

Estimated gear mesh noise as a sizing criteria

dBA air borne sound level estimate, KISSsoft 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

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1.3 References

- [1] KISSsoft 03-2017A
- [2] Teruo Masuda, Toru Abe, Kanji Hattori, Prediction Method of Gear Noise Considering the Influence of the Tooth Flank Finishing Method, Journal of Vibration, Acoustics, Stress and Reliability in Design, January 1986, Vol 108/95

2 Background

2.1 Noise model

Based on the research published in [2], an airborne noise level in dBA is calculated based on the gear properties and load data defined in KISSsoft.

All the limitations associated with the theory mentioned above are of course also applicable to the KISSsoft calculation. Therefore, the user must be aware of these limitations and should read and understand the underlying theory.

It is expected the noise model is valid for industrial gearboxes and geared motors of a typical center distance around 200mm.

The authors report that their model is in line with measurements in a range of approximately 5 dB.

2.2 KISSsoft implementation

The model described in [2] is implemented in KISSsoft release 03-2017 onwards. The sound level is shown at the end of the section as shown below:

8. ADDITIONAL DATA			
Mass (kg)	[m]	4.580	16.605
Total mass (kg)	[m]	21.185	
Moment of inertia (system with reference to the driv	/e):		
calculation without consideration of the exact tooth	shape		
single gears ((da+df)/2di) (kg*m²)	[TraeghMom]	0.01658	0.71892
System ((da+df)/2di) (kg*m²)	[TraeghMom]	0.09438	
Torsional stiffness at entry with driven force fixed:			
Torsional stiffness (MNm/rad)	[cr]	3.500	
Torsion when subjected to nominal torque (°)	[delcr]	0.027	
Mean coeff. of friction (acc. Niemann)	[mum]	0.062	
Wear sliding coef. by Niemann	[zetw]	0.903	
Gear power loss (kW)	[PVZ]	0.589	
(Meshing efficiency (%)	[etaz]	99.214)	
Sound pressure level (according to Masuda)	[dB(A)]	80.8	J

Figure 2.2-1 KISSsoft report, section «Additional data», lowermost line showing sound pressure level.

2.3 Recommended usage

We recommend to use this sound pressure level calculation as follows

- Use mainly for design comparisons, e.g. compare design A to design B and see which one gives lower sound pressure level
- Measurements were done for gear pairs with properties as shown below. The closer the gear design is to this reference, the more reliable the result will be
- The calculated sound pressure level is intended for an assessment of the gear macro geometry, not the gear micro geometry
- Great caution has to be applied if gears are not made of steel

	PINION	GEAR	1. TOOTH FLANK FINISHING METHOD
MODULE		4	HOBBED GEAR ; JIS GRADE 6
PRESSURE ANGLE	2	5'	NILES-GROUND GEAR : JIS GRADE 2 MAAG-GROUND GEAR : JIS GRADE 1
NUMBER OF TEETH	22	86	2 ARRANGEMENT
HELIX ANGLE	10*	56′	
PITCH CIRCLE DIAMETER	89,63mm	350,37mm	
ADDENDUM MODIFICATION COEFFICIENT	0	0	
CENTER DISTANCE	220	Omm	DRIVEN
FACE WIDTH	186,5mm	140m.m	3: ADDENDUM ha=1,1 mn DEDENDUM hf=1,3 mn
MATERIAL	SCM445	SCM440	4. WITHOUT PROFILE MODIFICATION
HEAT TREATMENT	QUENCH TEMP	ED AND ERED	5, LUBRICATING SYSTEM : OIL BATH
HARDNESS	Hs42~49	Hs41~48	6. GEARBOX : CAST IRON

Figure 2.3-1 Gear data used in the test based on which the methodology to predict a sound pressure level was developed.

3 Example application

3.1 Basic gear data

Let us consider a gear pair with the below basic parameters (see example "CylGearPair 1(spur gear)" in the KISSsoft installation).:

Basic data	Deference profil	e Tolerances Pat	ing Eactors							
	Reference profil	e roierances rea	ing ractors							
Geometry										
Normal mod	dule m _n		6.0000 mm	+			Gear 1	Gear 2		Details
Pressure ar	nmal section an		20.0000 °	\Leftrightarrow	Number of teeth	z [25	76		
Gear 1		spur gear	•	-21	Facewidth	ь [44.0000	44.0000	mm	+
Helix angle	\dots rence circle β		0.0000 °	$\langle \cdot \rangle$	Profilefficient	x* [0.2485	-0.2485		↔
Center dist	tance a		303.0000 mm 🗹	+	Quality8: 1995)	Q [6	6		ىلى-
Material and	d lubrication									
Gear 1	18CrNiMo7-6, Ca	ase-carburized steel, case	-hardened, ISO 6336	-5 Figure 9/10	(MQ), Core hardness	s >=2	25HRC Jominy J=	12mm <hrc28< td=""><td></td><td>+</td></hrc28<>		+
Gear 2	18CrNiMo7-6, Ca	ase-carburized steel, case	-hardened, ISO 6336	-5 Figure 9/10 ((MQ), Core hardness	s >=2	25HRC Jominy J=	12mm <hrc28< td=""><td></td><td>▼ +</td></hrc28<>		▼ +
Lubrication	Oil: Klüberoil GEN	1 1-220 N with details abo	ut wear coefficient kv	v 🔻 🕂	+ Oil bath l	lubrica	ation			• +

Figure 3.1-1 Basic gear geometry

The following load and rating data applies:

Basic data Reference profile	Tolerances Rating	Factors						
Strength								
Calculation method	ISO 6336:2006	Method B	•	Reference gear		Gear 1 🔹	0	etails
Calculation method scuffing	according to cal	culation method	•	Power	Ρ	75.0000 kW	0	+
Calculation method for micropittin	g ISO TR 15144		•	Torque	T1	1624.7669 Nm	۲	$\langle \neg \rangle$
Calculation method tooth flank fra	acture Draft ISO DTR 1	9042-1	•	Speed	nı	440.8000 1/min	0	
Driving gear	Gear 1		•	Requirece life	н	20000.0000 h		+
Working flank gear 1	right flank		▼ 1	Applica factor	Ka	1.2500		1
Sense of rotation gear 1			clockwise					

Figure 3.1-2 Rating settings and load data

We then find the below safety factors:

Results		
Results		
Contact ratio (Transverse/Overlap/Total)	1.662 / 0.000	1.662 / 0.000 / 1.662 Gear 2 34.982 465.018
	Gear 1	Gear 2
Actual tip circle (mm)	164.982	465.018
Root safety	2.602	2.514
Flank safety	1.329	1.384

Figure 3.1-3 Gear strength

And the below mesh:





3.2 Resulting sound pressure level

In the rating report (press F6 to generate it), we find the below shown sound pressure level result:

8. ADDITIONAL DATA			
Mass (kg)	[m]	4.580	16.605
Total mass (kg)	[m]	21.185	
Moment of inertia (system with reference to the drive	e):		
calculation without consideration of the exact tooth s	shape		
single gears ((da+df)/2di) (kg*m²)	[TraeghMom]	0.01658	0.71892
System ((da+df)/2di) (kg*m²)	[TraeghMom]	0.09438	
Torsional stiffness at entry with driven force fixed:			
Torsional stiffness (MNm/rad)	[cr]	3.500	
Torsion when subjected to nominal torque (°)	[delcr]	0.027	
Mean coeff. of friction (acc. Niemann)	[mum]	0.062	
Wear sliding coef. by Niemann	[zetw]	0.903	
Gear power loss (kW)	[PVZ]	0.589	
(Meshing efficiency (%)	[etaz]	99.214)	
Sound pressure level (according to Masuda)	[dB(A)]	80.8	J

Figure 3.2-1 Sound pressure level for basic gear design.

To ensure that all gear designs have a similar strength, define in the module specific settings target values as shown below (they are based on the strength of the basic gear design above):

K Module	specific se	ettings						×
General	Plastic	Sizings	Calculations	Required safeties	Face load factor/Contact analysis	Summary	Diagrams	Generation of 3D
Safeties a	re not depe	ending on si	ze					•
Required	l safeties fo	or metal (IS	D/DIN)					
Root saf	fety						SFmin	2.5
Flank sat	fety						SH _{min}	1.25

Figure 3.2-2 Defining target safety factors.

See file "THE-KSS-WW-1707-00-EES-Gear-Mesh-Noise-Step-1.z12"

4 Gear macro geometry optimization

4.1 Objective

We now want to design a gear pair that has roughly the same size and properties as the basic design shown above. Of course, the strength of the new design should be in a similar range too. The overall objective however is to reduce the above shown sound pressure level by choosing a suitable gear geometry.

4.2 Set up of fine sizing function, procedure 1

In this first step, we want to find a gear design while keeping the gear reference profile as it is.

Start the fine sizing function by pressing and define search parameters as follows:

Fine Sizing						-		×
Conditions I	Conditions II	Conditions	III Results	Graphics				
Maximal no of	solutions			999				
Nominal ratio/d	eviation in +-%	i, ic	3.0400	5.0000				
			Minimum	Maximum		Step		
Normal module		mn	5.0000	7.0000	mm [0.5000 mm	\checkmark	+
ressure angle	at normal section	O _n	20.0000	20.0000	•	0.0000 °		
Helix angle at r	eference circle	β	0.0000	0.0000	• [0.0000 °		+
Center distanc	e	а	295.0000	310.0000	mm	1.0000 mm	\checkmark	+
Range for prof	ile shift coefficient	x*	-0.6000	1.0000]			+
					Gear 1	Gear 2		
4aximum tip di	ameter			d _{a, max}	999999.0000	999999.0000	m	n
1inimum root d	iameter			d _{f, min}	0.0000	0.0000	m	n
ix number of	teeth			z	0	0		
ix profile shift	coefficient			x*	0.0000	0.0000		
acewidth				b	44.0000	44.0000	m	m 🗌
	Accept De	lete	Report	Calculate	Close	Contact analysis	Restr	ore

Figure 4.2-1 Setup of the fine sizing function, part 1.

Ensure that all solutions that do not meet the required target safety factors are removed from the set of proposed solutions and then run the calculation:

K Fine Sizing					-		>
Conditions I Conditions II C	onditions III	Results	Graphics				
Show values of KISSsoft main ca	lculation as ac	ditional varia	nt with number	0			
Calculate geometry only							
Strength calculation with load sp	ectrum						
Permit undercut							
Reject results with specific sliding	higher than	> [3]					
Consider minimum tooth thicknes	s at tip						
Allow small geometry errors							
Suppress integer gear ratios							
List of cutters for reference profile G	Gear 1 Own I	input				•	
List of cutters for reference profile G	Gear 2 Own I	input				•	
Deep tooth form	None					•	
Required transverse contact ratio				Eo target	2.000	0	
Contact analysis	Witho	ut calculation	of the transmis	sion error		•	-2
Suspend results which do not me	et required sa	afety factors					
Sizing of profile shift coefficient Gear	r 1 for ba	lanced specifi	iding			•	
Minimum number of teeth				Zmin		9 🛃	
Factor for minimum between root for	m diameter a	nd active root	t diameter	(d _N r - d _F r) / m _n	0.010	0	
Factor for minimum between root for	m diameter a	nd base circle		(d _{Ff} - d _b) / m _n	0.010	0	
Accept Delet	e Re	eport	Calculate	Close Cor	ntact analysis	Rest	ore

Figure 4.2-2 Setup of the fine sizing function, part 2.

4.3 Results of fine sizing function, procedure 1

We now find the resulting sound pressure level listed in the tab "Results". If we sort the list in ascending order, we find the lowest sound pressure level at 80.25 dBA while we had 80.78 dBA before. This is a minimal improvement only.

Condi	tions I	Cond	litions II	Co	nditions III	Results	Gr	aphics					
	T _{1 max} []	lm]	v _e [m/s]		η	Kv		dB(A)	`	H _{min, flank} [h]	4th amplitude	ΔT	^
.000	1	532.491	. ().912	0.992	1.	.027		30.280	102778.839	0.000		
.000	10	592.847	().915	0.993	1.	029	8	30.308	354739.282	0.000		
.000	1	780.577).998	0.992	1.	026	8	30.325	135805.786	0.000		
.000	10	527.749).905	0.992	1.	.027	8	30.332	116306.511	0.000		
.000	10	650.763).983	0.992	1.	.027	8	30.345	151853.671	0.000		
.000	10	540.440).910	0.992	1.	.027	8	30.358	117560.487	0.000		
.000	1	781.538).996	0.992	1.	026	8	30.360	145708.364	0.000		
.000	1	713.948).981	0.993	1.	029	8	30.371	1.000e+06	0.000		
.000	10	592.309).996	0.991	1.	.024	8	30.373	38856.022	0.000		
.000	10	571.014		.908	0.993	1.	029	8	30.387	1.000e+06	0.000		
.000	1	793.280		1.074	0.992	1.	026	8	30.394	206259.552	0.000		
.000	1	782.465).993	0.992	1.	026	8	30.394	156090.311	0.000		
.000	10	645.171).976	0.992	1.	.027	8	30.397	171974.774	0.000		
.000	1	757.907).977	0.992	1.	026	8	30.402	168504.842	0.000		
.000	10	699.651	. 0).993	0.991	1.	.024	8	30.409	41696.410	0.000		
.000	10	535.412).903	0.992	1.	.027	8	30.409	132381.831	0.000		
.000	1	817.032	1	1.071	0.991	1.	025	8	30.410	123847.411	0.000		
.000	10	587.545).977	0.992	1.	.024	8	30.415	45118.690	0.000		
.000	10	526.270).963	0.993	1.	027	8	30.422	188972.231	0.000		
.000	10	558.087		.981	0.992	1.	027	8	30.426	174196.662	0.000		
.000	1	819.628	1	1.074	0.991	1.	.025	8	30.429	126762.373	0.000		
.000	1	794.030	1	1.071	0.992	1.	026	8	30.430	221538.585	0.000		
.000	1	759.107).975	0.992	1.	026	8	30.436	180473.244	0.000		
.000	1	706.858).991	0.991	1.	.024	8	30.444	44673.346	0.000		
.000	1	717.967	1	1.071	0.991	1.	.024	8	30.446	60023.587	0.000		
.000	10	539.417	· (.968	0.992	1.	.027	8	30.448	193644.374	0.000		
.000	10	587.239		.961	0.993	1.	029	8	30.448	1.000e+06	0.000		
.000	1	821.965		1.077	0.991	1.	.025	8	30.448	129441.248	0.000		
.000	10	588.589).974	0.992	1.	.024	8	30.451	48270.053	0.000		
.000	1	794.753	1	1.068	0.992	1.	026	8	30.465	237549.059	0.000		
.000	1	771.773	1	1.052	0.992	1.	026	8	30.468	256009.965	0.000		
.000	1	786.952	1	1.252	0.991	1.	.024	8	30.469	94340.406	0.000		~
<												>	

Figure 4.3-1 Resulting sound pressure.

See file "THE-KSS-WW-1707-00-EES-Gear-Mesh-Noise-Step-2.z12"

4.4 Set up of fine sizing function, procedure 2

In a second step, we now introduce a helix angle in the fine sizing function (increase the number of possible solutions to 9999):

Fine Sizing						-	-		×
Conditions I Con	ditions II	Conditions III	Results	Graphics					
Maximal no of solution	ns	ſ		9999					
Nominal ratio/deviatio	on in +-%	i, iz	3.0400	5.0000					
			Minimum	Maximum		Step			
Normal module		mn	5.0000	7.0000	mm	0.5000	mm	\checkmark	+
Pressure angle at normal section		an	20.0000	20.0000	۰	0.0000	۰		
Helix angle at reference circle		β	5	10	•	1	•		+
Center distance		a	295.0000	310.0000	mm	1.0000	mm	\checkmark	+
									4.0

Figure 4.4-1 Defining a range for the helix angle in the fine sizing function.

4.5 Results of fine sizing function, procedure 2

Now, we find a higher number of possible gear designs and the one with the lowest sound pressure level now has a reduced level of 78.50 dBA.

Fine Sizi	ing										- 🗆	
Conditions	I Conditions	s II Conditi	ons III	Res	sults	Gra	aphi	cs				
Ŋ	T _{1 max} [Nm]	v. [m/s]	η		Kv		ſ	dB(A)	H _{min, fi}	₁∗[h]	4th amplitude	^
3664.127	1672.146	0.904	0	.993		1.0	20	78.508		1.000e+06	0.000	
8664.127	1652.781	0.903	0	.993		1.0	21	78.539		1.000e+06	0.000	
3664.127	1667.674	0.900	0	.993		1.0	21	70,550		1.000e+06	0.000	
3664.127	1648.869	0.898	0	.993		1.0	21	78.584		1.000e+06	0.000	
8761.837	1734.500	0.976	0	.992		1.0	20	78,592		16130.384	0.000	

Figure 4.5-1 Resulting sound pressure level in second sizing process.

See file "THE-KSS-WW-1707-00-EES-Gear-Mesh-Noise-Step-3.z12"

4.6 Set up of fine sizing function, procedure 3

In a third step, we now also include deep tooth form with a transverse contact ratio of $\epsilon \alpha$ >2.05:

K Fine Sizing						—		×	
Conditions I Conditions II Condi	itions III	Results	Graphics						
Show values of KISSsoft main calcula	ation as ad	ditional variar	nt with number	0					
Calculate geometry only									
Strength calculation with load spectro	um								
Permit undercut									
Reject results with specific sliding hig	her than >	3							
Consider minimum tooth thickness at	tip								
Allow small geometry errors									
Suppress integer gear ratios									
List of cutters for reference profile Gear	1 Own Ir	iput					•		
List of cutters for reference profile Gear	2 Own Ir	put					-		
Deep tooth form	All solu	tions with ε _α	>= E _{o target}						
Required transverse contact ratio				E _{o target}	[2.	05		
	and a second		6 A				_		

Figure 4.6-1 Setup of the fine sizing function such that gear design has a higher contact ratio.

4.7 Results of fine sizing function, procedure 3

Now, we find again a reduction of the lowest sound pressure level to 77.72 dBA:

Condition	s I Conditions	s II Conditi	ons III	Result	s	Graphi	cs					
ŋ	T _{1 max} [Nm]	v _o [m/s]	η	К	v	Г	dB(A)	H _{min} ,	_{ank} [h]	4th amplit	ude	^
3761.837	1782.981	1.207		0.989		1.014	77.723		1.000e+06		0.000	
8761.837	1756.946	1.301		0.989		1.014	77.725		1.000e+06		0.000	
3761.837	1752.296	1.197		0.989		1.014	77 705		1.000e+06		0.000	
8664.127	1709.010	1.070		0.990		1.016	77.725		1.000e+06		0.000	
3761.837	1740.403	1.287		0.989		1.014	77.726		1.000e+06		0.000	
3664.127	1743.967	1.109		0.990		1.016	77.726		1.000e+06		0.000	
8664.127	1647.201	1.088		0.991		1.016	77.726		1.000e+06		0.000	
8664.127	1674.496	1.080		0.991		1.016	77.727		1.000e+06		0.000	
3774,419	1782,714	1.393		0.988		1.015	77,728		1.000e+06		0.000	

Figure 4.7-1 Resulting sound pressure level in third sizing process.

See file "THE-KSS-WW-1707-00-EES-Gear-Mesh-Noise-Step-4.z12"

4.8 Graphics results display

Note that it is recommended to delete solution "0" from the list to compare the solutions of step 3 in the tab "Graphics".

In the tab "Graphics" the noise level can be shown as a color scale as a function of two axes. For the two axes, different parameters may be selected. E.g. below we see that the noise level is quite independent of the center distance (horizontal axis) but it is depending on the overlap ratio (vertical axis). This is in line with expectations.

K Fine Sizing																	-
Conditions I	Conditions II	Conditions III	Results	Graphics													
		Overlap ratio												501	und pres	ccure lev	al according to Mi
		0.500	,											300	ind pre	ssure iev	78.784
		-									397		518			761	
		0.450	20. 4	8 81	115	159	207	255	305	369	416	468	538	608	688	788	
		0.400 -14	19 19	101 80	114	185	206	251	301	358	409	463	530	645 596	678	99 9	78.254
		- 13 0.350	45 70 36 60	3 5 19190 79	147 135	195 189 156	22 9 299	290 279 248	346 329 296	396 388 353	453 435 405	517 495 468	587 568 526	665 642 595	758 725 673	859 839 776	
		17 -12	44 30. 60	108 1 95	146 126	178	240 279	289 2 68	345 378	375	452 438	516 490	586 568	66 3 632	757 725	856 875	77.723
		0.300 -16	44 7. 28 5	7 106	145 125	150	198 239 218	246 288 265	295 316	350 395 379	408 451 428	458 515 485	525 588	593 669 625	669 755	773 858 806	
		-	18 76		113	149		245	393	394	498	514	588	889	9 93	89	
		0.250	26 5	8 85	120	16 5	210	263	318	368	425	489	545	629	608	809	
		-	43 7	5	166	198	197	242	341	349	398	509	526	555	785	96	
		0.200	28 5 41 74	1 83 1	119 143	160 191	209	26 9 286	309. 340	36 8 392	4 28 446	478 506	5 38. 576	6 05 650	689 739.	796 842	
		0.150														_	
		295.0				300.0					305.0					310.0	
							G	enter dis	tance (m	m]							
Horizontal axis				a [mm]	- Cente	r distan	œ										•
Vertical axis				ε _β - Ον	erlap ra	tio											▼
Color scale				dB(A) -	- Sound	pressure	e level ac	cording t	to Masud	a							▼
						Accep	pt	Delet	e	Repor	t	Calcula	te	Close	C	ontact ana	alysis Restore

Figure 4.8-1 Display of sound pressure level results in tab "Graphics".