KISSSOFT
Calculation programs for machine design

System reliability calculation

System level reliability, KISSsys release 03-2017

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SHARING KNOWLEDGE

1 Document information

1.1 Document change record

Revision	Date	Author	Comments
0	15.5.15	HD	Original document

1.2 Table of content

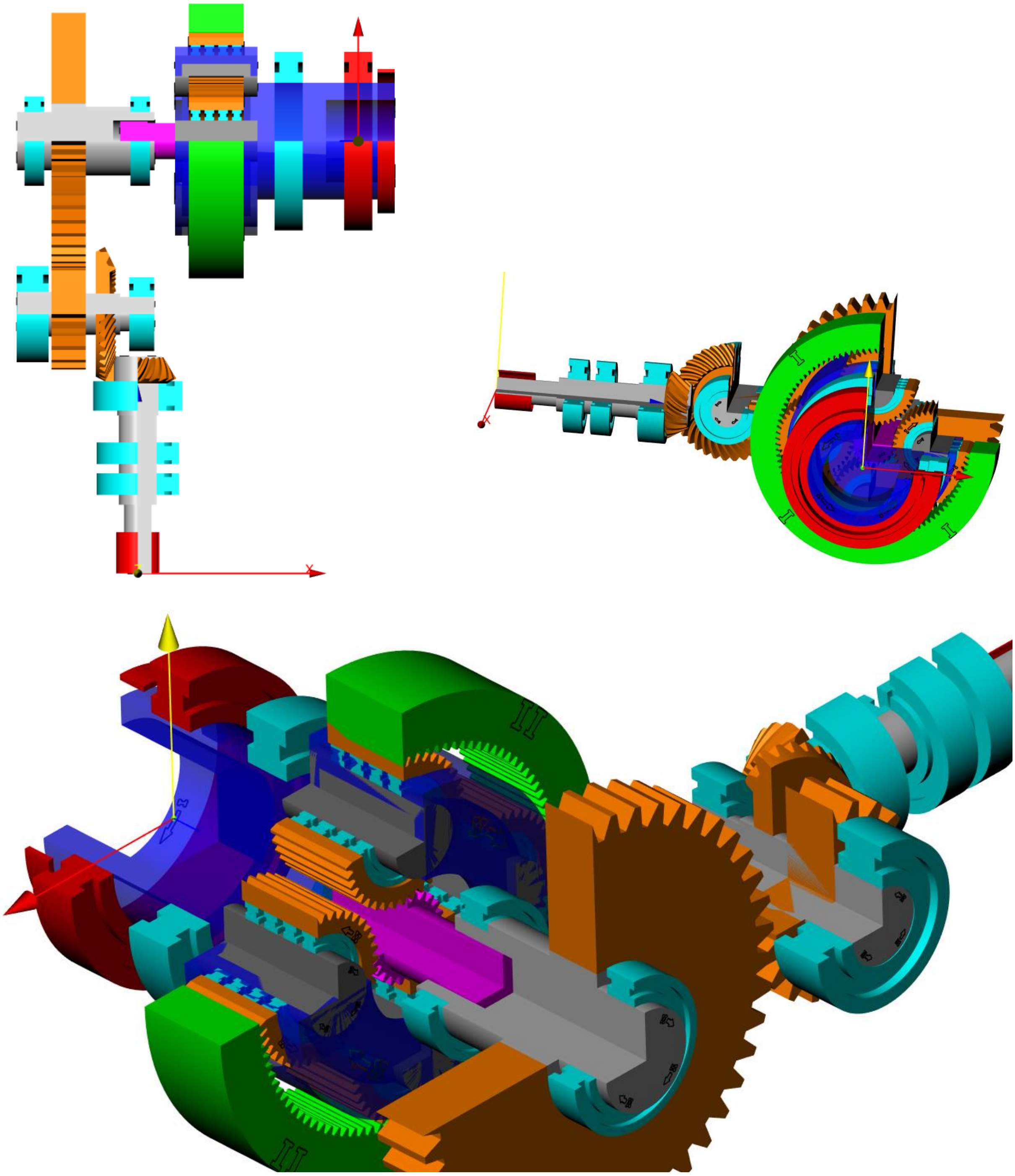
1.3 References

[1] KISSsoft 03-2017A

2 Reliability of a bevel-helical-planetary gearbox (BHP)

2.1 Basic calculation model

A bevel helical planetary gearbox with input speed of 1700RpM, input torque of 3000Nm and 534kW power is analyzed. The first stage is a spiral bevel gear. The second stage is a spur gear (cylindrical) and the output stage is a planetary stage with four planets. Each planet has four planet bearings. The system is shown below.



Load data input is through the user interface as shown below:

	A	B	C	D
1	Calculate	Input side	Output side	
2	Speed	1700	-65.744	RpM
3	Torque	3000	77573.86364	Nm
4	Power	534.07	534.07	kW
5	Ratio	1:	-25.858	

When calculating, we find the below gear safety factors in the user interface. They are quite high to start with.

7	GEARS	SF	SH	
8	z1	7.7818	1.8679	
9	z2	7.8801	2.0115	
10	z3	1.8158	1.393	
11	z4	1.8717	1.4195	
12	zs	3.837	1.3697	
13	zp	2.7217	1.5163	
14	zr	4.2429	1.8548	

The bearing lifetimes are shown in the table “BearingCalcualtions” (lowermost line in below figure). Note that the bearing life times are very high for all bearings except for the planet bearings as show:

Settings | UI | kSys3DView | BearingCalculations

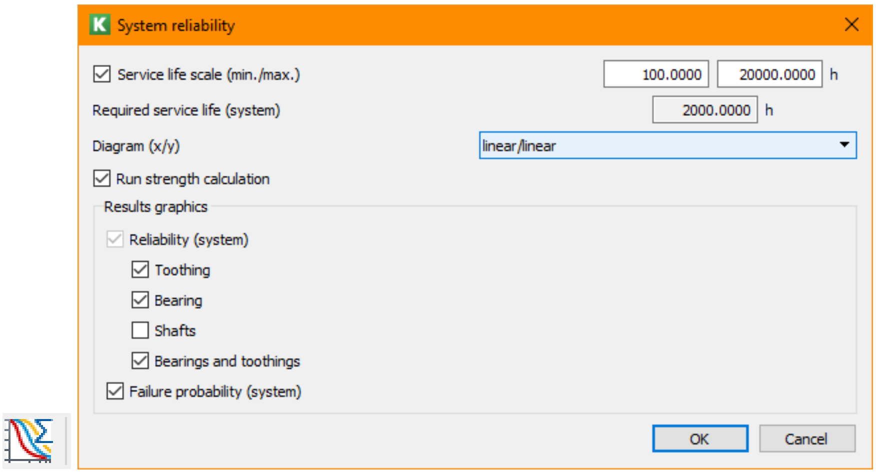
		b07	b12	b13	b01	b02	b03	b04	b05	b08	b09	b10	b11
shaft1		s3	sc	sc	s1	s1	s1	s2	s2	^.spp	^.spp	^.spp	^.spp
BForm	bearing (	Taper roller bearing (	Cylindrical roller bear	Cylindrical roller bear	Taper roller bearing (	Taper roller bearing (	Spherical roller bearir	Spherical roller bearir	Spherical roller bearir	Cylindrical roller bear	Cylindrical roller bear	Cylindrical roller bear	Cylindrical roller bear
BType		SKF 32034 X	SKF NJ 1068 MA	SKF NU 1068 MA	SKF 31322 XJ2	SKF 31322 XJ2	SKF 22324 CC/W33	SKF 22320 E	SKF 22326 CC/W33	SKF NU 1024 ML	SKF NU 1024 ML	SKF NU 1024 ML	SKF NU 1024 ML
d	170	170	340	340	110	110	120	100	130	120	120	120	120
D	260	260	520	520	240	240	260	215	280	180	180	180	180
b	57	57	82	82	63	63	86	73	93	28	28	28	28
Fx	3933.8	10094.18714	-0	-0	-1129.8	-10947	34394.31772	-23259	-1440.6	-476.94	-380.14	-380.13	-476.93
Fy	-10017	10017.48568	-0	-0	-977.39	11648.51236	-0	-0	22317.82012	0	0	0	0
Fz	-10808	-27733	-0	-0	1159	11049.21466	-46849	36691.50488	36491.17793	-28208	-22960	-22959	-28208
Tx	-360.45	880.87	-0	-0	50.496	-609.35	-0	-0	-0	3.4264	1.1693	-1.1686	-3.4257
Ty	2.0039	3.1657	2.5442	2.5442	2.9471	4.008	5.953	2.8216	8.2632	1.0174	0.85994	0.85992	1.0174
Tz	-131.19	320.63	-0	-0	49.428	-595.89	-0	-0	-0	[illegible]	[illegible]	[illegible]	[illegible]
Lh	2000000	2000000	2000000	2000000	2000000	2000000	2000000	2000000	2000000	9804.7	21004.51783	21006.04384	9804.6

See file THE-KSY-AS-1752-00-EES-System-Reliability-Step-01.ks.

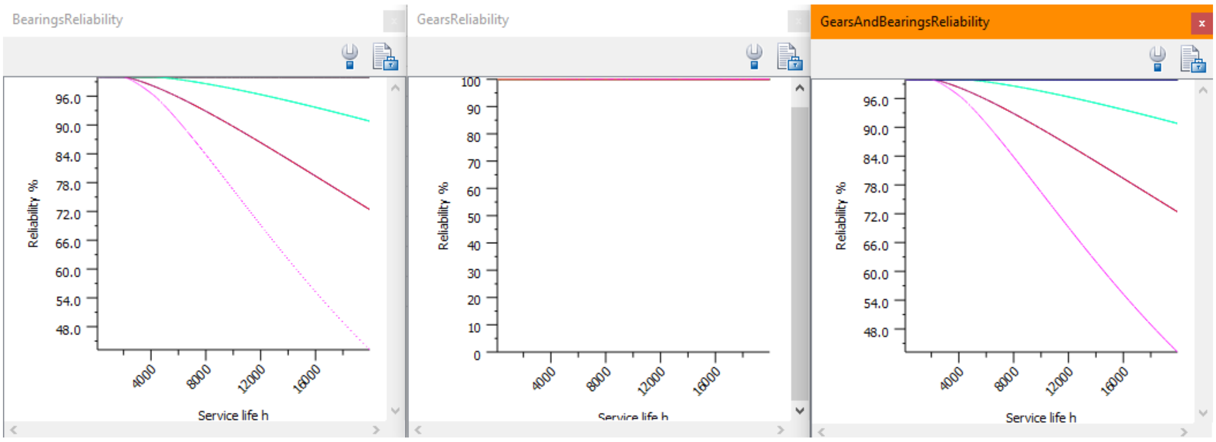
2.2 Reliability calculation with original settings

Now, let us add the reliability calculation by pressing the below button. We use the settings as shown below

- We want to see the results between 100h and 20’000h
- We use a linear / linear scale
- The strength calculations should be executed
- We want to see the gear and bearing reliability and failure probability



We then get several results, including graphics for the bearings, the gears and gears and bearings combined reliability:



We can see that the gear reliability is at 100% over the time period of interest because the safety factors are very high. But we do see that the bearing reliability gets quite low over time. When combining gears and bearings in the right figure, we see the same behavior as the bearings. This means that the system reliability is only influenced by the bearings in this example.

As a summary, we find the system reliability vs. life in the corresponding table:

	A	B
1	Reliability [%]	Lifetime [h]
2	99.9	2109.9
3	99	2784.3
4	90	6244.1
5	99.984	2000

See file THE-KSY-AS-1752-00-EES-System-Reliability-Step-02.ks.

2.3 Reliability calculation with increased gear load factor

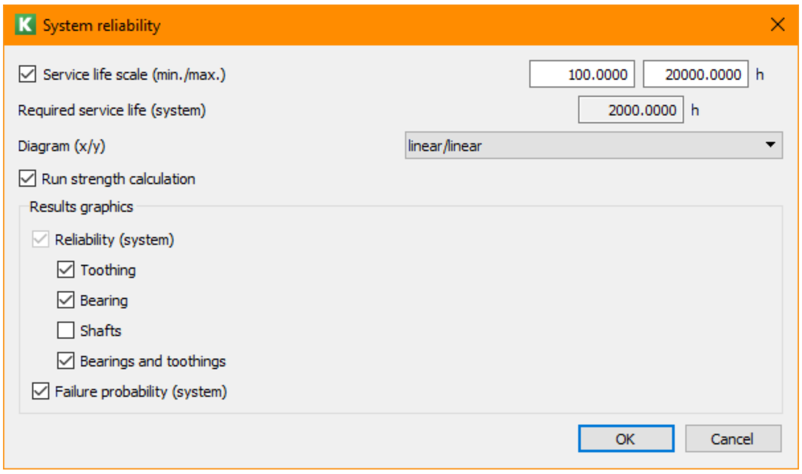
Now, we have seen that the gear safety factors are very high and the gears do therefore not affect the system reliability.

If we now change the application factor from KA=1.1 to KA=1.3 as shown below in the table “Settings”, the reliability behavior should change.

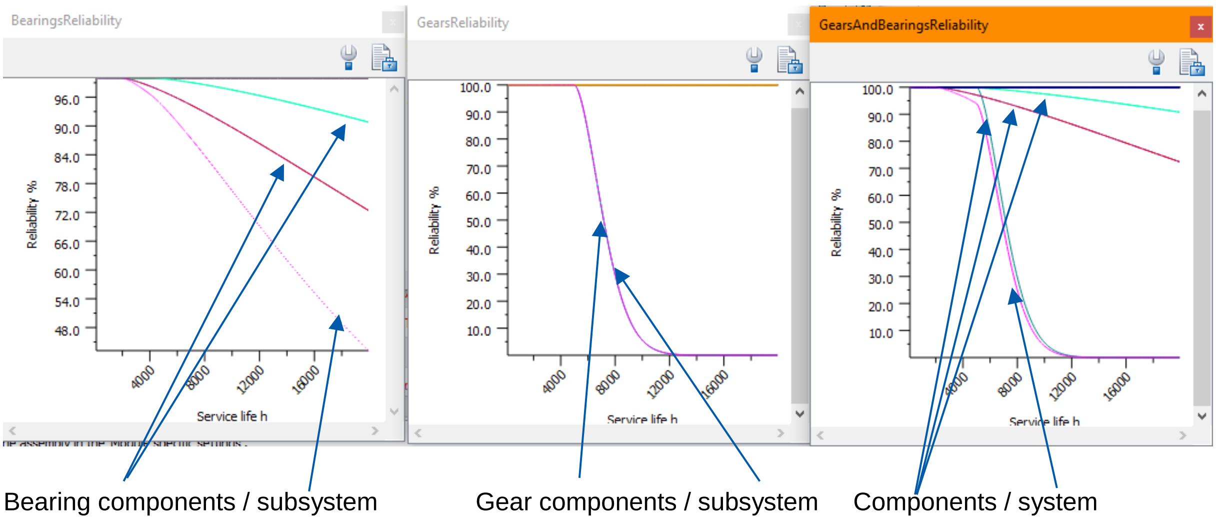
22	Face gears	Method ISO 6336:2006-B/ Literature	Disconnecte
23	KA	1.3	Connectec
24	Shafts	DIN 743:2012	Disconnecte

Now, this application factor is only considered in the gear rating. The bearing life and therefore the bearing reliability will not change.

Again, we run the calculation for the reliability with the same settings:



And we now find an influence from bearings and gears on the reliability



It is interesting to note that the life changes for different reliability

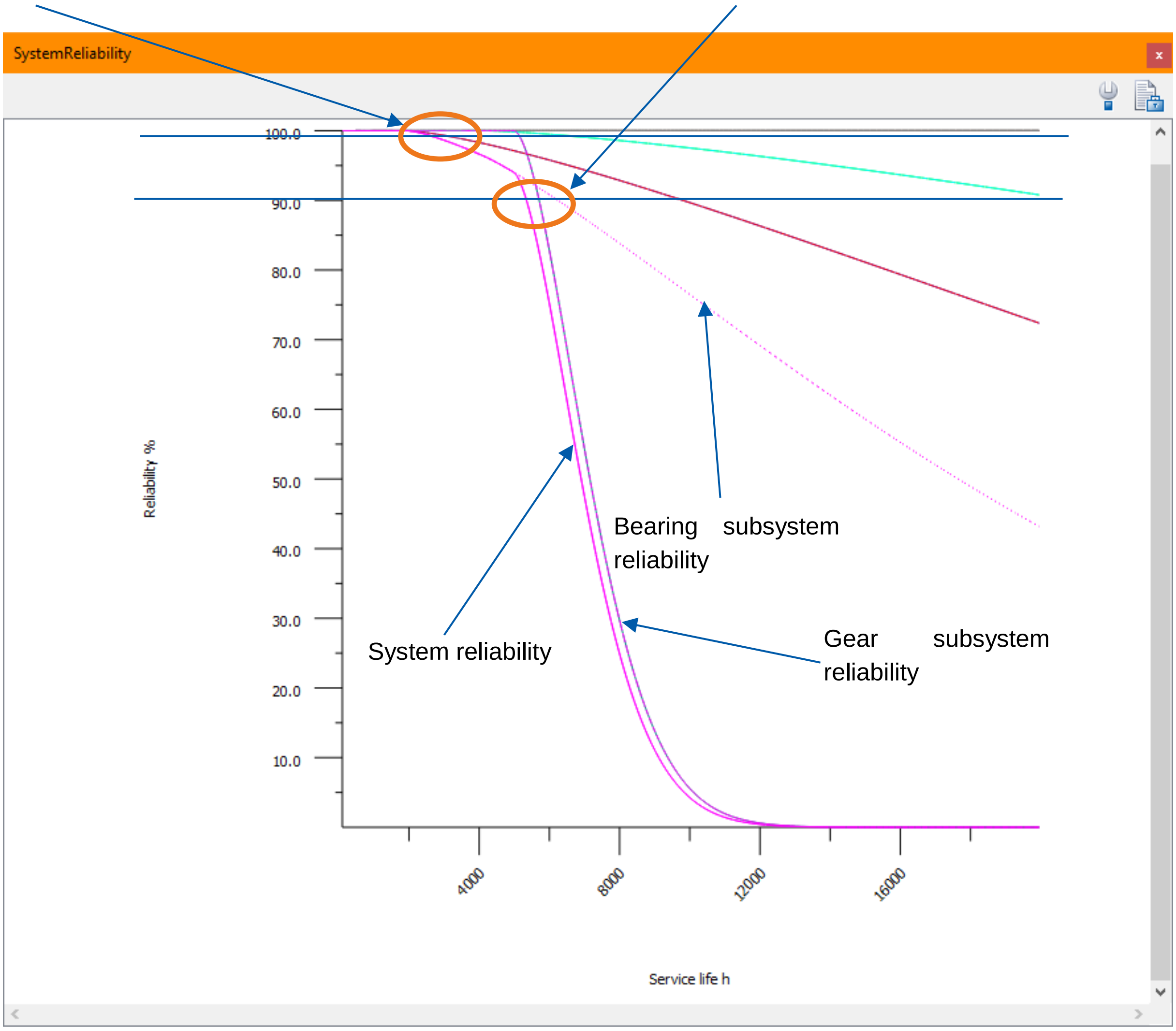
	A	B
1	Reliability [%]	Lifetime [h]
2	99.9	2109.9
3	99	2784.3
4	90	6244.1
5	99.984	2000

Left: previous calculation

	A	B
1	Reliability [%]	Lifetime [h]
2	99.9	2109.9
3	99	2784.3
4	90	5347.7
5	99.984	2000

Right: current calculation

We can see that the two results for 99.9% reliability do not change because these are governed by the bearing reliability. But the third result, for 90% reliability is governed by the gears and therefore changes.



See file THE-KSY-AS-1752-00-EES-System-Reliability-Step-03.ks.

2.4 Reliability calculation with improved lubrication

Finally, we study the effect of a changed lubrication cleanliness on the bearing and system reliability:

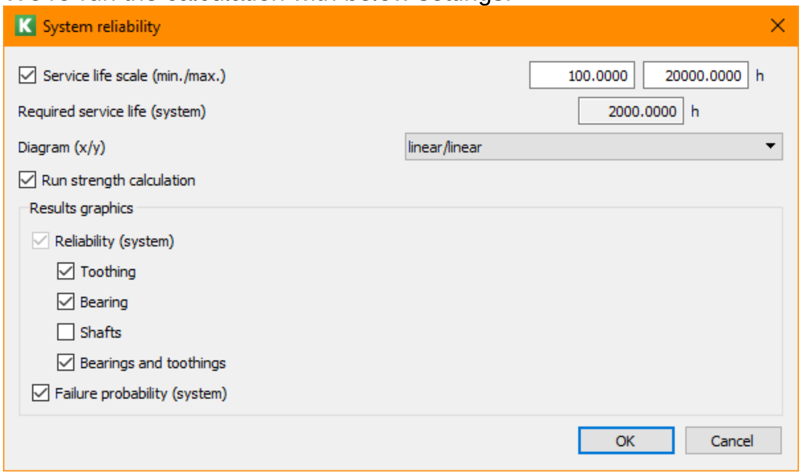
Previously, we used the below settings for bearing lubricant cleanliness:

5	Impurity	Oil lubrication with filtration, ISO 4406 -/17/14, beta25=75

This, we now change to a better cleanliness level:

5	Impurity	Oil lubrication with filtration, ISO 4406 -/13/10, beta6=200

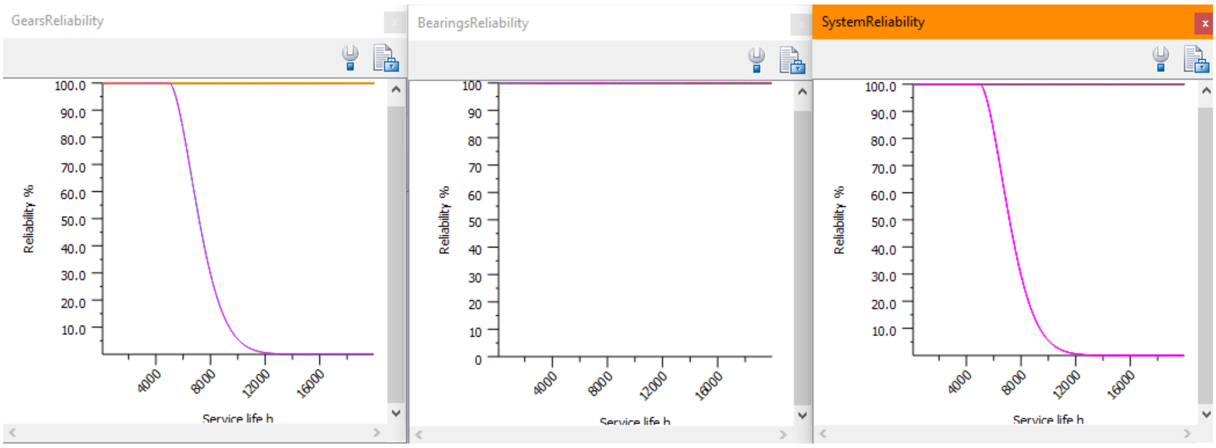
We re-run the calculation with below settings:



And find the below results (reliability vs. life):

	A	B
1	Reliability [%]	Lifetime [h]
2	99.9	5034.5
3	99	5172.8
4	90	5708.3
5	100	2000

The bearing reliability has improved a lot (see middle figure below) and the system reliability (right figure) is now only a function of the gear reliability (left figure):



See file THE-KSY-AS-1752-00-EES-System-Reliability-Step-03.ks.

3 Conclusions

From the above, we learn the following

- Reliability calculation is extremely sensitive to any change in the calculation settings because it is a life based calculation.
- Often, the system reliability is governed either by the bearing subsystem reliability or the gear subsystem reliability.
- It is however also possible that for a certain period of time, the gear subsystem controls the reliability while for a later or earlier time, the system reliability is governed bearing subsystem.