KISSsoft
Calculation programs for machine design

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

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 drive):				
calculation without consideration of the exact tooth shape				
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	0.01658		0.71892
System ((da+df)/2...di) (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	

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

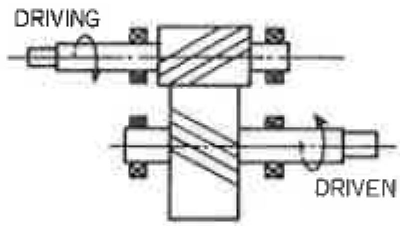
2.3 Recommended usage

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
MODULE	4	
PRESSURE ANGLE	25°	
NUMBER OF TEETH	22	86
HELIX ANGLE	10°56′	
PITCH CIRCLE DIAMETER	89.63mm	350.37mm
ADDENDUM MODIFICATION COEFFICIENT	0	0
CENTER DISTANCE	220mm	
FACE WIDTH	186.5mm	140mm
MATERIAL	SCM445	SCM440
HEAT TREATMENT	QUENCHED AND TEMPERED	
HARDNESS	Hs42~49	Hs41~48

1. TOOTH FLANK FINISHING METHOD AND ACCURACY
   HOBBED GEAR : JIS GRADE 6
   NILES-GROUND GEAR : JIS GRADE 2
   MAAG-GROUND GEAR : JIS GRADE 1
2. ARRANGEMENT



3. ADDENDUM ha=1.1 m_n
   DEDENDUM hf=1.3 m_n
4. WITHOUT PROFILE MODIFICATION
5. LUBRICATING SYSTEM : OIL BATH
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).:

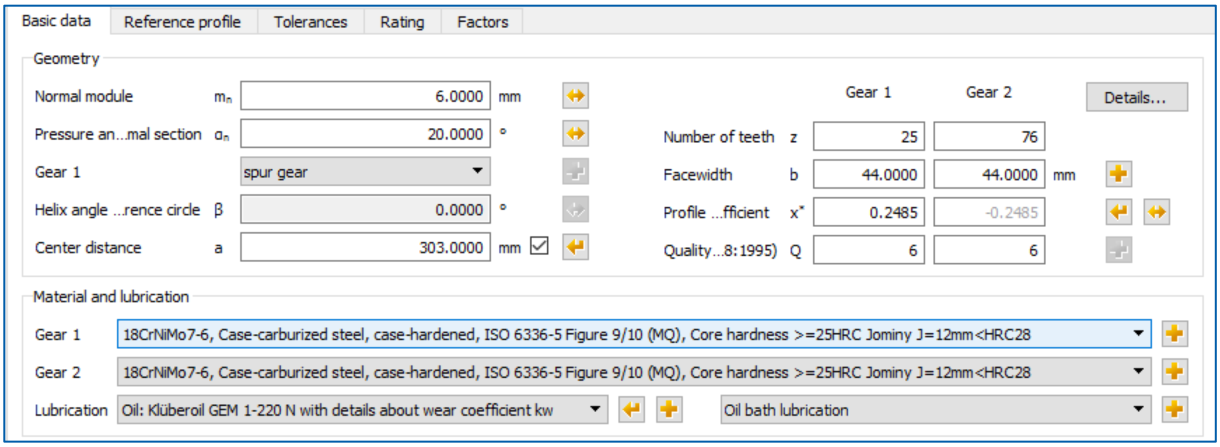


Figure 3.1-1 Basic gear geometry

The following load and rating data applies:

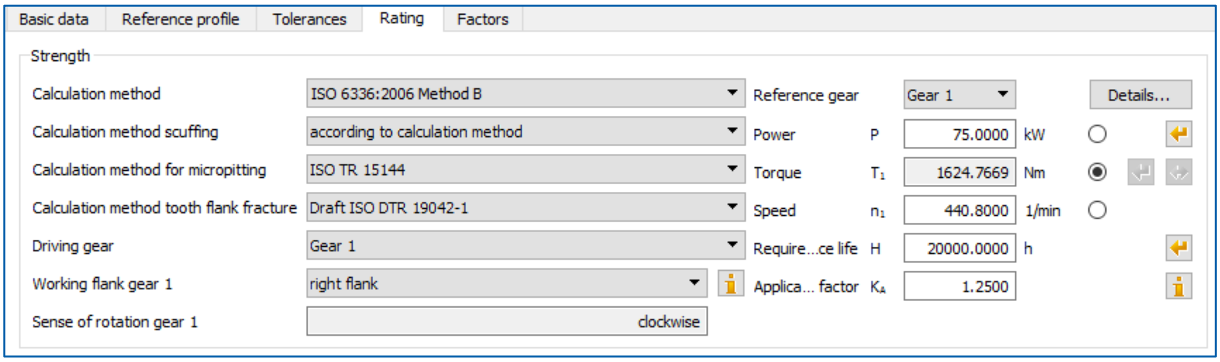


Figure 3.1-2 Rating settings and load data

We then find the below safety factors:

Results

Results		
Contact ratio (Transverse/Overlap/Total)	1.662 / 0.000 /	1.662
	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:

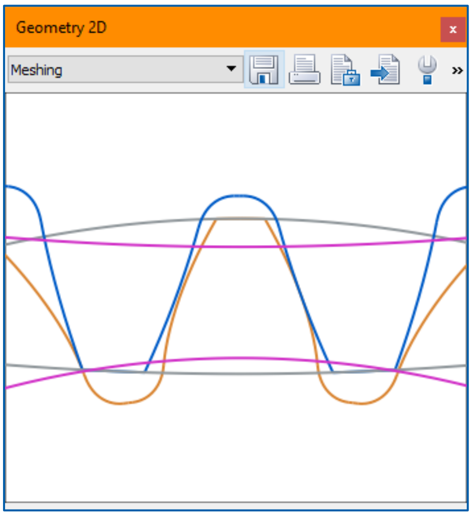


Figure 3.1-4 Meshing condition

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):			
calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	0.01658	0.71892
System ((da+df)/2...di) (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	

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):

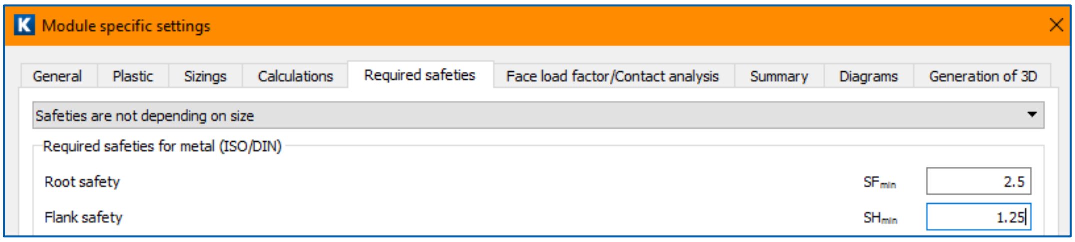


Figure 3.2-2 Defining target safety factors.

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:

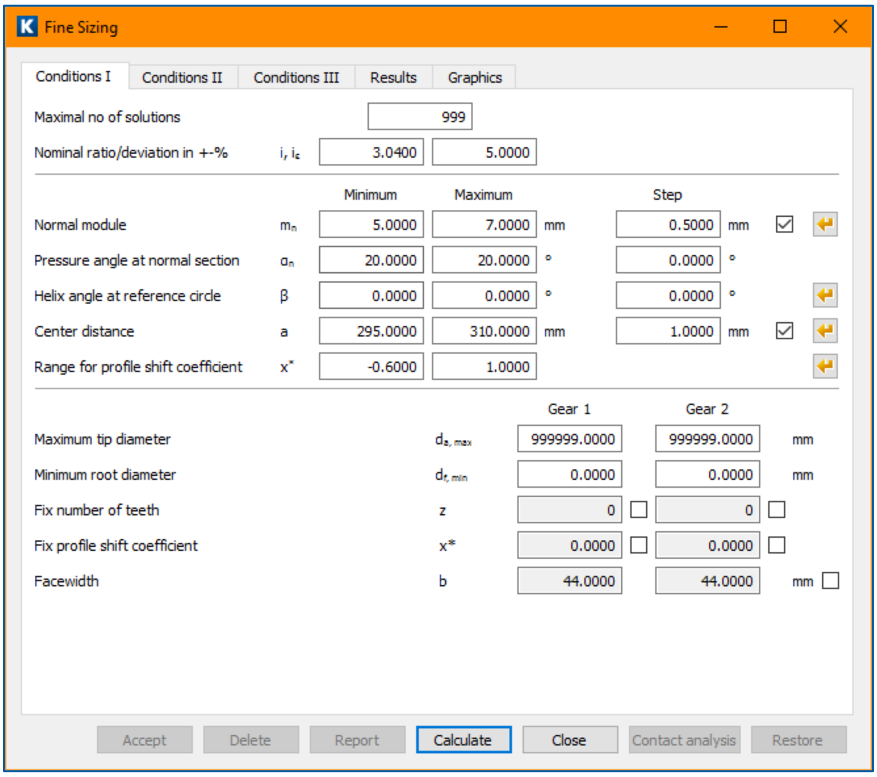


Figure 4.2-1 Setup of the fine sizing function, part 1.

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:

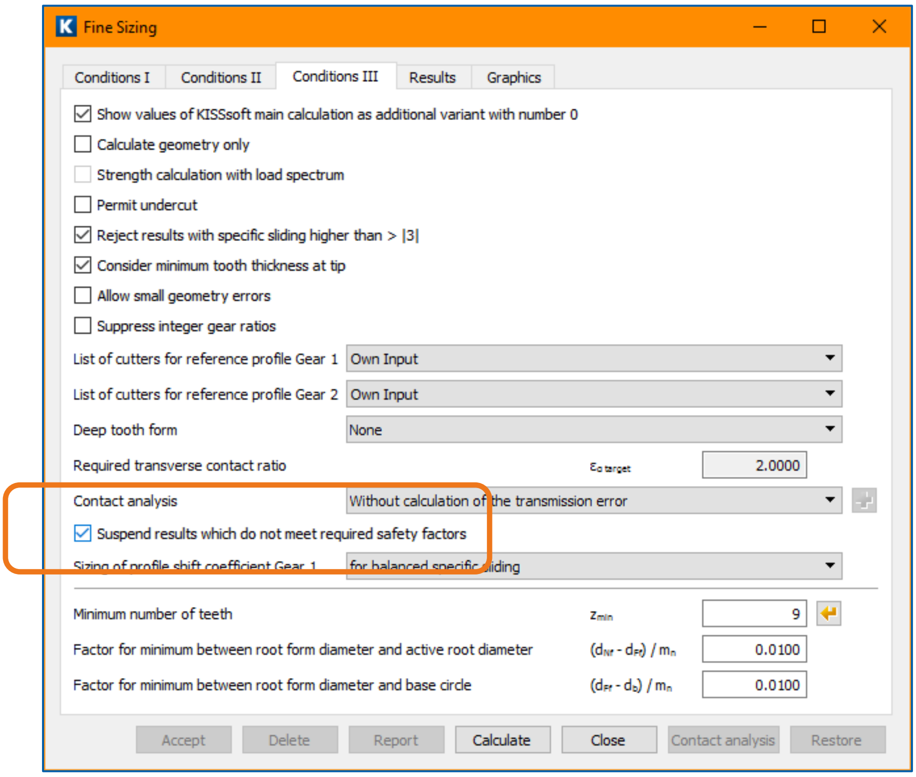
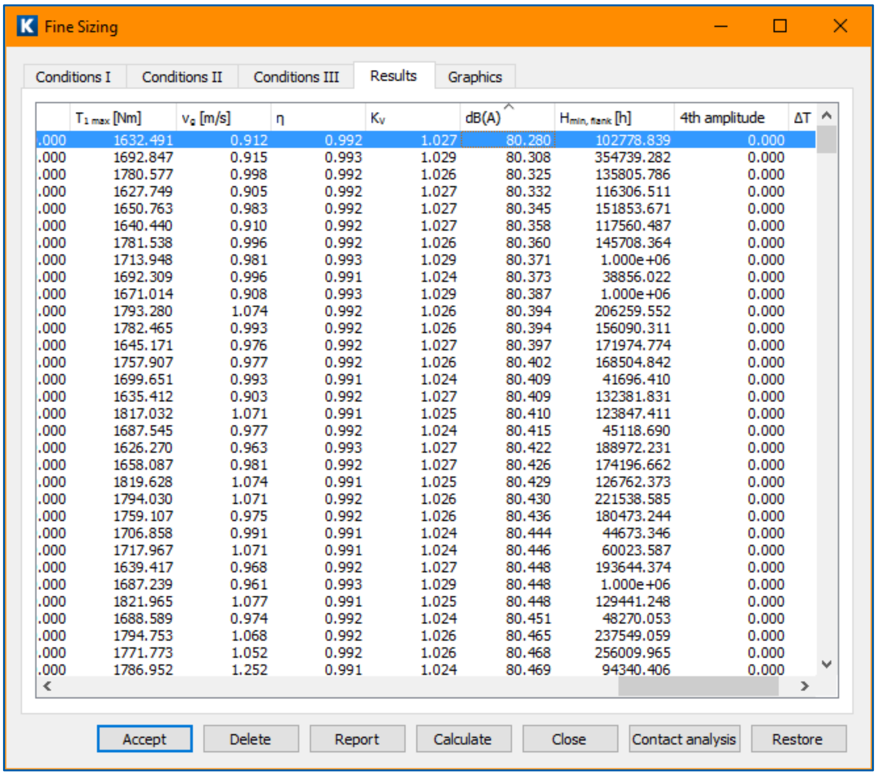


Figure 4.2-2 Setup of the fine sizing function, part 2.

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.



	$T_{1\,max}$ [Nm]	v_g [m/s]	η	K_v	dB(A)	$H_{min,\,flank}$ [h]	4th amplitude	ΔT
.000	1632.491	0.912	0.992	1.027	80.280	102778.839	0.000	
.000	1692.847	0.915	0.993	1.029	80.308	354739.282	0.000	
.000	1780.577	0.998	0.992	1.026	80.325	135805.786	0.000	
.000	1627.749	0.905	0.992	1.027	80.332	116306.511	0.000	
.000	1650.763	0.983	0.992	1.027	80.345	151853.671	0.000	
.000	1640.440	0.910	0.992	1.027	80.358	117560.487	0.000	
.000	1781.538	0.996	0.992	1.026	80.360	145708.364	0.000	
.000	1713.948	0.981	0.993	1.029	80.371	1.000e+06	0.000	
.000	1692.309	0.996	0.991	1.024	80.373	38856.022	0.000	
.000	1671.014	0.908	0.993	1.029	80.387	1.000e+06	0.000	
.000	1793.280	1.074	0.992	1.026	80.394	206259.552	0.000	
.000	1782.465	0.993	0.992	1.026	80.394	156090.311	0.000	
.000	1645.171	0.976	0.992	1.027	80.397	171974.774	0.000	
.000	1757.907	0.977	0.992	1.026	80.402	168504.842	0.000	
.000	1699.651	0.993	0.991	1.024	80.409	41696.410	0.000	
.000	1635.412	0.903	0.992	1.027	80.409	132381.831	0.000	
.000	1817.032	1.071	0.991	1.025	80.410	123847.411	0.000	
.000	1687.545	0.977	0.992	1.024	80.415	45118.690	0.000	
.000	1626.270	0.963	0.993	1.027	80.422	188972.231	0.000	
.000	1658.087	0.981	0.992	1.027	80.426	174196.662	0.000	
.000	1819.628	1.074	0.991	1.025	80.429	126762.373	0.000	
.000	1794.030	1.071	0.992	1.026	80.430	221538.585	0.000	
.000	1759.107	0.975	0.992	1.026	80.436	180473.244	0.000	
.000	1706.858	0.991	0.991	1.024	80.444	44673.346	0.000	
.000	1717.967	1.071	0.991	1.024	80.446	60023.587	0.000	
.000	1639.417	0.968	0.992	1.027	80.448	193644.374	0.000	
.000	1687.239	0.961	0.993	1.029	80.448	1.000e+06	0.000	
.000	1821.965	1.077	0.991	1.025	80.448	129441.248	0.000	
.000	1688.589	0.974	0.992	1.024	80.451	48270.053	0.000	
.000	1794.753	1.068	0.992	1.026	80.465	237549.059	0.000	
.000	1771.773	1.052	0.992	1.026	80.468	256009.965	0.000	
.000	1786.952	1.252	0.991	1.024	80.469	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):

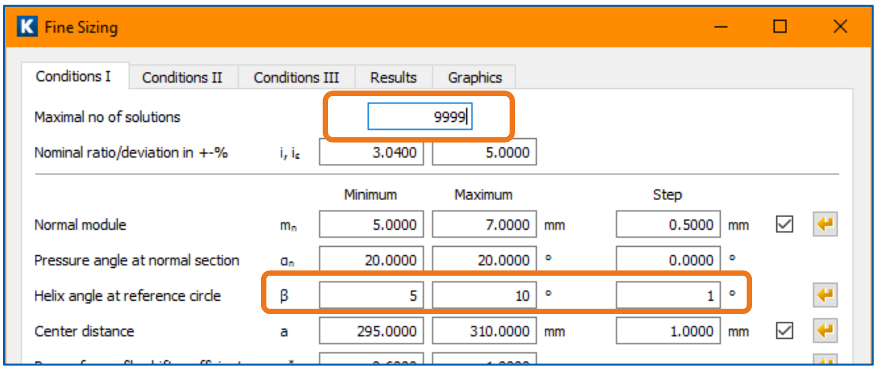


Figure 4.4-1 Defining a range for the helix angle in the fine sizing function.

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.

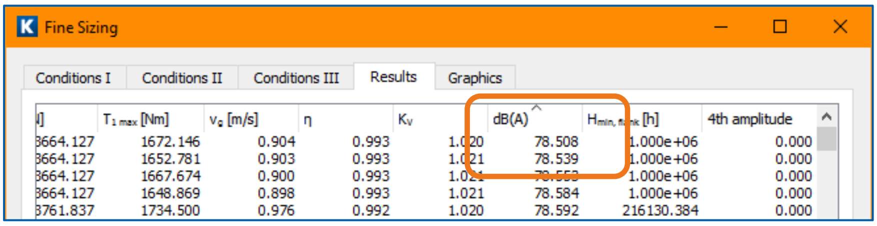


Figure 4.5-1 Resulting sound pressure level in second sizing process.

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 $\varepsilon\alpha$>2.05:

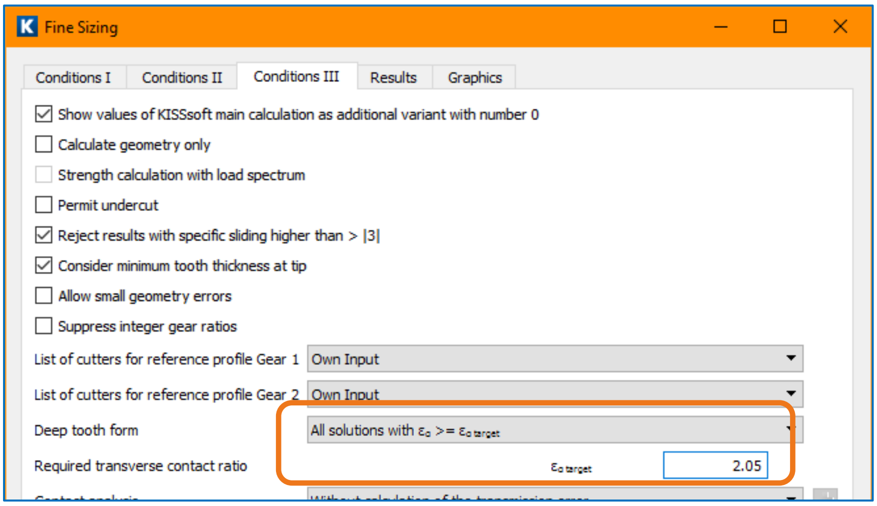


Figure 4.6-1 Setup of the fine sizing function such that gear design has a higher contact ratio.

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:

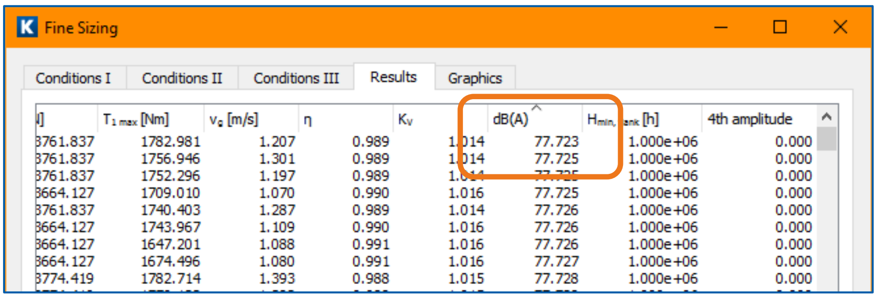


Figure 4.7-1 Resulting sound pressure level in third sizing process.

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.

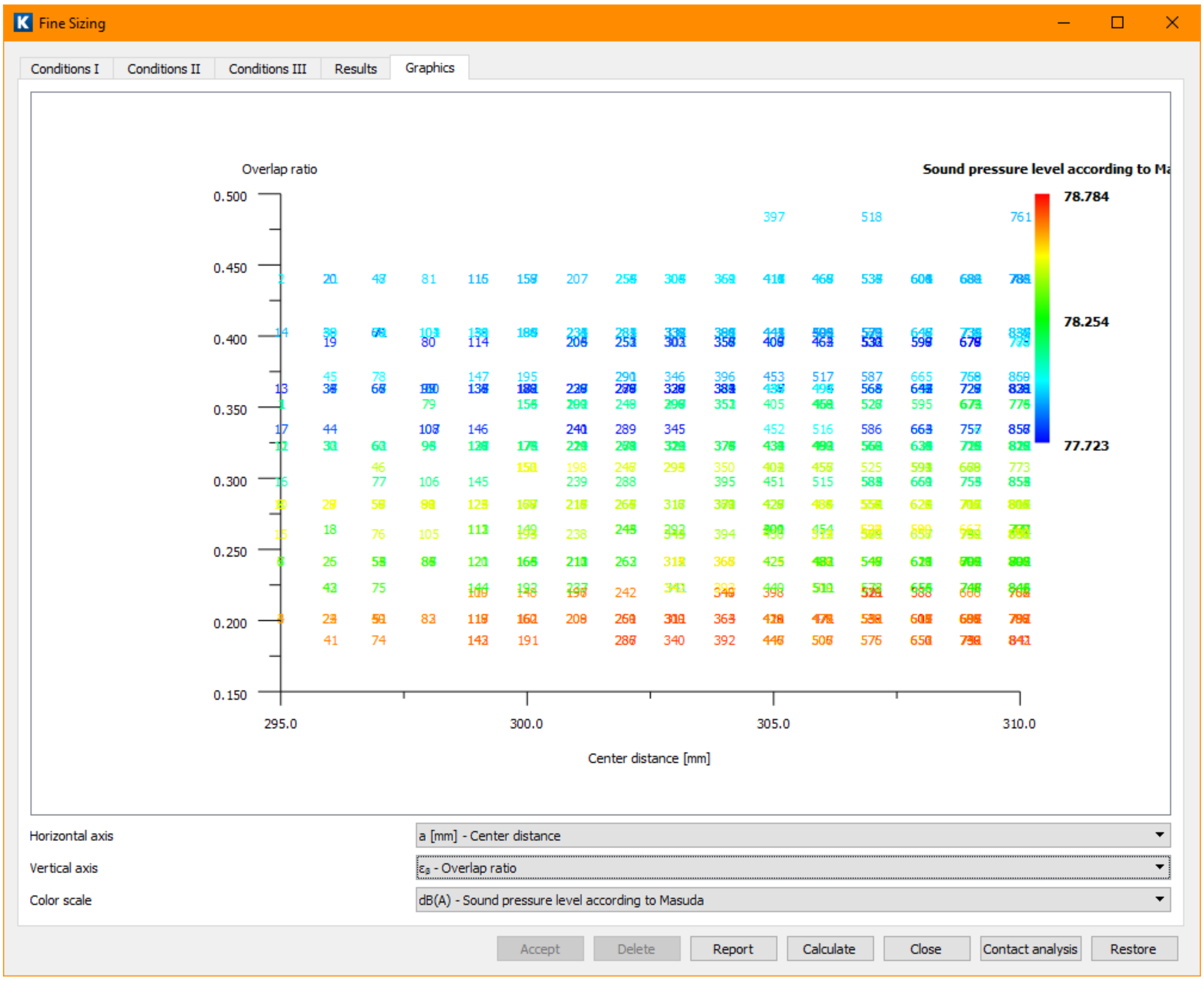


Figure 4.8-1 Display of sound pressure level results in tab “Graphics”.