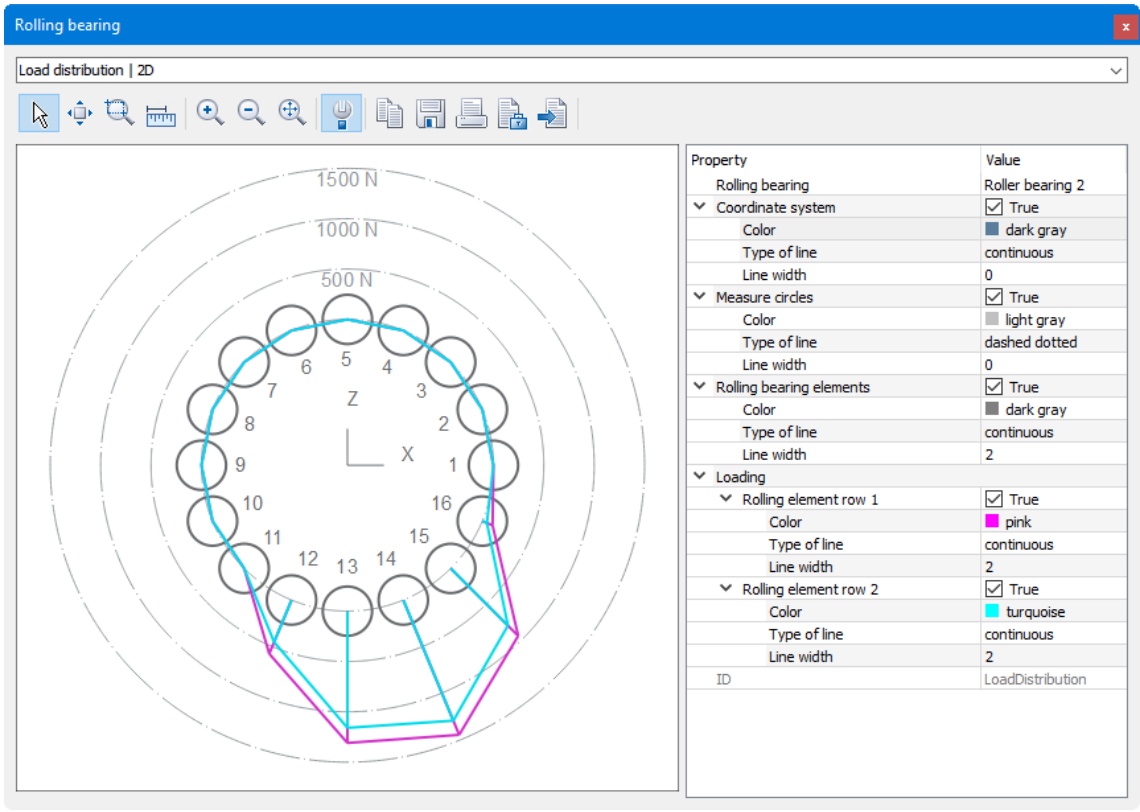
Life vs. clearance, Stribeck number

Release 2021



References

[1] Oswald et al., Effect of Internal Clearance on Load Distribution and Life of Radially Loaded Ball and Roller Bearings, NASA/TM—2012-217115

[2] Planetary Gear Bearing Arrangements in Industrial Gearboxes, Schaeffler Technologies publication TPI 08

[3] Keller et al., Comparison of planetary bearing load-sharing characteristics in wind turbine gearboxes, Wind Energ. Sci., 3, 947–960, 2018

[4] ISO 81400-4:2005, Wind turbines – Part 4: Design and specifications of gearboxes

[5] ISO 5753-1:2009, Rolling bearings — Internal clearance — Part 1: Radial internal clearance for radial bearings

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Summary

Key statements

A small pre-tension / negative clearance in operation typically results in highest life rating

Clearance below the optimum leads to rapid reduction of rating life

Clearance above the optimum leads to gradual reduction of rating life

Typically, most highly loaded ball in a deep groove ball with zero clearance bearing is loaded about 4.37 (found by Stribeck) or 4.08 (found by Palmgren) or 5 times (recommendation, rounded, accounting for other effects) higher than the average ball load.

Bearing clearances, five groups, 2, N, 3, 4, 5 (N = normal), ISO 5753 or ANSI/ABMA 20

Basic rating life is assuming load distribution for zero clearance

Clearance

Positive clearance → less than half of the circumference is loaded. Load distribution is determined

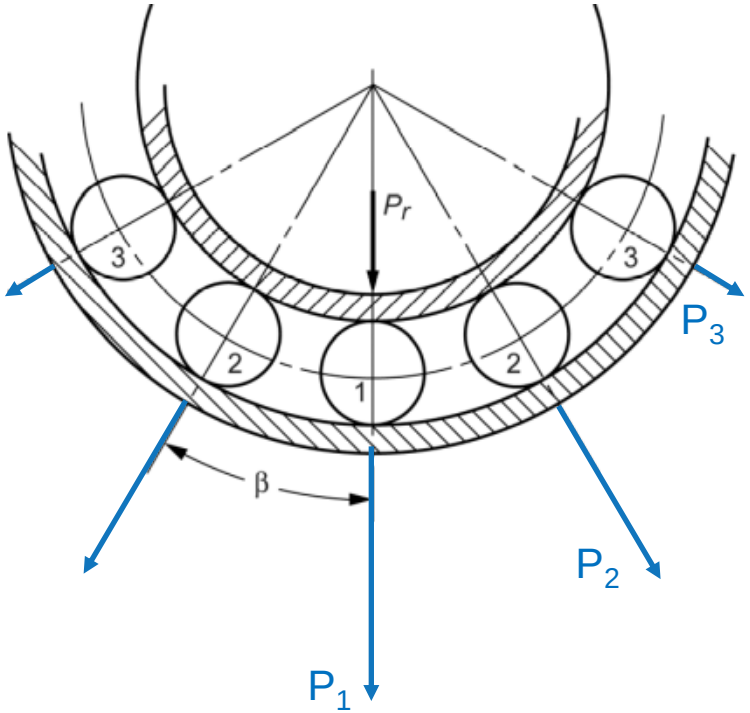
$$P_r = P_1 + 2P_2\cos\beta + 2P_3\cos 2\beta + \ldots + 2P_{n+1}\cos n\beta$$

Where n is the number of pairs of rolling bodies under load. n may be estimated from the number of rolling bodies in the bearing, z (INT = integer part of resulting number). The pitch angle β is as shown below.

$$n = INT\left(\frac{z-1}{4}\right) \qquad \beta = \frac{2\pi}{z}$$

The highest load Pmax = P1 may be estimated as a function of the Stribeck number St, use St≈5 to account for some uneven load distribution.

$$P_{max} = \frac{P_r}{Q} = \frac{S_t P_r}{z} \qquad S_t = \frac{z}{Q} = \frac{P_{max}}{P_r / z}$$



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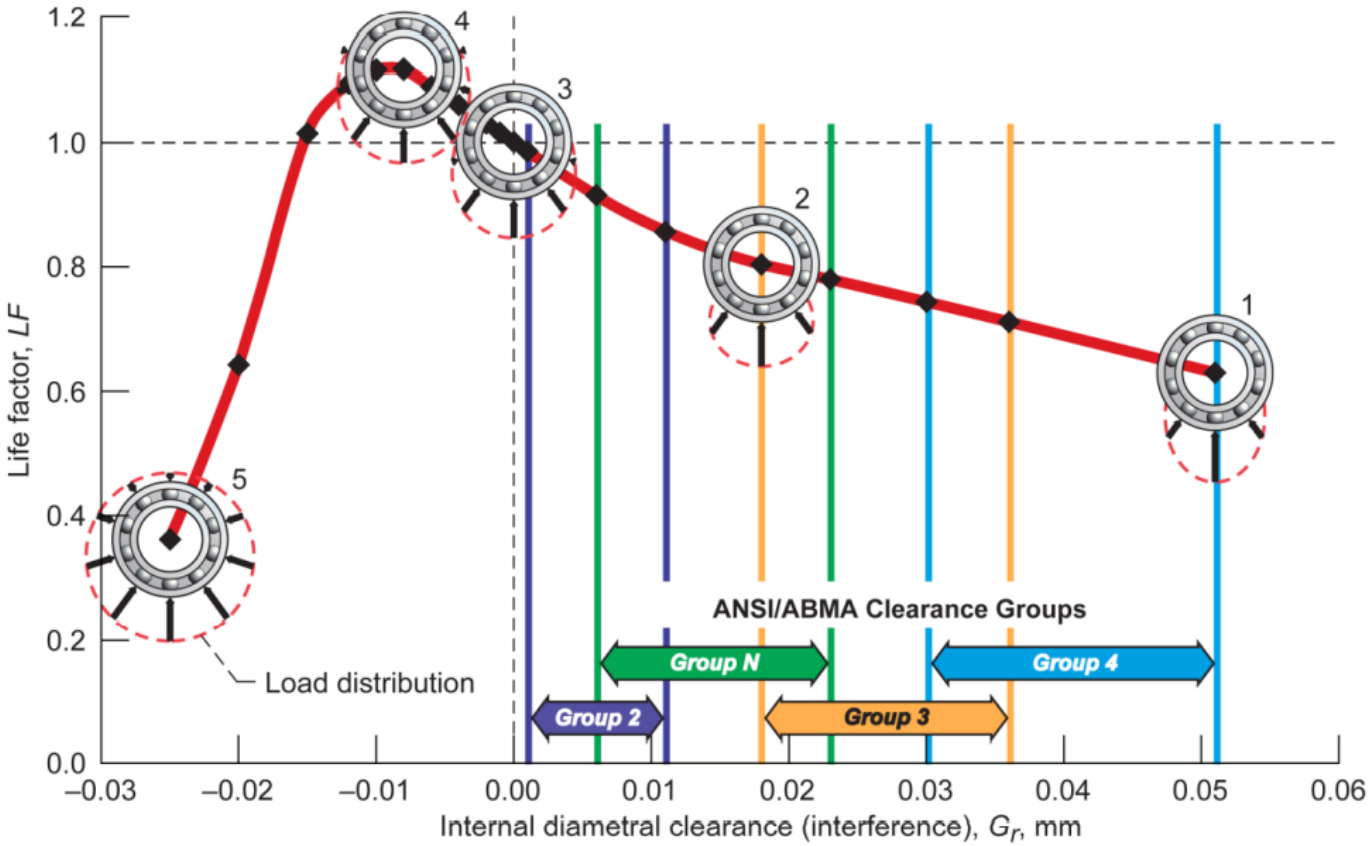
Bearing life vs. bearing operating clearance

Highest calculated life is reached for a small amount of pre-tension



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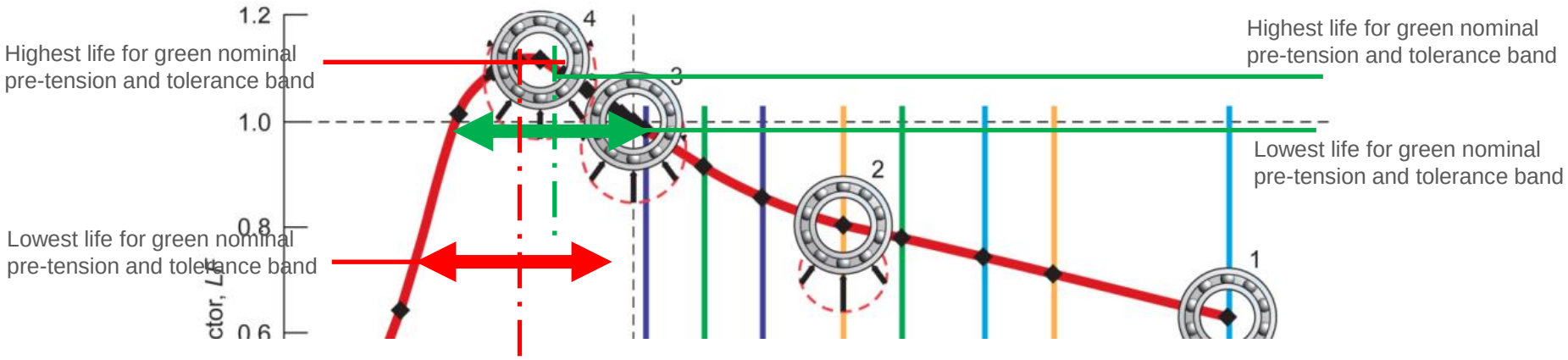
Effect of clearance

Optimal clearance / pre-tension

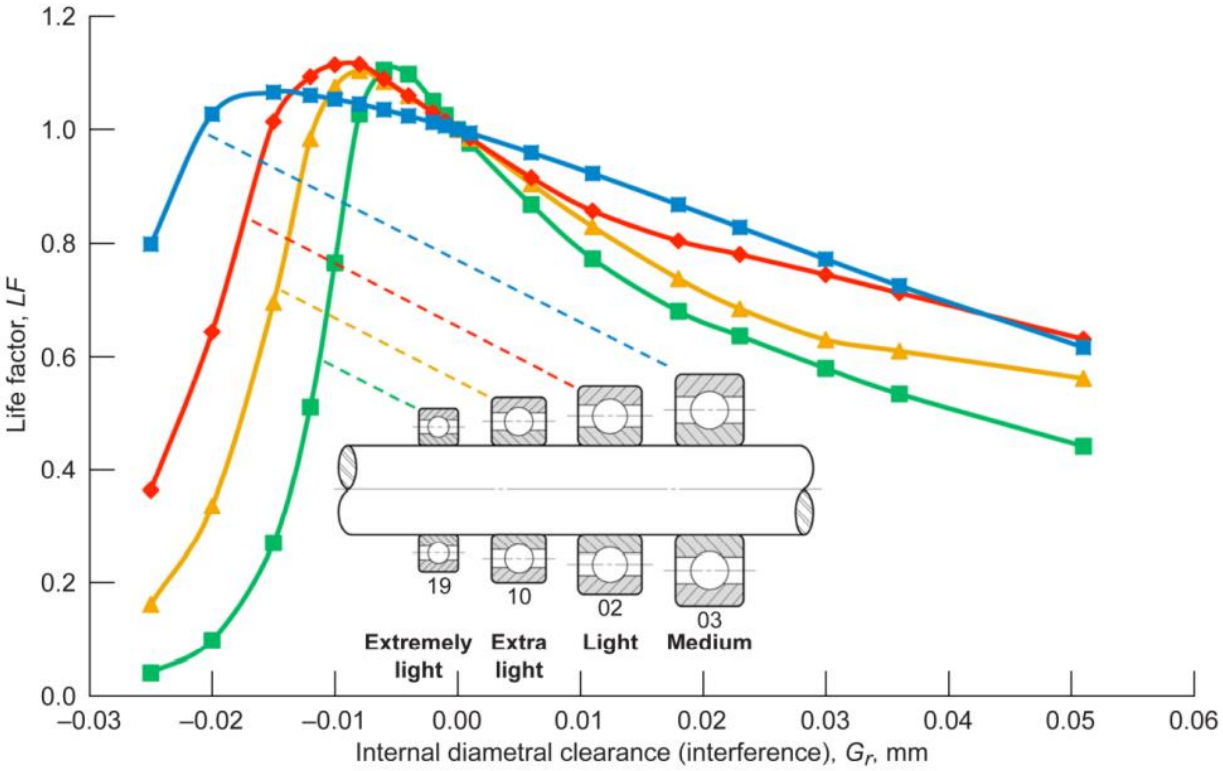
Assume tolerance band for clearance is as the tolerance band for N, optimal pre-tension is in the middle of this band (green vertical line

Note that the optimal pre-tension is not equal to the pre-tension giving maximum life (red vertical line). Reason is that – if lower end in tolerance band applies – bearing life drops drastically.



Effect of bearing size

The shape of the life vs. clearance curve depends on the bearing size envelope:



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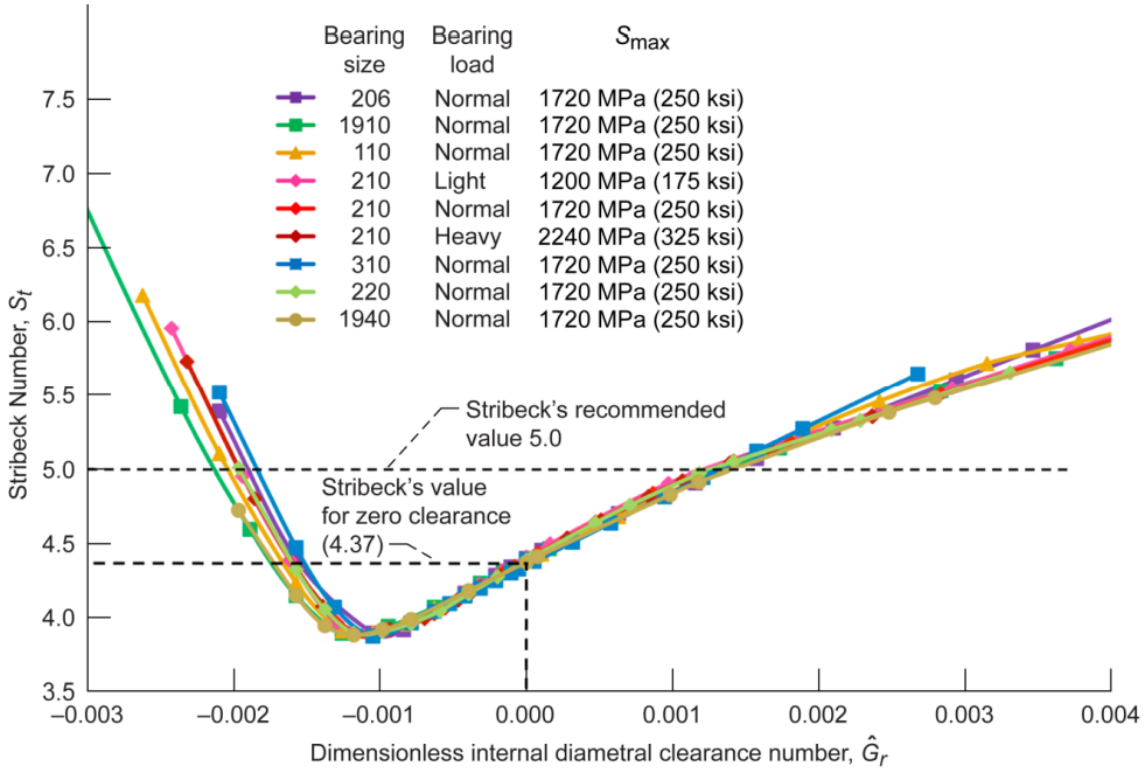
Effect of clearance

Stribeck number

For deep groove ball bearings, Stribeck found S_t = 4.37 (4.08 for CRB) for a bearing of zero clearance and recommends S_t = 5.00. If a suitable pre-tension is applied, S_t drops to below S_t = 4.00

$$S_t = \frac{z}{Q} = \frac{P_{max}}{P_r / z}$$



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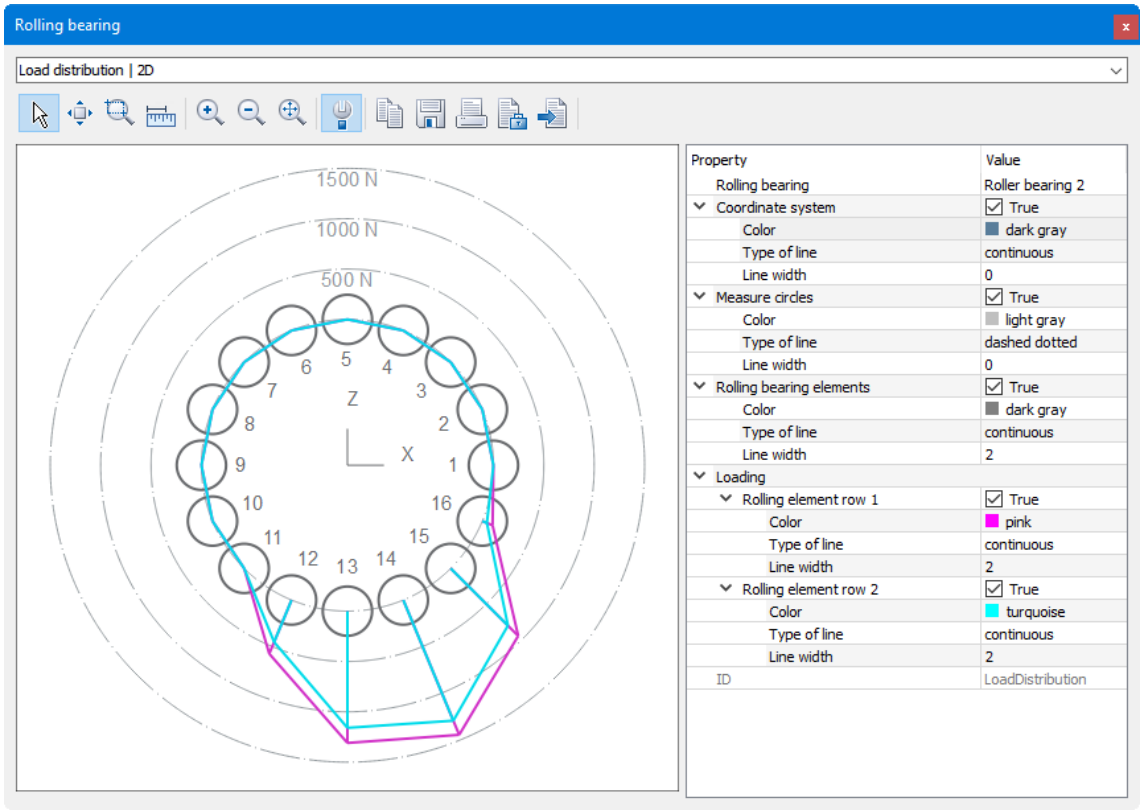
Thank you for your attention!



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