetrical.

3. METHOD OF EVALUATING DYNAMIC LOAD RATINGS OF THRUST BALL BEARINGS

3.1 Definitions

3.1.1 The *life* of an individual thrust ball bearing is defined as the number of revolutions (or hours at some given constant speed) which the bearing runs before the first evidence of fatigue develops in the material of any of the washers or any of the rolling elements.

3.1.2 The *rating life* of a group of apparently identical thrust ball bearings is defined as the number of revolutions (or hours at some given constant speed) that 90 per cent of that group of bearings will complete or exceed before the first evidence of fatigue develops.

3.1.3 The *basic load rating* is that constant central thrust load, which a group of apparently identical thrust ball bearings can endure for a rating life of one million revolutions of one of the bearing washers.

3.1.3.1 Load ratings, if given for specific speeds, should be based on a rating life of 500 hours.

3.1.4 The *equivalent thrust load* is defined as that constant, central, purely axial load which, if applied to a bearing with rotating shaft washer and stationary housing washer, would give the same life as that which the bearing will attain under the actual conditions of load and rotation.

3.2 Calculation of basic load rating

3.2.1 The magnitude of the basic load rating C_a for single-row, single- and double-direction thrust ball bearings is given by the following formulae:

(*a*) with balls of diameter not larger than 25.4 mm or 1 in:

$$\text{for } \alpha = 90°: C_a = f_c\, Z^{2/3}\, D^{1.8}$$

$$\text{for } \alpha \neq 90°: C_a = f_c\, (\cos\alpha)^{0.7}\, \text{tg}\,\alpha\, Z^{2/3}\, D^{1.8}$$

(*b*) with balls of diameter larger than 25.4 mm, when kilogramme and millimetre units are used:

$$\text{for } \alpha = 90°: C_a = f_c\, Z^{2/3} \times 3.647\, D^{1.4}$$

$$\text{for } \alpha \neq 90°: C_a = f_c\, (\cos\alpha)^{0.7}\, \text{tg}\,\alpha\, Z^{2/3} \times 3.647\, D^{1.4}$$

(*c*) with balls of diameter larger than 1 in, when pound and inch units are used:

$$\text{for } \alpha = 90°: C_a = f_c\, Z^{2/3}\, D^{1.4}$$

$$\text{for } \alpha \neq 90°: C_a = f_c\, (\cos\alpha)^{0.7}\, \text{tg}\,\alpha\, Z^{2/3}\, D^{1.4}$$

where α = nominal angle of contact = nominal angle between the line of action of the ball load and a plane perpendicular to the bearing axis,

Z = number of balls in a single row, single-direction bearing,

D = ball diameter,

f_c = factor which depends on the units used, the geometry of the bearing components, the accuracy to which the various bearing parts are made, and the material.

Values of f_c are obtained by multiplying

the values of $\frac{f_c}{f}$, from the appropriate column of Table 5,

by a factor f, covered in the note below.

NOTE. – Current tests of thrust ball bearings of good quality, hardened ball-bearing steel, indicate that the value of the factor f is:

f = 10 when kilogramme and millimetre units are used,
f = 7450 when pound and inch units are used.

TABLE 5. — **Factor** $\frac{f_c}{f}$

$\frac{D}{d_m}$ *	$\frac{f_c}{f}$	$\frac{D \cos \alpha}{d_m}$ *	$\frac{f_c}{f}$		
	$\alpha = 90°$		$\alpha = 45°$	$\alpha = 60°$	$\alpha = 75°$
0.01	0.374	0.01	0.429	0.399	0.381
0.02	0.461	0.02	0.527	0.490	0.468
0.03	0.521	0.03	0.594	0.553	0.527
0.04	0.568	0.04	0.645	0.600	0.572
0.05	0.607	0.05	0.686	0.639	0.609
0.06	0.641	0.06	0.720	0.670	0.639
0.07	0.671	0.07	0.749	0.697	0.665
0.08	0.699	0.08	0.774	0.720	0.687
0.09	0.724	0.09	0.795	0.740	0.705
0.10	0.747	0.10	0.812	0.756	0.721
0.12	0.789	0.12	0.840	0.782	
0.14	0.827	0.14	0.858	0.798	
0.16	0.860	0.16	0.868	0.808	
0.18	0.891	0.18	0.872	0.812	
0.20	0.920	0.20	0.871	0.811	
0.22	0.947	0.22	0.866		
0.24	0.972	0.24	0.856		
0.26	0.995	0.26	0.844		
0.28	1.02	0.28	0.829		
0.30	1.04	0.30	0.811		
0.32	1.06				
0.34	1.08				

* d_m = pitch diameter of the ball set.

The values of factor $\frac{f_c}{f}$ given in Table 5 apply to bearings whose washer raceways have a cross-sectional radius not larger than 54 per cent of the ball diameter.

The basic load rating is not necessarily increased by the use of smaller groove radii, but is reduced by the use of larger radii than those given above.