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

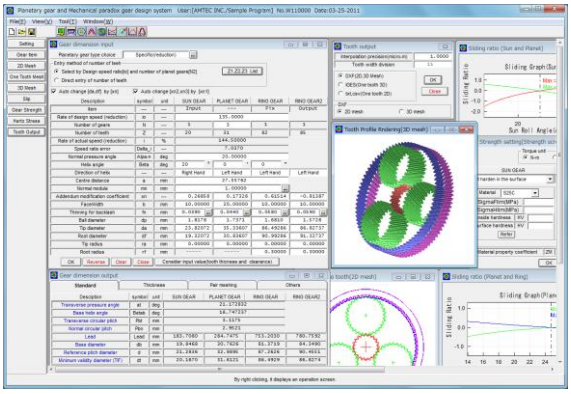


Fig.5.1 Planetary gear and Mechanical paradox Gear design

5.1 Introduction

The **"*Planetary gear and Mechanical paradox Gear design system*"** software can do the design of the planet gear and the mechanical paradox gear easily.

It is possible that it automatically decides combination and center distance of the troublesome teeth number, etc. in the design of the planet gear and simply designs gear dimension and gear strength. And, it is possible to also easily calculate interference check of planet gear and decision of addendum modification coefficient, efficiency calculation (See Fig.5.1).

5.2 Application

(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, Non-equal arrangement

5.3 Initial setting

In the setting the type of the tip diameter, basic rack, the design criterion (module or center distance), gear accuracy and friction coefficient (See Fig.5.2).

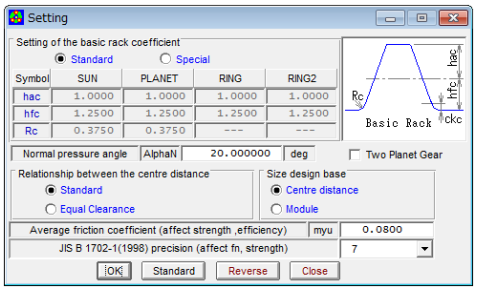


Fig.5.2 Initial setting

5.4 The selection of the planetary gear mechanism

The planet gear type is chosen (See Fig.5.3). (Planetary, Solar, Star and 3K paradox type)

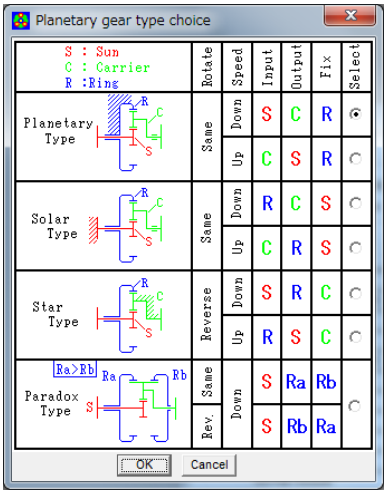


Fig.5.3 Planet gear type

5.5 Gear dimension

The gear dimension input screen is shown in Fig. 5.4.

(1) The number of the planet gear is 1～21.

(2) There are system for inputting directly and system for choosing from the teeth number list (Fig. 5.5) calculated from velocity ratio on the teeth number.

(3) There are determination method of module which made center distance to be a standard and two methods for deciding center distance from module on the relation between center distance and module.

(4) The addendum modification coefficient is calculated from module and center distance.

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

(6) Though the tip diameter is calculated from basic rack and addendum modification coefficient, it is also possible on the change.

(7) Root of tooth of external gear is fillet shape which is created by the generating motion. And, root of tooth of internal gear is single R type.

(8) It is possible to add R in the addendum edge of the gear.

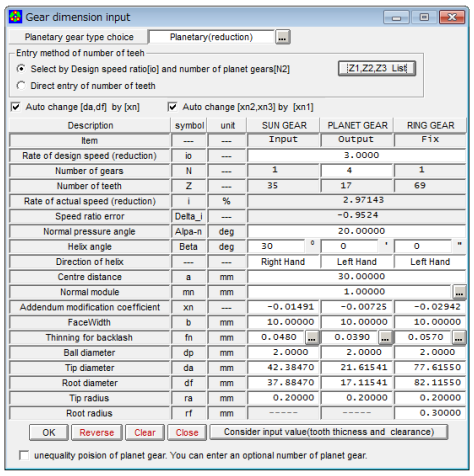
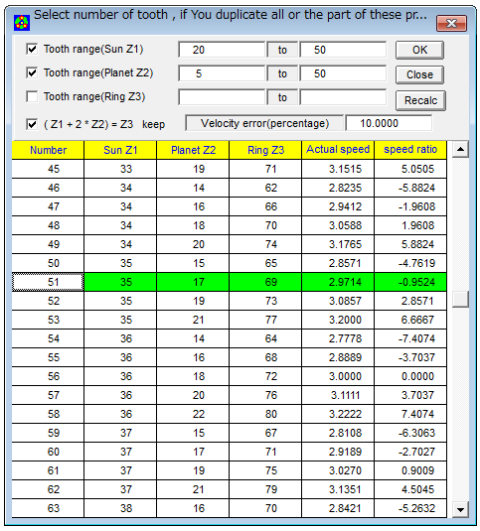


Fig.5.4 Gear dimension



Number	Sun Z1	Planet Z2	Ring Z3	Actual speed	speed ratio
45	33	19	71	3.1515	5.0505
46	34	14	62	2.8235	-5.8824
47	34	16	66	2.9412	-1.9608
48	34	18	70	3.0588	1.9608
49	34	20	74	3.1765	5.8824
50	35	15	65	2.8571	-4.7619
51	35	17	69	2.9714	-0.9524
52	35	19	73	3.0857	2.8571
53	35	21	77	3.2000	6.6667
54	36	14	64	2.7778	-7.4074
55	36	16	68	2.8889	-3.7037
56	36	18	72	3.0000	0.0000
57	36	20	76	3.1111	3.7037
58	36	22	80	3.2222	7.4074
59	37	15	67	2.8108	-6.3063
60	37	17	71	2.9189	-2.7027
61	37	19	75	3.0270	0.9009
62	37	21	79	3.1351	4.5045
63	38	16	70	2.8421	-5.2632

Fig.5.5 The number of teeth list

(9) The other addendum-modification-coefficient is connected when the addendum-modification-coefficient changes one kind and changes. However, it is possible to enter respectively, too.
(10) It is possible to use Fig. 5.6 for clearance adjustment and tooth thickness adjustment. Then, it is possible to confirm addendum modification coefficient and tooth profile which tip diameter was changed and clearance, interference in this screen. However, the tooth profile here is only tooth surface, and the root of tooth shape is not included.

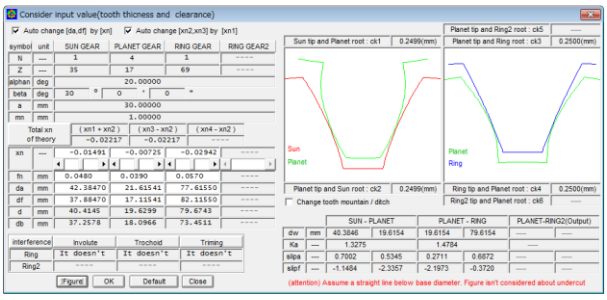
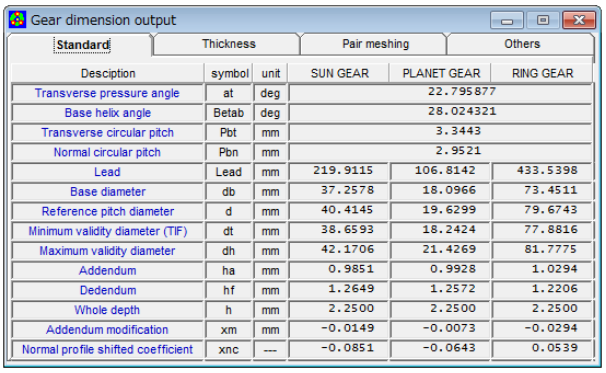


Fig.5.6 Support of the dimension

(11) The calculation result after it determines the gear dimension is shown in Fig. 5.7 ～ 5.10.

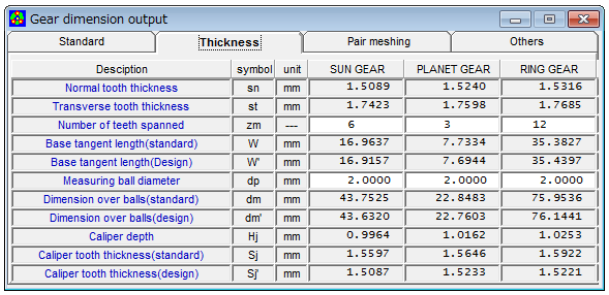


Gear dimension output

Standard | Thickness | Pair meshing | Others

Desciption	symbol	unit	SUN GEAR	PLANET GEAR	RING GEAR
Transverse pressure angle	at	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	Lead	mm	219.9115	106.8142	433.5398
Base diameter	db	mm	37.2578	18.0966	73.4511
Reference pitch diameter	d	mm	40.4145	19.6299	79.6743
Minimum validity diameter (TIF)	dt	mm	38.6593	18.2424	77.8816
Maximum validity diameter	dh	mm	42.1706	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 shifted coefficient	xnc	---	-0.0851	-0.0643	0.0539

Fig.5.7 Result (Gear dimension)

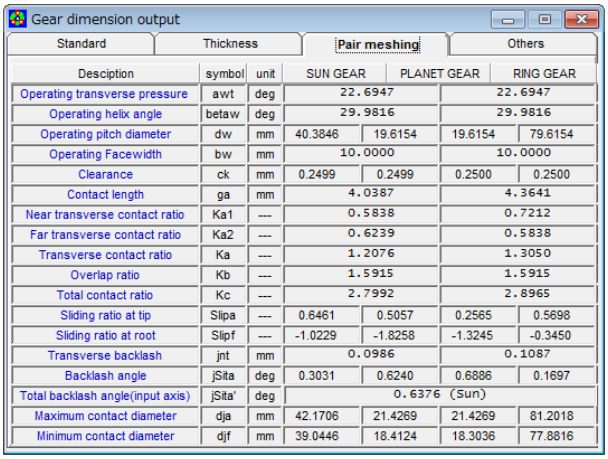


Gear dimension output

Standard | Thickness | Pair meshing | Others

Desciption	symbol	unit	SUN GEAR	PLANET GEAR	RING GEAR
Normal tooth thickness	sn	mm	1.5089	1.5240	1.5316
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	2.0000	2.0000	2.0000
Dimension over balls(standard)	dm	mm	43.7525	22.8483	75.9536
Dimension over balls(design)	dm'	mm	43.6320	22.7603	76.1441
Caliper depth	Hj	mm	0.9964	1.0162	1.0253
Caliper tooth thickness(standard)	Sj	mm	1.5597	1.5646	1.5922
Caliper tooth thickness(design)	Sj'	mm	1.5087	1.5233	1.5221

Fig.5.8 Result (Tooth thickness)

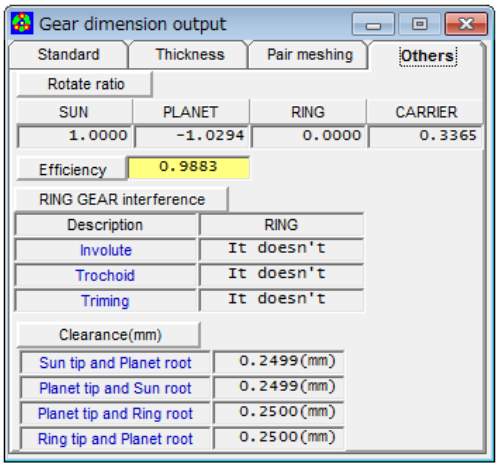


Gear dimension output

Standard | Thickness | Pair meshing | Others

Desciption	symbol	unit	SUN GEAR		PLANET GEAR	RING GEAR
Operating transverse pressure	awt	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	0.2499	0.2499	0.2500	0.2500
Contact length	ga	mm	4.0387		4.3641	
Near transverse contact ratio	Ka1	---	0.5838		0.7212	
Far transverse contact ratio	Ka2	---	0.6239		0.5838	
Transverse contact ratio	Ka	---	1.2076		1.3050	
Overlap ratio	Kb	---	1.5915		1.5915	
Total contact ratio	Kc	---	2.7992		2.8965	
Sliding ratio at tip	Slipa	---	0.6461	0.5057	0.2565	0.5698
Sliding ratio at root	Slipf	---	-1.0229	-1.8258	-1.3245	-0.3450
Transverse backlash	jnt	mm	0.0986		0.1087	
Backlash angle	jSita	deg	0.3031	0.6240	0.6886	0.1697
Total backlash angle(input axis)	jSita'	deg	0.6376 (Sun)			
Maximum contact diameter	dja	mm	42.1706	21.4269	21.4269	81.2018
Minimum contact diameter	djf	mm	39.0446	18.4124	18.3036	77.8816

Fig.5.9 Result (Pair mashing)



Gear dimension output

Standard | Thickness | Pair meshing | Others

Rotate ratio

SUN	PLANET	RING	CARRIER
1.0000	-1.0294	0.0000	0.3365

Efficiency 0.9883

RING GEAR interference

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

Clearance(mm)

Sun tip and Planet root	0.2499(mm)
Planet tip and Sun root	0.2499(mm)
Planet tip and Ring root	0.2500(mm)
Ring tip and Planet root	0.2500(mm)

Fig.5.10 Result (Efficiency, etc,.)

5.6 Tooth profile figure

5.6.1 Tooth profile (2D)

The 2D-meshing of the tooth profile is displayed in Fig. 5.11 and Fig. 5.12. The confirmation of the contact location in tooth surface is easy, because to display support circle and common normal line in the control screen is possible. And, it is possible to display by changing rotation angle of the gear in the zoom.

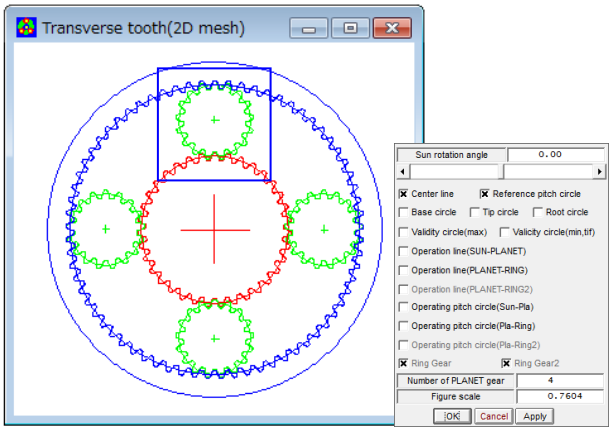


Fig.5.11 Meshing of the tooth profile (2D)

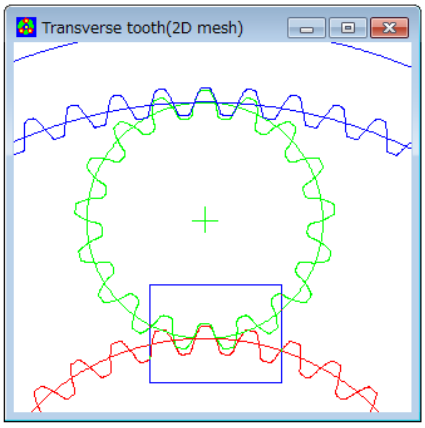


Fig.5.12 Meshing of the tooth profile (Zoom)

5.6.2 Meshing of a pair tooth profile (2D)

It is possible to confirm the meshing of a tooth pair in Fig. 5.13. And, It is possible to confirm the interference of internal gear and addendum of external gear and root of tooth part in detail in this screen.

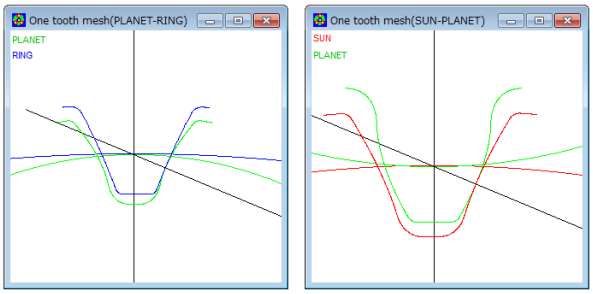


Fig.5.13 Meshing figure of a pair tooth

5.6.3 Meshing of teeth profile (3D)

The meshing of the gear is displayed in the three-dimensional figure. Then, it is possible that the gear is made to rotate in the X, Y, Z axial direction. And, control form of the tooth profile rendering is shown in Fig. 5.16.

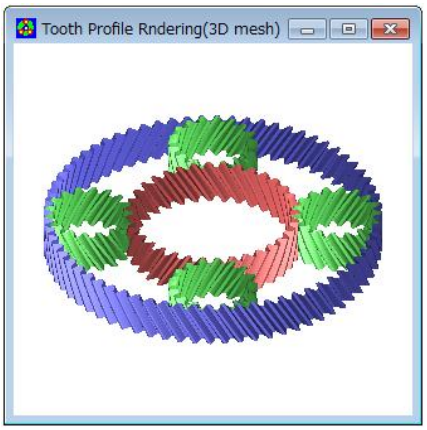


Fig.5.14 Teeth rendering

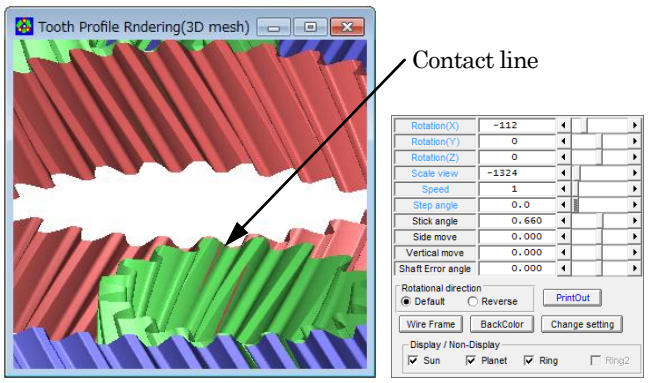
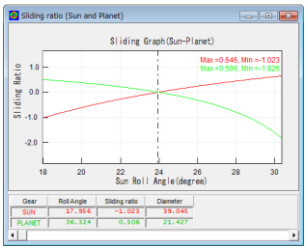


Fig.5.15 profile (Zoom) Fig.5.16 Control form

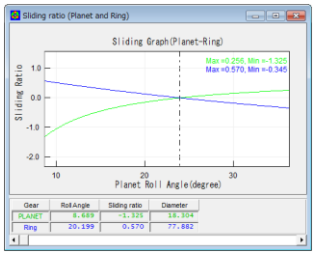
5.7 Sliding ratio graph

A 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 setting

It is possible to choose steel and plastic material in the setting initial screen (See Fig. 5.19). Bending allowable stress (σ_{Flim}) and Hertz allowable stress (σ_{Hlim}) are chosen from Fig. 5.20. Or, it is possible to input the allowable stress directly. It is possible to choose the torque unit from "N-m", "N-cm", "kgf-m", "kgf-cm", "gf-cm".

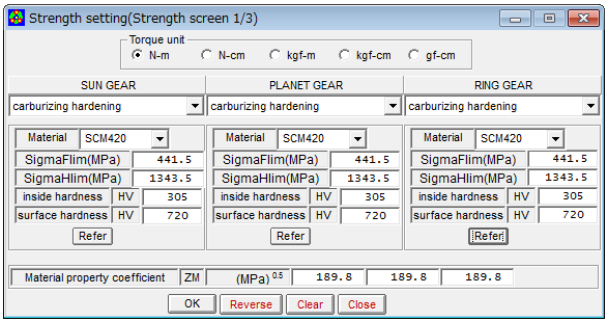


Fig.5.19 Input (Material)

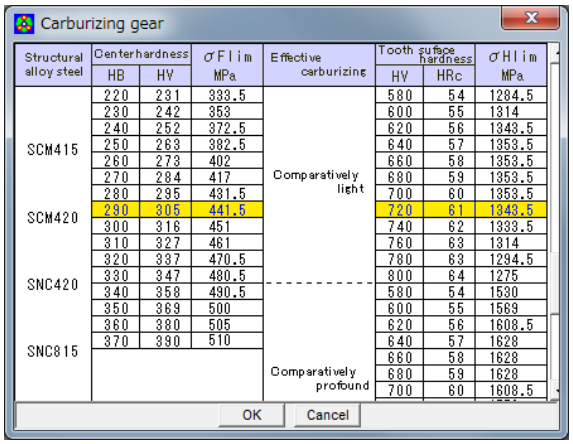


Fig.5.20 Example of the allowable stress of the steel

5.8.2 Input (Gear strength dimension)

The numerical value is input into the strength dimension input screen (See Fig. 5.21). Torque and rotational speed can be set even in the output side even in the input side.

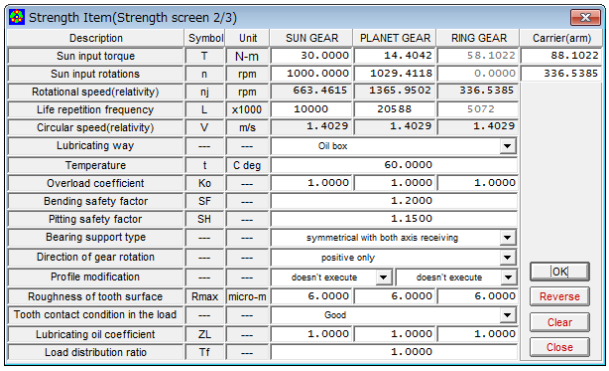
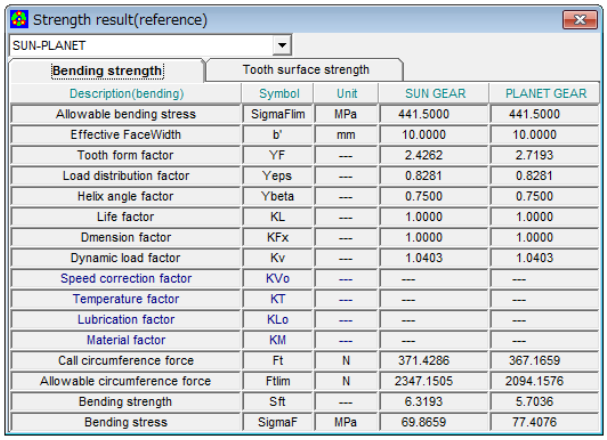


Fig.5.21 Input (Gear strength dimension)

5.8.3 Gear strength calculation result

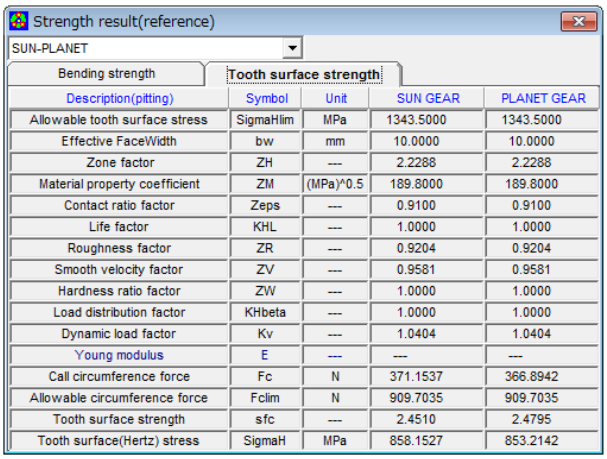
The strength calculation result screen is displayed in Fig. 5.22 and Fig. 5.23. The strength calculation also considers efficiency and contact ratio.

The steel gear does the strength calculation based on JGMA401-01:1974 and JGMA401-02:1975. Allowable stress value of the plastic gear material has adopted temperature and material experimental value considering life, etc..



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)



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 Hertzian stress graph

The Hertz stress graph is shown in Fig. 5.24 and Fig. 5.25. By this graph, It is possible to confirm the difference between the Hertz stress of the meshing.

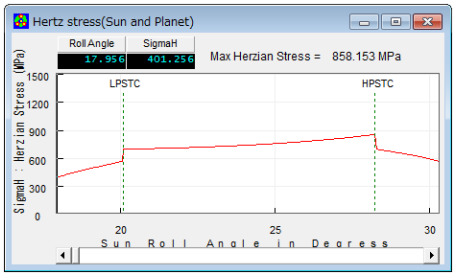


Fig.5.24 Hertzian stress (Sun)

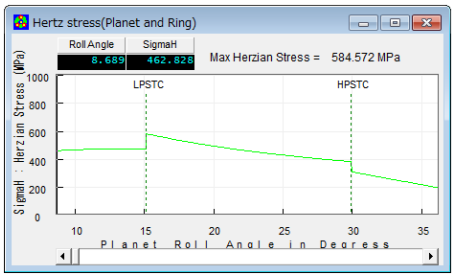


Fig.5.25 Hertzian stress (Planet)

5.10 Other

(1) Tooth profile output

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

(2) Print out (Gear dimension, Strength, Tooth form figure, Sliding ratio graph, Hertzian stress graph)

(3) Saving and reading of design data

5.11 Mechanical paradox Gear design system (3K-Type)

Mechanical paradox Gear which increases a gear reduction ratio is well known but this design is very troublesome. However, it is possible to simply design Mechanical paradox Gear by using this software.

This mechanism uses the one sun gear, one planet gear, the two inside gears. Same direction deceleration and reverse-directional deceleration depend on the number of teeth of internal gear-1 and internal gear-2. Design example is shown in the following.

5.11.1 Setting of gear dimension

(1) The module standard is chosen in the setting screen dimension the initial stage (Fig.5.2).

(2) It chooses a 3 K type in the planet gear of Fig. 5.3.

(3) It inputs 135 in the gear reduction ratio as the example and it inputs three in the number of the planet gear.

(4) The teeth number list screen is displayed, and the combination of the appropriate teeth number is chosen (See Fig.5.27).

Note point in this case

(a) The error of real velocity ratio and design velocity ratio.

(b) The number of teeth isn't too small and isn't too big.

(c) That there is the relation of "z1+2×z 2" between the z3 and z4 tooth number of the internal gear.

Here, the following are chosen as an example: z1=20, z2=31, z3=82 and z4=85.

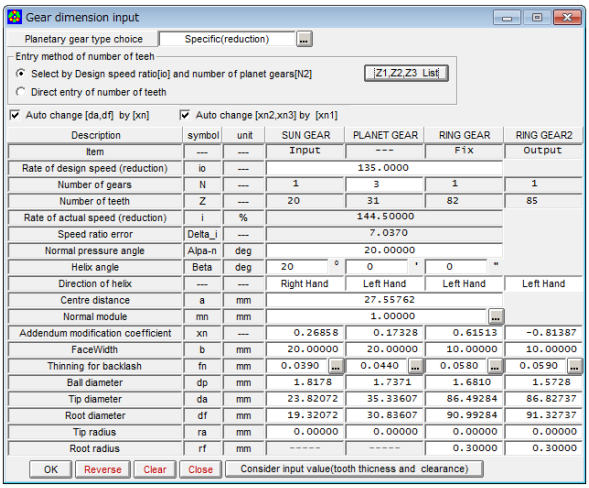


Fig.5.26 Input of gear dimension

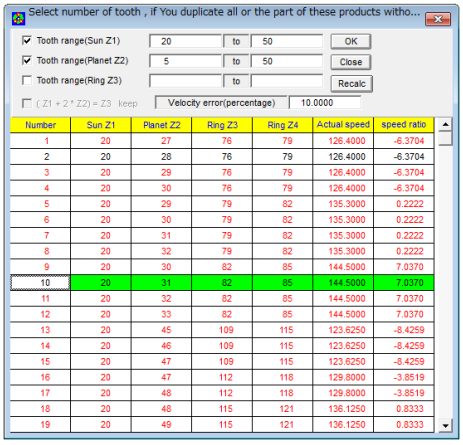


Fig.5.27 The number of teeth list

(5) The tooth profile is confirmed in the input support screen (See Fig.5.28).

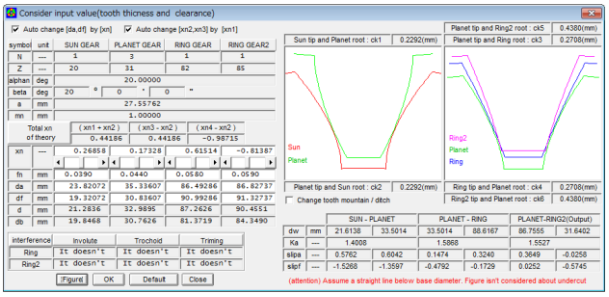


Fig.5.28 Input support screen

(6) Efficiency and contact ratio and sliding ratio of the size calculation result screen are confirmed, as it is shown in Fig. 5.29～5.31. The efficiency of the mechanical paradox gear of this case is 73.1%, as it is shown in Fig. 5.32.

The dimension result is shown in the following (See Fig.5.29 ～5.32).

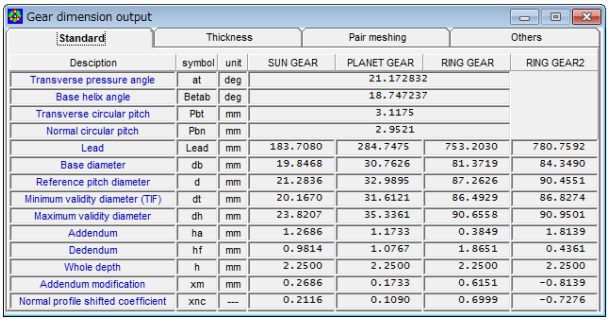


Fig.5.29 Result (Gear dimension)

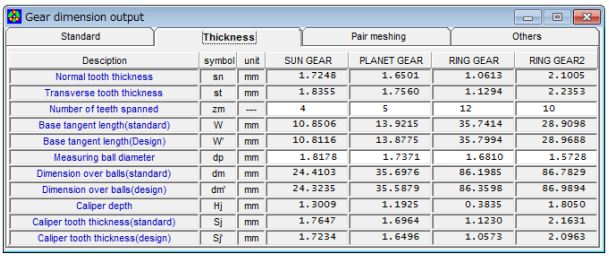
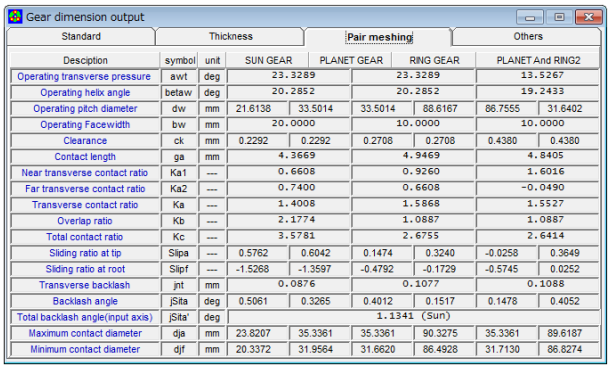


Fig.5.30 Result (Tooth thickness)

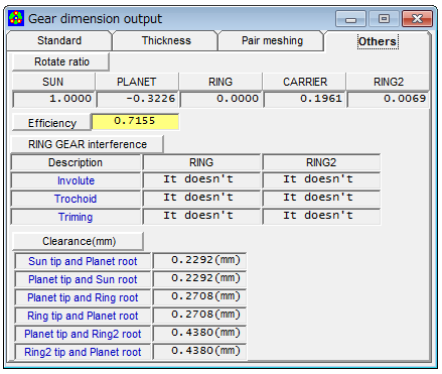


Gear dimension output

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)

A meshing figure is shown in figure 5.33. In the enlarged view of figure of 5.34, two internal gears prove well that it has meshing in planet gear each other. And, it is possible to observe the aspect of the meshing rotation of the mechanical paradox gear in tooth profile rendering shown in Fig. 5.35.

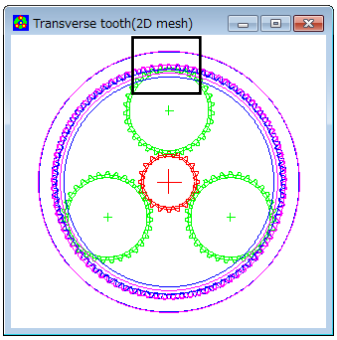


Fig.5.33 Meshing of the tooth profile (2D)

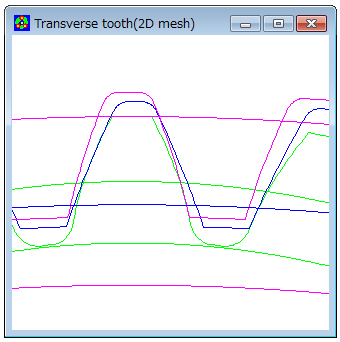


Fig.5.34 Meshing of the tooth profile (Zoom)

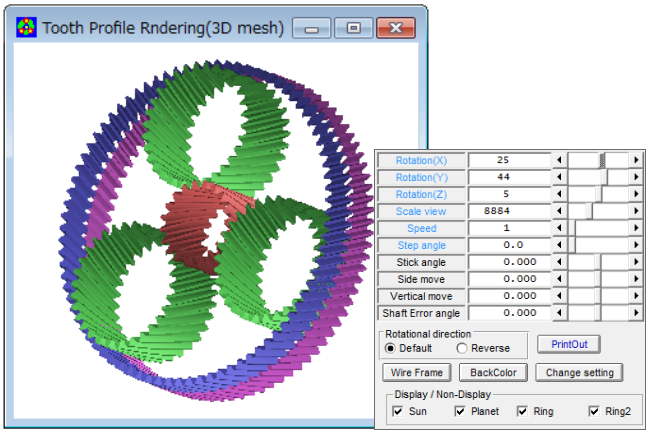


Fig.5.35 Teeth rendering (Gear ratio=144)

5.11.3 Mechanical paradox Gear (Spur gear)

(1) It is possible to calculate gear strength calculation and sliding ratio and Hertz stress graph as well as the planet gear (explanation omission).

（2） Construction example of the Mechanical paradox Gear of the spur gear is shown in figures of 5.36.

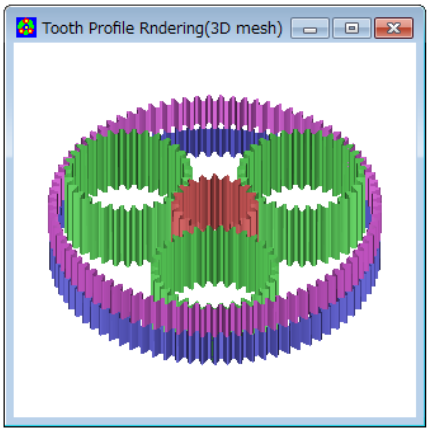


Fig.5.36 Teeth rendering (Spur gear, Gear ratio=93.8)

5.12 Small number of teeth（Option）

The number of teeth can design a planet gear below 4 teeth. The minimum number of teeth is 1 tooth. The small teeth number makes angle of helix increase, because the transverse contact ratio decreases. The construction example is shown in figures of 5.37 and 5.38.

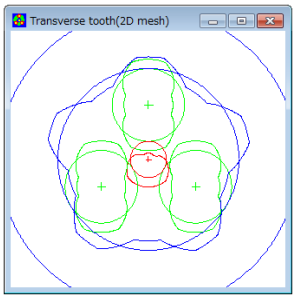


Fig.5.37 Teeth profile(2D)

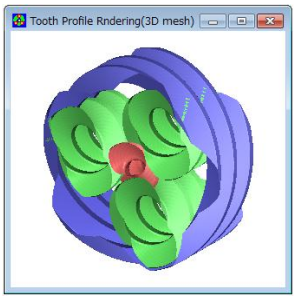
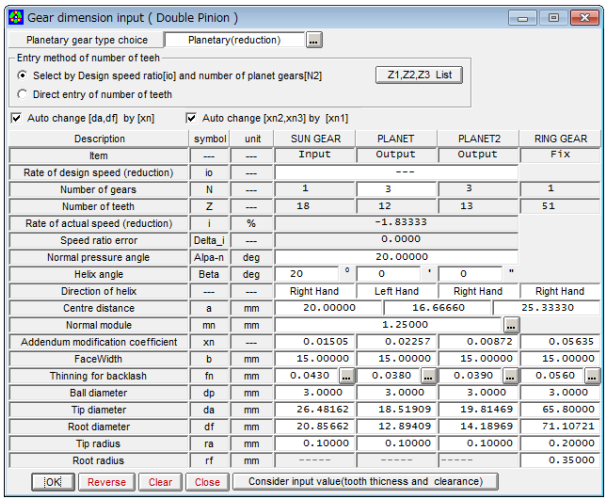


Fig.5.38 Teeth profile (3D)

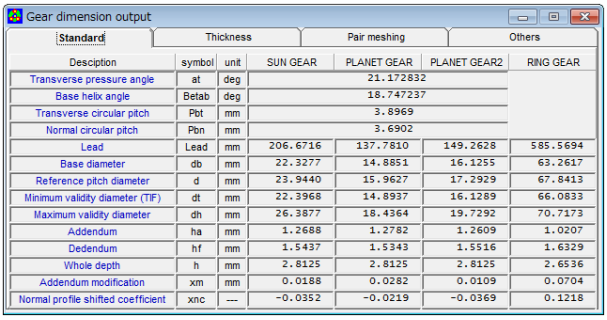
5.13 Double pinion（Option）

The design example of the double pinion is shown in the following.



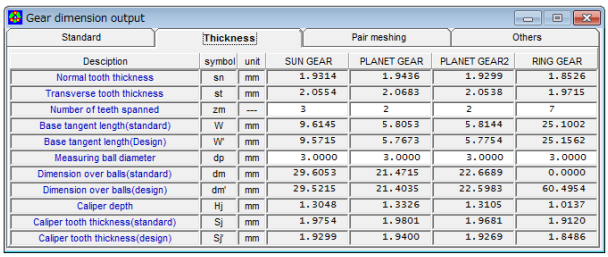
Description	symbol	unit	SUN GEAR	PLANET	PLANET2	RING GEAR
Item	---	---	Input	Output	Output	Fix
Rate of design speed (reduction)	io	---	---			
Number of gears	N	---	1	3	3	1
Number of teeth	Z	---	18	12	13	51
Rate of actual speed (reduction)	i	%	-1.83333			
Speed ratio error	Delta_i	---	0.0000			
Normal pressure angle	Alpa-n	deg	20.00000			
Helix angle	Beta	deg	20 °	0 '	0 "	
Direction of helix	---	---	Right Hand	Left Hand	Right Hand	Right Hand
Centre distance	a	mm	20.00000	16.66660	25.33330	
Normal module	mn	mm	1.25000			
Addendum modification coefficient	xn	---	0.01505	0.02257	0.00872	0.05635
FaceWidth	b	mm	15.00000	15.00000	15.00000	15.00000
Thinning for backlash	fn	mm	0.0430	0.0380	0.0390	0.0560
Ball diameter	dp	mm	3.0000	3.0000	3.0000	3.0000
Tip diameter	da	mm	26.48162	18.51909	19.81469	65.80000
Root diameter	df	mm	20.85662	12.89409	14.18969	71.10721
Tip radius	ra	mm	0.10000	0.10000	0.10000	0.20000
Root radius	rf	mm	-----	-----	-----	0.35000

Fig.5.39 Input dimension



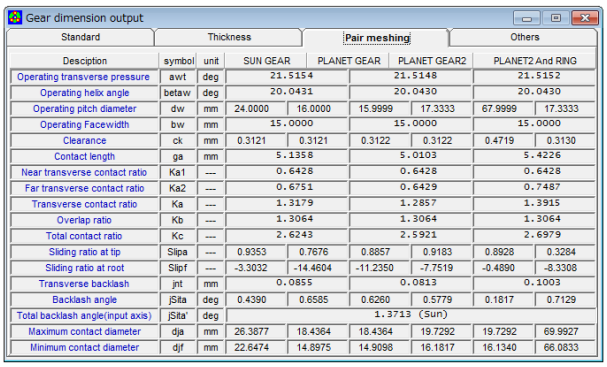
Desciption	symbol	unit	SUN GEAR	PLANET GEAR	PLANET GEAR2	RING GEAR
Transverse pressure angle	at	deg	21.172832			
Base helix angle	Betab	deg	18.747237			
Transverse circular pitch	Pbt	mm	3.8969			
Normal circular pitch	Pbn	mm	3.6902			
Lead	Lead	mm	206.6716	137.7810	149.2628	585.5694
Base diameter	db	mm	22.3277	14.8851	16.1255	63.2617
Reference pitch diameter	d	mm	23.9440	15.9627	17.2929	67.8413
Minimum validity diameter (TIF)	dt	mm	22.3968	14.8937	16.1289	66.0833
Maximum validity diameter	dh	mm	26.3877	18.4364	19.7292	70.7173
Addendum	ha	mm	1.2688	1.2782	1.2609	1.0207
Dedendum	hf	mm	1.5437	1.5343	1.5516	1.6329
Whole depth	h	mm	2.8125	2.8125	2.8125	2.6536
Addendum modification	xm	mm	0.0188	0.0282	0.0109	0.0704
Normal profile shifted coefficient	xnc	---	-0.0352	-0.0219	-0.0369	0.1218

Fig.5.40 Result (Gear dimension)



Desciption	symbol	unit	SUN GEAR	PLANET GEAR	PLANET GEAR2	RING GEAR
Normal tooth thickness	sn	mm	1.9314	1.9436	1.9299	1.8526
Transverse tooth thickness	st	mm	2.0554	2.0683	2.0538	1.9715
Number of teeth spanned	zm	---	3	2	2	7
Base tangent length(standard)	W	mm	9.6145	5.8053	5.8144	25.1002
Base tangent length(Design)	W'	mm	9.5715	5.7673	5.7754	25.1562
Measuring ball diameter	dp	mm	3.0000	3.0000	3.0000	3.0000
Dimension over balls(standard)	dm	mm	29.6053	21.4715	22.6689	0.0000
Dimension over balls(design)	dm'	mm	29.5215	21.4035	22.5983	60.4954
Caliper depth	Hj	mm	1.3048	1.3326	1.3105	1.0137
Caliper tooth thickness(standard)	Sj	mm	1.9754	1.9801	1.9681	1.9120
Caliper tooth thickness(design)	Sj'	mm	1.9299	1.9400	1.9269	1.8486

Fig.5.41 Result (Tooth thickness)



Desciption	symbol	unit	SUN GEAR		PLANET GEAR		PLANET GEAR2		PLANET2 And RING	
Operating transverse pressure	awt	deg	21.5154		21.5148		21.5152			
Operating helix angle	betaw	deg	20.0431		20.0430		20.0430			
Operating pitch diameter	dw	mm	24.0000	16.0000	15.9999	17.3333	67.9999	17.3333		
Operating Facewidth	bw	mm	15.0000		15.0000		15.0000			
Clearance	ck	mm	0.3121	0.3121	0.3122	0.3122	0.4719	0.3130		
Contact length	ga	mm	5.1358		5.0103		5.4226			
Near transverse contact ratio	Ka1	---	0.6428		0.6428		0.6428			
Far transverse contact ratio	Ka2	---	0.6751		0.6429		0.7487			
Transverse contact ratio	Ka	---	1.3179		1.2857		1.3915			
Overlap ratio	Kb	---	1.3064		1.3064		1.3064			
Total contact ratio	Kc	---	2.6243		2.5921		2.6979			
Sliding ratio at tip	Slipa	---	0.9353	0.7676	0.8857	0.9183	0.8928	0.3284		
Sliding ratio at root	Slipf	---	-3.3032	-14.4604	-11.2350	-7.7519	-0.4890	-8.3308		
Transverse backlash	jnt	mm	0.0855		0.0813		0.1003			
Backlash angle	jSita	deg	0.4390	0.6585	0.6260	0.5779	0.1817	0.7129		
Total backlash angle(input axis)	jSita'	deg	1.3713 (Sun)							
Maximum contact diameter	dja	mm	26.3877	18.4364	18.4364	19.7292	19.7292	69.9927		
Minimum contact diameter	djf	mm	22.6474	14.8975	14.9098	16.1817	16.1340	66.0833		

Fig.5.42 Result (Pair mashing)

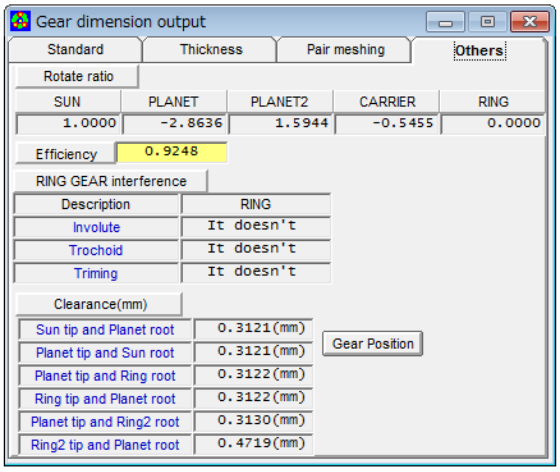


Fig.5.43 Result (Efficiency, etc,.)

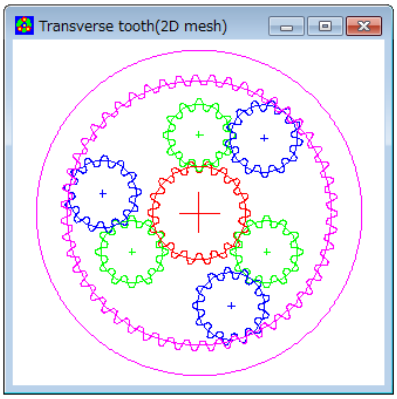


Fig.5.44 Meshing of the tooth profile (2D)

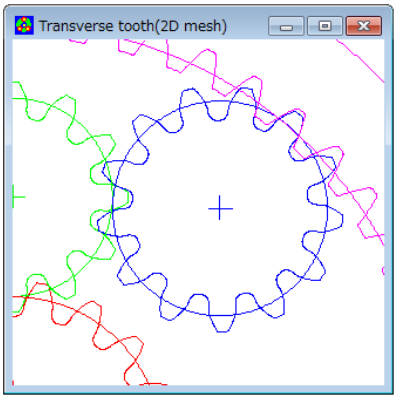


Fig.5.45 Meshing of the tooth profile (Zoom)

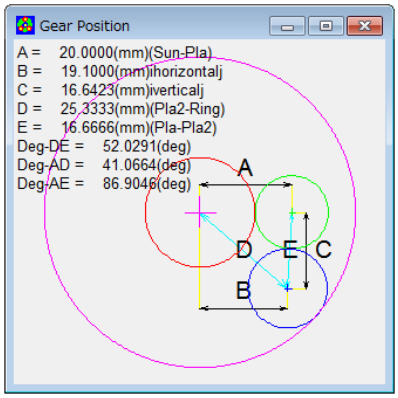


Fig.5.46 Configuration of the gear

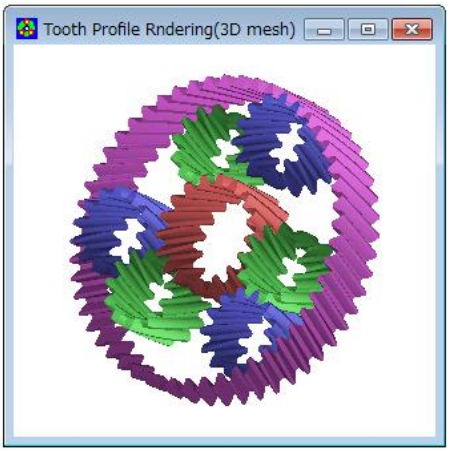


Fig.5.47 Teeth rendering

Strength Item(Strength screen 2/3)

Description	Symbol	Unit	SUN GEAR	PLANET GEAR	PLANET GEAR2	RING GEAR	Carrier(arm)
Sun input torque	T	N-m	100.0000	65.3843	69.2901	269.5505	169.5505
Sun input rotations	n	rpm	1000.0000	2863.6364	1594.4056	0.0000	545.4545
Rotational speed(relativity)	nj	rpm	1545.4545	2318.1818	2139.8601	545.4545	
Life repetition frequency	L	x1000	10000	15000	13846	3529	
Circular speed(relativity)	V	m/s	1.9421	1.9421	1.9421	1.9421	
Lubricating way	---	---	Gris				
Temperature	t	C deg	60.0000				
Overload coefficient	Ko	---	1.0000	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	doesn't exec		
Roughness of tooth surface	Rmax	micro-m	6.0000	6.0000	6.0000	6.0000	
Tooth contact condition in the load	---	---	Good				
Lubricating oil coefficient	ZL	---	1.0000	1.0000	1.0000	1.0000	
Load distribution ratio	Tf	---	1.0000				

OK Reverse Clear Close

Fig.5.48 Gear strength (Bending)

Strength result(Strength screen 3/3)

Bending strength | Tooth surface strength

Description(bending)	Symbol	Unit	SUN GEAR	PLANET GEAR	PLANET GEAR2	RING GEAR
Allowable bending stress	SigmaFlim	MPa	441.5000	441.5000	441.5000	441.5000
Effective FaceWidth	b'	mm	15.0000	15.0000	15.0000	15.0000
Tooth form factor	YF	---	2.8091	3.2102	3.1421	2.0650
Load distribution factor	Yeps	---	0.7588	0.7778	0.7778	0.7186
Helix angle factor	Ybeta	---	0.8333	0.8333	0.8333	0.8333
Life factor	KL	---	1.0000	1.0000	1.0000	1.0000
Dmension factor	KFx	---	1.0000	1.0000	1.0000	1.0000
Dynamic load factor	Kv	---	1.0942	1.0942	1.0942	1.0942
Speed correction factor	KVo	---	---	---	---	---
Temperature factor	KT	---	---	---	---	---
Lubrication factor	KLo	---	---	---	---	---
Material factor	KM	---	---	---	---	---
Call circumference force	Ft	N	2777.7779	2724.3567	2665.0146	2642.6557
Allowable circumference force	Ftlim	N	3549.4064	3030.0017	3095.6166	5097.9676
Bending strength	Sft	---	1.2778	1.1122	1.1616	1.9291
Bending stress	SigmaF	MPa	345.5194	396.9646	380.0871	228.8623

Fig.5.49 Gear strength (Pitting)

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

5.13 Non-equality position of planet gear (Option)

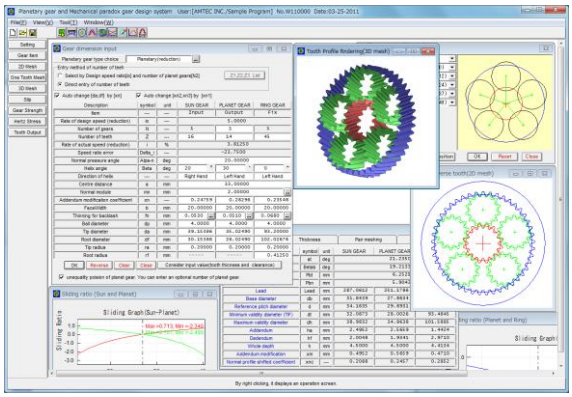


Fig.5.50 Non-equality position of planet gear

5.13 Outline

To the Planetary gear and Mechanical paradox Gear design system software, the Non-equality position of planet gear option was added. This can be designed by the feeling which is the same as the equality position of planet gear. But, it doesn't apply to the Mechanical paradox Gear and the double pinion.

5.14 Design example

The design example of the Non-equality position of planet gear of the planetary type is shown in the following. In the condition of the equality position, it becomes and so on sun teeth number of 15, planet teeth number of 21, internal gear teeth number of 57 in case of Fig. 5.51.

When making an internal-gear number of teeth 56 here, it doesn't become equality position of planet gear.

Therefore, it makes Direct entry of number of teeth of figure 5.51 and unequality poision of planet gear. valid.

Gear dimension input

Planetary gear type choice: Planetary(reduction)

Entry method of number of teeh

Select by Design speed ratio[io] and number of planet gears[N2] — Z1,Z2,Z3 List

Direct entry of number of teeth

Auto change [da,df] by [xn] — Auto change [xn2,xn3] by [xn1]

Description	symbol	unit	SUN GEAR	PLANET GEAR	RING GEAR
Item	---	---	Input	Output	Fix
Rate of design speed (reduction)	io	---	5.0000		
Number of gears	N	---	1	3	1
Number of teeth	Z	---	15	21	57
Rate of actual speed (reduction)	i	%	4.80000		
Speed ratio error	Delta_i	---	-4.0000		
Normal pressure angle	Alpa-n	deg	20.00000		
Helix angle	Beta	deg	0 °	0 '	0 "
Direction of helix	---	---	-----	-----	-----
Centre distance	a	mm	33.00000		
Normal module	mn	mm	1.80000		
Addendum modification coefficient	xn	---	0.20724	0.14802	0.50328
FaceWidth	b	mm	20.00000	20.00000	20.00000
Thinning for backlash	fn	mm	0.0470	0.0510	0.0670
Ball diameter	dp	mm	3.0000	3.0000	3.0000
Tip diameter	da	mm	31.34606	41.93287	100.81181
Root diameter	df	mm	23.24606	33.83287	108.91181
Tip radius	ra	mm	0.00000	0.00000	0.00000
Root radius	rf	mm	-----	-----	0.41250

OK Reverse Clear Close Consider input value(tooth thicness and clearance)

unequality poision of planet gear. You can enter an optional number of planet gear.

Fig.5.51 Equality position of planet gear

The screen which changed the number of teeth of the internal-gear into 56 is shown in Fig. 5.52. The addendum modification coefficient of internal gear is big, because the module is m_n1.8 equal to Fig. 5.51. Though the example shows the spur gear, it is possible to also design the helical gear. And, the function of Consider input value(tooth is also usable. See Fig. 5.6 for more information.

Dimension results, etc. are shown in Fig. 5.53～5.55.

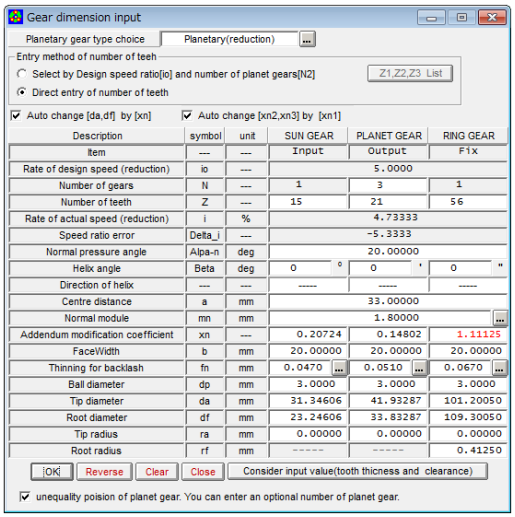


Fig.5.52 Non-equality position of planet gear

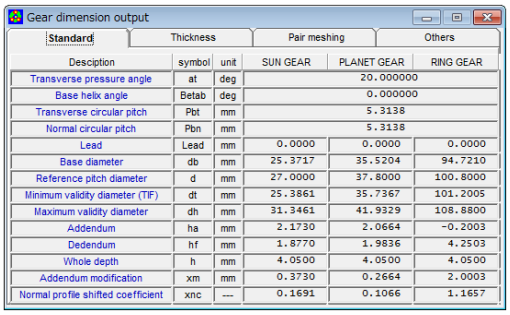


Fig.5.53 Result (Gear dimension)

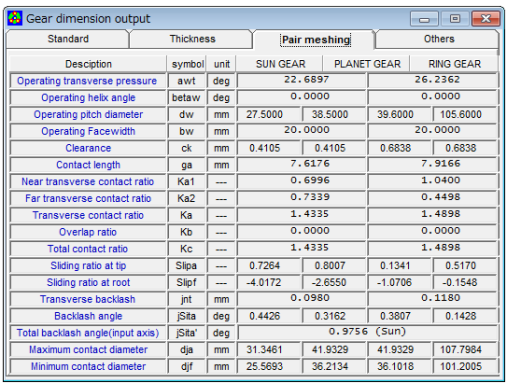


Fig.5.54 Result (Pair mashing)

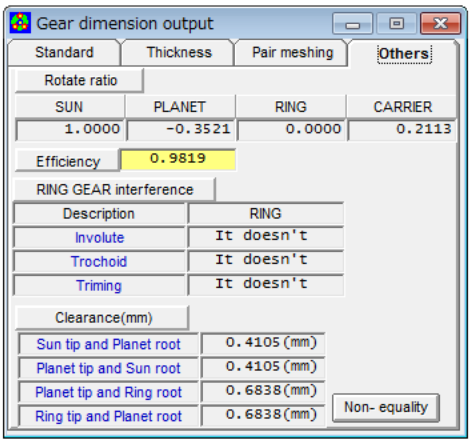


図 5.55 Result (Efficiency, etc,.)

Fig. 5.56 is displayed, when it clicks Non- equality of Fig. 5.55. As for Non-equality position of planet gear, the [A1] gear of figure 5.56 is a standard position. And, it chooses from angle table shown at the [B] of figures of 5.57, because to freely input the Non-equality position angle is not possible. In case of the example, configuration angle of the planet gear exists in 71 types.

The tooth profile meshing in choosing the second 10.1408 degrees from the angle of [B] of Fig. 5.57 is shown in Fig. 5.58. Enlarged view and tooth profile rendering of [C] are shown in Fig.5.59 and 5.60.

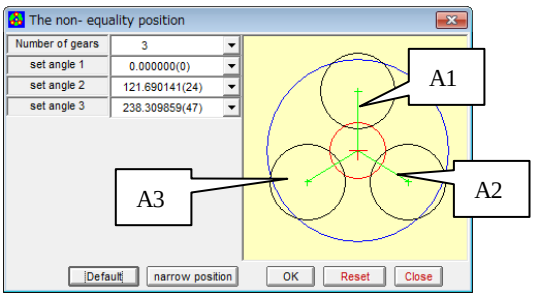


Fig.5.56 Non-equality position-1

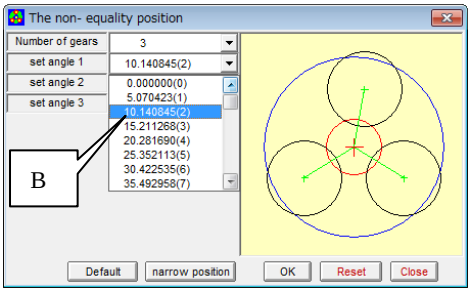


Fig.5.57 Non-equality position-2

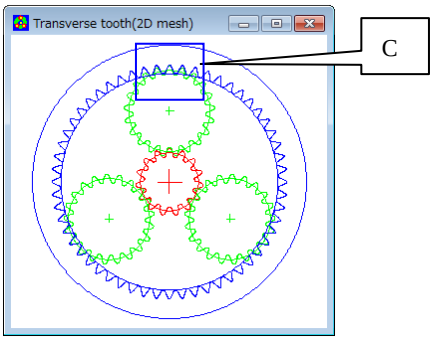


Fig.5.58 Non-equality position of planet gear

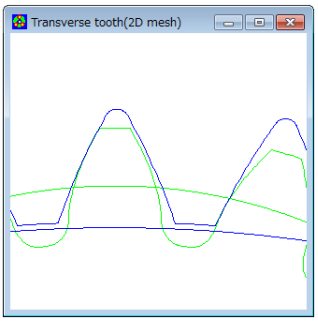


Fig5.59 [C] in Fig.5.58

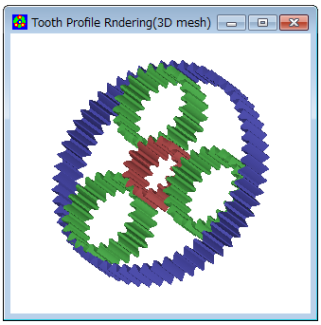


Fig.5.60 Tooth rendering

In addition, gear strength calculation, tooth profile data file output, etc. are equal to the basic software. Non-equality position of planet gear design example of the helical gear is shown in Fig. 5.61～5.63.

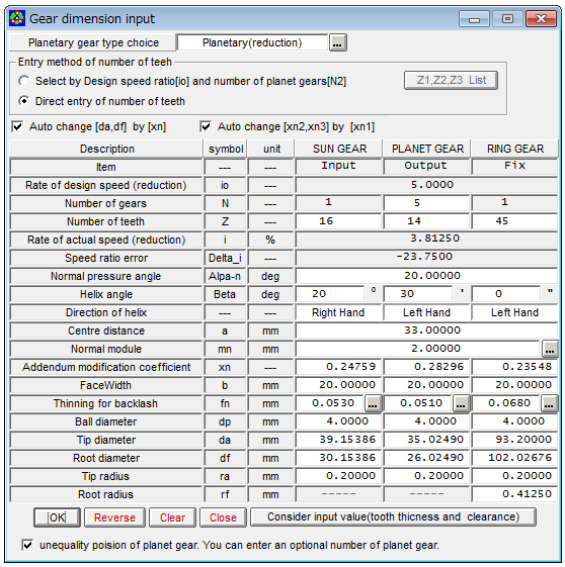


Fig.5.61 Non-equality position of planet gear design

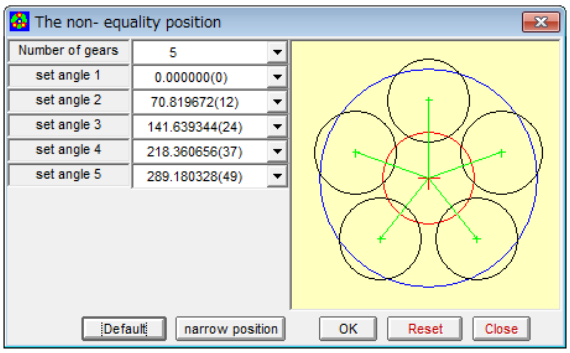


Fig.5.62 Non-equality position-3

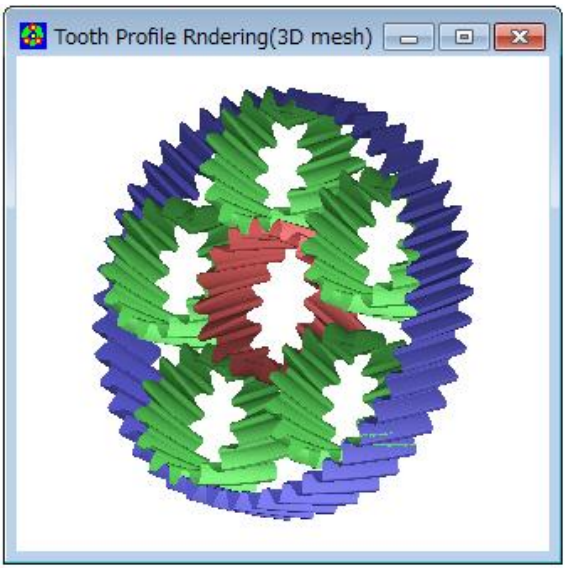


Fig.5.63 Tooth rendering