[20] Face gear design system iii English version

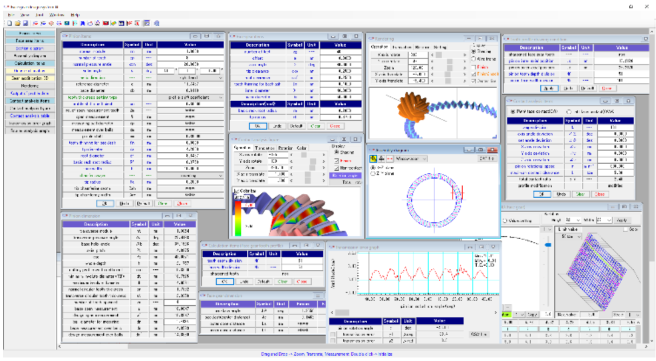


Fig.20.1 Face gear design system iii

20.1 Abstract

This software is a new product of Face Gear Design System. Functions that have been handled as options until now are also included in the basic software. In addition, the axis angle can be calculated other than 90 °, and it corresponds to one pinion teeth number (small number of teeth number option). Based on the tooth form (involute) of the pinion, this software determines the three-dimensional tooth form of the face gear engaging with it. In addition, the function of tooth contact (contact distance), actual mesh ratio, transmission error, slip speed, and slip ratio at the time of engagement when adding an axis angle error was also added. Figure 20.1 shows the entire software screen.

20.2 Software structure

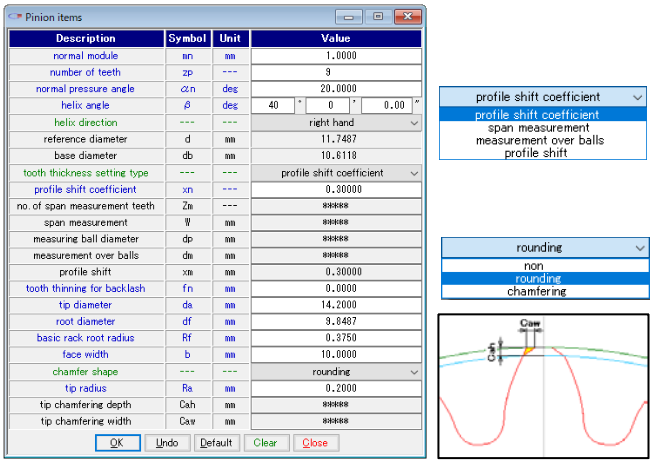
Table 20.1 shows the software configuration. The ○ mark in the table is included in the basic software and ◎ is optional.

Table 20.1 software structure

No.	Item	Clause	Structure
1	Pinion items	20.3	○
2	Face gear items	20.4	○
3	Assembly drawing	20.4	○
4	Section	20.5	○
5	Tooth profile	20.6	○
6	Profile modification	20.7	○
7	Arbitrary modification	20.7	○
8	Rendering	20.8	○
9	Contact analysis	20.9	○
10	Tooth profile data(3D-IGES)	20.10	○
11	Small number of teeth	20.12	◎
12	Property	20.13	○

20.3 Pinion items

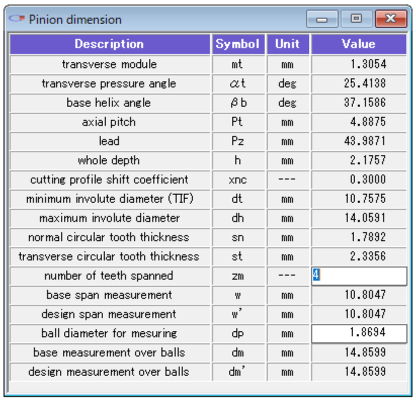
Figure 20.2 shows the setting screen of the pinion specifications. You can input 6 to 99 pinion teeth, but you can enter 1 to 5 teeth as a function of small number of teeth (option). A design example of a small number of teeth is shown in Section 20.12. The helix angle can be set from 0° to 80°. Also, with the tooth thickness input method, you can choose from profile shift coefficient, tooth thickness, ODB and profile shift amount. And, the chamfer can be set with C face and R face. Figure 20.3 shows the calculation result of pinion dimensions. Although the theoretical value is displayed for the over ball diameter, it can be changed according to the ball diameter to be used.



Pinion items

Description	Symbol	Unit	Value
normal module	mn	mm	1.0000
number of teeth	zp	---	9
normal pressure angle	αn	deg	20.0000
helix angle	β	deg	40 ° 0 ' 0.00 "
helix direction	---	---	right hand
reference diameter	d	mm	11.7487
base diameter	db	mm	10.6118
tooth thickness setting type	---	---	profile shift coefficient
profile shift coefficient	xn	---	0.30000
no. of span measurement teeth	Zm	---	*****
span measurement	W	mm	*****
measuring ball diameter	dp	mm	*****
measurement over balls	dm	mm	*****
profile shift	xm	mm	0.30000
tooth thinning for backlash	fn	mm	0.0000
tip diameter	da	mm	14.2000
root diameter	df	mm	9.8487
basic rack root radius	Rf	mm	0.3750
face width	b	mm	10.0000
chamfering shape	---	---	rounding
tip radius	Ra	mm	0.2000
tip chamfering depth	Cah	mm	*****
tip chamfering width	Caw	mm	*****

Fig.20.2 Pinion specification



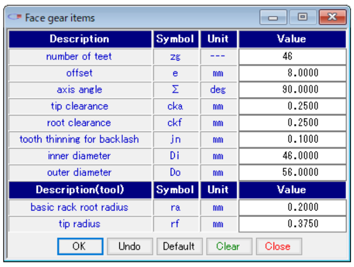
Pinion dimension

Description	Symbol	Unit	Value
transverse module	mt	mm	1.3054
transverse pressure angle	αt	deg	25.4138
base helix angle	βb	deg	37.1586
axial pitch	Pt	mm	4.8875
lead	Pz	mm	43.9871
whole depth	h	mm	2.1757
cutting profile shift coefficient	xnc	---	0.3000
minimum involute diameter (TIF)	dt	mm	10.7575
maximum involute diameter	dh	mm	14.0591
normal circular tooth thickness	sn	mm	1.7892
transverse circular tooth thickness	st	mm	2.3356
number of teeth spanned	zm	---	4
base span measurement	w	mm	10.8047
design span measurement	w'	mm	10.8047
ball diameter for mesuring	dp	mm	1.8694
base measurement over balls	dm	mm	14.8599
design measurement over balls	dm'	mm	14.8599

Fig. 20.3 Pinion dimension

20.4 Face gear items

Figure 20.4 shows the face gear specification setting screen. The shaft angle input range is 45° to 135°. Giving an offset strongly affects the generation of the tooth form of the face gear, so a tooth tip will occur on the outer diameter side of the face gear. Also, undercuts tend to occur on the inner diameter side. Therefore, caution is required at the time of input, but input is easy because it shows standard value and limit value. The "cutting edge R" shows the cutting-edge R of the tool when generating the face gear. Definitions of offset, inner diameter, and outer diameter are shown in Figure 20.5, and the dimensional results and assembled drawings are shown in Figure 20.6 and Figure 20.7. There are restrictions on offset and helix angle.



Face gear items

Description	Symbol	Unit	Value
number of teet	zg	---	46
offset	e	mm	8.0000
axis angle	Σ	deg	90.0000
tip clearance	cka	mm	0.2500
root clearance	ckf	mm	0.2500
tooth thinning for backlash	jn	mm	0.1000
inner diameter	Di	mm	46.0000
outer diameter	Do	mm	56.0000
Description(tool)	**Symbol**	**Unit**	**Value**
basic rack root radius	ra	mm	0.2000
tip radius	rf	mm	0.3750

Fig. 20.4 Face gear specification

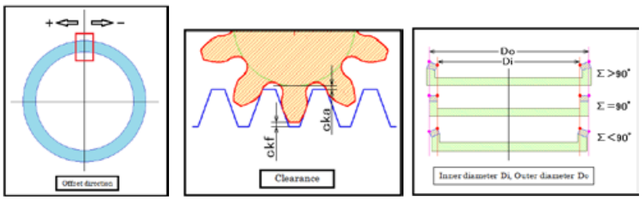
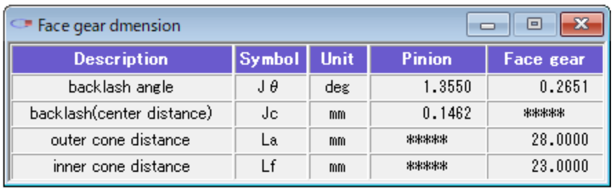


Fig. 20.5 Offset, clearance, tip diameter



Face gear dmension

Description	Symbol	Unit	Pinion	Face gear
backlash angle	Jθ	deg	1.3550	0.2651
backlash(center distance)	Jc	mm	0.1462	*****
outer cone distance	La	mm	*****	28.0000
inner cone distance	Lf	mm	*****	23.0000

Fig. 20.6　gear dimension

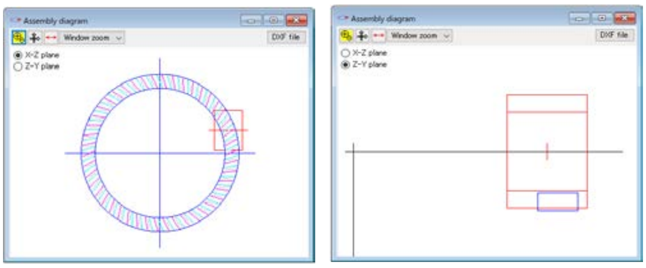


Fig. 20.7　Assembled drawings

20.5　Sectional view

Figure 20.8 shows pinion tooth profile. However, the tooth profile of the red line of the pinion is the tooth profile based on the pinion specifications set in Figure 20.2, and the green line is the blade profile of the tool to process the gear.

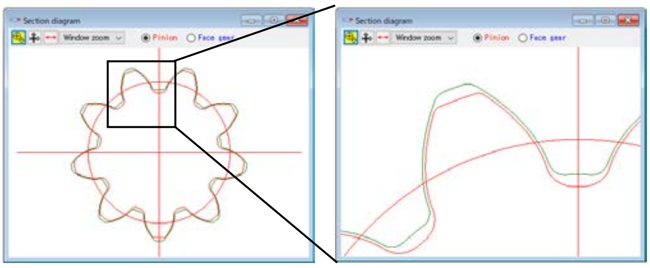


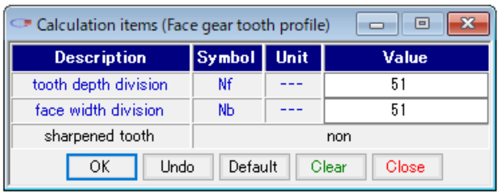
Fig. 20.8　Pinion tooth profile

20.6　Tooth profile calculation

When calculating the gear tooth profile, set the tooth profile division number (see Figure 20.9) and the tooth width division number (see Figure 20.11).

At this time, the presence or absence of occurrence in the edge of the blade is displayed in Figure 20.9. If a cutting edge is generated, it is impossible to correctly generate the tooth profile of the face gear.

Figure 20.10 is displayed after calculating the tooth form. The definition of the pinion and gear position (Js, Je) is shown in Figure 20.12, and the gear tooth profile (cross section) is shown in Figure 20.13.

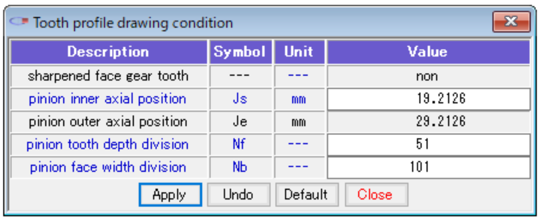


Calculation items (Face gear tooth profile)

Description	Symbol	Unit	Value
tooth depth division	Nf	---	51
face width division	Nb	---	51
sharpened tooth			non

OK　Undo　Default　Clear　Close

Fig. 20.9　Profile division number (Face gear)



Tooth profile drawing condition

Description	Symbol	Unit	Value
sharpened face gear tooth	---	---	non
pinion inner axial position	Js	mm	19.2126
pinion outer axial position	Je	mm	29.2126
pinion tooth depth division	Nf	---	51
pinion face width division	Nb	---	101

Apply　Undo　Default　Close

Fig. 20.10　Calculation result

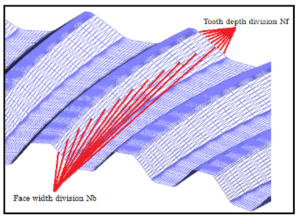


Fig. 20.11division of tooth profile

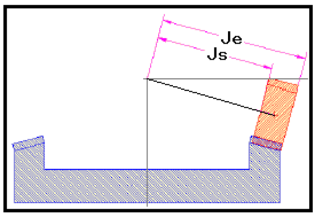
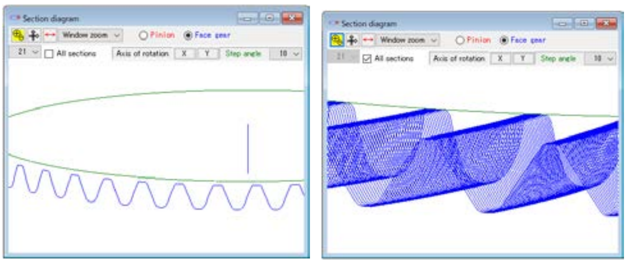


Fig. 20.12　position of the pinion



(a) No.21section profile　　(b) profile (No.1～51)

Fig. 20.13　Face gear profile (section)

20.7　Tooth profile / lead modification

The tooth profile and the lead modification can be given as a fixed form as shown in Figures 20.14 to 20.16, and the set modification can be displayed as shown in Figure 20.16. In addition, as for the retouching set as a fixed form, as shown in Figure 20.17, data can be transferred to arbitrary modification.

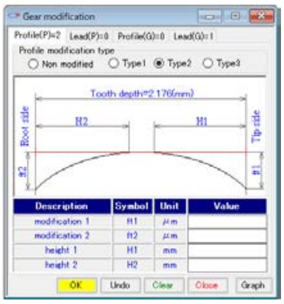


Fig. 20.14　profile modification

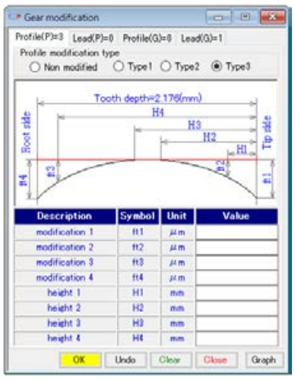


Fig. 20.15　lead modification

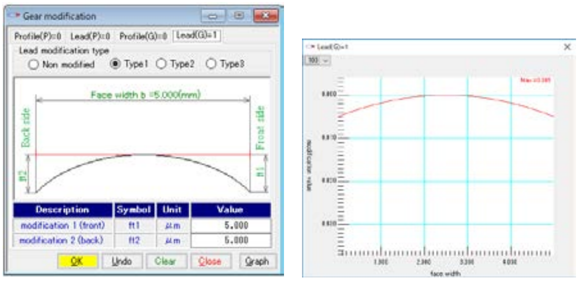
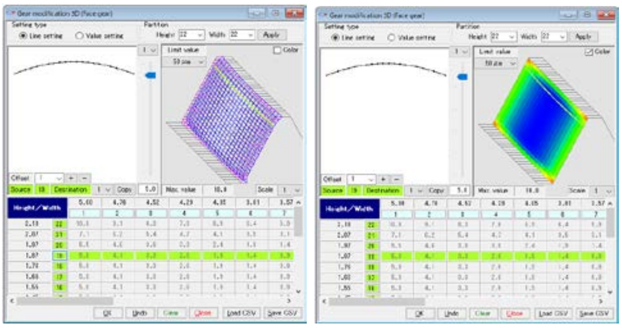


Fig. 20.16　lead modification (sample)

In the arbitrary modification shown in Figure 20.17, it is easy to divide the tooth surface and change the data at each position, and you can express the modification as a color distribution as shown in Figure 20.17 (b). In this example, as shown in Fig. 20.17, the pinion is assumed to be unmodified, and the tooth surface modification is given to the gear. The tooth surface modification set here can be output as a CSV file, and you can also import a CSV file created elsewhere.

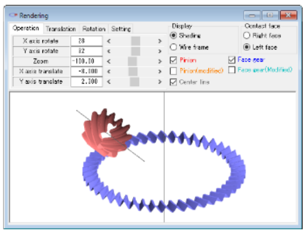


(a) tooth surface (b) color distribution

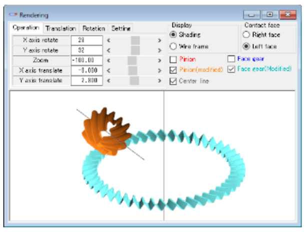
Fig. 20.17 Toth surface modification, Face gear (sample)

20.8 Tooth profile rendering

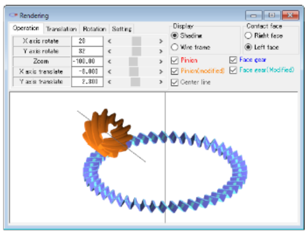
The generated tooth profile can be displayed as shown in Figure 20.18. In order to check the contact of teeth, it is possible to calculate the contact of the teeth by giving an error to the automatic rotation function, rotation correction and the shaft angle.



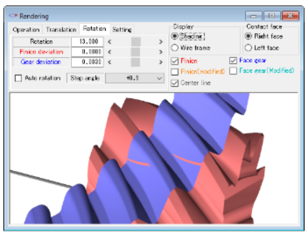
(a) theory tooth profile



(b) modified tooth profile



(c) theory and modified profile

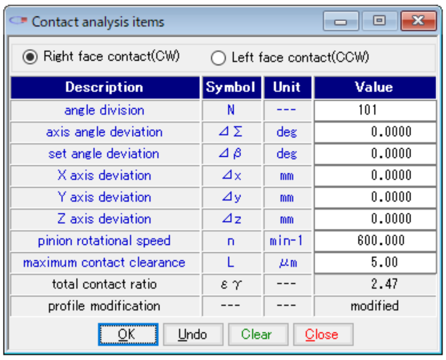


(d) contact line

Fig. 20.18 Tooth profile rendering

20.9 Contact analysis of tooth surface

In figure 20.19 setting the contact analysis and pressing [OK], we will calculate transmission error analysis, tooth contact (contact distance) and slip speed of the generated tooth profile.



Contact analysis items

◉ Right face contact(CW) ○ Left face contact(CCW)

Description	Symbol	Unit	Value
angle division	N	---	101
axis angle deviation	⊿Σ	deg	0.0000
set angle deviation	⊿β	deg	0.0000
X axis deviation	⊿x	mm	0.0000
Y axis deviation	⊿y	mm	0.0000
Z axis deviation	⊿z	mm	0.0000
pinion rotational speed	n	min-1	600.000
maximum contact clearance	L	μm	5.00
total contact ratio	εγ	---	2.47
profile modification	---	---	modified

OK Undo Clear Close

Fig. 20.19 Contact analysis (setting)

Then consider the tooth surface modification and calculate the total meshing ratio ($\varepsilon\gamma$ = 2.29 in this example) based on the contact ratio. The transmission error analysis result (TE = 0.19 μm) is shown in Figure 20.20, and the Fourier analysis result is shown in Figure 21.21.

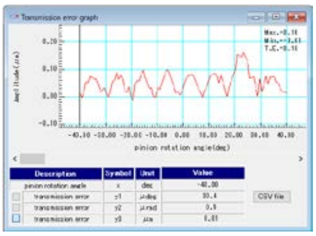


Fig. 20.20 Transmission error

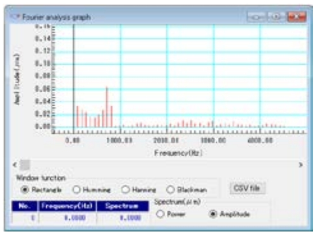
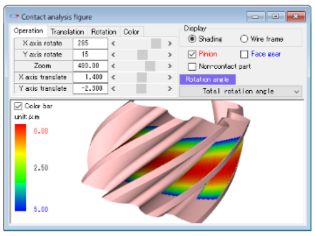
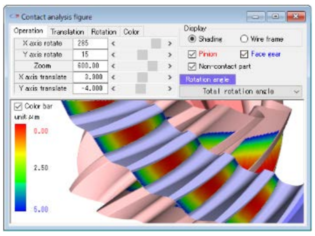


Fig. 20.21 Fourier analysis

The tooth contact analysis (contact distance), sliding speed, and slip ratio are shown in Figures 20.22 to 20.24. In this example, since the tooth surface modification is given to the gear in Fig. 20.17, it is understood that the contact is weakened at both ends of the tooth surface in Fig. 20.22. Also, since the difference in slippage between the face gear and the inside of the gear becomes large, the sliding speed can be confirmed in Fig. 20.23 and Fig. 20.25. The transmission error and the sliding rate (rate) can be analyzed even when giving shaft mounting error, and these can be analyzed for both tooth flanks.

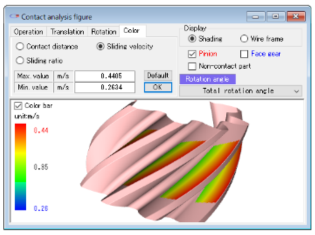


(a) pinion

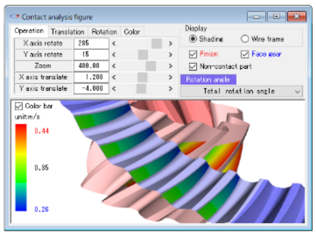


(b) face gear

Fig. 20.22 Contact analysis (contact length)

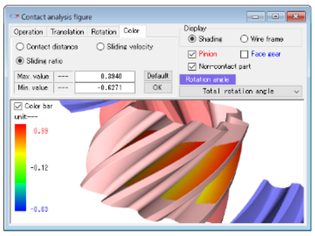


(a) pinion

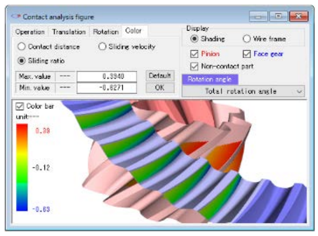


(b) face gear

Fig. 20.23 Sliding speed



(a) pinion



(b) face gear

Fig. 20.24 Sliding ratio

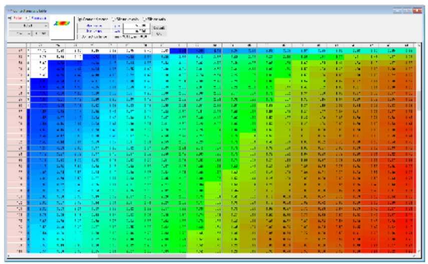


Fig. 20.25 Contact analysis (cell display)

20.10 Tooth Profile Output

The generated tooth profile can be output in Figure 20.26. Figure

20.27 shows an example of outputting the tooth profile of Figure 20.18 with 3D-IGES and drawing with CAD.

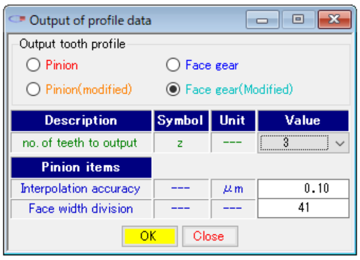
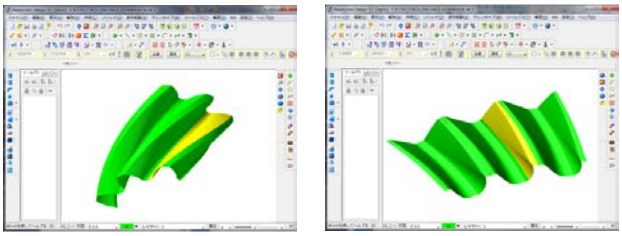


Fig. 20.26 Output profile data



(a) pinion (b) face gear

Fig. 20.27 CAD drawing (sample)

20.11 Examples of axis angle Σ = 120 ° and Σ = 70 °

Figures 20.29 to 20.31 show calculation examples when the axis angle is Σ = 120° as shown in Figure 20.28 with the same pinion and gear specifications.

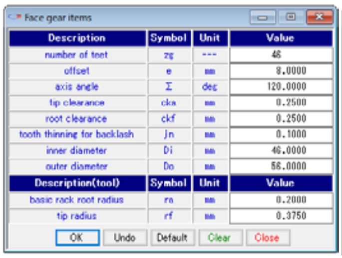


Fig. 20.28 Face gear specification

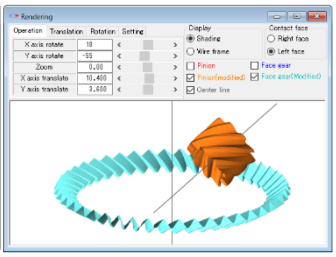


Fig. 0.29 Tooth profile rendering

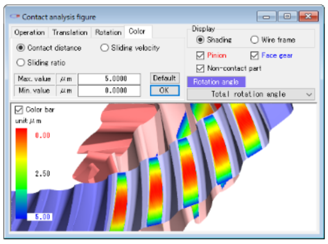


Fig. 20.30 Contact length

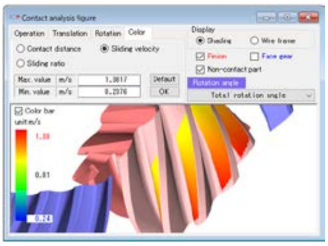


Fig. 20.31 Sliding speed

In addition, the calculation example when the axis angle is Σ =70° as shown in Figure 20.32 with the same pinion and gear specifications is shown below.

Fig. 20.32 Face gear specification

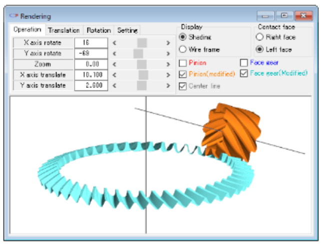


Fig. 20.33 Tooth profile rendering

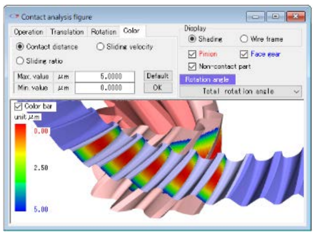


Fig. 20.34 Contact length

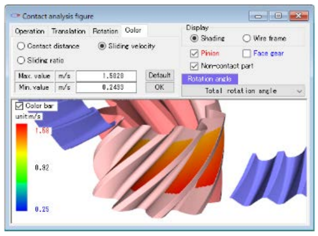


Fig. 20.35 Sliding speed

20.12 Small number of teeth (option)

To obtain a high reduction ratio, you can set the number of pinion teeth z_1=1. Here is an example where z_1 = 2 and the number of gear teeth is z_2 =51. Even in the case of a small number of teeth, it is possible to design the shaft angle other than 90° as shown in Figure 20.28.

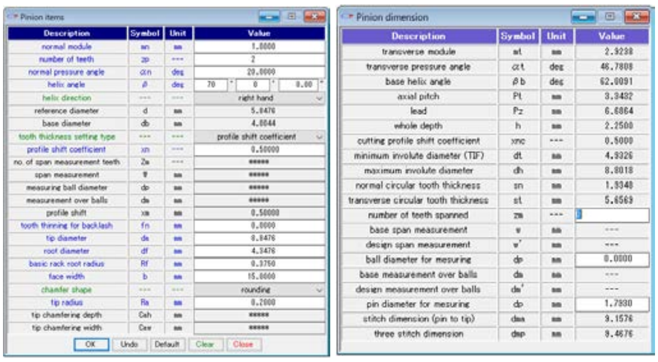


Fig. 20.36 Pinion specification and dimension

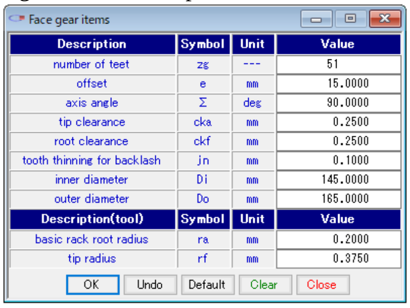


Fig. 20.37 Face gear specification

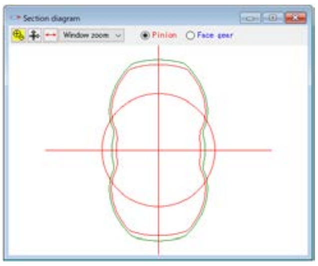


Fig. 20.38 Pinion tooth profile

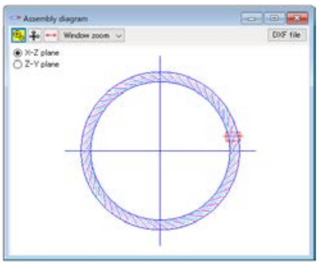
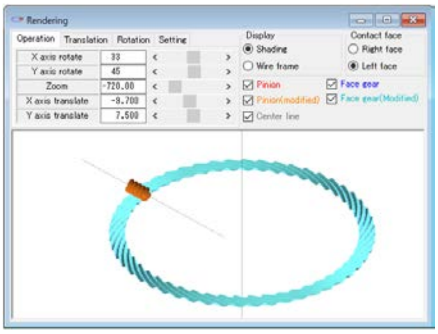


Fig. 20.39 Assembled drawings



z_1=2, z_2=51, Σ=90°, offset=15

Fig. 20.40 Tooth profile rendering

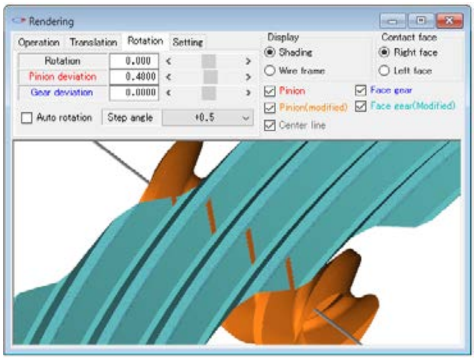
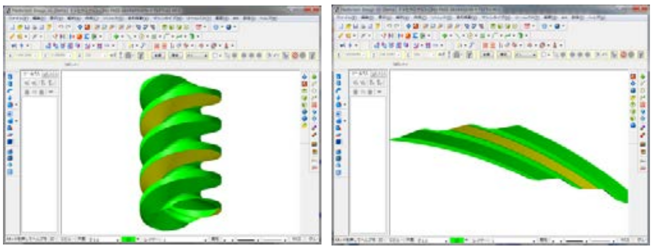


Fig. 20.41　Tooth profile rendering (contact line)



(a) pinion　　　　(b) face gear

Fig. 20.42　CAD drawing (sample)

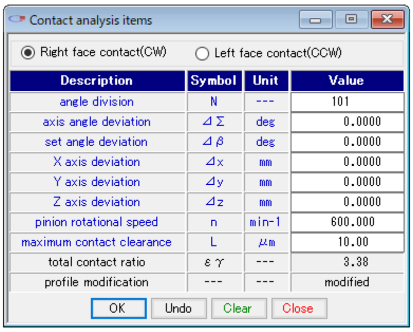


Fig. 20.43　Contact analysis (setting)

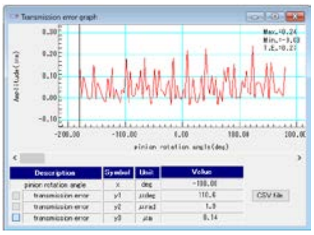


Fig. 20.44　Transmission error

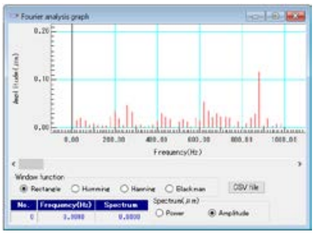


Fig. 20.45　Fourier analysis

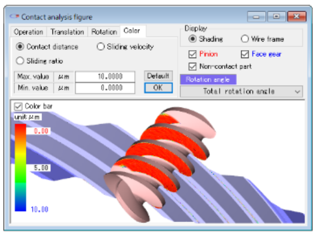


Fig. 20.46　Contact length

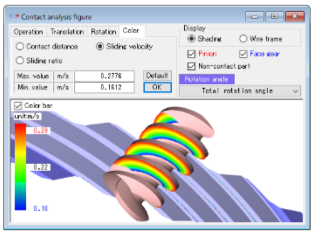


Fig. 20.47　Sliding speed

20.13　Property

Property includes setting of reference rack and design data management. The setting of the reference rack is shown in Figure 20.48.

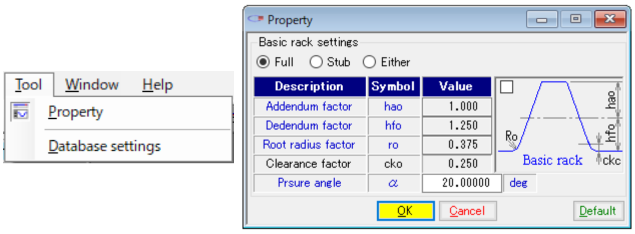


Fig. 20.48　Basic rack

The database setting can be selected as shown in Fig. 20.49. In addition, design data can be saved as shown in Figure 20.50, and data can be read as shown in Figure 20.51. In addition to the control number and title, data reading can also be searched from the gear specification (module, number of teeth, pressure angle, helix angle).

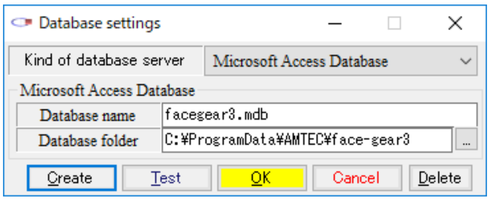


Fig. 20.49　Database setting

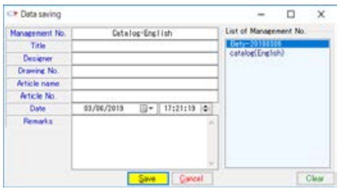


Fig. 20.50　Data save

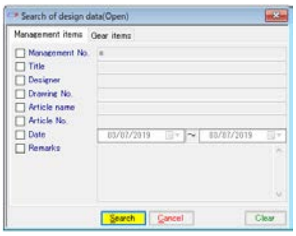


Fig. 20.51　Data open

20.14　HELP

You can use the [Help] function if you want to know the operation method. An example of display is shown in Figure 20.52.

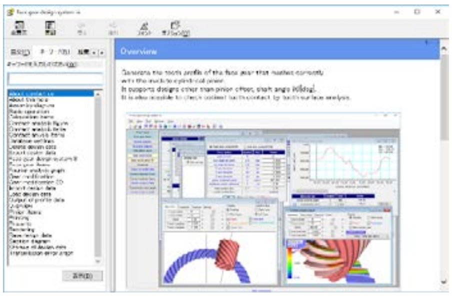


Fig.20.52　HELP