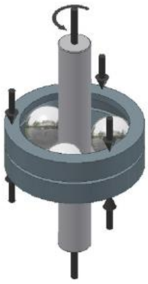
Guidance – RCF: Ball on Rod versus Disc on Rod



There are two key differences between the roller on rod and ball on rod test geometries, as provided by RCF 3 and RCF 6 machines, both of which affect the resulting test performance.

Lubrication Regime

A key difference between the two test geometries is the surface speed, hence lubricant entrainment velocity, in the contact. This is best illustrated by preforming comparative film thickness calculations for the two geometries. For this example, the lubricant is assumed to have a viscosity of 68 centiStokes at 40°C, reducing to 8.7 centiStokes at 100°C, with tests run at this higher temperature.

For the roller on rod test geometry, the parameters are assumed to be as follows:

Roller Diameter:	200	mm
Roller Crown Radius:	100	mm
Speed:	3,000	rpm
Rod Diameter:	20	mm
Speed:	30,000	rpm
Load:	12,000	N
Materials:	Steel	

Disc 1

R1x	0.100	m
R1y	0.100	m
E1	2.07E+11	N m^-2
Sigma1	0.30	
Rotational Speed	3000	rpm

Disc 2

R2x	0.010	m
R2y	1000000.000	m
E2	2.07E+11	N m^-2
Sigma2	0.30	
Rotational Speed	30000	rpm

Lubricant

Viscosity @40C	68.00	centiStokes (mm^2 s^-1)
Density @40C	886	kg m^-3
Viscosity @100C	8.70	centiStokes (mm^2 s^-1)
Density @100C	886	kg m^-3
Pressure Viscosity Coefficient	2.00E-08	Pa^-1

EHD Equation Parameters	Foord & Cameron	Hamrock & Dowson
k	1.840	1.9
a	0.667	0.67
b	-0.050	-0.067
c	0.600	0.53

Preliminary Calculations

R (reduced radius)	5.4693E-03	m
E' (reduced elastic modulus)	2.27E+11	N m^-2
U (entrainment velocity)	31.420	m s^-1
Dynamic Viscosity @ 40C	0.0602	Pas
Dynamic Viscosity @ 100C	0.0077	Pas

Test Conditions

Load	12000	N
Dynamic Viscosity	0.0077	Pas

Film Thickness Calculations

Velocity-Viscosity Parameter	3.33E-07	
Load Parameter	1.37E+00	
Pressure-Viscosity Parameter	1.57E+02	
Film Thickness	0.721	Microns

For the ball on rod test geometry, the parameters are assumed to be as follows:

Rod Diameter:	10	mm
Speed:	15,000	rpm
Ball Diameter:	12.7	mm
Speed:	11,811	rpm
Load:	1,200	N
Materials:	Steel	

Disc 1

R1x	0.00635	m
R1y	0.00635	m
E1	2.07E+11	N m^-2
Sigma1	0.30	
Rotational Speed	11811	rpm

Disc 2

R2x	0.005	m
R2y	1000000.000	m
E2	2.07E+11	N m^-2
Sigma2	0.30	
Rotational Speed	15000	rpm

Lubricant

Viscosity @40C	68.00	centiStokes (mm^2 s^-1)
Density @40C	886	kg m^-3
Viscosity @100C	8.70	centiStokes (mm^2 s^-1)
Density @100C	886	kg m^-3
Pressure Viscosity Coefficient	2.00E-08	Pa^-1

EHD Equation Parameters	Foord & Cameron	Hamrock & Dowson
k	1.840	1.9
a	0.667	0.67
b	-0.050	-0.067
c	0.600	0.53

Preliminary Calculations

R (reduced radius)	1.8844E-03	m
E' (reduced elastic modulus)	2.27E+11	N m^-2
U (entrainment velocity)	7.855	m s^-1
Dynamic Viscosity @ 40C	0.0602	Pas
Dynamic Viscosity @ 100C	0.0077	Pas

Test Conditions

Load	1200	N
Dynamic Viscosity	0.0077	Pas

Film Thickness Calculations

Velocity-Viscosity Parameter	2.69E-07	
Load Parameter	1.38E+00	
Pressure-Viscosity Parameter	1.57E+02	
Film Thickness	0.202	Microns

The roller on rod test conditions are typical of those used on RCF 3 and the ball on rod test conditions are the maximum achievable on RCF 6. The comparative film thicknesses are 0.721 microns and 0.202 microns. Assuming a typical bearing surface roughness of, say, 0.02 microns, the corresponding lambda values are:

Roller on rod: λ = 36 - full EHD separation

Ball on rod: λ = 10 - mixed lubrication

The ball on rod test geometry will most likely run under, at best, a mixed lubrication regime, which will produce something closely approximating to surface propagated, low cycle fatigue.

The roller on rod test geometry, with the potential for much higher surface speeds, will comfortably run under elastohydrodynamic lubrication, with surfaces fully separated, producing pressure generated high cycle fatigue, with sub-surface crack propagation cracks, usually initiated at inclusions or other sources of stress concentrations.

Material Properties

The other difference between the roller on rod and the ball on rod test geometries is that the specimens for the former can potentially be of much larger diameter than the 10 mm rod diameter in the ball on rod test geometry. When it comes to both the homogeneity of the specimen material and the heat treatment, the larger the diameter of the specimen, the less homogenous it becomes, the bigger the variation in grain size through the material and the greater the number of inclusions, so roller on rod geometry, especially with larger diameter rods, will tend to be much more representative of the material that is actually used to make real bearings. A 10 mm rod sample will have much more uniform material properties, plus, when it is hardened, it will be almost impossible to avoid through-hardening the material.

A further difference between roller on rod and ball on rod test geometries is that the former can, of course, be run with a line, as opposed to a point, contact, increasing the contact width, hence the area of material sampled.