[34] Hypo-Trochoid gear design system

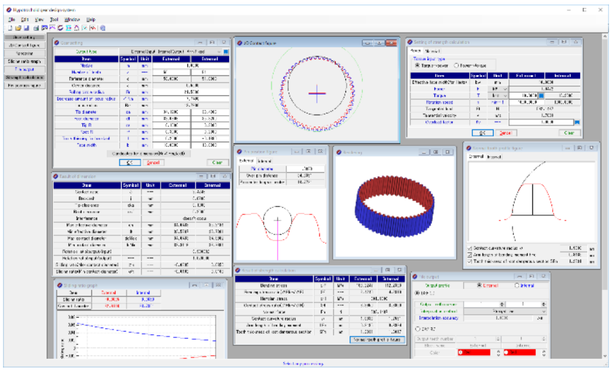


Fig. 34.1 Hypo-Trochoid gear design system

34.1 Abstract

The Hypo-Trochoid gear design system is software for designing trochoid curved gears (external gear × internal gear). The contact ratio is several times that of the involute tooth profile, and tooth profile design and tooth contact ratio can be calculated. Since the tooth profile of this gear is a trochoid curve, the sliding ratio is smaller than the involute tooth profile and is almost constant, which is effective in reducing power loss. Also, as shown in this example (Fig. 34.3), if the pinion is made to rotate and mesh as meshing gear, a high reduction ratio (this example i = 1/49) can be achieved with one pair of gears.

34.2 Gear design and tooth profile

An adduction trochoidal tooth profile is generated according to the concept in Figure 34.2. The rolling circle radius (Rr) is rotated without sliding while in contact with the pitch circle radius (Rp), and the locus described by one point on the moving locus radius (Rm) is taken as the tooth profile coordinates. If Rm = Rr, then it is an epicycloid curve.

The gear ratio can be reduced (one or two teeth difference) and the speed ratio can be increased by using the self-rotation of the pinion (external gear). However, it is very difficult to directly enter a numerical value for designing the contact ratio to 1 or more. Therefore, this software has a function to display the design standard value based on the contact ratio after inputting the module and the number of teeth.

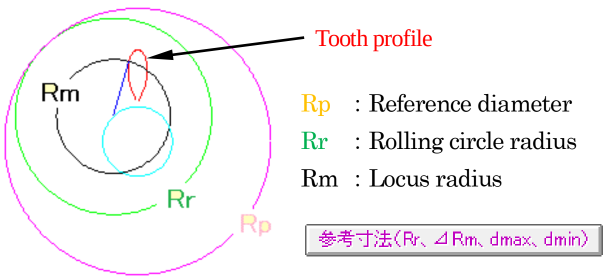


Fig. 34.2 Inversion trochoidal tooth

34.3 Dimension setting

In this example, we will show an example of the generation of a tooth profile in which the pinion and gear mesh properly. In the example, design is based on the combination shown in Figure 34.3 (external gear: output, internal gear: fixed, arm: input). When setting the rolling circle radius (Rr) or locus radius (Rm), after entering the module and the number of teeth in Fig. 34.3, the design standard value can be determined by [Candidates for dimension(Rr,⊿Rm,da,df)]. Figure 34.4 is a combination when the minimum contact ratio is 3.0, and the purple item in Figure 34.3 becomes the value shown in Figure 34.5 when the 11th dimension is selected from these.

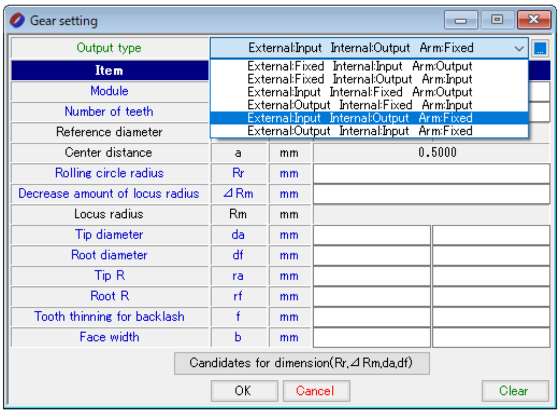


Fig. 34.3 Dimension setting

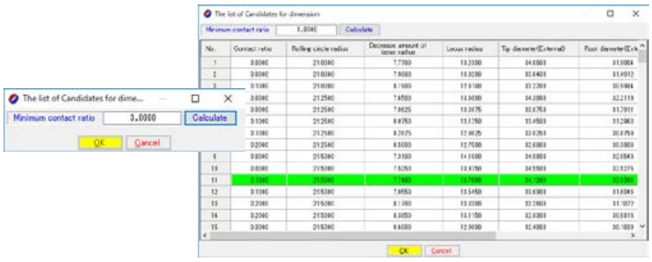
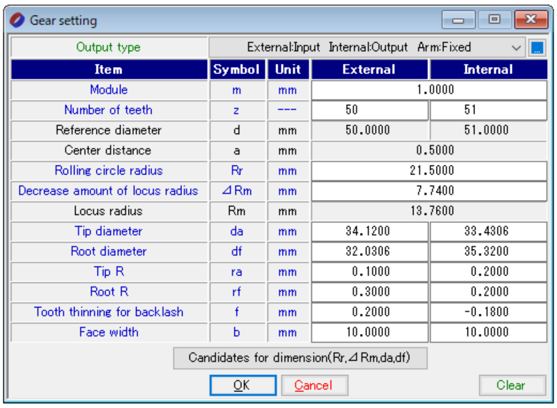


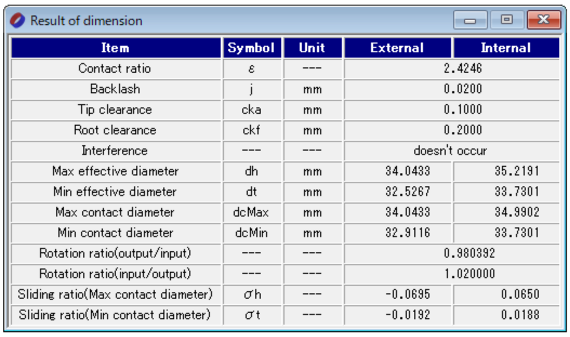
Fig. 34.4 Dimensions



Item	Symbol	Unit	External	Internal
Module	m	mm	1.0000	
Number of teeth	z	---	50	51
Reference diameter	d	mm	50.0000	51.0000
Center distance	a	mm	0.5000	
Rolling circle radius	Rr	mm	21.5000	
Decrease amount of locus radius	⊿Rm	mm	7.7400	
Locus radius	Rm	mm	13.7600	
Tip diameter	da	mm	34.1200	33.4306
Root diameter	df	mm	32.0306	35.3200
Tip R	ra	mm	0.1000	0.2000
Root R	rf	mm	0.3000	0.2000
Tooth thinning for backlash	f	mm	0.2000	-0.1800
Face width	b	mm	10.0000	10.0000

Fig. 34.5 Dimension setting

By giving the large radius round radius (ra), the small radius round radius (rf), and the reduction in tooth thickness "f" in Fig. 34.5, the tooth shape and dimensions of each part can be determined. The calculation results are shown in Fig. 34.6, but the contact ratio decreases to ε = 2.425 by giving the tip R. Here, the tooth thickness of the external gear is reduced (0.20 mm) and the tooth thickness of the internal gear is increased (0.18 mm) to give a backlash jt of 0.02 mm. The rotation ratio (1/50 in this example), clearance, and the occurrence of interference are displayed.



Result of dimension

Item	Symbol	Unit	External	Internal
Contact ratio	ε	---	2.4246	
Backlash	j	mm	0.0200	
Tip clearance	cka	mm	0.1000	
Root clearance	ckf	mm	0.2000	
Interference	---	---	doesn't occur	
Max effective diameter	dh	mm	34.0433	35.2191
Min effective diameter	dt	mm	32.5267	33.7301
Max contact diameter	dcMax	mm	34.0433	34.9902
Min contact diameter	dcMin	mm	32.9116	33.7301
Rotation ratio(output/input)	---	---	0.980392	
Rotation ratio(input/output)	---	---	1.020000	
Sliding ratio(Max contact diameter)	σh	---	-0.0695	0.0650
Sliding ratio(Min contact diameter)	σt	---	-0.0192	0.0188

Fig. 34.6　Dimension calculation result

34.4　Tooth profile

The trochoidal tooth profile is generated based on the gear specifications set in Fig. 34.5, and is drawn as shown in Fig. 34.7. Fig. 34.8 is an enlarged view of meshing part A in Fig. 34.7 (the three teeth of ○ in the figure are simultaneously in contact), and Fig. 34.9 is an enlarged view of B as well. In the meshing diagram (2D), distance measurement (distance between tips = 0.096 mm) can be performed as shown in Fig. 34.10.

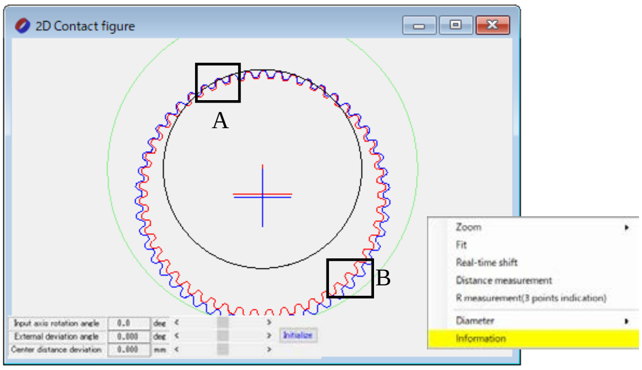


Fig. 34.7　Tooth mesh (2D)

Fig. 34.8　Tooth mesh (A)

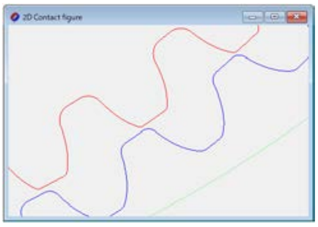


Fig. 34.9　Tooth mesh (B)

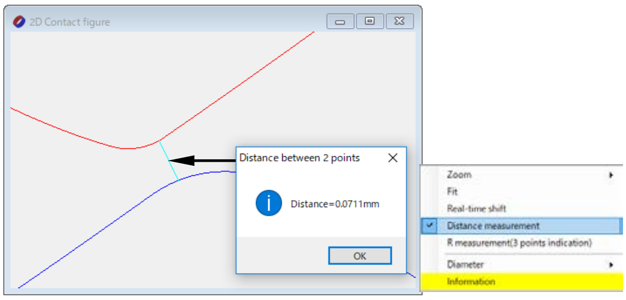


Fig. 34.10　Tooth mesh (Distance measurement)

Figures 34.11 and 34.12 show tooth profile rendering. In this figure, the gears rotate according to the combination of gears set in Figure 34.3. You can also observe the contact line as shown in Figure 34.12.

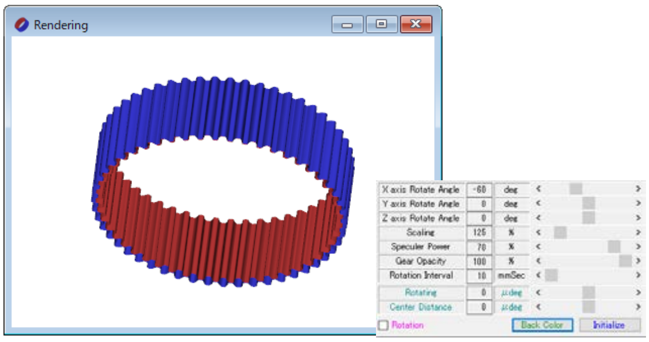


Fig. 34.11　Teeth rendering-1

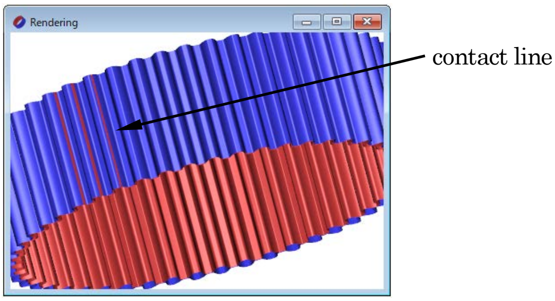


Fig. 34.12　Teeth rendering-2

34.5　Over ball distance

Over ball (and between) distance can be calculated as shown in Figure 34.13 and Figure 34.14 to manage the generated tooth profile.

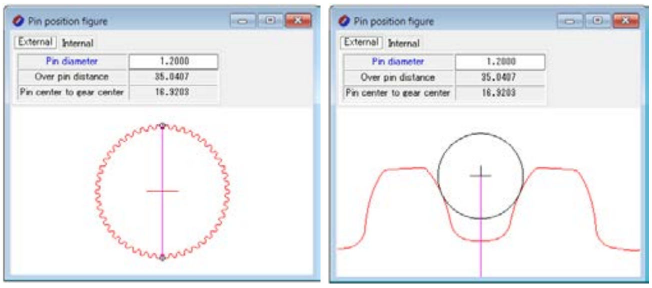


Fig. 34.13　Over ball distance (external gear)

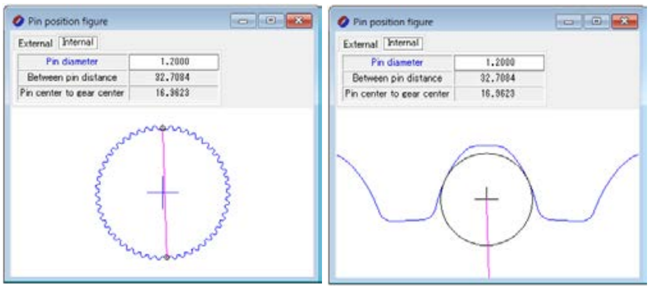


Fig. 34.14　Between distance (internal gear)

34.6　Sliding ratio

The sliding ratio of the hypo-trochoidal tooth profile in this example is σ_h = 0.0695 at the maximum contact diameter, as shown in the dimension calculation results in Figure 34.6. In addition, with the minimum contact diameter, σt = 0.0192, and the change in the sliding ratio at the tooth profile position (diameter) can be seen in Fig. 34.15. From this figure, it can be seen that the slip ratio of the adduction trochoidal tooth profile in this example is almost constant.

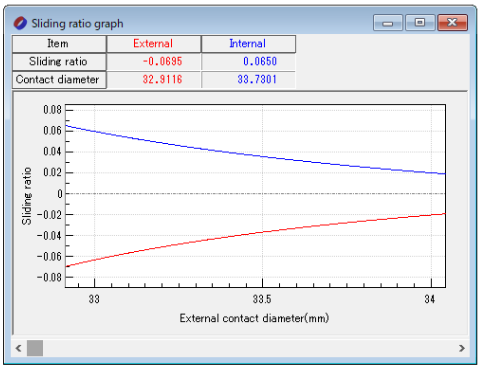


Fig. 34.15 Sliding ratio

34.7 Gear strength calculation

For gear strength calculation, enter torque, rotational speed, overload coefficient, etc. on the strength setting screen shown in Fig. 34.16. The allowable stress of the material can be input directly or can be set using the material selection table in Figure 34.16.

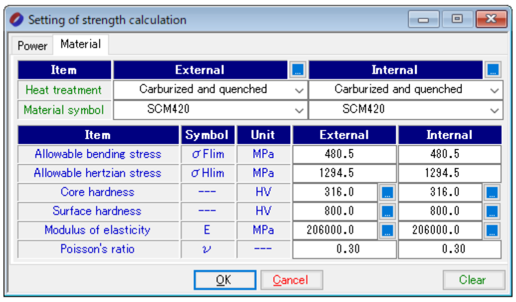


Fig. 34.15 Gear strength setting

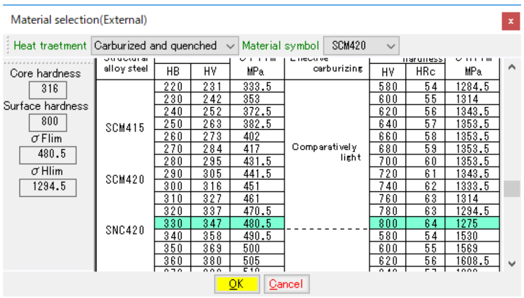


Fig. 34.16 Material selection

The bending strength of the tooth is based on the radius of curvature of the tooth profile at the center position of the tooth. In addition, the weakest cross-section tooth thickness is determined by the 30-degree tangent method (the internal teeth are 60-degree tangent method), and the stress generated at the tooth base is calculated assuming that the load acts on the tooth tip. Furthermore, the radius of curvature, the bending height and the weakest cross-section tooth thickness can be confirmed in the tooth profile in Figure 34.17.

Tooth surface strength is also calculated based on the radius of curvature of the tooth profile at the center of the tooth ridge as well as bending strength to calculate the generated Hertz stress. The bending strength and pitting strength are the ratio of the allowable stress of the material to the generated stress. Fig. 34.17 shows an example of gear strength calculation result.

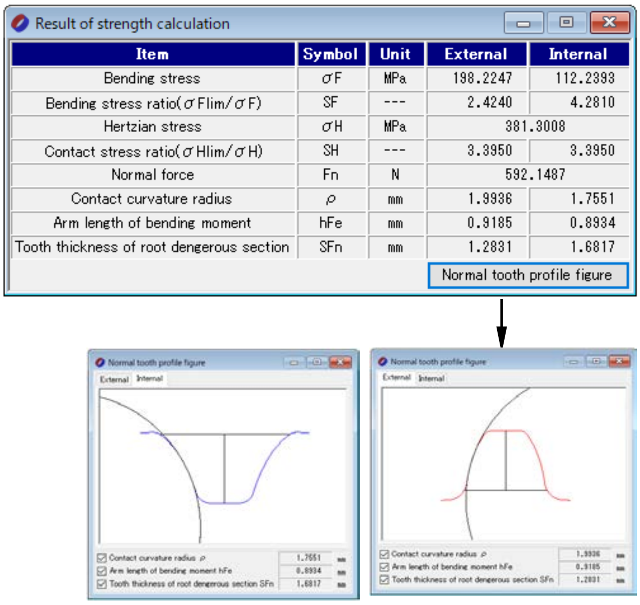


Fig. 34.17 Gear strength calculation result

34.8 Toth profile output

The generated tooth profile can be output as a CAD file using the tooth profile output function shown in Figure 34.18. Figures 34.19 to 34.20 show examples of drawing tooth profiles.

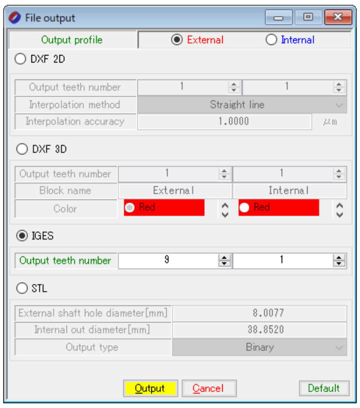
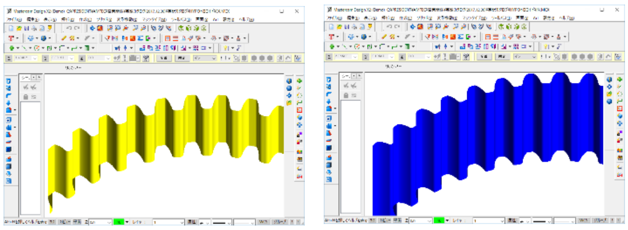
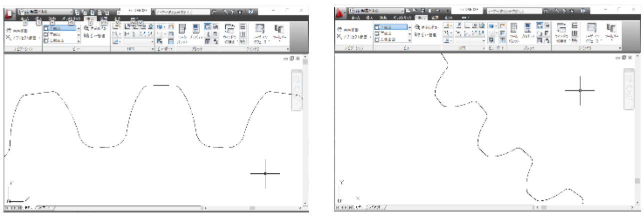


Fig. 18 Tooth profile output



(a) External gear (b) Internal gear

Fig. 34.19 CAD drawing example (3D)



(a) External gear (b) Internal gear

Fig. 34.20 CAD drawing example (2D)