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Rolling Bearing Calculation

Input data

Bearing Geometry

| | | |
|----------------------------|----------|----------------------------------|
| Type of rolling bearing | | Four point ball bearing (radial) |
| Bearing inner diameter | d | 1300.0 mm |
| Bearing outer diameter | D | 1500.0 mm |
| Bearing width | B | 100.000 mm |
| Number of rolling elements | Z | 60 |
| Roller diameter | Dw | 60.000 mm |
| Pitch diameter | Dpw | 1400.0 mm |
| Conformity inner race | fi | 0.53 |
| Conformity outer race | fe | 0.53 |
| Nominal contact angle | α | 45.000 ° |

| | | |
|---------------------------------|----|-----------------------------------|
| Definition of clearance | | User input as operating clearance |
| Definition of bearing tolerance | | Not considered |
| Nominal axial clearance | Pa | 0.0100 mm |
| Clearance generation type | | axial direction |

Loading

| | | | |
|------------------------------------|-------------|------------|---|
| Speed of inner ring | ni | 0.0000 rpm | inner ring is stationary relative to load |
| Speed of outer ring | ne | 10.000 rpm | outer ring rotates relative to load |
| Axial force | Fx | 500.000 kN | |
| Radial force Y | Fy | 0.0000 kN | |
| Radial force Z | Fz | 100.000 kN | |
| Moment Y | My | 150000 Nm | |
| Moment Z | Mz | 0.0000 Nm | |
| Temperature of inner ring | T_i | 20.000 °C | |
| Temperature of outer ring | T_e | 20.000 °C | |
| Dynamic load rating | Cr | 762.661 kN | |
| Static load rating | C0r | 3370.2 kN | |
| Fatigue load limit | Cur | 60.151 kN | |
| Reliability | reliability | 90.000 % | |
| Maximal permissible value for aISO | aISOMax | 50 | |

Material

| | | |
|--------------------------------------|-------|------------|
| Surface hardness inner race | HRC_i | 54 |
| Surface hardness outer race | HRC_e | 54 |
| Ultimate strength of core inner race | Rm_i | 1000.0 MPa |

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| | | |
|---|---|----------------------------|
| Ultimate strength of core outer race | Rm_e | 1000.0 MPa |
| Material for inner ring | Steel | |
| Material for outer ring | Steel | |
| Material for rolling element | Steel | |
| Lubrication | | |
| Lubricant | ISO VG 220 mineral oil | |
| Kinematic viscosity at 40°C | v40 | 220.000 mm ² /s |
| Kinematic viscosity at 100°C | v100 | 19.000 mm ² /s |
| Oil density | rhoOil | 890.000 kg/m ³ |
| Oil temperature | θOil | 70.000 °C |
| Oil does not contain effective EP additives | | |
| Effective kinematic viscosity | v(θ) | 51.794 mm ² /s |
| Effective oil density | ρ(θ) | 851.593 kg/m ³ |
| Lubricant cleanliness | Grease lubrication, Slight to typical contamination | |
| Results | | |
| Centrifugal loads are not considered | | |
| Bearing inner geometry | | |
| Number of rolling elements | Z | 60 |
| Roller diameter | Dw | 60.000 mm |
| Pitch diameter | Dpw | 1400.0 mm |
| Conformity inner race | fi | 0.53 |
| Conformity outer race | fe | 0.53 |
| Nominal contact angle | α | 45.000 ° |
| Distance between center of curvature inner and outer ring | δCC | 2.5406 mm |
| Distance between center of curvature inner ring | δCC_i | 2.5406 mm |
| Distance between center of curvature outer ring | δCC_e | 2.5406 mm |
| Nominal diametral clearance | Pd | 0.0100 mm |
| Nominal axial clearance | Pa | 0.0100 mm |
| Diameter inner race | di | 1338.9 mm |
| Diameter outer race | de | 1461.1 mm |
| Radius inner race | ri | 31.800 mm |
| Radius outer race | re | 31.800 mm |
| Distance between rolling elements | δRE | 13.270 mm |
| Shoulder diameter inner ring | dSi | 1376.0 mm |
| Limit contact angle inner ring | αlim_i | 65.330 ° |
| Shoulder diameter outer ring | dSe | 1424.0 mm |
| Limit contact angle outer ring | αlim_e | 65.330 ° |
| Extension contact ellipse inner ring | dCimax | 1369.4 mm |
| Extension contact ellipse outer ring | dCemin | 1430.6 mm |
| Ellipse length ratio inner race | eLR_i | 130.815 % |
| Ellipse length ratio outer race | eLR_e | 131.215 % |
| Circumferential ball advance | Δb_circ | 1.5016 mm |
| Axial ball excursion | Δb_ax | 0.1011 mm |

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|----------------------------|---------------|---------|
| Maximum spin to roll ratio | maxSpinToRoll | 13.4424 |
|----------------------------|---------------|---------|

Forces and displacement

| | | |
|----------------------------------|--------|-------------|
| Axial force | Fx | 500.000 kN |
| Radial force Y | Fy | 0.0000 kN |
| Radial force Z | Fz | 100.000 kN |
| Displacement X | ux | 97.592 μm |
| Displacement Y | uy | 0.0000 μm |
| Displacement Z | uz | -65.4682 μm |
| Moment Y | My | 150000 Nm |
| Moment Z | Mz | 0.0000 Nm |
| Rotation around Y | ry | 0.1445 mrad |
| Rotation around Z | rz | 0.0000 mrad |
| Frictional moment | Mloss | 761.689 Nm |
| Power loss | Ploss | 797.646 W |
| Maximal pressure inner race | pmax_i | 1818.0 MPa |
| Maximal pressure outer race | pmax_e | 1771.8 MPa |
| Maximal pressure | pmax | 1818.0 MPa |
| Average pressure | pavg | 1212.0 MPa |
| Static safety factor (ISO 17956) | S0eff | 9.60183 |

Static safety is reduced because of hardness

| | | |
|-----------------------------------|----------|-----------|
| Limit for axial force, inner ring | Fa_max_i | 3523.8 kN |
| Limit for axial force, outer ring | Fa_max_e | 3563.5 kN |
| Limit for axial force | Fa_max | 3523.8 kN |

Life

| | | |
|---------------------|-----|------------|
| Dynamic load rating | Cr | 762.661 kN |
| Static load rating | C0r | 3370.2 kN |
| Fatigue load limit | Cur | 60.151 kN |

The load ratings according ISO, for comparison only:

Load ratings C_ISO and C0_ISO are reduced because of hardness

Reduction of load rating because of hardness according to Harris

| | | |
|--|--------|------------|
| | C_ISO | 762.661 kN |
| | C0_ISO | 3370.2 kN |
| | Cu_ISO | 60.151 kN |
| Life modification factor for reliability | a1 | 1 |
| Viscosity ratio | κ | 0.291162 |
| Contamination factor | eC | 0.349479 |
| Life modification factor | aISO | 0.206981 |
| Reference load | Pref | 405137 N |
| Basic reference rating life | L10r | 6.67098 |
| Basic reference rating life | L10rh | 11118.3 h |
| Modified reference rating life | Lnmr | 1.38077 |
| Modified reference rating life | Lnmrh | 2301.3 h |

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Life according ISO 281

| | | |
|-------------------------------|-------------------|----------|
| Dynamic radial load factor | X | 0.54 |
| Dynamic axial load factor | Y | 0.81 |
| Dynamic equivalent load | P | 459000 N |
| Basic life | L10 | 4.58729 |
| Basic life | L10h | 7645.5 h |
| Life modification factor | aISO | 0.200706 |
| Modified life | Ln _m | 0.920697 |
| Modified life | Ln _m h | 1534.5 h |
| Static equivalent load | P ₀ | 310000 N |
| Static safety factor (ISO 76) | S ₀ | 10.8715 |

Wear parameters

| | | |
|--------------------------------------|-----------------------|-----------------|
| Frictional moment | M _{loss} | 761.689 Nm |
| Power loss | P _{loss} | 797.646 W |
| Power loss inner race | P _{loss_i} | 411.619 W |
| Power loss outer race | P _{loss_e} | 386.026 W |
| Wear parameter PV _{max} | PV _{max} | 159.108 MPa·m/s |
| Wear parameter PV _{avg_max} | PV _{avg_max} | 106.293 MPa·m/s |
| Wear parameter QV | QV | 7976.5 W |
| Total thermal resistance | R | 0.1386 K/W |

Subsurface stresses

| | | |
|---|--------------------|-------------|
| Maximal shear stress for inner race | τ_{max_i} | 579.496 MPa |
| Depth for maximal shear stress inner race | $h(\tau_{max_i})$ | 0.6892 mm |
| Shear yield stress for core inner race | τ_{yield_i} | 425.000 MPa |
| Shear fatigue limit for core inner race | τ_{a_i} | 255.000 MPa |
| Shear stress at core inner race | τ_i | 255.000 MPa |
| Maximal shear stress for outer race | τ_{max_e} | 565.437 MPa |
| Depth for maximal shear stress outer race | $h(\tau_{max_e})$ | 0.7090 mm |
| Shear yield stress for core outer race | τ_{yield_e} | 425.000 MPa |
| Shear fatigue limit for core outer race | τ_{a_e} | 255.000 MPa |
| Shear stress at core outer race | τ_e | 255.000 MPa |
| Required hardness depth inner race | hd_{min_i} | 2.9052 mm |
| Required hardness depth outer race | hd_{min_e} | 2.9055 mm |

Damage Frequencies

| | | | |
|--------------------------------------|----------|-----------|-----------|
| Speed of inner ring | n_i | 0.00 1/s | (0rpm) |
| Speed of outer ring | n_e | 0.17 1/s | (10rpm) |
| Rotation speed of cage | f_c | 0.09 1/s | (5rpm) |
| Damage frequency for inner race | f_{ip} | -5.15 1/s | (-309rpm) |
| Damage frequency for outer race | f_{ep} | 4.85 1/s | (291rpm) |
| Damage frequency for rolling element | f_{rp} | 3.89 1/s | (233rpm) |

Bearing stiffness matrix

| | u_x [μm] | u_y [μm] | u_z [μm] | r_y [mrad] | r_z [mrad] |
|-----------|------------|------------|------------|--------------|--------------|
| F_x [N] | 10040.783 | -0.000 | 2169.967 | -130622.857 | -0.105 |
| F_y [N] | 0.000 | 4238.116 | 0.000 | -0.051 | -2615096.909 |

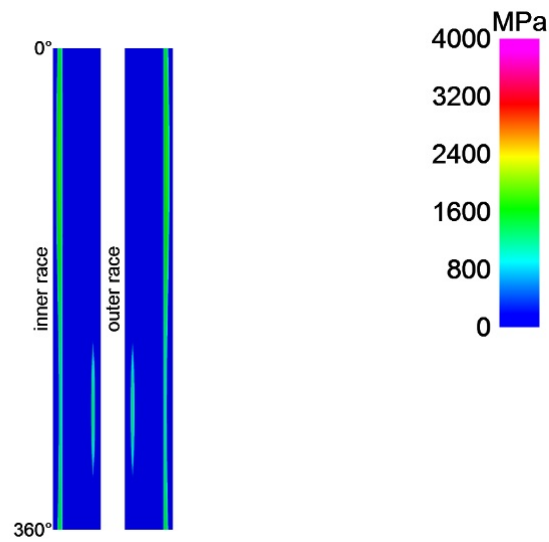
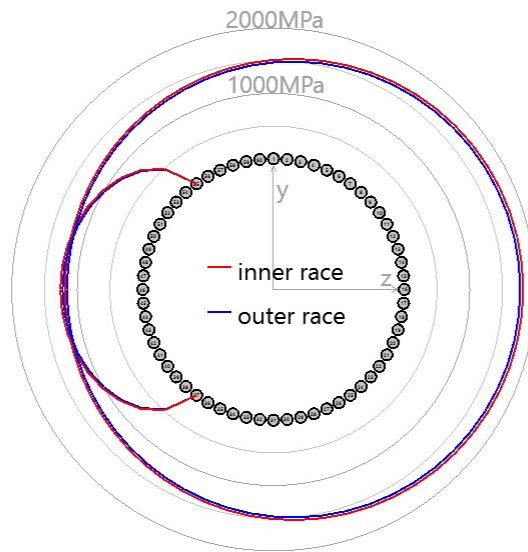
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| | ux [μm] | uy [μm] | uz [μm] | ry [mrad] | rz [mrad] |
|---------|----------------------|----------------------|----------------------|-------------|-------------|
| Fz [N] | 2169.976 | 0.000 | 5214.629 | 1918044.536 | 0.051 |
| My [Nm] | -129.950 | 0.000 | 1918.420 | 2698493.673 | 0.038 |
| Mz [Nm] | -0.000 | -2615.269 | -0.000 | 0.038 | 2221642.209 |

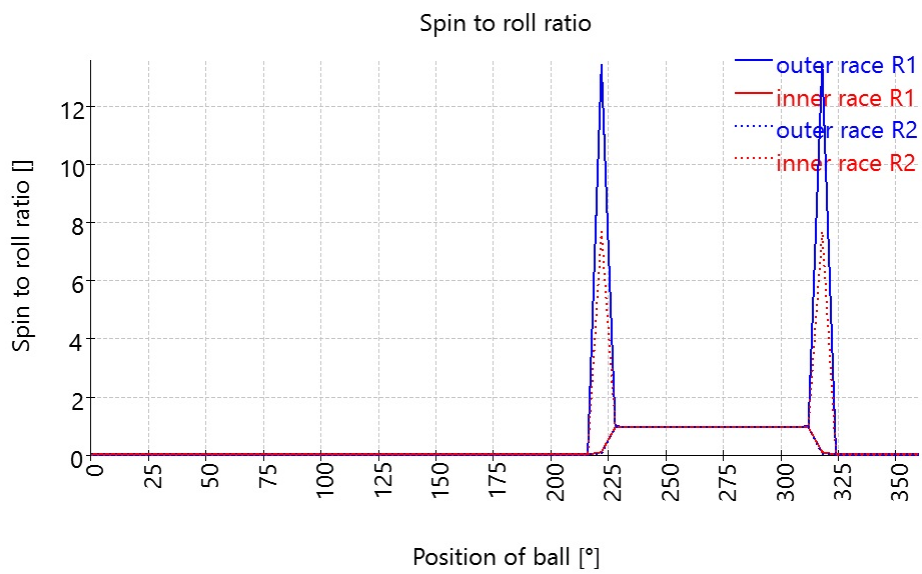
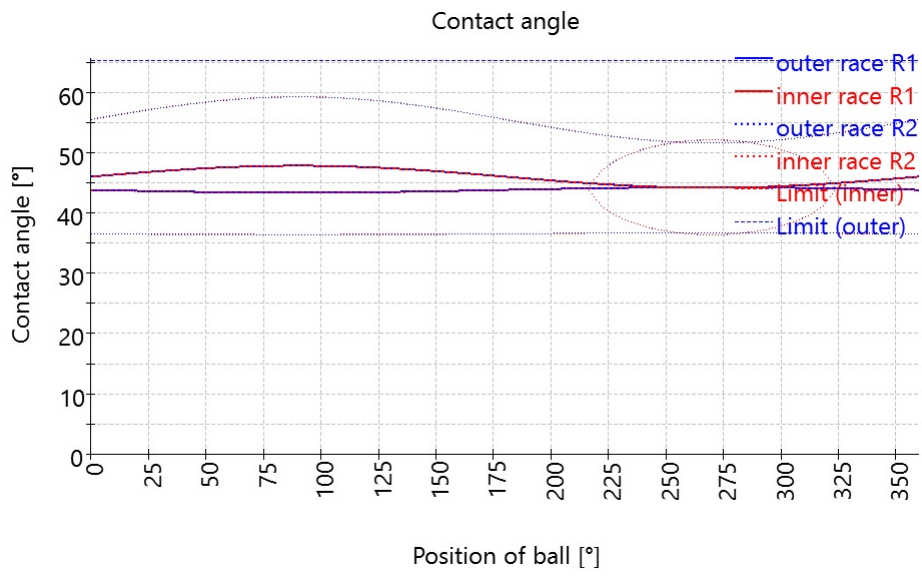
Bearing compliance matrix

| | Fx [N] | Fy [N] | Fz [N] | My [Nm] | Mz [Nm] |
|----------------------|----------|---------|----------|----------|---------|
| ux [μm] | 0.00011 | 0.00000 | -0.00007 | 0.00005 | 0.00000 |
| uy [μm] | 0.00000 | 0.00086 | 0.00000 | 0.00000 | 0.00102 |
| uz [μm] | -0.00007 | 0.00000 | 0.00030 | -0.00022 | 0.00000 |
| ry [mrad] | 0.00000 | 0.00000 | -0.00000 | 0.00000 | 0.00000 |
| rz [mrad] | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |



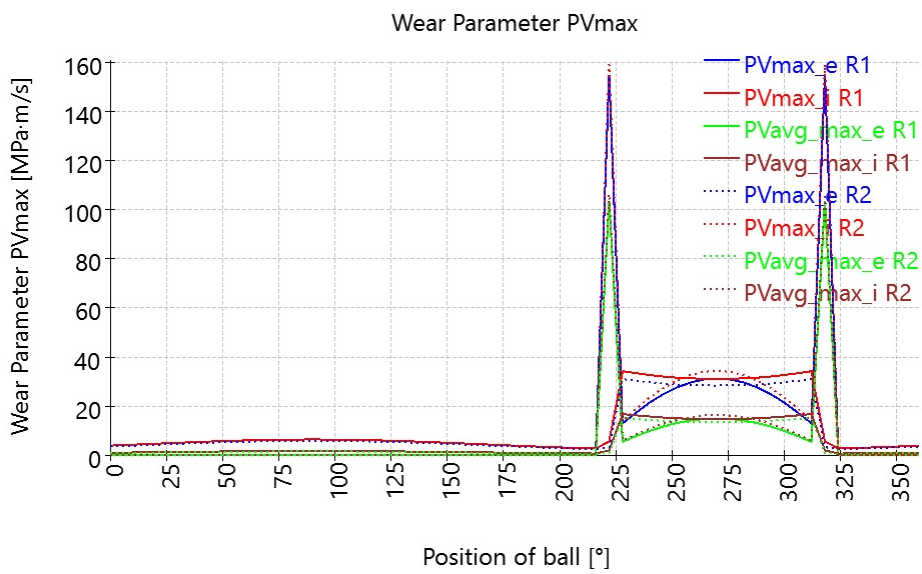
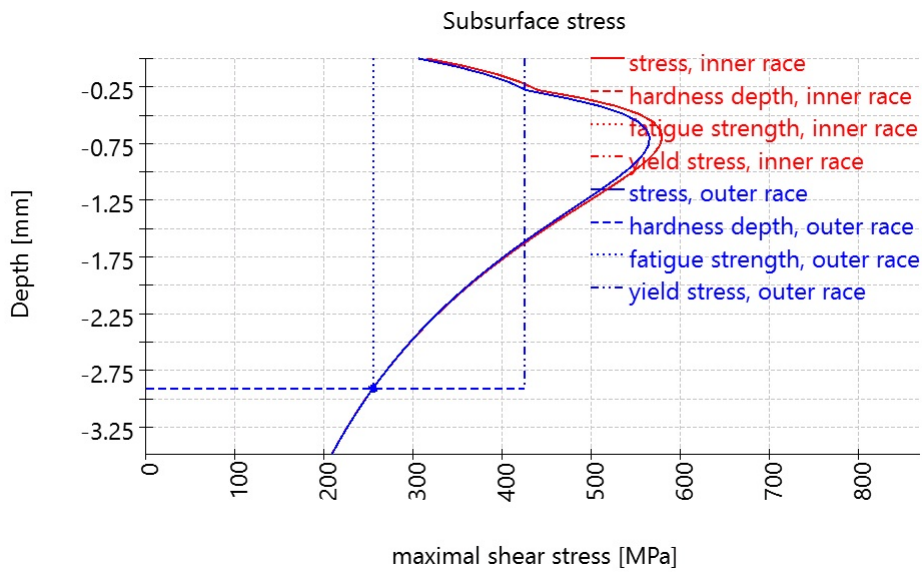
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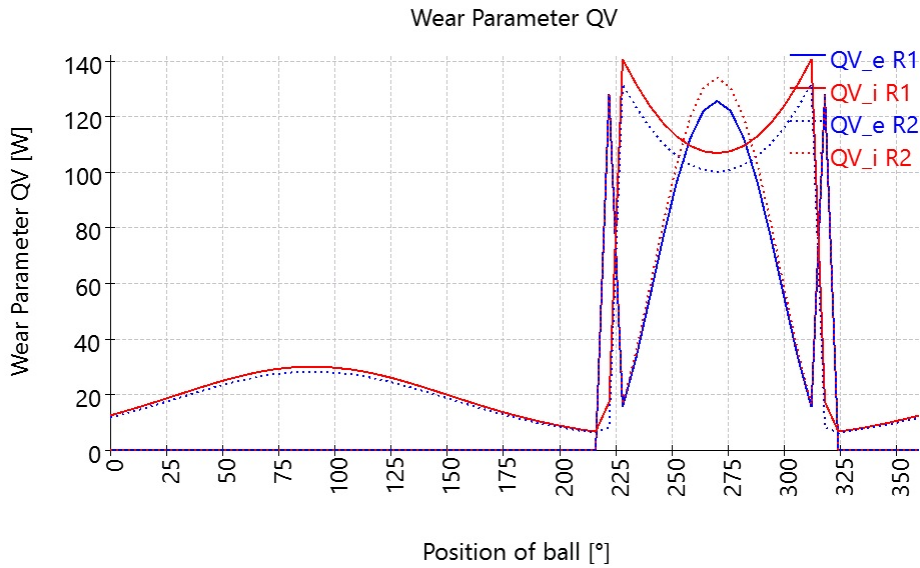
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Result table for bearing 1

| Ball | ψ [°] | α_{i_l} [°] | α_{e_l} [°] | Q_{i_l} [N] | Q_{e_l} [N] | p_{i_l} [MPa] | p_{e_l} [MPa] | α_{i_r} [°] | α_{e_r} [°] | Q_{i_r} [N] | Q_{e_r} [N] | p_{i_r} [MPa] | p_{e_r} [MPa] | eLR _i | eLR _e |
|------|------------|--------------------|--------------------|---------------|---------------|-----------------|-----------------|--------------------|--------------------|---------------|---------------|-----------------|-----------------|------------------|------------------|
| 1 | 0.00 | 46.02 | 43.83 | 11948.4 | 0 | 1514.80 | 0.00 | 43.82 | 46.02 | 0 | 11948.4 | 0.00 | 1475.01 | 1.57 | 1.58 |
| 2 | 6.00 | 46.21 | 43.78 | 12737 | 0 | 1547.35 | 0.00 | 43.77 | 46.21 | 0 | 12737 | 0.00 | 1506.84 | 1.54 | 1.54 |
| 3 | 12.00 | 46.40 | 43.73 | 13544.7 | 0 | 1579.31 | 0.00 | 43.72 | 46.40 | 0 | 13544.7 | 0.00 | 1538.11 | 1.51 | 1.51 |
| 4 | 18.00 | 46.59 | 43.69 | 14361.6 | 0 | 1610.37 | 0.00 | 43.68 | 46.59 | 0 | 14361.6 | 0.00 | 1568.50 | 1.48 | 1.48 |
| 5 | 24.00 | 46.77 | 43.64 | 15176.8 | 0 | 1640.21 | 0.00 | 43.63 | 46.77 | 0 | 15176.8 | 0.00 | 1597.70 | 1.45 | 1.46 |
| 6 | 30.00 | 46.93 | 43.60 | 15978.5 | 0 | 1668.53 | 0.00 | 43.59 | 46.93 | 0 | 15978.5 | 0.00 | 1625.42 | 1.43 | 1.43 |
| 7 | 36.00 | 47.09 | 43.56 | 16754.6 | 0 | 1695.04 | 0.00 | 43.55 | 47.09 | 0 | 16754.6 | 0.00 | 1651.38 | 1.40 | 1.41 |
| 8 | 42.00 | 47.24 | 43.52 | 17492.4 | 0 | 1719.51 | 0.00 | 43.51 | 47.24 | 0 | 17492.4 | 0.00 | 1675.34 | 1.38 | 1.39 |
| 9 | 48.00 | 47.38 | 43.49 | 18179.6 | 0 | 1741.67 | 0.00 | 43.48 | 47.38 | 0 | 18179.6 | 0.00 | 1697.04 | 1.37 | 1.37 |
| 10 | 54.00 | 47.49 | 43.46 | 18803.8 | 0 | 1761.33 | 0.00 | 43.44 | 47.49 | 0 | 18803.8 | 0.00 | 1716.30 | 1.35 | 1.35 |
| 11 | 60.00 | 47.60 | 43.43 | 19353.8 | 0 | 1778.29 | 0.00 | 43.42 | 47.60 | 0 | 19353.8 | 0.00 | 1732.92 | 1.34 | 1.34 |
| 12 | 66.00 | 47.68 | 43.41 | 19819.2 | 0 | 1792.40 | 0.00 | 43.39 | 47.68 | 0 | 19819.2 | 0.00 | 1746.73 | 1.33 | 1.33 |
| 13 | 72.00 | 47.75 | 43.39 | 20191.1 | 0 | 1803.51 | 0.00 | 43.38 | 47.75 | 0 | 20191.1 | 0.00 | 1757.62 | 1.32 | 1.32 |
| 14 | 78.00 | 47.80 | 43.38 | 20462.2 | 0 | 1811.52 | 0.00 | 43.36 | 47.80 | 0 | 20462.2 | 0.00 | 1765.47 | 1.31 | 1.32 |
| 15 | 84.00 | 47.83 | 43.37 | 20627 | 0 | 1816.36 | 0.00 | 43.36 | 47.83 | 0 | 20627 | 0.00 | 1770.21 | 1.31 | 1.31 |
| 16 | 90.00 | 47.84 | 43.37 | 20682.3 | 0 | 1817.97 | 0.00 | 43.35 | 47.84 | 0 | 20682.3 | 0.00 | 1771.80 | 1.31 | 1.31 |
| 17 | 96.00 | 47.83 | 43.37 | 20627 | 0 | 1816.36 | 0.00 | 43.36 | 47.83 | 0 | 20627 | 0.00 | 1770.21 | 1.31 | 1.31 |
| 18 | 102.00 | 47.80 | 43.38 | 20462.2 | 0 | 1811.52 | 0.00 | 43.36 | 47.80 | 0 | 20462.2 | 0.00 | 1765.47 | 1.31 | 1.32 |
| 19 | 108.00 | 47.75 | 43.39 | 20191.1 | 0 | 1803.51 | 0.00 | 43.38 | 47.75 | 0 | 20191.1 | 0.00 | 1757.62 | 1.32 | 1.32 |
| 20 | 114.00 | 47.68 | 43.41 | 19819.2 | 0 | 1792.40 | 0.00 | 43.39 | 47.68 | 0 | 19819.2 | 0.00 | 1746.73 | 1.33 | 1.33 |
| 21 | 120.00 | 47.60 | 43.43 | 19353.8 | 0 | 1778.29 | 0.00 | 43.42 | 47.60 | 0 | 19353.8 | 0.00 | 1732.92 | 1.34 | 1.34 |
| 22 | 126.00 | 47.49 | 43.46 | 18803.8 | 0 | 1761.33 | 0.00 | 43.44 | 47.49 | 0 | 18803.8 | 0.00 | 1716.30 | 1.35 | 1.35 |
| 23 | 132.00 | 47.38 | 43.49 | 18179.6 | 0 | 1741.67 | 0.00 | 43.48 | 47.38 | 0 | 18179.6 | 0.00 | 1697.04 | 1.37 | 1.37 |
| 24 | 138.00 | 47.24 | 43.52 | 17492.4 | 0 | 1719.51 | 0.00 | 43.51 | 47.24 | 0 | 17492.4 | 0.00 | 1675.34 | 1.38 | 1.39 |
| 25 | 144.00 | 47.09 | 43.56 | 16754.6 | 0 | 1695.04 | 0.00 | 43.55 | 47.09 | 0 | 16754.6 | 0.00 | 1651.38 | 1.40 | 1.41 |
| 26 | 150.00 | 46.93 | 43.60 | 15978.5 | 0 | 1668.53 | 0.00 | 43.59 | 46.93 | 0 | 15978.5 | 0.00 | 1625.42 | 1.43 | 1.43 |
| 27 | 156.00 | 46.77 | 43.64 | 15176.8 | 0 | 1640.21 | 0.00 | 43.63 | 46.77 | 0 | 15176.8 | 0.00 | 1597.70 | 1.45 | 1.46 |
| 28 | 162.00 | 46.59 | 43.69 | 14361.6 | 0 | 1610.37 | 0.00 | 43.68 | 46.59 | 0 | 14361.6 | 0.00 | 1568.50 | 1.48 | 1.48 |
| 29 | 168.00 | 46.40 | 43.73 | 13544.7 | 0 | 1579.31 | 0.00 | 43.72 | 46.40 | 0 | 13544.7 | 0.00 | 1538.11 | 1.51 | 1.51 |
| 30 | 174.00 | 46.21 | 43.78 | 12737 | 0 | 1547.35 | 0.00 | 43.77 | 46.21 | 0 | 12737 | 0.00 | 1506.84 | 1.54 | 1.54 |
| 31 | 180.00 | 46.02 | 43.83 | 11948.4 | 0 | 1514.80 | 0.00 | 43.82 | 46.02 | 0 | 11948.4 | 0.00 | 1475.01 | 1.57 | 1.58 |
| 32 | 186.00 | 45.83 | 43.87 | 11187.6 | 0 | 1482.01 | 0.00 | 43.87 | 45.83 | 0 | 11187.6 | 0.00 | 1442.96 | 1.61 | 1.61 |

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| Ball | ψ [°] | α_i [°] | α_e [°] | Q_i [N] | Q_e [N] | p_i [MPa] | p_e [MPa] | α_{i_r} [°] | α_{e_r} [°] | Q_{i_r} [N] | Q_{e_r} [N] | p_{i_r} [MPa] | p_{e_r} [MPa] | eLR _i | eLR _e |
|------|------------|----------------|----------------|-----------|-----------|-------------|-------------|--------------------|--------------------|---------------|---------------|-----------------|-----------------|------------------|------------------|
| 33 | 192.00 | 45.64 | 43.92 | 10462.2 | 0 | 1449.33 | 0.00 | 43.91 | 45.64 | 0 | 10462.2 | 0.00 | 1411.01 | 1.64 | 1.65 |
| 34 | 198.00 | 45.46 | 43.96 | 9778.57 | 0 | 1417.12 | 0.00 | 43.96 | 45.46 | 0 | 9778.57 | 0.00 | 1379.52 | 1.68 | 1.68 |
| 35 | 204.00 | 45.28 | 44.00 | 9141.71 | 0 | 1385.72 | 0.00 | 44.00 | 45.28 | 0 | 9141.71 | 0.00 | 1348.84 | 1.72 | 1.72 |
| 36 | 210.00 | 45.11 | 44.04 | 8555.54 | 0 | 1355.50 | 0.00 | 44.04 | 45.11 | 0 | 8555.54 | 0.00 | 1319.32 | 1.75 | 1.76 |
| 37 | 216.00 | 44.94 | 44.08 | 8022.92 | 0 | 1326.82 | 0.00 | 44.08 | 44.94 | 0 | 8022.92 | 0.00 | 1291.31 | 1.79 | 1.80 |
| 38 | 222.00 | 44.79 | 44.11 | 7545.76 | 387.888 | 1300.03 | 470.33 | 44.11 | 44.80 | 387.103 | 7545.73 | 483.13 | 1265.14 | 1.83 | 1.83 |
| 39 | 228.00 | 44.65 | 44.14 | 7125.15 | 1346.52 | 1275.45 | 712.16 | 44.15 | 44.66 | 1345.6 | 7125.09 | 731.85 | 1241.14 | 1.86 | 1.87 |
| 40 | 234.00 | 44.53 | 44.17 | 6761.6 | 2478.42 | 1253.42 | 872.77 | 44.17 | 44.54 | 2477.39 | 6761.47 | 896.98 | 1219.62 | 1.90 | 1.90 |
| 41 | 240.00 | 44.42 | 44.19 | 6455.1 | 3628.1 | 1234.21 | 990.99 | 44.20 | 44.43 | 3626.98 | 6454.88 | 1018.50 | 1200.87 | 1.92 | 1.93 |
| 42 | 246.00 | 44.34 | 44.21 | 6205.34 | 4692.15 | 1218.11 | 1079.70 | 44.22 | 44.35 | 4690.97 | 6205.02 | 1109.68 | 1185.15 | 1.95 | 1.96 |
| 43 | 252.00 | 44.27 | 44.23 | 6011.84 | 5594.28 | 1205.34 | 1144.89 | 44.23 | 44.28 | 5593.06 | 6011.43 | 1176.68 | 1172.68 | 1.97 | 1.98 |
| 44 | 258.00 | 44.21 | 44.24 | 5874.1 | 6277.97 | 1196.08 | 1189.75 | 44.25 | 44.23 | 6276.72 | 5873.6 | 1222.79 | 1163.63 | 1.95 | 1.96 |
| 45 | 264.00 | 44.18 | 44.25 | 5791.65 | 6703.78 | 1190.46 | 1216.06 | 44.25 | 44.20 | 6702.51 | 5791.1 | 1249.84 | 1158.15 | 1.92 | 1.93 |
| 46 | 270.00 | 44.17 | 44.25 | 5764.2 | 6848.3 | 1188.58 | 1224.74 | 44.25 | 44.19 | 6847.03 | 5763.64 | 1258.76 | 1156.31 | 1.91 | 1.92 |
| 47 | 276.00 | 44.18 | 44.25 | 5791.65 | 6703.78 | 1190.46 | 1216.06 | 44.25 | 44.20 | 6702.51 | 5791.1 | 1249.84 | 1158.15 | 1.92 | 1.93 |
| 48 | 282.00 | 44.21 | 44.24 | 5874.1 | 6277.97 | 1196.08 | 1189.75 | 44.25 | 44.23 | 6276.72 | 5873.6 | 1222.79 | 1163.63 | 1.95 | 1.96 |
| 49 | 288.00 | 44.27 | 44.23 | 6011.84 | 5594.28 | 1205.34 | 1144.89 | 44.23 | 44.28 | 5593.06 | 6011.43 | 1176.68 | 1172.68 | 1.97 | 1.98 |
| 50 | 294.00 | 44.34 | 44.21 | 6205.34 | 4692.15 | 1218.11 | 1079.70 | 44.22 | 44.35 | 4690.97 | 6205.02 | 1109.68 | 1185.15 | 1.95 | 1.96 |
| 51 | 300.00 | 44.42 | 44.19 | 6455.1 | 3628.1 | 1234.21 | 990.99 | 44.20 | 44.43 | 3626.98 | 6454.88 | 1018.50 | 1200.87 | 1.92 | 1.93 |
| 52 | 306.00 | 44.53 | 44.17 | 6761.6 | 2478.42 | 1253.42 | 872.77 | 44.17 | 44.54 | 2477.39 | 6761.47 | 896.98 | 1219.62 | 1.90 | 1.90 |
| 53 | 312.00 | 44.65 | 44.14 | 7125.15 | 1346.52 | 1275.45 | 712.16 | 44.15 | 44.66 | 1345.6 | 7125.09 | 731.85 | 1241.14 | 1.86 | 1.87 |
| 54 | 318.00 | 44.79 | 44.11 | 7545.76 | 387.888 | 1300.03 | 470.33 | 44.11 | 44.80 | 387.103 | 7545.73 | 483.13 | 1265.14 | 1.83 | 1.83 |
| 55 | 324.00 | 44.94 | 44.08 | 8022.92 | 0 | 1326.82 | 0.00 | 44.08 | 44.94 | 0 | 8022.92 | 0.00 | 1291.31 | 1.79 | 1.80 |
| 56 | 330.00 | 45.11 | 44.04 | 8555.54 | 0 | 1355.50 | 0.00 | 44.04 | 45.11 | 0 | 8555.54 | 0.00 | 1319.32 | 1.75 | 1.76 |
| 57 | 336.00 | 45.28 | 44.00 | 9141.71 | 0 | 1385.72 | 0.00 | 44.00 | 45.28 | 0 | 9141.71 | 0.00 | 1348.84 | 1.72 | 1.72 |
| 58 | 342.00 | 45.46 | 43.96 | 9778.57 | 0 | 1417.12 | 0.00 | 43.96 | 45.46 | 0 | 9778.57 | 0.00 | 1379.52 | 1.68 | 1.68 |
| 59 | 348.00 | 45.64 | 43.92 | 10462.2 | 0 | 1449.33 | 0.00 | 43.91 | 45.64 | 0 | 10462.2 | 0.00 | 1411.01 | 1.64 | 1.65 |
| 60 | 354.00 | 45.83 | 43.87 | 11187.6 | 0 | 1482.01 | 0.00 | 43.87 | 45.83 | 0 | 11187.6 | 0.00 | 1442.96 | 1.61 | 1.61 |

- ψ : Position of ball
- α_i : Contact angle inner race
- α_e : Contact angle outer race
- Q_i : Force at inner race
- Q_e : Force at outer race
- p_i : Maximal pressure inner race
- p_e : Maximal pressure outer race
- eLR_i : Ellipse length ratio inner race
- eLR_e : Ellipse length ratio outer race

| Ball | ω_{spin_i} [rad/s] | ω_{spin_e} [rad/s] | ω_{roll_i} [rad/s] | ω_{roll_e} [rad/s] | QV _i [W] | QV _e [W] | PVmax _i [MPa·m/s] | PVmax _e [MPa·m/s] | $\omega_{spin_i_r}$ [rad/s] | $\omega_{spin_e_r}$ [rad/s] | $\omega_{roll_i_r}$ [rad/s] | $\omega_{roll_e_r}$ [rad/s] | QV _{i_r} [W] | QV _{e_r} [W] | PVmax _{i_r} [MPa·m/s] | PVmax _{e_r} [MPa·m/s] |
|------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------|---------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|-----------------------|-----------------------|--------------------------------|--------------------------------|
| 1 | 0.4 | 0.0 | 12.6 | 0.0 | 12.6 | 0.0 | 4.0 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 11.8 | 0.0 | 3.6 |
| 2 | 0.4 | 0.0 | 12.6 | 0.0 | 13.9 | 0.0 | 4.2 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 13.1 | 0.0 | 3.8 |
| 3 | 0.4 | 0.0 | 12.6 | 0.0 | 15.4 | 0.0 | 4.4 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 14.4 | 0.0 | 4.0 |
| 4 | 0.4 | 0.0 | 12.6 | 0.0 | 16.9 | 0.0 | 4.7 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 15.8 | 0.0 | 4.2 |
| 5 | 0.4 | 0.0 | 12.6 | 0.0 | 18.4 | 0.0 | 4.9 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 17.3 | 0.0 | 4.5 |
| 6 | 0.4 | 0.0 | 12.6 | 0.0 | 20.0 | 0.0 | 5.1 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 18.7 | 0.0 | 4.7 |

MESYS Shaft and Rolling Bearing Calculation

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| Ball | $\omega_{spin_i_l}$ [rad/s] | $\omega_{spin_e_l}$ [rad/s] | $\omega_{roll_i_l}$ [rad/s] | $\omega_{roll_e_l}$ [rad/s] | QV_i_l [W] | QV_e_l [W] | PVmax_i_l [MPa·m/s] | PVmax_e_l [MPa·m/s] | $\omega_{spin_i_r}$ [rad/s] | $\omega_{spin_e_r}$ [rad/s] | $\omega_{roll_i_r}$ [rad/s] | $\omega_{roll_e_r}$ [rad/s] | QV_i_r [W] | QV_e_r [W] | PVmax_i_r [MPa·m/s] | PVmax_e_r [MPa·m/s] |
|------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|---------------|---------------|------------------------|------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|---------------|---------------|------------------------|------------------------|
| 7 | 0.4 | 0.0 | 12.6 | 0.0 | 21.5 | 0.0 | 5.3 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 20.2 | 0.0 | 4.9 |
| 8 | 0.4 | 0.0 | 12.6 | 0.0 | 23.1 | 0.0 | 5.6 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 21.7 | 0.0 | 5.1 |
| 9 | 0.4 | 0.0 | 12.6 | 0.0 | 24.5 | 0.0 | 5.7 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 23.0 | 0.0 | 5.2 |
| 10 | 0.4 | 0.0 | 12.6 | 0.0 | 25.9 | 0.0 | 5.9 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 24.3 | 0.0 | 5.4 |
| 11 | 0.4 | 0.0 | 12.6 | 0.0 | 27.1 | 0.0 | 6.1 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 25.5 | 0.0 | 5.6 |
| 12 | 0.4 | 0.0 | 12.6 | 0.0 | 28.2 | 0.0 | 6.2 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 26.5 | 0.0 | 5.7 |
| 13 | 0.4 | 0.0 | 12.6 | 0.0 | 29.0 | 0.0 | 6.3 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 27.3 | 0.0 | 5.8 |
| 14 | 0.4 | 0.0 | 12.6 | 0.0 | 29.6 | 0.0 | 6.4 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 27.8 | 0.0 | 5.8 |
| 15 | 0.4 | 0.0 | 12.6 | 0.0 | 30.0 | 0.0 | 6.4 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 28.2 | 0.0 | 5.9 |
| 16 | 0.4 | 0.0 | 12.6 | 0.0 | 30.0 | 0.0 | 6.5 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 28.2 | 0.0 | 5.9 |
| 17 | 0.4 | 0.0 | 12.6 | 0.0 | 30.0 | 0.0 | 6.4 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 28.2 | 0.0 | 5.9 |
| 18 | 0.4 | 0.0 | 12.6 | 0.0 | 29.5 | 0.0 | 6.4 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 27.7 | 0.0 | 5.9 |
| 19 | 0.4 | 0.0 | 12.6 | 0.0 | 29.0 | 0.0 | 6.3 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 27.3 | 0.0 | 5.8 |
| 20 | 0.4 | 0.0 | 12.6 | 0.0 | 28.2 | 0.0 | 6.2 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 26.5 | 0.0 | 5.7 |
| 21 | 0.4 | 0.0 | 12.6 | 0.0 | 27.1 | 0.0 | 6.1 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 25.5 | 0.0 | 5.6 |
| 22 | 0.4 | 0.0 | 12.6 | 0.0 | 25.9 | 0.0 | 5.9 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 24.3 | 0.0 | 5.4 |
| 23 | 0.4 | 0.0 | 12.6 | 0.0 | 24.5 | 0.0 | 5.7 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 23.0 | 0.0 | 5.2 |
| 24 | 0.4 | 0.0 | 12.6 | 0.0 | 23.1 | 0.0 | 5.6 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 21.7 | 0.0 | 5.1 |
| 25 | 0.4 | 0.0 | 12.6 | 0.0 | 21.5 | 0.0 | 5.3 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 20.2 | 0.0 | 4.9 |
| 26 | 0.4 | 0.0 | 12.6 | 0.0 | 20.0 | 0.0 | 5.1 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 18.7 | 0.0 | 4.7 |
| 27 | 0.4 | 0.0 | 12.6 | 0.0 | 18.4 | 0.0 | 4.9 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 17.3 | 0.0 | 4.5 |
| 28 | 0.4 | 0.0 | 12.6 | 0.0 | 16.9 | 0.0 | 4.7 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 15.8 | 0.0 | 4.2 |
| 29 | 0.4 | 0.0 | 12.6 | 0.0 | 15.4 | 0.0 | 4.4 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 14.4 | 0.0 | 4.0 |
| 30 | 0.4 | 0.0 | 12.6 | 0.0 | 13.9 | 0.0 | 4.2 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 13.1 | 0.0 | 3.8 |
| 31 | 0.4 | 0.0 | 12.6 | 0.0 | 12.6 | 0.0 | 4.0 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 11.8 | 0.0 | 3.6 |
| 32 | 0.4 | 0.0 | 12.6 | 0.0 | 11.4 | 0.0 | 3.7 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 10.7 | 0.0 | 3.4 |
| 33 | 0.4 | 0.0 | 12.6 | 0.0 | 10.2 | 0.0 | 3.5 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 9.6 | 0.0 | 3.2 |
| 34 | 0.4 | 0.0 | 12.6 | 0.0 | 9.2 | 0.0 | 3.3 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 8.6 | 0.0 | 3.0 |
| 35 | 0.4 | 0.0 | 12.6 | 0.0 | 8.3 | 0.0 | 3.1 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 7.8 | 0.0 | 2.8 |
| 36 | 0.4 | 0.0 | 12.6 | 0.0 | 7.4 | 0.0 | 3.0 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 7.0 | 0.0 | 2.7 |
| 37 | 0.4 | 0.0 | 12.6 | 0.0 | 6.7 | 0.0 | 2.8 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 6.3 | 0.0 | 2.5 |
| 38 | 1.4 | 11.8 | 12.6 | 0.9 | 17.4 | 128.1 | 5.7 | 154.9 | 12.6 | 0.7 | 1.6 | 11.8 | 127.7 | 8.3 | 159.1 | 3.3 |
| 39 | 12.1 | 11.6 | 12.6 | 11.7 | 140.6 | 15.6 | 34.2 | 13.0 | 12.3 | 11.4 | 12.4 | 11.8 | 16.5 | 131.7 | 14.1 | 31.0 |
| 40 | 12.2 | 11.6 | 12.6 | 11.7 | 131.7 | 33.3 | 33.4 | 17.4 | 12.3 | 11.5 | 12.5 | 11.8 | 35.4 | 123.4 | 19.0 | 30.3 |
| 41 | 12.2 | 11.5 | 12.6 | 11.8 | 124.0 | 54.6 | 32.7 | 21.4 | 12.3 | 11.5 | 12.5 | 11.8 | 58.2 | 116.2 | 23.5 | 29.7 |
| 42 | 12.2 | 11.5 | 12.6 | 11.8 | 117.7 | 76.4 | 32.1 | 24.9 | 12.2 | 11.5 | 12.5 | 11.8 | 81.5 | 110.3 | 27.3 | 29.2 |
| 43 | 12.2 | 11.5 | 12.5 | 11.8 | 112.9 | 96.3 | 31.6 | 27.6 | 12.2 | 11.5 | 12.5 | 11.8 | 102.7 | 105.8 | 30.4 | 28.8 |
| 44 | 12.2 | 11.5 | 12.5 | 11.8 | 109.5 | 112.0 | 31.3 | 29.6 | 12.2 | 11.5 | 12.5 | 11.8 | 119.5 | 102.7 | 32.6 | 28.6 |
| 45 | 12.2 | 11.5 | 12.5 | 11.8 | 107.5 | 122.1 | 31.2 | 30.9 | 12.2 | 11.5 | 12.5 | 11.8 | 130.3 | 100.8 | 34.0 | 28.5 |
| 46 | 12.2 | 11.5 | 12.5 | 11.8 | 106.9 | 125.6 | 31.1 | 31.3 | 12.2 | 11.5 | 12.5 | 11.8 | 134.0 | 100.2 | 34.4 | 28.4 |
| 47 | 12.2 | 11.5 | 12.5 | 11.8 | 107.5 | 122.1 | 31.2 | 30.9 | 12.2 | 11.5 | 12.5 | 11.8 | 130.3 | 100.8 | 34.0 | 28.5 |
| 48 | 12.2 | 11.5 | 12.5 | 11.8 | 109.5 | 112.0 | 31.3 | 29.6 | 12.2 | 11.5 | 12.5 | 11.8 | 119.5 | 102.7 | 32.6 | 28.6 |
| 49 | 12.2 | 11.5 | 12.5 | 11.8 | 112.9 | 96.3 | 31.6 | 27.6 | 12.2 | 11.5 | 12.5 | 11.8 | 102.7 | 105.8 | 30.4 | 28.8 |
| 50 | 12.2 | 11.5 | 12.6 | 11.8 | 117.7 | 76.4 | 32.1 | 24.9 | 12.2 | 11.5 | 12.5 | 11.8 | 81.5 | 110.3 | 27.3 | 29.2 |
| 51 | 12.2 | 11.5 | 12.6 | 11.8 | 124.0 | 54.6 | 32.7 | 21.4 | 12.3 | 11.5 | 12.5 | 11.8 | 58.2 | 116.2 | 23.5 | 29.7 |
| 52 | 12.2 | 11.6 | 12.6 | 11.7 | 131.7 | 33.3 | 33.4 | 17.4 | 12.3 | 11.5 | 12.5 | 11.8 | 35.4 | 123.4 | 19.0 | 30.3 |
| 53 | 12.1 | 11.6 | 12.6 | 11.7 | 140.6 | 15.6 | 34.2 | 13.0 | 12.3 | 11.4 | 12.4 | 11.8 | 16.5 | 131.7 | 14.1 | 31.0 |
| 54 | 1.4 | 11.8 | 12.6 | 0.9 | 17.4 | 128.1 | 5.7 | 154.9 | 12.6 | 0.7 | 1.6 | 11.8 | 127.7 | 8.3 | 159.1 | 3.3 |
| 55 | 0.4 | 0.0 | 12.6 | 0.0 | 6.7 | 0.0 | 2.8 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 6.3 | 0.0 | 2.5 |

MESYS Shaft and Rolling Bearing Calculation

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| Ball | $\omega_{spin_i_l}$ [rad/s] | $\omega_{spin_e_l}$ [rad/s] | $\omega_{roll_i_l}$ [rad/s] | $\omega_{roll_e_l}$ [rad/s] | QV _{i_l} [W] | QV _{e_l} [W] | PVmax _{i_l} [MPa·m/s] | PVmax _{e_l} [MPa·m/s] | $\omega_{spin_i_r}$ [rad/s] | $\omega_{spin_e_r}$ [rad/s] | $\omega_{roll_i_r}$ [rad/s] | $\omega_{roll_e_r}$ [rad/s] | QV _{i_r} [W] | QV _{e_r} [W] | PVmax _{i_r} [MPa·m/s] | PVmax _{e_r} [MPa·m/s] |
|------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|--------------------------|--------------------------|-----------------------------------|-----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|--------------------------|--------------------------|-----------------------------------|-----------------------------------|
| 56 | 0.4 | 0.0 | 12.6 | 0.0 | 7.4 | 0.0 | 3.0 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 7.0 | 0.0 | 2.7 |
| 57 | 0.4 | 0.0 | 12.6 | 0.0 | 8.3 | 0.0 | 3.1 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 7.8 | 0.0 | 2.8 |
| 58 | 0.4 | 0.0 | 12.6 | 0.0 | 9.2 | 0.0 | 3.3 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 8.6 | 0.0 | 3.0 |
| 59 | 0.4 | 0.0 | 12.6 | 0.0 | 10.2 | 0.0 | 3.5 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 9.6 | 0.0 | 3.2 |
| 60 | 0.4 | 0.0 | 12.6 | 0.0 | 11.4 | 0.0 | 3.7 | 0.0 | 0.0 | 0.4 | 0.0 | 11.9 | 0.0 | 10.7 | 0.0 | 3.4 |