Table 1. Fatigue life reduction of rolling-element bearings due to lubricant water contamination (mineral oil).

Base oil description	Wet oil water content, %	Fatigue life reduction, %	Test equipment and Hertzian stress
Mineral	0.002	48	Rolling 4-ball
Oil dried	0.014	54	Bearing tester
Over sodium	3.0	78	8.6 GPa
	6.0	83	GPa (1.25 x 10^4psi)

$a_{SKF} = f(k, \eta_c, P_u/P)$

Here,

k represents the lubricant film thickness

η_c takes into account solid contaminants

P_u is fatigue load limit.

Influence of contamination on bearing life. The damage mechanism can be rather complicated but in the case of relatively large hard particles it usually occurs in two steps. First, the hard particles induce permanent indentations. As a result the smooth surfaces of the bearing components are destroyed. Secondly, the rough surfaces will produce higher contact stresses resulting in shorter bearing life. Abrasive wear caused by contamination can also change the load zones in the bearing.

It is also known that hard particles larger than the oil film thickness decrease bearing life. Typical oil film thickness is on the order of 0.1 to 3 μm. In tests conducted under ultra-clean conditions where the oil was filtered through a 3 μm filter, bearing life was found to increase by a factor of 40 compared to calculated values. Under standard test conditions the bearings were known to have 4 to 5 times their theoretical lives.

It was observed that damage to the bearing by particles during the first half-hour of operation was enough to cause early failures. Also, even if the contaminated oil was replaced the bearing did not "recover" and its life was significantly reduced.

It should be noted that only a very small number of hard particles is needed to reduce bearing life to a fraction of its undamaged life. Tests conducted by FAG on 7208B angular contact bearings showed a reduction of bearing life by a factor of 10 resulting from plastic indentations of 0.1 mm diameter. A contamination factor, η_c, is used in the new life equation. This somewhat complicated parameter depends on size, hardness, shape and quantity of solid particles, bearing size, lubricant film thickness, loads, etc. The factor can be expressed as:

$\eta_c, f\,(k_1\, d_m, P_u, P, R_t, D_p, HV, S)$

where:

d_m= mean diameter of bearing

R_t = a contamination balance factor, it takes into account the amount of contaminants entering and removed from the system.

D_p = particle size

HV = particle hardness

S = safety factor.

The effect of water on bearing life is well documented but not well understood. Tests conducted by various researchers showed that a concentration of water as small as 0.01% can decrease bearing life to half of its original value. Interestingly, a change in failure mode from ball failures to raceway failures occurred when water content was increased.

For these reasons the new SFK life theory does not at this stage take into account the influence of water on bearing life. It is assumed that the water content does not exceed 0.05%. Rough guidelines, applicable to fully oxidation-inhibited lubricants, suggest that the calculated life may be halved by water content of 0.1% and a further 50% reduction may be assumed in heavily loaded bearings if the water content increases to 0.2%. Curtailment of bearing fatigue life is considerably more severe for pure, uninhibited mineral oils. Here, 0.002% water (20 ppm, or roughly one drop of water per quart of oil) has been found to reduce bearing life by 48% (Table 1).

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