[5] Planetary gear design system
(Planetary gear and Mechanical paradox gear)

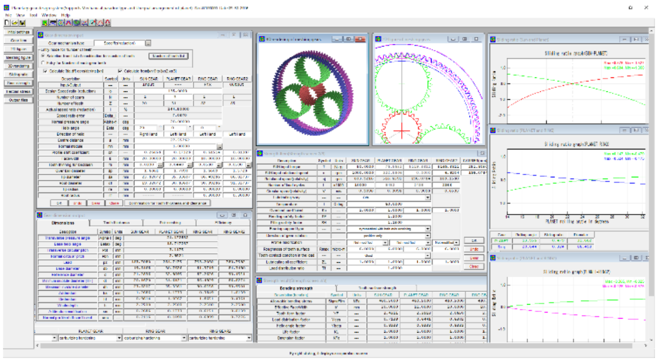


Fig. 5.1 Planetary gear design system

5.1 Abstract

This software is a software that can easily design planetary gear s and mechanical paradox gears, and can automatically determine t he combination of the number of teeth, the center distance, etc., a nd can easily design the gear dimensions and gear strength. In add ition, interference check of planetary gears, profile shift factor calcu lation, etc. can be easily calculated. Figure 5.1 shows the whole sc reen of the calculation result.

5.2 Gear to apply

(1)Type : Equal arrangement (Planetary, Solar, Star)
(2) Material of the gear : Steel, Plastic
(3)Tooth profile : Involute
(4)Option : 3K paradox type, Small number of teeth, Double pinion, and Non-equal arrangement

5.3 Property (Basic rack)

In the properties, set the tip diameter determination method, basic rack, module or center distance reference, gear accuracy and friction coefficient. Figure 5.2 shows the property screen.

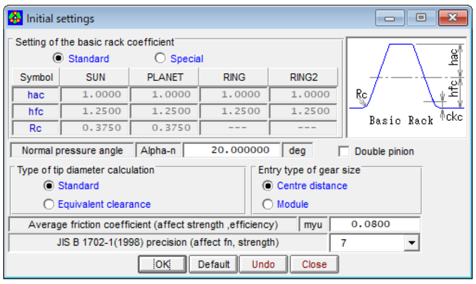


Fig. 5.2 Property (basic rack)

5.4 Selection of planetary gear mechanism

Select the planetary gear type shown in Figure 5.3.

(1) The number of planet gears is 1 to 21.

(2) The number of teeth can be selected from the method of direct input or the number of teeth list calculated from the speed ratio (Fig. 5.5).

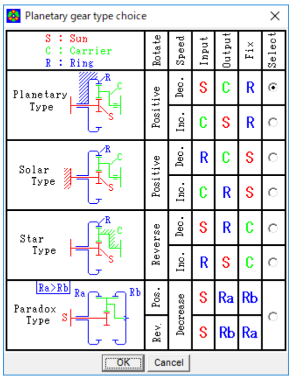


Fig. 5.3 Type of planetary gear

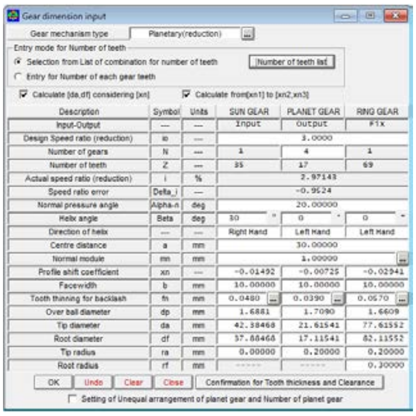


Fig. 5.4 Gear specification (input)

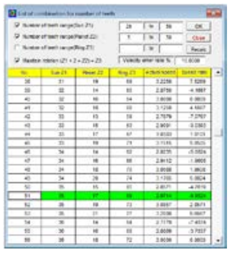


Fig. 5.5 teeth list

(3) You can calculate module distance from center distance or center distance from module.

(4) The calculation of the profile shift factor is performed so that the backlash becomes zero from the module and the center distance.

(5) The default value of thinning for backlash is 1/2 of the JIS backlash standard middle value.

(6) The tip circle diameter is calculated from the basic rack and dislocation coefficient set in the property, but it can be changed.

(7) The shape of the tooth root of the external gear is a trochoid based on the basic rack. The tooth root of the internal gear is the input R connection.

(8) Gear tips can be created with a single R.

(9) Changing one profile shift factor changes the remaining ones in tandem, but you can enter each gear individually. The tooth shape can be confirmed by confirming the tooth thickness and the crest in Fig. 5.6. You can also check the tooth profile and clearance after changing the profile shift factor and tip diameter on this screen. The tooth shape at this point is only the tooth surface, and the root shape is not included.

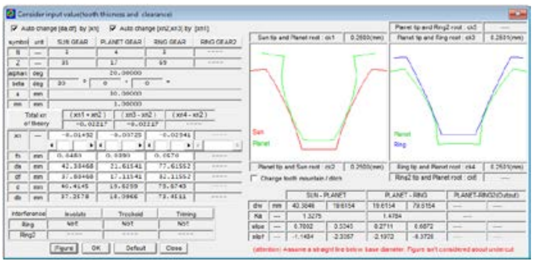


Fig.5.6 Support of the dimension

5.5 Gear dimension

The various calculation results are shown in Fig. 5.7 to Fig. 5.10. On this screen, you can check the interference, efficiency, clearance and backlash.

Gear dimension output

Dimensions | Tooth thickness | Pair meshing | Efficiency

Desciption	Symbol	Units	SUN GEAR	PLANET GEAR	RING GEAR
Transverse pressure angle	Alpha-t	deg	22.795877		
Base helix angle	Betab	deg	28.024321		
Transverse circular pitch	Pbt	mm	3.3443		
Normal circular pitch	Pbn	mm	2.9521		
Lead	pz	mm	219.9115	106.8142	433.5398
Base diameter	db	mm	37.2578	18.0966	73.4511
Reference diameter	d	mm	40.4145	19.6299	79.6743
Minimum involute diameter (TIF)	dt	mm	38.6593	18.2424	77.8816
Maximum involute diameter	dh	mm	42.3847	21.4269	81.7775
Addendum	ha	mm	0.9851	0.9928	1.0294
Dedendum	hf	mm	1.2649	1.2572	1.2206
Whole depth	h	mm	2.2500	2.2500	2.2500
Addendum modification	xm	mm	-0.0149	-0.0073	-0.0294
Normal profile shift coefficient	xnc	---	-0.0851	-0.0643	0.0539

Fig.5.7 Result (Gear dimension)

Gear dimension output

Dimensions | Tooth thickness | Pair meshing | Efficiency

Desciption	Symbol	Units	SUN GEAR	PLANET GEAR	RING GEAR
Normal tooth thickness	sn	mm	1.5089	1.5240	1.5315
Transverse tooth thickness	st	mm	1.7423	1.7598	1.7685
Number of teeth spanned	zm	---	6	3	12
Base tangent length(standard)	W	mm	16.9637	7.7334	35.3827
Base tangent length(Design)	W'	mm	16.9157	7.6944	35.4397
Measuring ball diameter	dp	mm	1.6881	1.7090	1.6609
Measurement over balls(standard)	dm	mm	42.6297	21.8687	77.3801
Measurement over balls(design)	dm'	mm	42.4983	21.7696	77.5533
Caliper depth	Hj	mm	0.9964	1.0162	1.0253
Caliper tooth thickness(standard)	Sj	mm	1.5597	1.5646	1.5921
Caliper tooth thickness(design)	Sj'	mm	1.5087	1.5233	1.5221

Fig.5.8 Result (Tooth thickness)

Gear dimension output

Dimensions | Tooth thickness | Pair meshing | Efficiency

Desciption	Symbol	Units	SUN GEAR	PLANET GEAR	PLANET GEAR	RING GEAR
Operating transverse pressure	Alpha-wt	deg	22.6947		22.6947	
Operating helix angle	betaw	deg	29.9816		29.9816	
Operating pitch diameter	dw	mm	40.3846	19.6154	19.6154	79.6154
Operating facewidth	bw	mm	10.0000		10.0000	
Clearance	ck	mm	0.2500	0.2500	0.2501	0.2501
Contact length	ga	mm	4.2652		4.3641	
Near transverse contact ratio	Ka1	---	0.5838		0.7212	
Far transverse contact ratio	Ka2	---	0.6916		0.5838	
Transverse contact ratio	Ka	---	1.2754		1.3050	
Overlap ratio	Kb	---	1.5915		1.5915	
Total contact ratio	Kc	---	2.8669		2.8965	
Sliding ratio at tip	Slipa	---	0.7002	0.5057	0.2565	0.5698
Sliding ratio at root	Slipf	---	-1.0229	-2.3357	-1.3245	-0.3450
Transverse backlash	jnt	mm	0.0986		0.1088	
Backlash angle	jTheta	deg	0.3031	0.6241	0.6887	0.1697
Total backlash angle(input axis)	jTheta'	deg	0.6376 (Sun)			
Maximum contact diameter	dja	mm	42.3847	21.4269	21.4269	81.2018
Minimum contact diameter	djf	mm	39.0446	18.3343	18.3036	77.8816

Fig.5.9 Result (Pair mashing)

Gear dimension output

Dimensions | Tooth thickness | Pair meshing | Efficiency

Rotate ratio

SUN	PLANET	RING	CARRIER
1.0000	-1.0294	0.0000	0.3365

Efficiency 0.9880

RING GEAR interference

Description	RING
Involute	Not occurrence
Trochoid	Not occurrence
Trimming	Not occurrence

Clearance(mm)	
Sun tip and Planet root	0.2500(mm)
Planet tip and Sun root	0.2500(mm)
Planet tip and Ring root	0.2501(mm)
Ring tip and Planet root	0.2501(mm)

Fig.5.10 Result (Efficiency, etc.)

5.6 Tooth profile figure

5.6.1 Tooth profile (2D)

The meshing of the gears is displayed in a two-dimensional view as shown in Figure 5.11 and Figure 5.12. Since the auxiliary circle and the common normal can be displayed by the operation screen, it is easy to check the contact position of the tooth surface. You can change the rotation angle of the gear to zoom in.

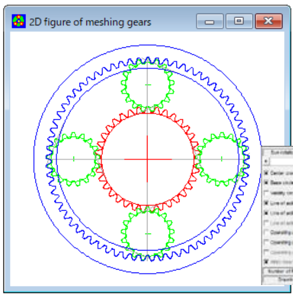


Fig.5.11 Meshing of the tooth profile

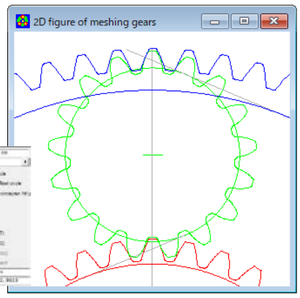


Fig.5.12 Zoom

5.6.2 Meshing of a pair tooth profile (2D)

The meshing of one tooth can be confirmed in the two-dimensional view of Fig. 5.13. On this screen, you can check the interference between the internal gear and external gear teeth and the tooth base in more detail. You can change the rotation angle of the gear to zoom in.

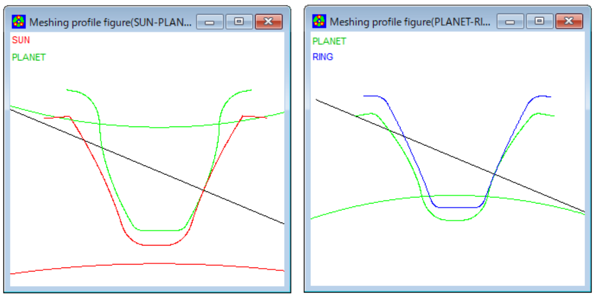


Fig. 5.13 Meshing of a pair tooth profile (2D)

5.6.3 rendering

Gear mesh can be displayed in a three-dimensional view as shown in Figure 5.14 and Figure 5.15. In addition, a control form that can be rotated in the X, Y, and Z directions is shown in Figure 5.16.

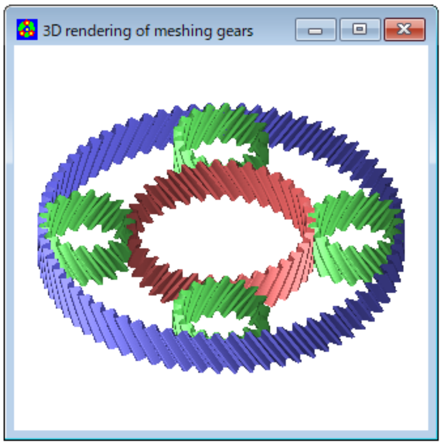


Fig.5.14 Teeth rendering

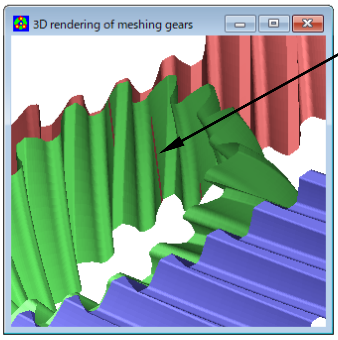


Fig.5.15　profile (Zoom)

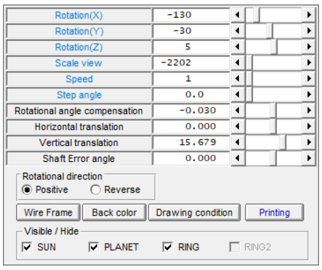
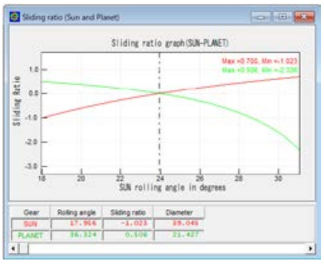


Fig.5.16　Control form

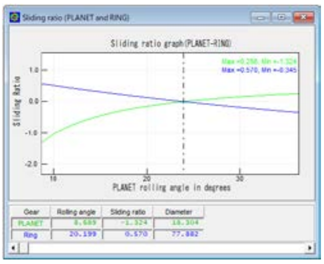
5.7　Sliding ratio graph

The sliding ratio graph is shown in Fig. 5.17 and Fig. 5.18.



(Sun　×Planet)

Fig.5.17　sliding ratio graph1



(Planet　×　Internal)

Fig5.18　sliding ratio graph2

5.8　Gear strength

5.8.1　Initial settings for gear strength calculation

You can select metal material and plastic on the strength initial setting screen shown in Fig. 5.19. Select the allowable stress σFlim and σHlim from Fig. 5.20. Note that σ_{Flim} and σ_{Hlim} can be input arbitrary numbers. The torque unit can be selected from N･m, N･cm, kgf･m, kgf･cm and gf･cm.

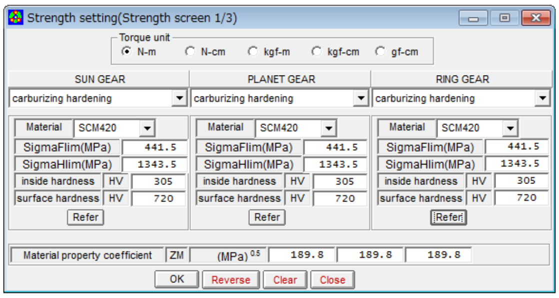
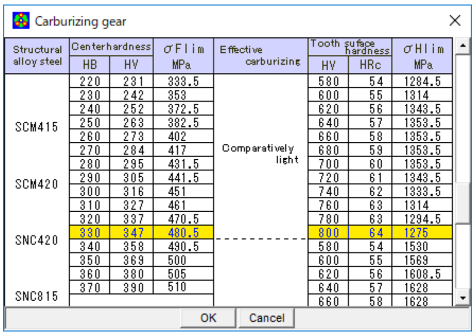


Fig.5.19　Input (Material)



Carburizing gear

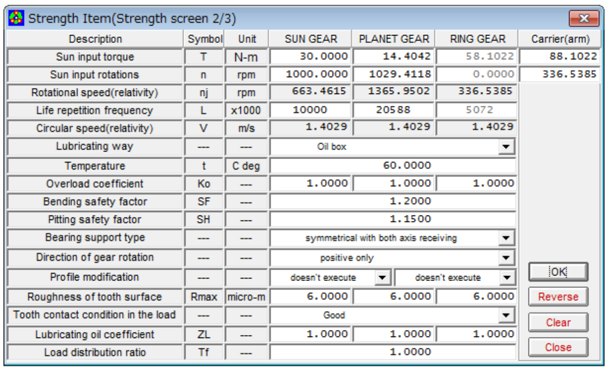
Structural alloy steel	Centerhardness HB	Centerhardness HV	σFlim MPa	Effective carburizing	Tooth suface hardness HV	Tooth suface hardness HRc	σHlim MPa
	220	231	333.5		580	54	1284.5
	230	242	353		600	55	1314
	240	252	372.5		620	56	1343.5
SCM415	250	263	382.5		640	57	1353.5
	260	273	402		660	58	1353.5
	270	284	417	Comparatively light	680	59	1353.5
	280	295	431.5		700	60	1353.5
SCM420	290	305	441.5		720	61	1343.5
	300	316	451		740	62	1333.5
	310	327	461		760	63	1314
	320	337	470.5		780	63	1294.5
SNC420	330	347	480.5		800	64	1275
	340	358	490.5		580	54	1530
	350	369	500		600	55	1569
	360	380	505		620	56	1608.5
	370	390	510		640	57	1628
SNC815					660	58	1628

OK　Cancel

Fig.5.20　Example of the allowable stress of the steel

5.8.2　Strength specification input

Enter various values in the strength specification input screen shown in Fig. 5.21. The torque and rotational speed can be set by either input side or output side.



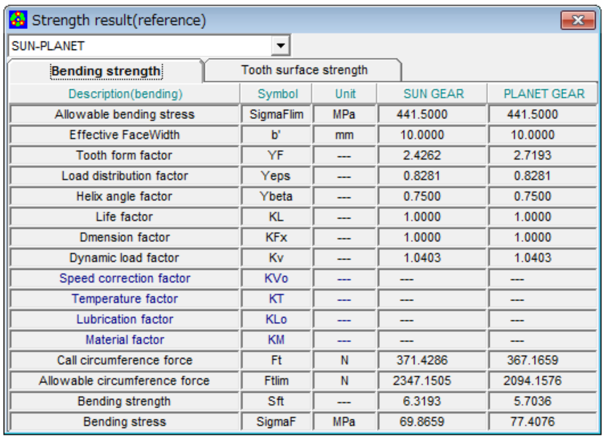
Strength Item(Strength screen 2/3)

Description	Symbol	Unit	SUN GEAR	PLANET GEAR	RING GEAR	Carrier(arm)
Sun input torque	T	N-m	30.0000	14.4042	58.1022	88.1022
Sun input rotations	n	rpm	1000.0000	1029.4118	0.0000	336.5385
Rotational speed(relativity)	nj	rpm	663.4615	1365.9502	336.5385	
Life repetition frequency	L	x1000	10000	20588	5072	
Circular speed(relativity)	V	m/s	1.4029	1.4029	1.4029	
Lubricating way	---	---	Oil box			
Temperature	t	C deg	60.0000			
Overload coefficient	Ko	---	1.0000	1.0000	1.0000	
Bending safety factor	SF	---	1.2000			
Pitting safety factor	SH	---	1.1500			
Bearing support type	---	---	symmetrical with both axis receiving			
Direction of gear rotation	---	---	positive only			
Profile modification	---	---	doesn't execute	doesn't execute		OK
Roughness of tooth surface	Rmax	micro-m	6.0000	6.0000	6.0000	Reverse
Tooth contact condition in the load	---	---	Good			Clear
Lubricating oil coefficient	ZL	---	1.0000	1.0000	1.0000	
Load distribution ratio	Tf	---	1.0000			Close

Fig.5.21　Input (Gear strength dimension)

5.8.3　Strength calculation result

The intensity calculation result screen is displayed in Fig. 5.22 and Fig. 5.23. The strength calculation also takes into account the efficiency and meshing ratio. The metal gears are subjected to strength calculation based on JGMA 401-01: 1974, JGMA 401-02: 1975. Moreover, the stress value of the resin material adopts the experimental value of the material in consideration of the temperature, life and so on.



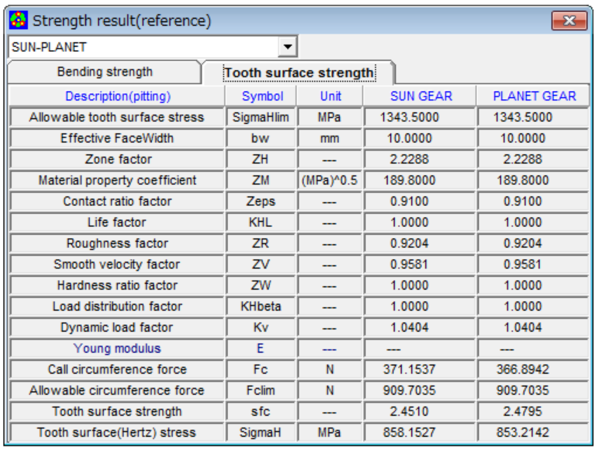
Strength result(reference)

SUN-PLANET

Bending strength　Tooth surface strength

Description(bending)	Symbol	Unit	SUN GEAR	PLANET GEAR
Allowable bending stress	SigmaFlim	MPa	441.5000	441.5000
Effective FaceWidth	b'	mm	10.0000	10.0000
Tooth form factor	YF	---	2.4262	2.7193
Load distribution factor	Yeps	---	0.8281	0.8281
Helix angle factor	Ybeta	---	0.7500	0.7500
Life factor	KL	---	1.0000	1.0000
Dmension factor	KFx	---	1.0000	1.0000
Dynamic load factor	Kv	---	1.0403	1.0403
Speed correction factor	KVo	---	---	---
Temperature factor	KT	---	---	---
Lubrication factor	KLo	---	---	---
Material factor	KM	---	---	---
Call circumference force	Ft	N	371.4286	367.1659
Allowable circumference force	Ftlim	N	2347.1505	2094.1576
Bending strength	Sft	---	6.3193	5.7036
Bending stress	SigmaF	MPa	69.8659	77.4076

Fig.5.22　Gear strength calculation result (Bending)



Strength result(reference)

SUN-PLANET

Bending strength　Tooth surface strength

Description(pitting)	Symbol	Unit	SUN GEAR	PLANET GEAR
Allowable tooth surface stress	SigmaHlim	MPa	1343.5000	1343.5000
Effective FaceWidth	bw	mm	10.0000	10.0000
Zone factor	ZH	---	2.2288	2.2288
Material property coefficient	ZM	(MPa)^0.5	189.8000	189.8000
Contact ratio factor	Zeps	---	0.9100	0.9100
Life factor	KHL	---	1.0000	1.0000
Roughness factor	ZR	---	0.9204	0.9204
Smooth velocity factor	ZV	---	0.9581	0.9581
Hardness ratio factor	ZW	---	1.0000	1.0000
Load distribution factor	KHbeta	---	1.0000	1.0000
Dynamic load factor	Kv	---	1.0404	1.0404
Young modulus	E	---	---	---
Call circumference force	Fc	N	371.1537	366.8942
Allowable circumference force	Fclim	N	909.7035	909.7035
Tooth surface strength	sfc	---	2.4510	2.4795
Tooth surface(Hertz) stress	SigmaH	MPa	858.1527	853.2142

Fig.5.23　Gear strength calculation result (Pitting)

5.9 Hertz stress graph

Hertz stress graphs are shown in Figure 5.24 and Figure 5.25.

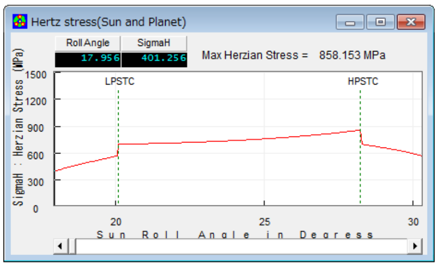


Fig.5.24 Hertzian stress (Sun)

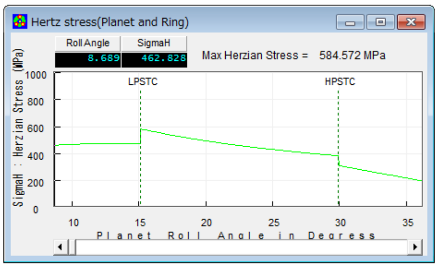


Fig.5.25 Hertzian stress (Planet)

5.10 Other

(1) Tooth profile data of gears can be output.

- DXF file : 2D, 3D All teeth meshing
- IGES file : 3D(Tooth)
- TEXT file : 2-dimensional tooth profile coordinate

(2) You can print dimensional calculation results, strength calculation results, 2D tooth profiles, slip ratio graphs, and Hertz stress graphs.

(3) You can save and load design data.

5.11 Mechanical paradox gears (3K type)

A Mechanical paradox gears using a total of four gears of the sun, planets, and two internal teeth is well known. Mechanical paradox gears are very computationally expensive, but can be easily designed using this software. The input is for the sun gear, the fixed for the internal gear 1, and the output for the internal gear 2 type 3K type only.

The number of teeth of internal gear 1 and internal gear 2 determines the same direction deceleration and the reverse direction deceleration. The design example is shown below.

5.11.1 Specification of gear specifications

(1) In Properties, select module criteria.

(2) Select the 3K type in Figure 5.3 and proceed to the mechanical paradox gears in Figure 5.26.

(3) Input the design reduction ratio as 135 and the number of planet gears as three.

(4) Display the tooth number list screen, and select the combination of the number of teeth that seems appropriate. (See Figure 5.27)

As selection conditions at this time,

(a) Difference between the actual speed ratio and the design speed ratio error.

(b) The number of teeth must be correct.

Here we choose z_1=20, z_2=31, z_3=82, z_4=85 as an example.

(5) Then press the Tab key and enter α=20, β=20, m_n=1 in order. When the module is entered, the standard center distance, profile shift factor, tip circle diameter and root circle diameter are determined based on the basic rack in Figure 5.2.

(6) The theoretical center distance is 27.6686 mm, but it can be changed according to the purpose. Fig. 5.26 shows the gear specification screen.

(7) Once the center distance and module have been determined, you can change the tooth height and tooth thickness. On this screen (Fig.5.28), you can change the profile shift factor and tip diameter while checking the tooth profile. Check the contact of the teeth, interference with the teeth, clearance and internal gear.

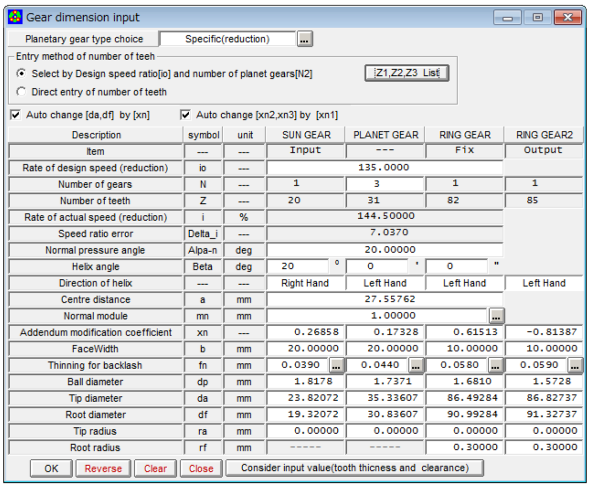


Fig.5.26 Input of gear dimension

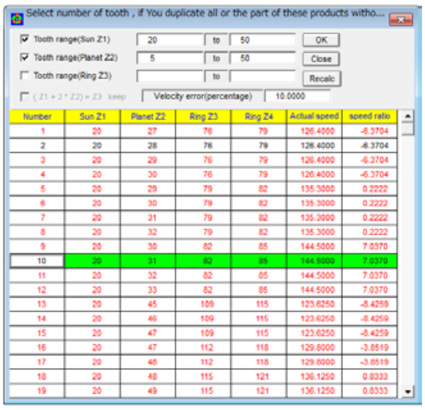


Fig.5.27 The number of teeth list

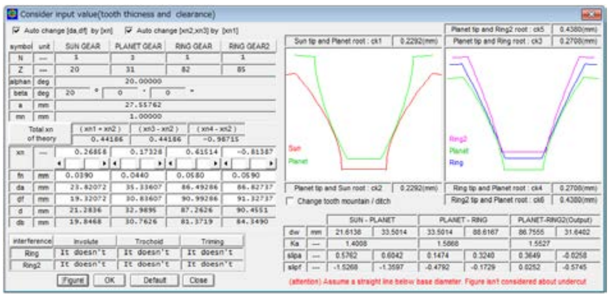


Fig.5.28 Input support screen

(8) Check the efficiency, meshing ratio and slip ratio on the dimension calculation result screen as shown in Figure 5.29-5.32. The efficiency of

the mechanical paradox gears in this example is 73.1% as shown in Figure 5.32.

(9) Also, check how much the interference between the external gear and the internal gear can actually be secured by one tooth engagement.

(10) In the case of the example, the dimensions of module 1 have been determined, but it may be necessary to change the size by strength calculation. In that case, change the tooth width or increase the module distance, center distance and tip diameter, etc. The strength calculation should be done carefully as the ratio of torque increases as the rotation ratio increases.

Gear dimension output — Standard | Thickness | Pair meshing | Others

Desciption	symbol	unit	SUN GEAR	PLANET GEAR	RING GEAR	RING GEAR2
Transverse pressure angle	at	deg	21.172832			
Base helix angle	Betab	deg	18.747237			
Transverse circular pitch	Pbt	mm	3.1175			
Normal circular pitch	Pbn	mm	2.9521			
Lead	Lead	mm	183.7080	284.7475	753.2030	780.7592
Base diameter	db	mm	19.8468	30.7626	81.3719	84.3490
Reference pitch diameter	d	mm	21.2836	32.9895	87.2626	90.4551
Minimum validity diameter (TIF)	dt	mm	20.1670	31.6121	86.4929	86.8274
Maximum validity diameter	dh	mm	23.8207	35.3361	90.6558	90.9501
Addendum	ha	mm	1.2686	1.1733	0.3849	1.8139
Dedendum	hf	mm	0.9814	1.0767	1.8651	0.4361
Whole depth	h	mm	2.2500	2.2500	2.2500	2.2500
Addendum modification	xm	mm	0.2686	0.1733	0.6151	-0.8139
Normal profile shifted coefficient	xnc	---	0.2116	0.1090	0.6999	-0.7276

Fig.5.29　Result (Gear dimension)

Gear dimension output — Standard | Thickness | Pair meshing | Others

Desciption	symbol	unit	SUN GEAR	PLANET GEAR	RING GEAR	RING GEAR2
Normal tooth thickness	sn	mm	1.7248	1.6501	1.0613	2.1005
Transverse tooth thickness	st	mm	1.8355	1.7560	1.1294	2.2353
Number of teeth spanned	zm	---	4	5	12	10
Base tangent length(standard)	W	mm	10.8506	13.9215	35.7414	28.9098
Base tangent length(Design)	W'	mm	10.8116	13.8775	35.7994	28.9688
Measuring ball diameter	dp	mm	1.8178	1.7371	1.6810	1.5728
Dimension over balls(standard)	dm	mm	24.4103	35.6976	86.1985	86.7829
Dimension over balls(design)	dm'	mm	24.3235	35.5879	86.3598	86.9894
Caliper depth	Hj	mm	1.3009	1.1925	0.3835	1.8050
Caliper tooth thickness(standard)	Sj	mm	1.7647	1.6964	1.1230	2.1631
Caliper tooth thickness(design)	Sj'	mm	1.7234	1.6496	1.0573	2.0963

Fig.5.30　Result (Tooth thickness)

Gear dimension output — Standard | Thickness | Pair meshing | Others

Desciption	symbol	unit	SUN GEAR	PLANET GEAR	RING GEAR		PLANET And RING2	
Operating transverse pressure	awt	deg	23.3289		23.3289		13.5267	
Operating helix angle	betaw	deg	20.2852		20.2852		19.2433	
Operating pitch diameter	dw	mm	21.6138	33.5014	33.5014	88.6167	86.7555	31.6402
Operating Facewidth	bw	mm	20.0000		10.0000		10.0000	
Clearance	ck	mm	0.2292	0.2292	0.2708	0.2708	0.4380	0.4380
Contact length	ga	mm	4.3669		4.9469		4.8405	
Near transverse contact ratio	Ka1	---	0.6608		0.9260		1.6016	
Far transverse contact ratio	Ka2	---	0.7400		0.6608		-0.0490	
Transverse contact ratio	Ka	---	1.4008		1.5868		1.5527	
Overlap ratio	Kb	---	2.1774		1.0887		1.0887	
Total contact ratio	Kc	---	3.5781		2.6755		2.6414	
Sliding ratio at tip	Slipa	---	0.5762	0.6042	0.1474	0.3240	-0.0258	0.3649
Sliding ratio at root	Slipf	---	-1.5268	-1.3597	-0.4792	-0.1729	-0.5745	0.0252
Transverse backlash	jnt	mm	0.0876		0.1077		0.1088	
Backlash angle	jSita	deg	0.5061	0.3265	0.4012	0.1517	0.1478	0.4052
Total backlash angle(input axis)	jSita'	deg	1.1341 (Sun)					
Maximum contact diameter	dja	mm	23.8207	35.3361	35.3361	90.3275	35.3361	89.6187
Minimum contact diameter	djf	mm	20.3372	31.9564	31.6620	86.4928	31.7130	86.8274

Fig.5.31　Result (Pair mashing)

Gear dimension output — Standard | Thickness | Pair meshing | Others

Rotate ratio

SUN	PLANET	RING	CARRIER	RING2
1.0000	-0.3226	0.0000	0.1961	0.0069

Efficiency	0.7155

RING GEAR interference

Description	RING	RING2
Involute	It doesn't	It doesn't
Trochoid	It doesn't	It doesn't
Triming	It doesn't	It doesn't

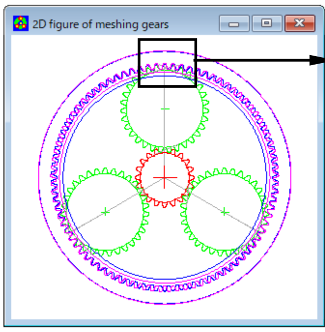
Clearance(mm)

Sun tip and Planet root	0.2292(mm)
Planet tip and Sun root	0.2292(mm)
Planet tip and Ring root	0.2708(mm)
Ring tip and Planet root	0.2708(mm)
Planet tip and Ring2 root	0.4380(mm)
Ring2 tip and Planet root	0.4380(mm)

Fig.5.32　Result (Efficiency, etc.)

5.11.2　Tooth profile (2D)

The meshing figure is shown in Fig. 5.33. In the enlarged view of Fig. 5.34, it can be clearly seen that the planetary gear is engaged with the two internal gears. In addition, you can observe the state of the meshing rotation of the strange planet by the tooth profile rendering shown in Fig. 5.35.



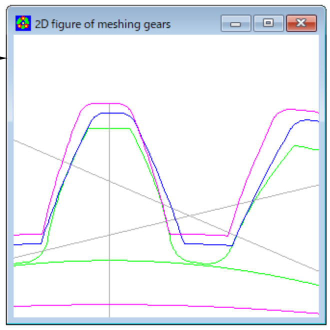


Fig.5.33　Meshing tooth profile　　　Fig. 5.34　Zoom

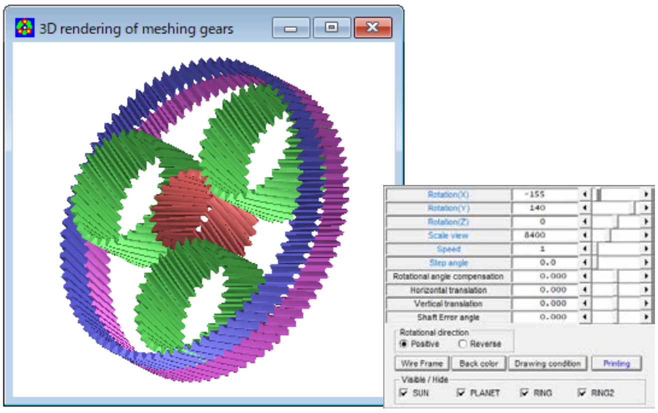


Fig.5.35　Teeth rendering (Gear ratio=135)

5.11.3　Mechanical paradox gears example (spur gear)

(1) Gear strength calculation, sliding ratio and Hertz stress graph can be calculated in the same way as planetary gears.

(2) Figure 5.36 shows an example of drawing a mechanical paradox gears with a spur gear.

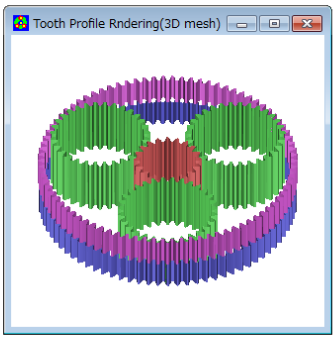


Fig.5.36　Teeth rendering (Spur gear, Gear ratio=93.8)

5.12　Small number of teeth (optional)

You can design a planetary gear with 4 or fewer teeth. In the case of a small number of teeth, it is necessary to increase the helix angle because the contact ratio decreases. The following is an example of drawing a planetary gear with 1 sun gear, 1 planet gear and 2 internal gear teeth.

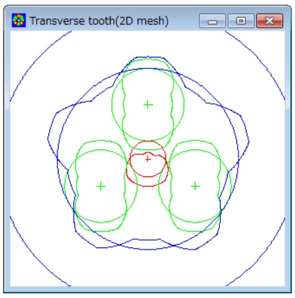


Fig.5.37 Teeth profile(2D)

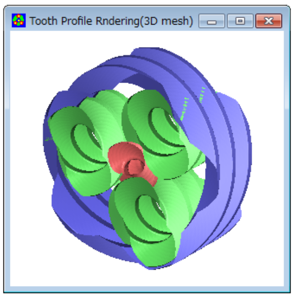


Fig.5.38 Teeth profile (3D)

5.13 Double pinion (option)

Set the double pinion in Figure 5.2 Properties. The design example is shown below.

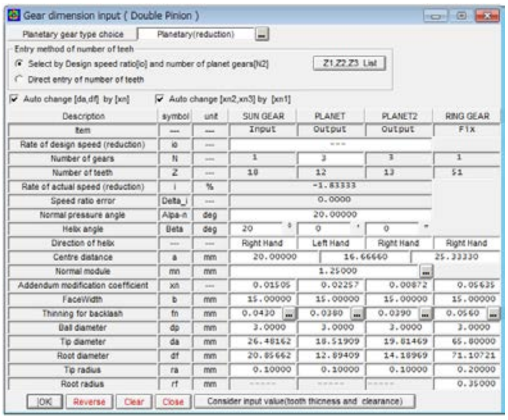


Fig.5.39 Input dimension

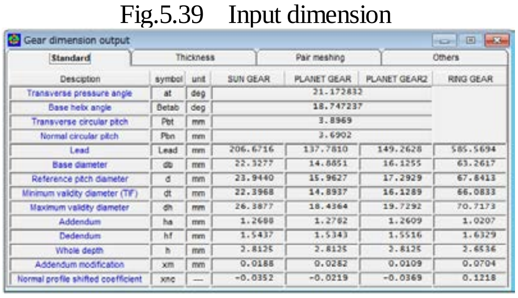


Fig.5.40 Result (Gear dimension)

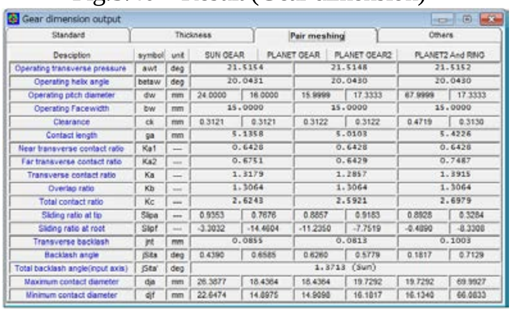


Fig.5.41 Result (Tooth thickness)

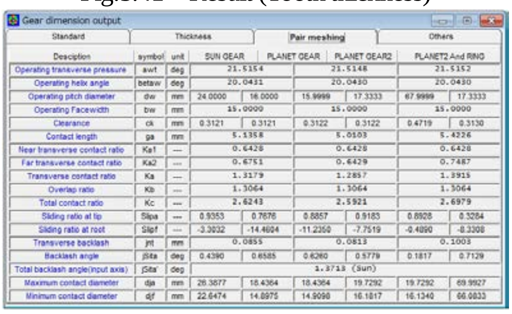


Fig.5.42 Result (Pair mashing)

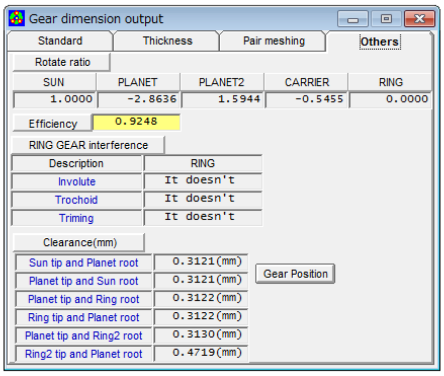


Fig.5.43 Result (Efficiency, etc.)

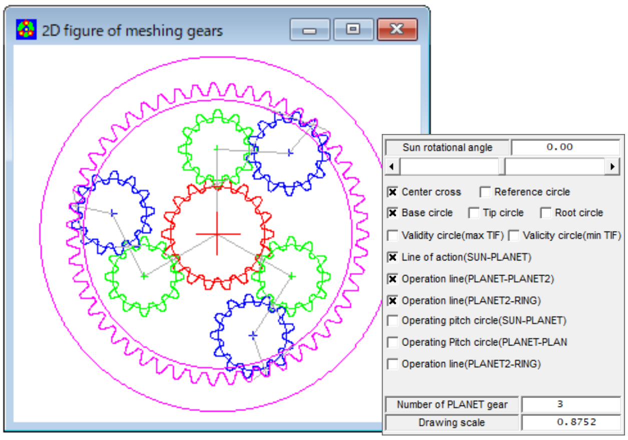


Fig.5.44 Meshing of the tooth profile (2D)

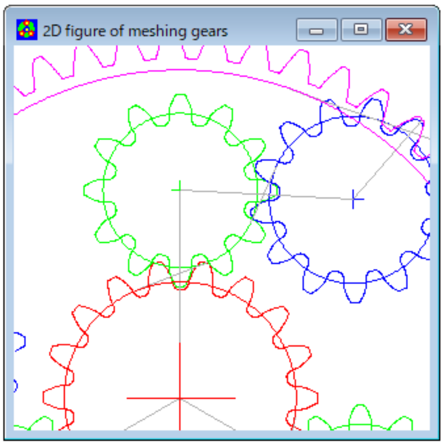


Fig.5.45 Meshing of the tooth profile (Zoom)

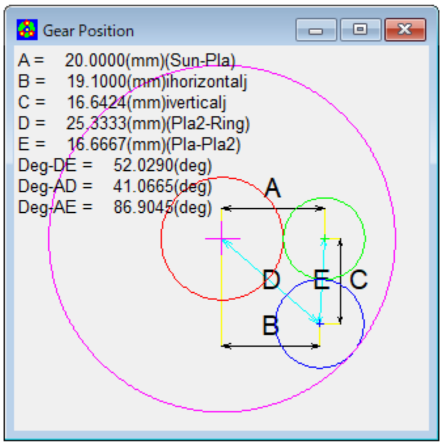


Fig.5.46 Configuration of the gear

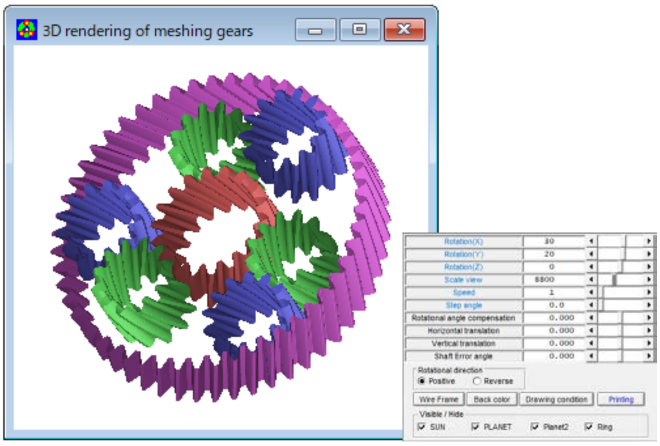


Fig.5.47 Teeth rendering

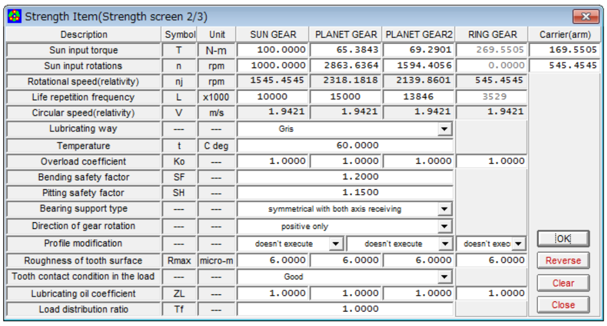


Fig.5.48 Gear strength (Bending)

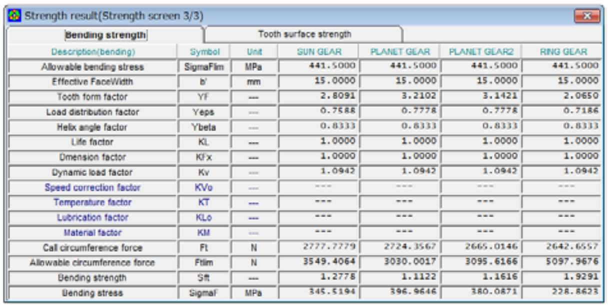


Fig.5.49 Gear strength (Pitting)

Tooth profile data file output and sliding ratio graph, etc. are equal to the basic software.

5.14 Non-equality position of planet gear (Option)

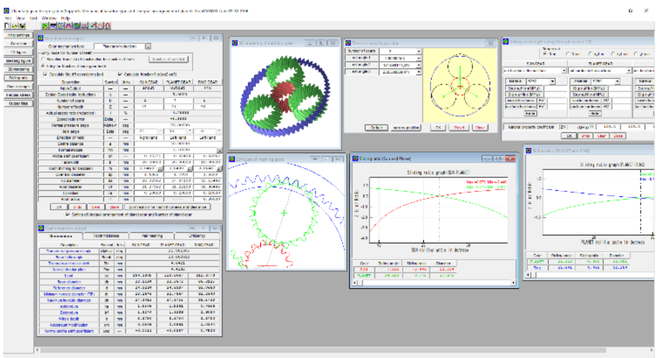


Fig.5.50 Non-equality position of planet gear

The design example of the planetary type (deceleration) nonuniform layout is shown below. In the case of Fig. 5.51, the number of sun teeth is 15, the number of planet teeth is 21, and the number of internal gear teeth is 57 under the condition of equal arrangement. If the number of internal gear teeth is 56, it can be calculated by setting the unequal arrangement shown in Fig. 5.51.

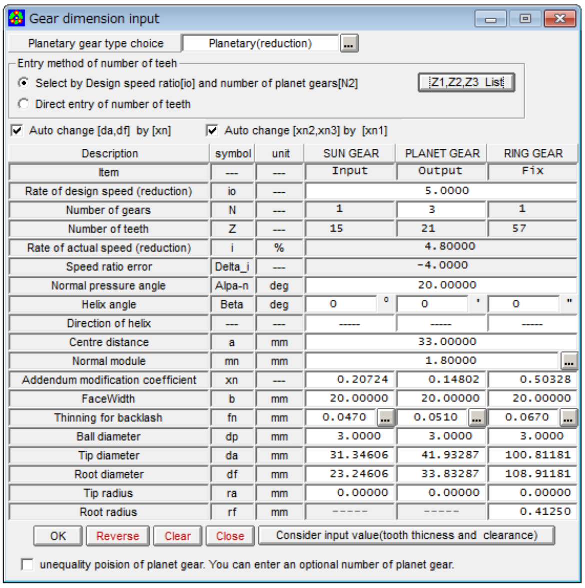


Fig.5.51 Equality position of planet gear

The input screen with the number of internal gear teeth changed to 56 is shown in Figure 5.52. The module has mn = 1.5 as in Figure 5.51, so the internal gear profile shift factor is slightly larger. The input screen with the number of internal gear teeth changed to 56 is shown in Figure 5.52. The module has mn = 1.5 as in Figure 5.51, so the internal gear profile shift factor is slightly larger. Figures 5.53 to 5.55 show the dimension results.

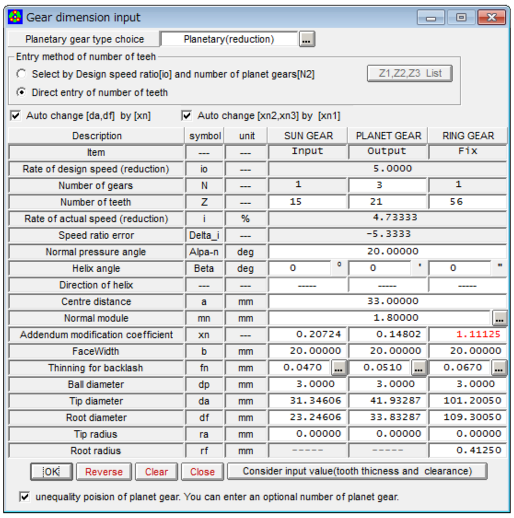
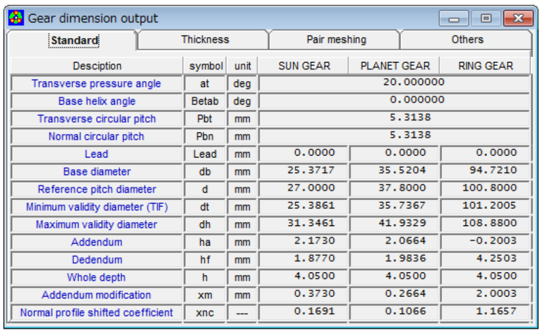


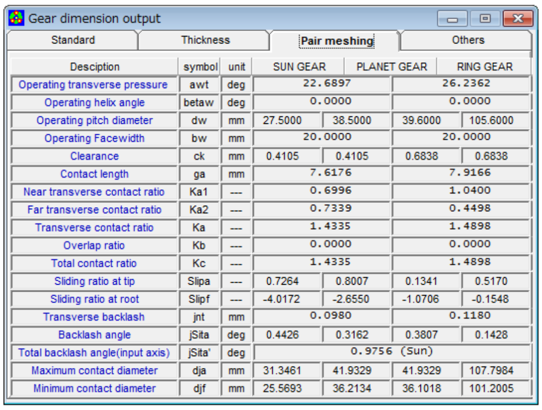
Fig.5.52 Non-equality position of planet gear



Gear dimension output — Standard | Thickness | Pair meshing | Others

Desciption	symbol	unit	SUN GEAR	PLANET GEAR	RING GEAR
Transverse pressure angle	at	deg	20.000000		
Base helix angle	Betab	deg	0.000000		
Transverse circular pitch	Pbt	mm	5.3138		
Normal circular pitch	Pbn	mm	5.3138		
Lead	Lead	mm	0.0000	0.0000	0.0000
Base diameter	db	mm	25.3717	35.5204	94.7210
Reference pitch diameter	d	mm	27.0000	37.8000	100.8000
Minimum validity diameter (TIF)	dt	mm	25.3861	35.7367	101.2005
Maximum validity diameter	dh	mm	31.3461	41.9329	108.8800
Addendum	ha	mm	2.1730	2.0664	-0.2003
Dedendum	hf	mm	1.8770	1.9836	4.2503
Whole depth	h	mm	4.0500	4.0500	4.0500
Addendum modification	xm	mm	0.3730	0.2664	2.0003
Normal profile shifted coefficient	xnc	---	0.1691	0.1066	1.1657

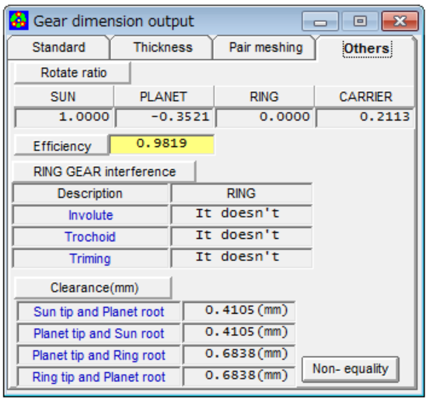
Fig.5.53 Result (Gear dimension)



Gear dimension output — Standard | Thickness | Pair meshing | Others

Desciption	symbol	unit	SUN GEAR	PLANET GEAR		RING GEAR
Operating transverse pressure	awt	deg	22.6897		26.2362	
Operating helix angle	betaw	deg	0.0000		0.0000	
Operating pitch diameter	dw	mm	27.5000	38.5000	39.6000	105.6000
Operating Facewidth	bw	mm	20.0000		20.0000	
Clearance	ck	mm	0.4105	0.4105	0.6838	0.6838
Contact length	ga	mm	7.6176		7.9166	
Near transverse contact ratio	Ka1	---	0.6996		1.0400	
Far transverse contact ratio	Ka2	---	0.7339		0.4498	
Transverse contact ratio	Ka	---	1.4335		1.4898	
Overlap ratio	Kb	---	0.0000		0.0000	
Total contact ratio	Kc	---	1.4335		1.4898	
Sliding ratio at tip	Slipa	---	0.7264	0.8007	0.1341	0.5170
Sliding ratio at root	Slipf	---	-4.0172	-2.6550	-1.0706	-0.1548
Transverse backlash	jnt	mm	0.0980		0.1180	
Backlash angle	jSita	deg	0.4426	0.3162	0.3807	0.1428
Total backlash angle(input axis)	jSita'	deg	0.9756 (Sun)			
Maximum contact diameter	dja	mm	31.3461	41.9329	41.9329	107.7984
Minimum contact diameter	djf	mm	25.5693	36.2134	36.1018	101.2005

Fig.5.54 Result (Pair mashing)



Gear dimension output — Standard | Thickness | Pair meshing | Others

Rotate ratio

SUN	PLANET	RING	CARRIER
1.0000	-0.3521	0.0000	0.2113

Efficiency 0.9819

RING GEAR interference

Description	RING
Involute	It doesn't
Trochoid	It doesn't
Triming	It doesn't

Clearance(mm)

Sun tip and Planet root	0.4105 (mm)
Planet tip and Sun root	0.4105 (mm)
Planet tip and Ring root	0.6838 (mm)
Ring tip and Planet root	0.6838 (mm)

Non- equality

Fig. 5.55 Result (Efficiency, etc.)

By clicking "Uneven layout setting" on the toolbar, Fig. 5.56 is displayed. As for the indication of unequal arrangement, the [A1] gear in Figure 5.56 is the reference gear. Also, since the unequal arrangement angle can not be input arbitrarily, select from the angle table shown in [B] of Fig. 5.57. There are 71 types of arrangement angles of planetary gears in the example.

The arrangement is shown in Fig. 5.58 so that the tip circle of the [A2] gear and [A3] gear does not come in contact with clicking the "minimum arrangement" in Fig. 5.56.

Now, the tooth shape meshing in the case of selecting the second 10.1408 ° from the angle of "B" in Fig. 5.57 is shown in Fig. 5.59. An enlarged view of [C] is shown in Fig. 5.60, and tooth rendering is shown in Fig. 5.61.

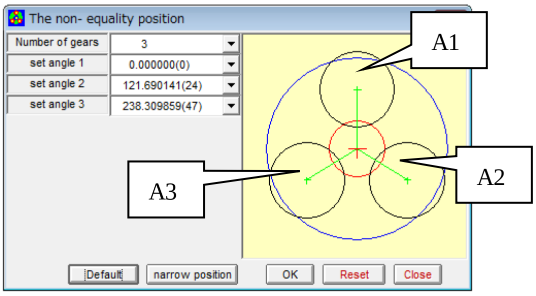


Fig.5.56 Non-equality position-1

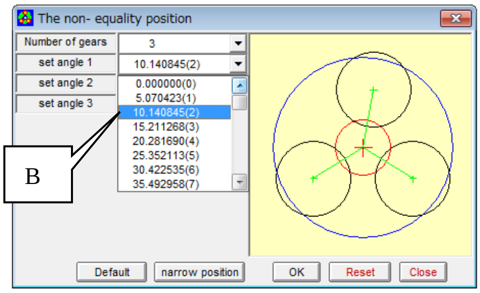


Fig.5.57 Non-equality position-2

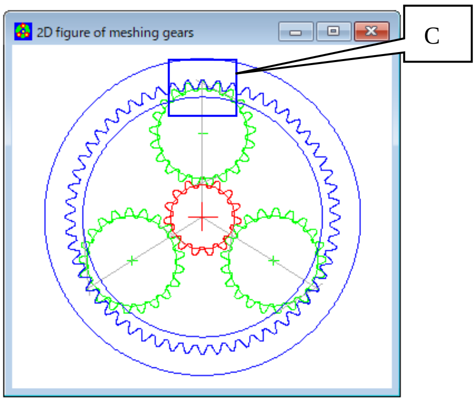
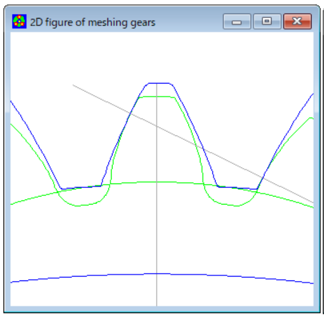


Fig.5.58 Non-equality position of planet gear



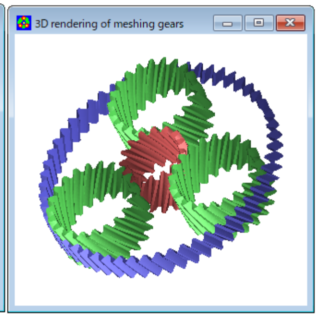


Fig5.59 [C] in Fig.5.58 Fig.5.60 Tooth rendering

In addition, strength calculation, tooth profile data file output, etc. are the same as the basic software. Calculation examples when the number of planets is 5 are shown in Figure 5.62 to 5.64.

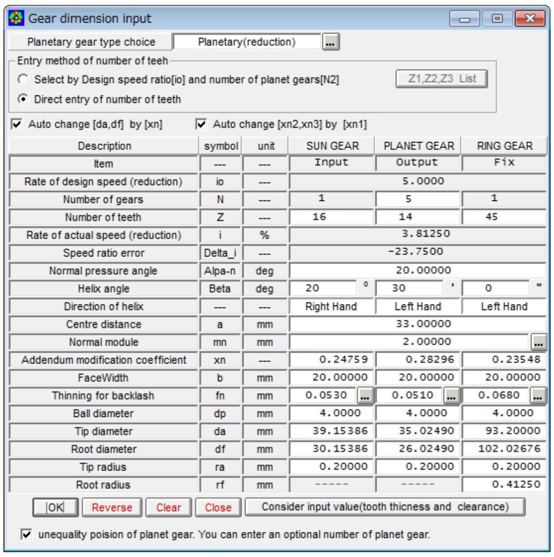


Fig.5.62 Non-equality position of planet gear design

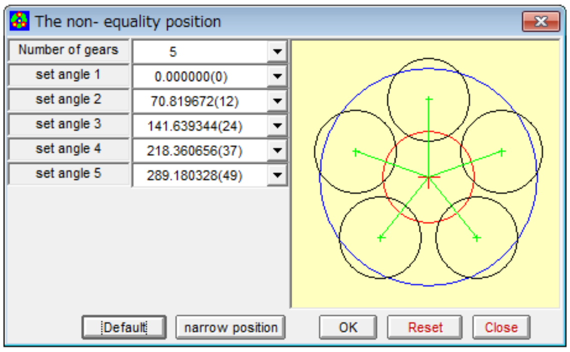


Fig.5.63 Non-equality position-3

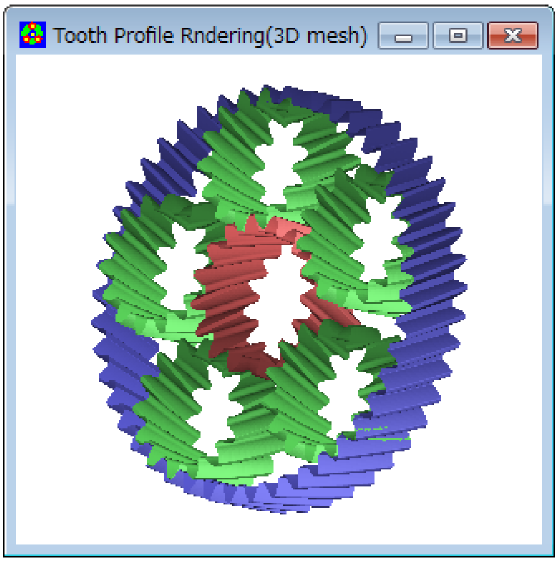


Fig.5.64 Tooth rendering

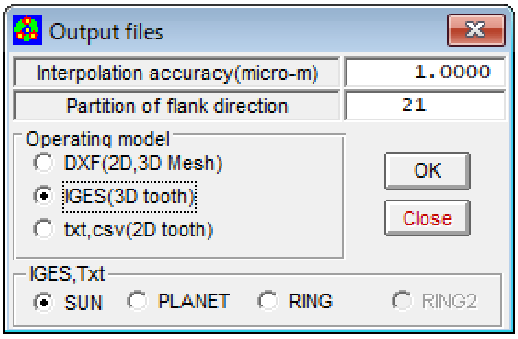


Fig. 5.65 Output file setting

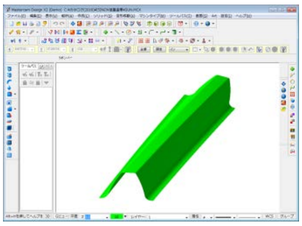


Fig. 5.66 CAD (san gear)

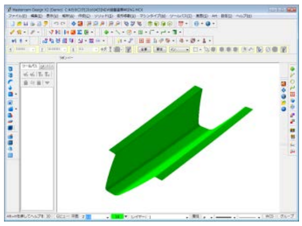


Fig. 5.67 CAD (ring gear)

5.15 Tooth profile data file output

The tooth profile of the generated gear can be output as a file in Figure 5.65. Fig. 5.66 and Fig. 5.67 show CAD drawing examples.