[35] K-H-V Differential gear design system

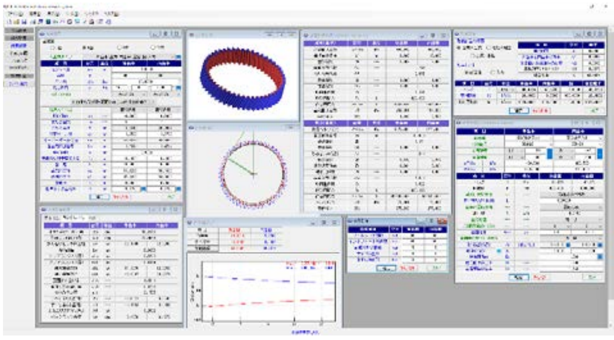


Fig. 35.1 K-H-V Differential gear design system

35.1 Abstract

The K-H-V Differential gear design system is the reduction gear shown in Figure 35.2. The software is a differential reduction (acceleration) mechanism design (three types of gear difference 0, 1 and 2) software for involute gears, and can perform tooth profile design, tooth meshing, sliding ratio, and gear strength calculation. If the difference in the number of teeth is small, involute interference etc. will occur if it is designed with a standard gear with a profile shift of 0. However, with this software, it is possible to calculate gears with combinations of profile shift factor that have a contact ratio of 1 or more and do not generate interference. Please see catalog **[34]** for differential gear software with trochoid curve.

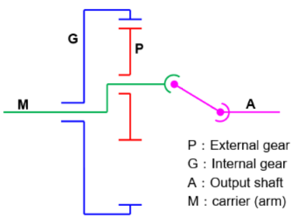


Fig. 35.2 KH-V type reduction mechanism

35.2 Propaty (Basic rack)

As shown in Figure 35.3, set the basic rack and display the actual dimensions of the basic rack set as an auxiliary function.

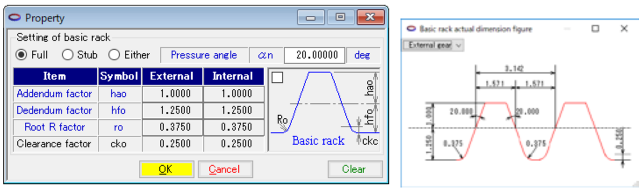


Fig. 35.3 Basic rack

35.2 Gear dimension setting

As shown in Fig. 35.4, select the difference in number of teeth (one tooth difference, two teeth difference, zero tooth difference), and then select the combination (arm fixed / input / output). When the difference in the number of teeth is 0, the tooth shape is drawn with the arm fixed.

After inputting mn, z, αn, β in Fig. 35.4, set the profile shift factor (xn). However, there are innumerable ways of giving profile shift factor, so use the auxiliary function shown in Figure 35.3 to determine combinations with an contact ratio of 1.0 or more and no involute interference. In the case of this example, 55 pieces are displayed. If the profile shift factor No.26 (x_{n1} = -0.6, ● circle in the figure) is selected from these, the specifications will be determined as shown in Fig. 35.7. The profile shift factor, contact ratio and gear dimensions can be confirmed and selected in the table in Figure 35.6.

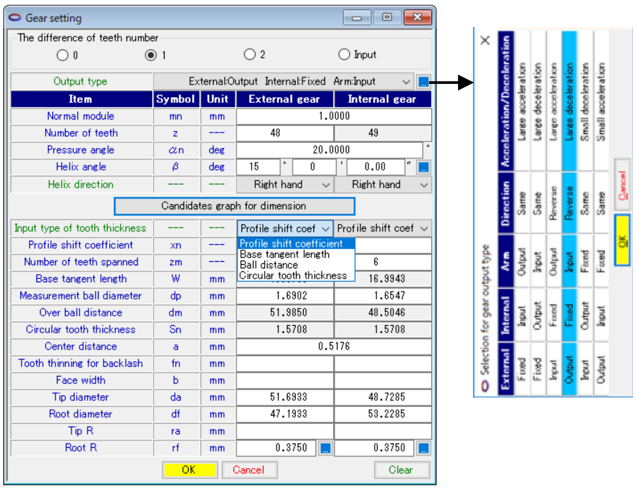


Fig. 35.4 Gear specifications 1

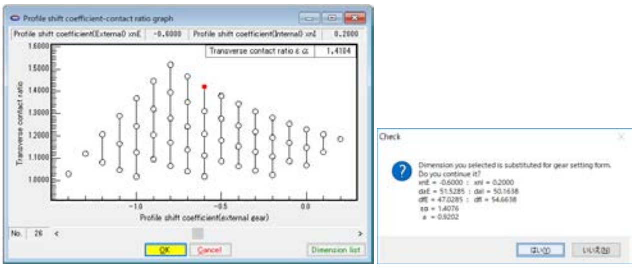


Fig. 35.5 Auxiliary function (x_n and ε)

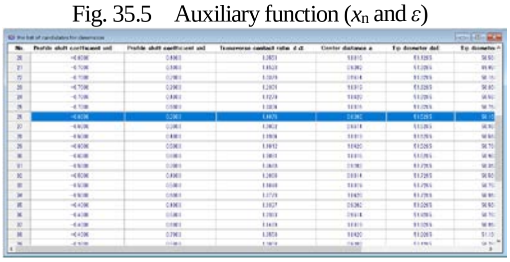


Fig. 35.6 Auxiliary function ((No. 27, x_n and ε)

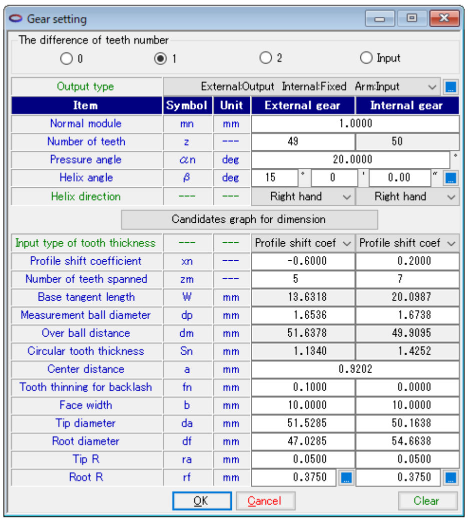
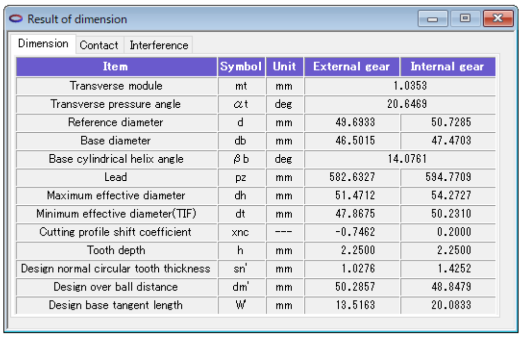


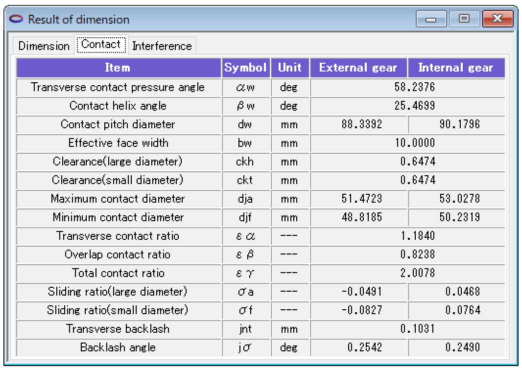
Fig. 35.7 Gear specifications 2

When the gear specifications in Fig. 35.7 are confirmed, dimensions and interference calculation results are displayed as in Fig. 35.8 to Fig. 35.10. In the case of this example, although the trimming has occurred, the calculation will proceed as it is because there is no influence on the mesh.



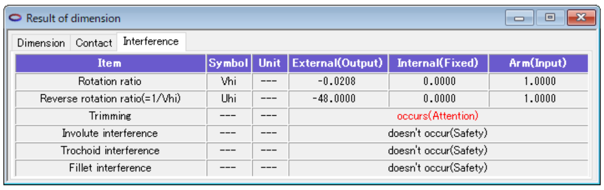
Item	Symbol	Unit	External gear	Internal gear
Transverse module	mt	mm	1.0353	
Transverse pressure angle	αt	deg	20.6469	
Reference diameter	d	mm	49.6933	50.7285
Base diameter	db	mm	46.5015	47.4703
Base cylindrical helix angle	βb	deg	14.0761	
Lead	pz	mm	582.6327	594.7709
Maximum effective diameter	dh	mm	51.4712	54.2727
Minimum effective diameter(TIF)	dt	mm	47.8675	50.2310
Cutting profile shift coefficient	xnc	---	-0.7462	0.2000
Tooth depth	h	mm	2.2500	2.2500
Design normal circular tooth thickness	sn'	mm	1.0276	1.4252
Design over ball distance	dm'	mm	50.2857	48.8479
Design base tangent length	W	mm	13.5163	20.0833

Fig. 35.8　Gear basic dimensions



Item	Symbol	Unit	External gear	Internal gear
Transverse contact pressure angle	αw	deg	58.2376	
Contact helix angle	βw	deg	25.4699	
Contact pitch diameter	dw	mm	88.3392	90.1796
Effective face width	bw	mm	10.0000	
Clearance(large diameter)	ckh	mm	0.6474	
Clearance(small diameter)	ckt	mm	0.6474	
Maximum contact diameter	dja	mm	51.4723	53.0278
Minimum contact diameter	djf	mm	48.8185	50.2319
Transverse contact ratio	εα	---	1.1840	
Overlap contact ratio	εβ	---	0.8238	
Total contact ratio	εγ	---	2.0078	
Sliding ratio(large diameter)	σa	---	-0.0491	0.0468
Sliding ratio(small diameter)	σf	---	-0.0827	0.0764
Transverse backlash	jnt	mm	0.1031	
Backlash angle	jσ	deg	0.2542	0.2490

Fig. 35.9　Gear contact dimensions



Item	Symbol	Unit	External(Output)	Internal(Fixed)	Arm(Input)
Rotation ratio	Vhi	---	-0.0208	0.0000	1.0000
Reverse rotation ratio(=1/Vhi)	Uhi	---	-48.0000	0.0000	1.0000
Trimming	---	---	occurs(Attention)		
Involute interference	---	---	doesn't occur(Safety)		
Trochoid interference	---	---	doesn't occur(Safety)		
Fillet interference	---	---	doesn't occur(Safety)		

Fig. 35.10　Gear interference

35.4　Tooth profile

The tooth profile of the gear specifications (Fig. 35.7) can be drawn as shown in Fig. 35.11. Figure 34.12 shows a close-up view of the tooth profile (A) and (B). Also, distance measurement is possible as shown in Figure 34.12 (b).　Figure 35.14 shows teeth rendering.

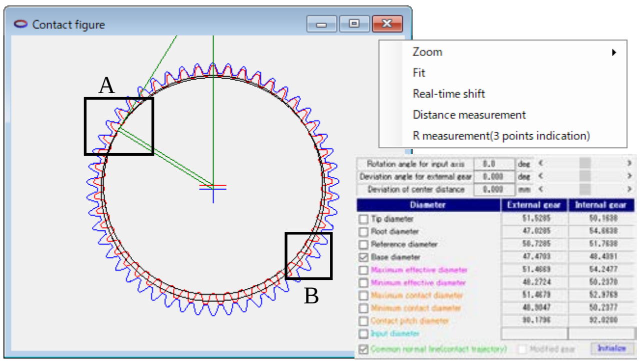
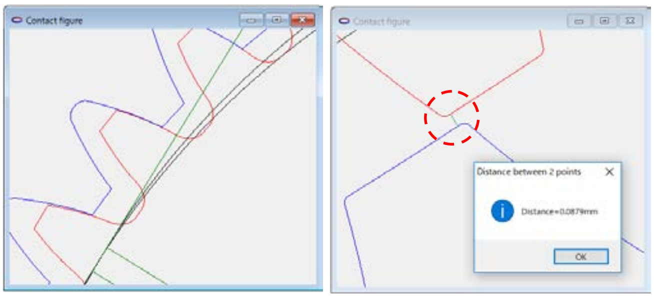


Fig. 35.11　Gear mesh diagram



(a) A part　　　　　(b) B part

Fig. 35.12　Gear mesh diagram, distance measurement

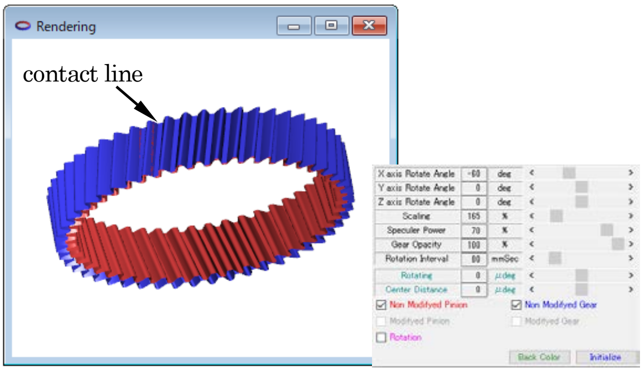


Fig. 35.13　Tooth rendering, tooth profile, rotation

35.5　Tooth profile / tooth lead modification (option)

When modifying tooth profile and tooth lead, you can apply modifications as shown in Fig. 35.149～35.16. In Figure 35.16, you can enter a specified number of points (maximum = 50) to be modified, and you can also enter an arc pattern. Then, the contact of the modified tooth profile can be confirmed as shown in Figure 35.17.

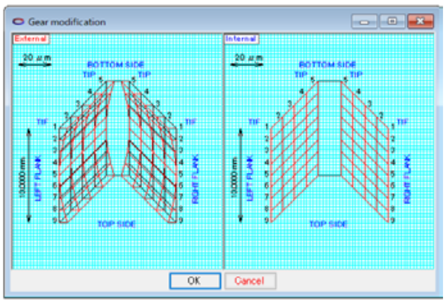


Fig. 35.14　Tooth rendering, tooth profile and topo-graph

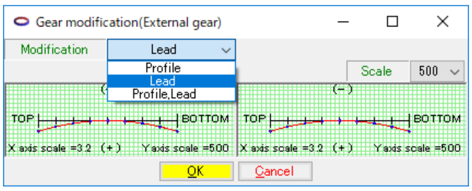


Fig. 35.15　Tooth lead input example

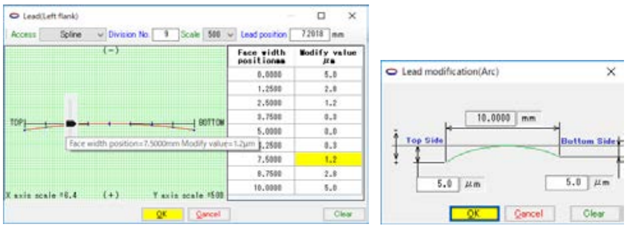


Fig. 35.16　Tooth lead input and arc input example

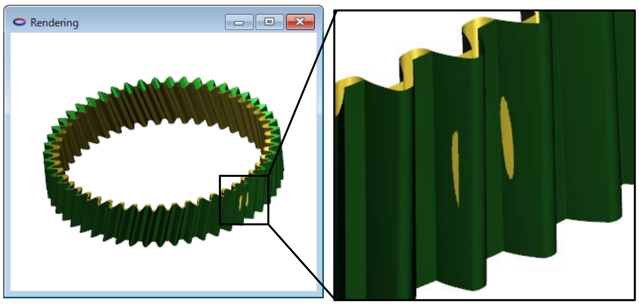


Fig. 35.17 Tooth rendering, modified tooth form

35.6 Sliding ratio

The sliding ratio of this example gear is shown in the dimension calculation result of Fig. 35.9, and the change of the sliding ratio at the tooth profile position (roll angle) is shown in Fig. 35.18.

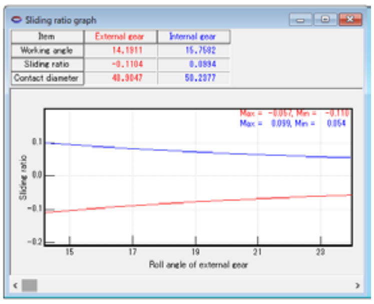


Fig. 35.18 Sliding ratio

35.7 Gear strength

For gear strength calculation, enter the coefficient of friction, torque and rotational speed on the strength setting screen as shown in Figure 35.19. In this example, when the coefficient of friction is 0.10, the input torque of the arm is 1 (Nm), and the rotational speed is 1000 min-1, the torque and rotational speed of the pinion and gear are displayed with the **[OK]** button.

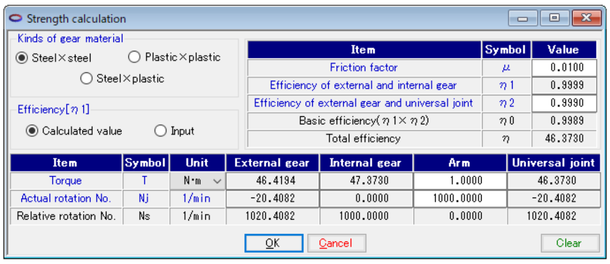


Fig. 35.19 Gear strength calculation specification setting

The input screen of gear strength specifications (materials, factors) is shown in Figure 35.21. Material selection can be made from the table in Figure 35.20, but you can also input σ_{Flim} and σ_{Hlim} directly. Figure 35.22 shows the gear strength results.

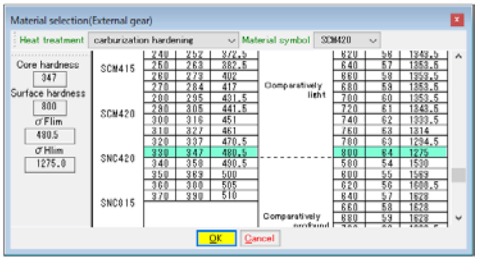


Fig. 35.20 Selection of material

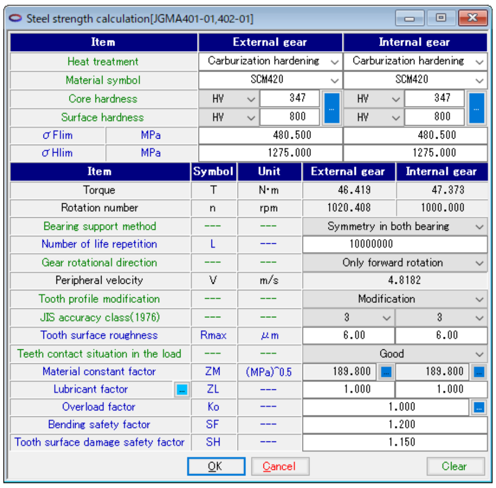


Fig. 35.21 Gear strength calculation (strength specification)

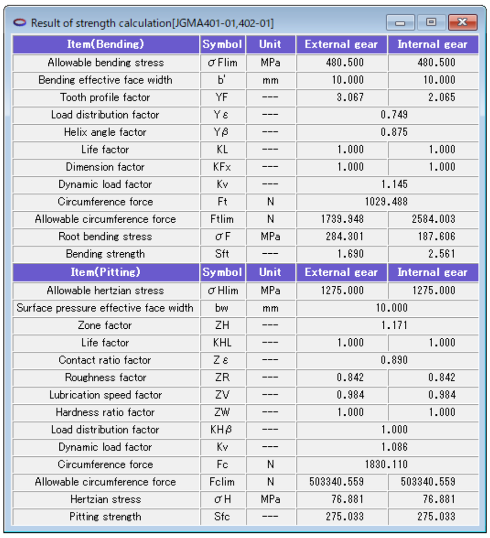


Fig. 35.22 Gear strength result

35.8 Tooth profile output

The generated tooth profile can be output as CAD data. Figures 35.24 and 35.25 show examples of drawing CAD data output by the tooth profile output function shown in Figure 35.23.

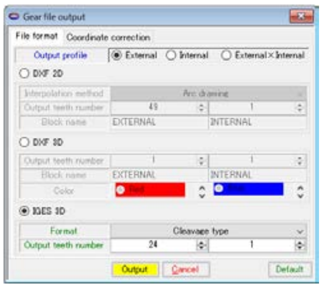


Fig. 35.23 Tooth profile output

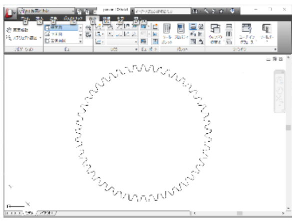


Fig. 35.24 CAD example (2D)

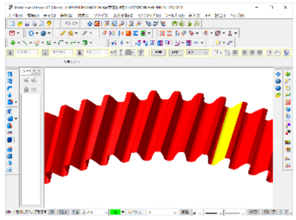


Fig. 35.25 CAD example (3D)

35.9 Design example of the difference in number of teeth 0

An example of the gear mechanism (K-H-V) connected in two stages is shown in Figure 35.26. The 1st gear is an external and internal gear with one tooth gap (internal gear fixed, external gear output, arm input). The 2nd stage (follower side) is an external / internal gear with a zero-tooth difference. By connecting the 1st stage external gear and the 2nd stage internal gear, output can be made on the same axis as the input axis.

In Figure 35.26, none of the external gear, internal gear and arms in the second step, with 0-tooth difference, is fixed. The rotation ratio of the driven side of the green (differential external gear + internal gear with zero tooth difference) and the external gear (red) of the red is the same. Therefore, it is possible to take out the reduction ratio of the differential gear coaxially. The following is a design example of a zero-tooth differential gear.

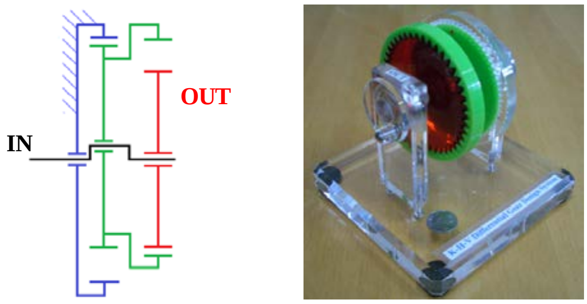
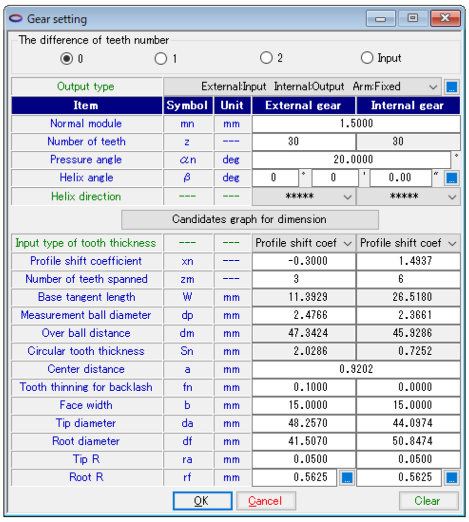


Fig. 35.26 Mechanism (1st stage differential, 2nd stage z_1=z_2), model

In Fig. 35.27, select 0 in gear number difference, and set the module, number of teeth, pressure angle and helix angle. Next, select No. 25 out of 25 items that fit in the auxiliary function (Fig. 35. 28). The dimensions of this gear are shown in Fig. 35.29 and in Fig. 35.30. Also, Fig. 35.31 shows an enlarged view of the meshing parts C and D in Fig. 35.30. Teeth rendering is shown in Figure 35.32.



Gear setting

The difference of teeth number: ◉ 0 ○ 1 ○ 2 ○ Input

Item	Symbol	Unit	External gear	Internal gear
Output type			External:Input Internal:Output Arm:Fixed	
Normal module	mn	mm	1.5000	
Number of teeth	z	---	30	30
Pressure angle	αn	deg	20.0000	
Helix angle	β	deg	0 ° 0 ' 0.00 "	
Helix direction	---	---	*****	*****
Candidates graph for dimension				
Input type of tooth thickness	---	---	Profile shift coef	Profile shift coef
Profile shift coefficient	xn	---	-0.3000	1.4937
Number of teeth spanned	zm	---	3	6
Base tangent length	W	mm	11.3929	26.5180
Measurement ball diameter	dp	mm	2.4766	2.3661
Over ball distance	dm	mm	47.3424	45.9286
Circular tooth thickness	Sn	mm	2.0286	0.7252
Center distance	a	mm	0.9202	
Tooth thinning for backlash	fn	mm	0.1000	0.0000
Face width	b	mm	15.0000	15.0000
Tip diameter	da	mm	48.2570	44.0974
Root diameter	df	mm	41.5070	50.8474
Tip R	ra	mm	0.0500	0.0500
Root R	rf	mm	0.5625	0.5625

OK Cancel Clear

Fig. 35.27 Gear specification setting

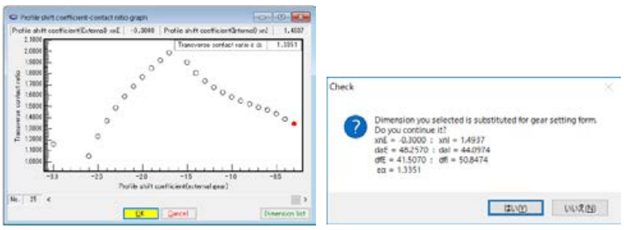
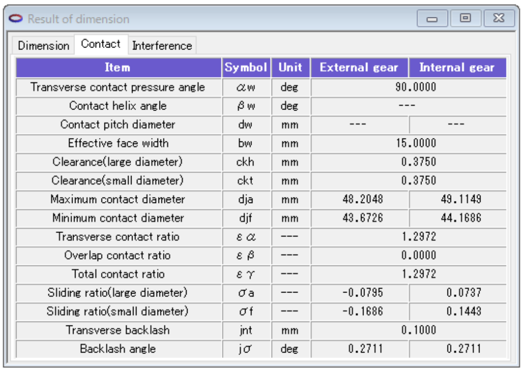


Fig. 35.28 Auxiliary function (x_n and contact ratio)



Result of dimension

Dimension | Contact | Interference

Item	Symbol	Unit	External gear	Internal gear
Transverse contact pressure angle	αw	deg	90.0000	
Contact helix angle	βw	deg	---	
Contact pitch diameter	dw	mm	---	---
Effective face width	bw	mm	15.0000	
Clearance(large diameter)	ckh	mm	0.3750	
Clearance(small diameter)	ckt	mm	0.3750	
Maximum contact diameter	dja	mm	48.2048	49.1149
Minimum contact diameter	djf	mm	43.6726	44.1686
Transverse contact ratio	εα	---	1.2972	
Overlap contact ratio	εβ	---	0.0000	
Total contact ratio	εγ	---	1.2972	
Sliding ratio(large diameter)	σa	---	-0.0795	0.0737
Sliding ratio(small diameter)	σf	---	-0.1686	0.1443
Transverse backlash	jnt	mm	0.1000	
Backlash angle	jσ	deg	0.2711	0.2711

Fig. 35.29 Gear contact dimensions

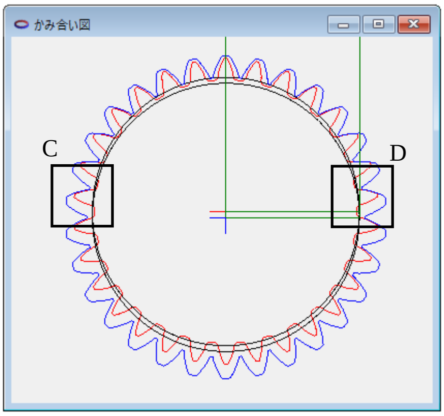
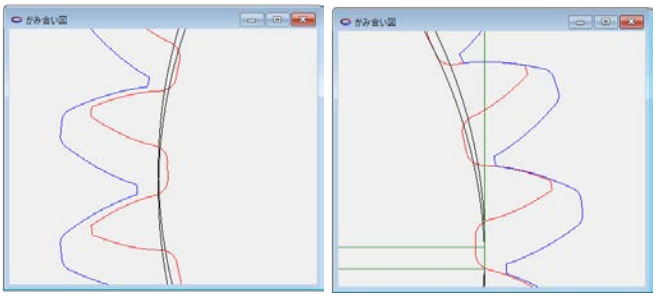


Fig. 35.30 Gear mesh diagram (z_1=z_2)



(a) A part (b) B part

Fig. 35.31 Gear mesh diagram (zoom)

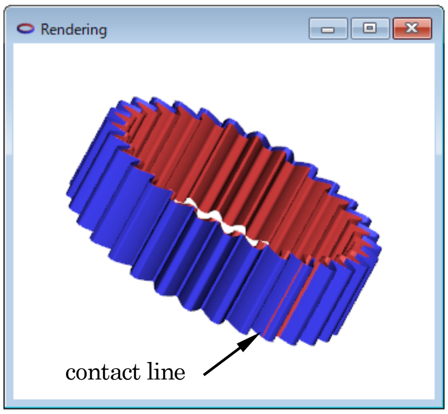


Fig. 35.32 Teeth rendering