[1] involute Σ iii(spur and helical gear design system)

English version

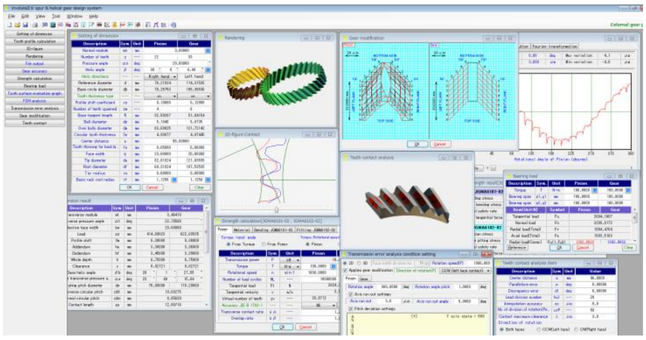


Fig.1.1 involute Σ iii(spur and helical)

1. 1 Abstract

involute Σ iii (spur and helical) has functions such as cylindrical gear dimensions, strength (steel, resin), axial load, tooth surface modification, transmission error, tooth surface evaluation, FEM analysis, tooth profile data, etc. for efficient and accurate design. Fig.1.1 shows the whole screen.

1.2 Software structure

The structure of involute Σ iii is shown in Table 1.1. ○ in the table is included in the basic software, and ◎ is optional. Applicable gear: involute spur and helical gear (external gear, internal gear)

Table 1.1 Software structure

No.	Item	Page	Structure
1	Basic rack setup	1.3	○
2	Dimension	1.4	○
3	Inference	1.5	○
4	Tooth creation drawing	1.6	○
5	Meshing drawing	1.6	○
6	Meshing rotation function	1.6	○
7	Tooth profile rendering	1.7	○
8	Gear accuracy	1.8	○
9	Gear strength calculation (steel)	1.9	○
10	Gear strength calculation (resin)	1.10	○
11	Metal × resin gear strength	1.10	○
12	Bearing load	1.11	○
13	Sliding ratio, Hertzian stress	1.12	○
14	Tooth profile output (DXF, IGES)	1.17	○
15	HELP menu	1.19	○
16	Design data management	1.20	○
17	FEM Tooth Profile Analysis	1.13	◎
18	Rotational transmission error (Fourier analysis, Wow · flutter, CSV output)	1.16	◎
19	Tooth surface evaluation (surface temp, film thickness, sliding velocity, PV value)	1.12	◎
20	Tooth modification (involute, lead, bias)	1.14	◎
21	Contact pattern	1.15	◎

1.3 Property（Basic rack, accuracy, strength）

Setup screen is shown in Fig.1.2～1.5.

- gear combination : external × external, external × internal
- Basic rack : normal, low, special
- tooth tip circle decision : normal, equal clearance
- steel gear strength calculation spec is shown in Fig.1.5 as 3 types;
  - JGMA 401-02:1974, 402-02:1975
  - JGMA 6101-02:2007, 6102-02:2009
  - ISO6336:2006

Plastic strength calculation spec is JIS B 1759(2013).

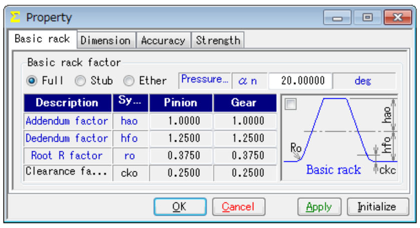


Fig.1.2 Basic rack

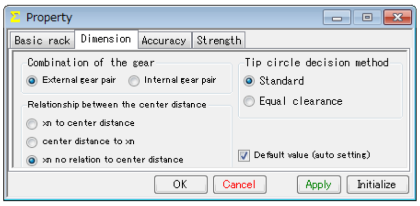


Fig.1.3 Dimension

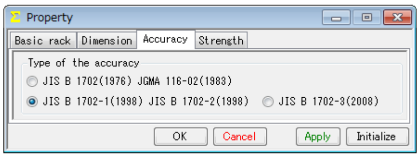


Fig.1.4 Accuracy

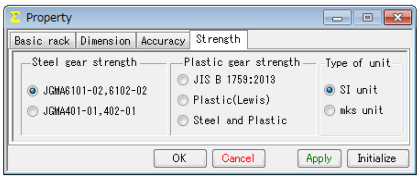


Fig.1.5 Strength

1.4 Dimension

Gear dimension calculates parts dimensions, contact ratio, sliding ratio, tooth thickness and so on. The gear with undercut determines the contact rate based on the TIF (True Involute Form) diameter. If tooth tip is rounded, R is considered in contact ratio.

(1)center distance and shift coefficient have the following 3 relationships.

<1> shift coefficient is given to pinion and gear to determine center distance.

<2> based on center distance, shift coefficient of each gear is determined.

<3> center distance is set, regardless of shift coefficient.

(2)shift coefficient is set per following 4 types;

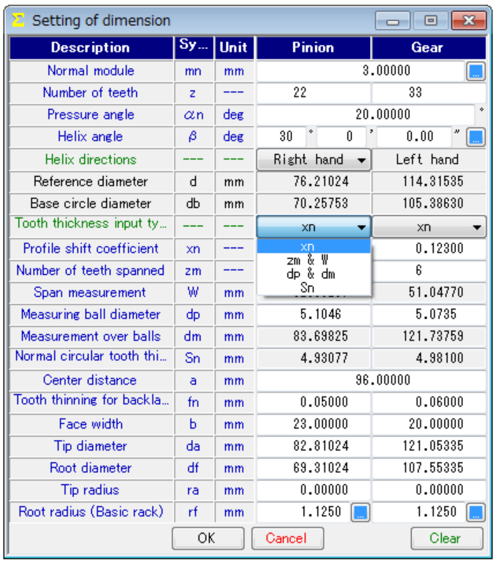
<1>directly enter shift coefficient

<2>based on split tooth thickness, shift coefficient is set

<3>based on over pin dimension, shift coefficient is set

<4>based on arc tooth thickness, shift coefficient is set

Dimension setup screen is shown in Fig.1.6. Shift coefficient can be set by tooth thickness. See Fig.1.7 for dimension result.

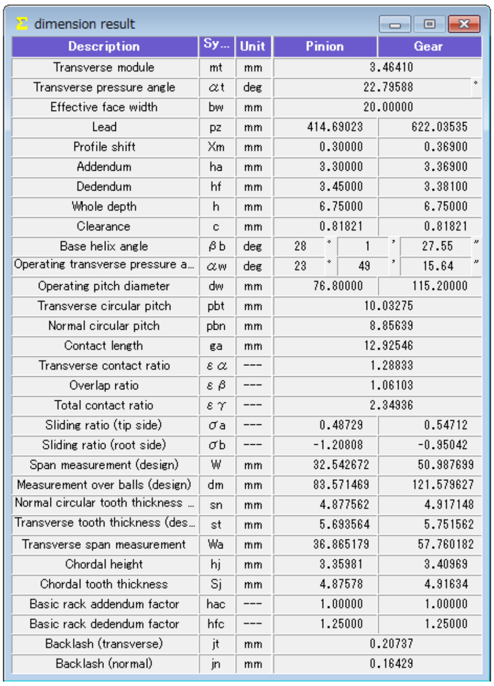


Setting of dimension

Description	Sy...	Unit	Pinion	Gear
Normal module	mn	mm	3.00000	
Number of teeth	z	---	22	33
Pressure angle	αn	deg	20.00000 °	
Helix angle	β	deg	30 ° 0 ' 0.00 "	
Helix directions	---	---	Right hand	Left hand
Reference diameter	d	mm	76.21024	114.31535
Base circle diameter	db	mm	70.25753	105.38630
Tooth thickness input ty...	---	---	xn	xn
Profile shift coefficient	xn	---	xn / zm & W / dp & dm / Sn	0.12300
Number of teeth spanned	zm	---		6
Span measurement	W	mm		51.04770
Measuring ball diameter	dp	mm	5.1046	5.0735
Measurement over balls	dm	mm	83.69825	121.73759
Normal circular tooth thi...	Sn	mm	4.93077	4.98100
Center distance	a	mm	96.00000	
Tooth thinning for backla...	fn	mm	0.05000	0.06000
Face width	b	mm	23.00000	20.00000
Tip diameter	da	mm	82.81024	121.05335
Root diameter	df	mm	69.31024	107.55335
Tip radius	ra	mm	0.00000	0.00000
Root radius (Basic rack)	rf	mm	1.1250	1.1250

OK Cancel Clear

Fig.1.6 Dimension setup



dimension result

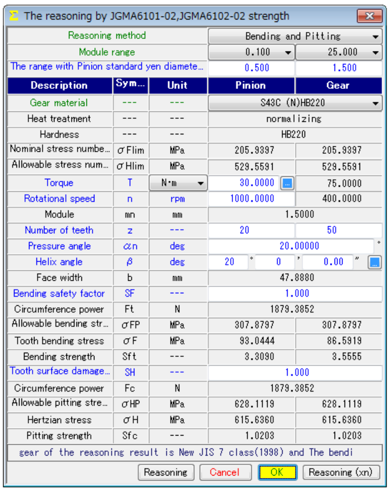
Description	Sy...	Unit	Pinion	Gear
Transverse module	mt	mm	3.46410	
Transverse pressure angle	αt	deg	22.79588	
Effective face width	bw	mm	20.00000	
Lead	pz	mm	414.69023	622.03535
Profile shift	Xm	mm	0.30000	0.36900
Addendum	ha	mm	3.30000	3.36900
Dedendum	hf	mm	3.45000	3.38100
Whole depth	h	mm	6.75000	6.75000
Clearance	c	mm	0.81821	0.81821
Base helix angle	βb	deg	28 ° 1 '	27.55 "
Operating transverse pressure a...	αw	deg	23 ° 49 '	15.64 "
Operating pitch diameter	dw	mm	76.80000	115.20000
Transverse circular pitch	pbt	mm	10.03275	
Normal circular pitch	pbn	mm	8.85639	
Contact length	ga	mm	12.92546	
Transverse contact ratio	εα	---	1.28833	
Overlap ratio	εβ	---	1.06103	
Total contact ratio	εγ	---	2.34936	
Sliding ratio (tip side)	σa	---	0.48729	0.54712
Sliding ratio (root side)	σb	---	-1.20808	-0.95042
Span measurement (design)	W	mm	32.542672	50.987699
Measurement over balls (design)	dm	mm	83.571469	121.579627
Normal circular tooth thickness ...	sn	mm	4.877562	4.917148
Transverse tooth thickness (des...	st	mm	5.693564	5.751562
Transverse span measurement	Wa	mm	36.865179	57.760182
Chordal height	hj	mm	3.35981	3.40969
Chordal tooth thickness	Sj	mm	4.87578	4.91634
Basic rack addendum factor	hac	---	1.00000	1.00000
Basic rack dedendum factor	hfc	---	1.25000	1.25000
Backlash (transverse)	jt	mm	0.20737	
Backlash (normal)	jn	mm	0.16429	

Fig.1.7 Dimension result

1.5 Inference

For Inference-1, bending strength is used to set module and tooth width. Based on the estimated module and tooth width, next step of the design can be carried out. As there are multiple combinations of module/tooth width/material to satisfy strength, inference can be used to determine concept design.

For Inference-2, shift coefficient can be set based on sliding ratio and contact ratio. Fig.1.9 shows max sliding ratio for pinion in red line, gear in blue line, and contact ratio in green line. In Fig.1.9, the most suitable shift coefficient is 0.3 based on sliding ratio and contact ratio. Reasons for determining the shift coefficient are prevention of undercut, change of center distance, adjustment of meshing pressure angle, etc. However, by using this inference function, it is necessary to determine the shift coefficient based on the relationship between sliding ratio and contact ratio. When undercut is observed, sliding ratio will be large.



The reasoning by JGMA6101-02,JGMA6102-02 strength

Description	Sym...	Unit	Pinion	Gear
Reasoning method			Bending and Pitting	
Module range			0.100	25.000
The range with Pinion standard yen diamete...			0.500	1.500
Gear material	---	---	S43C (N)HB220	
Heat treatment	---	---	normalizing	
Hardness	---	---	HB220	
Nominal stress numbe...	σFlim	MPa	205.9397	205.9397
Allowable stress num...	σHlim	MPa	529.5591	529.5591
Torque	T	N·m	30.0000	75.0000
Rotational speed	n	rpm	1000.0000	400.0000
Module	mn	mm	1.5000	
Number of teeth	z	---	20	50
Pressure angle	αn	deg	20.00000 °	
Helix angle	β	deg	20 ° 0 ' 0.00 "	
Face width	b	mm	47.8880	
Bending safety factor	SF	---	1.000	
Circumference power	Ft	N	1879.3852	
Allowable bending str...	σFP	MPa	307.8797	307.8797
Tooth bending stress	σF	MPa	93.0444	86.5919
Bending strength	Sft	---	3.3090	3.5555
Tooth surface damage...	SH	---	1.000	
Circumference power	Fc	N	1879.3852	
Allowable pitting stre...	σHP	MPa	628.1119	628.1119
Hertzian stress	σH	MPa	615.6360	615.6360
Pitting strength	Sfc	---	1.0203	1.0203

gear of the reasoning result is New JIS 7 class(1998) and The bendi

Reasoning Cancel OK Reasoning (xn)

Fig.1.8 Inference-1 (Bending strength)

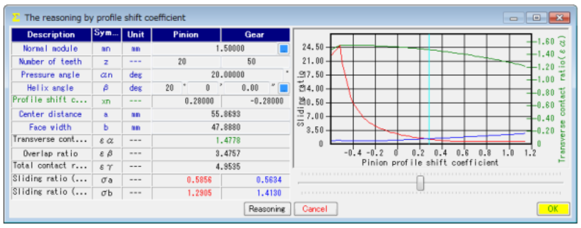


Fig.1.9 Inference-2 (Shift coefficient)

1.6 Tooth profile (Involute) drawing

Meshing drawing is shown in Fig.1.10. As shown in support form, zoom, distance measurement (Fig.1.11), R-measurement (Fig.1.12), diameter, involute modification, line of action, tooth tip width, odd teeth Y-measurement value display and rotation function are available. Involute creation is shown in Fig.1.13.

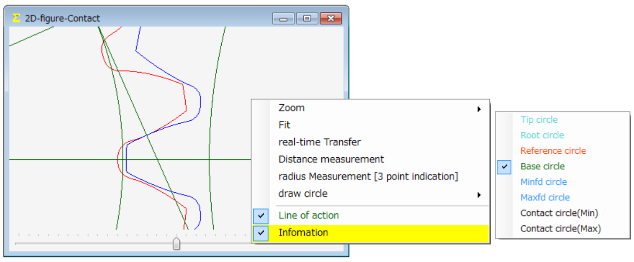


Fig.1.10 Meshing drawing & support form

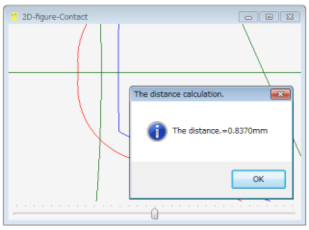


Fig. 1.11 distance measurement

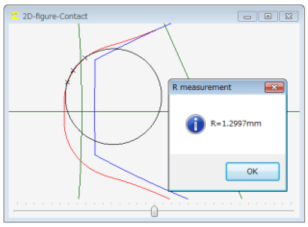


Fig.1.12 R measurement

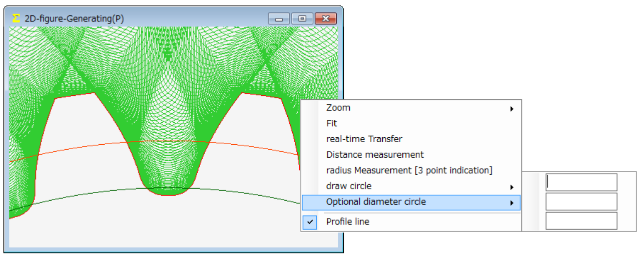


Fig.1.13 Involute creation (Pinion) & support form

1.7 Tooth profile rendering

3D tooth profile meshing can be created as shown in Fig.1.14, and contact line can be also observed. Control form allows the users to change tooth profile direction and size.

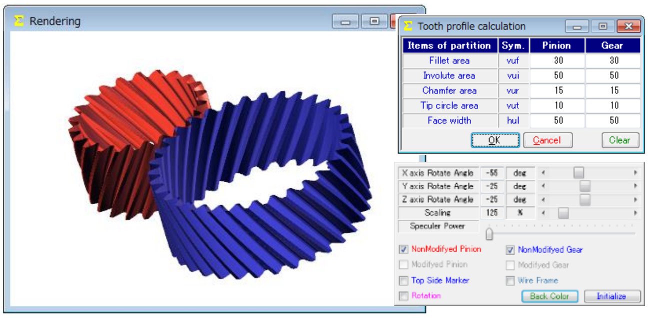


Fig.1.14 Tooth profile rendering

1.8 Gear accuracy

In Fig.1.15 & Fig.1.16, new JIS gear accuracy spec JIS B 1702-1:1998and JIS B 1702-2:1998 are shown for tolerances. Also, New JIS and Old JIS can be switched as shown in Fig.1.4. Gear accuracy spec are 5 types as shown below;

- JIS B 1702-1:1998, JIS B 1702-2:1998, JIS B 1702-3:2008
- JIS B 1702:1976
- JGMA 116-02:1983

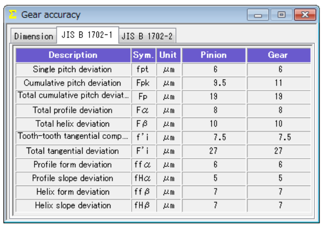


Fig.1.15 JIS B 1702-1

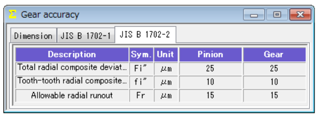


Fig.1.16 JIS B 1702-2

1.9 Gear strength calculation(steel)

Gear strength calculation has several spec types as shown in Fig.1.5 for ISO6336:2006 based JGMA6101-02:2007 and JGMA 6102-02:2009 spec and JGMA401-01:1974, 402-01:1975. Design unit can be switched between SI and MKS unit. Strength calculation power setup menu is shown in Fig.1.17. Material selection is shown in Fig.1.18 for material and heat treatment. Bending coefficient setup menu is in Fig.1.19, stress coefficient setup menu in Fig.1.20, strength results are shown in Fig.1.21.

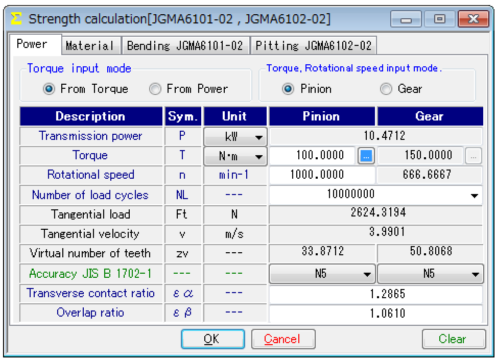


Fig.1.17 Strength calculation（Power setup）

1.10 Gear strength calculation(resin)

Plastic gear strength can be calculated by JIS B 1759(2013) or Lewis as shown by Fig.1.5. According to JIS B 1759 "Method for evaluating

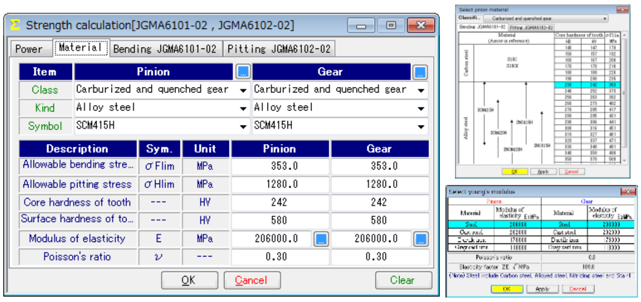


Fig.1.18 Strength calculation（material）

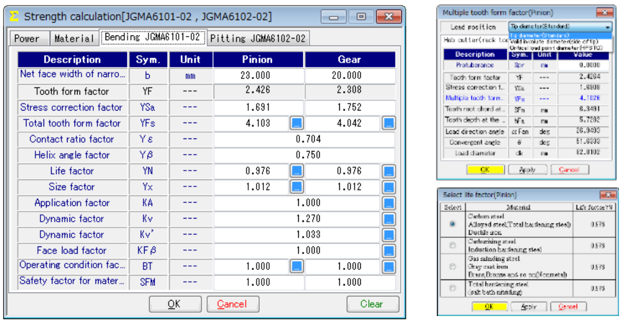


Fig.1.19 Strength calculation（bending coefficient）

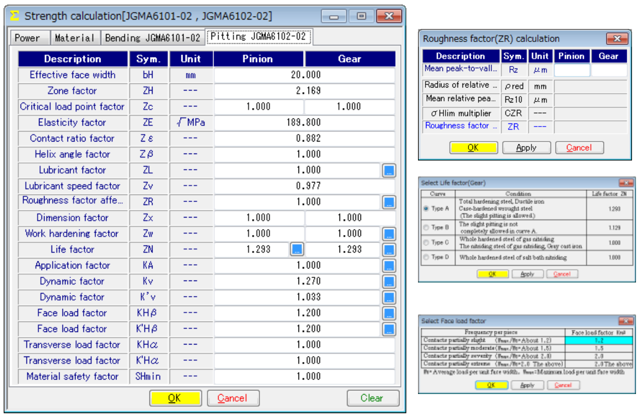


Fig.1.20 Strength calculation（stress coefficient）

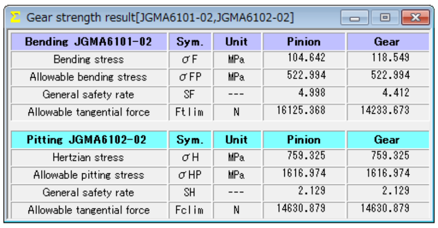


Fig.1.21 Strength results

bending strength of plastic cylindrical gears", a method for determining the allowable bending stress of gears is based on testing, and POM allowable bending stress is set as 80.0[MPa] based on testing, and materials other than POM can be determined based on spec. Root bending stress and allowable root bending stress by considering each coefficient (root profile coefficient, life coefficient, ambient temperature coefficient etc) can be compared to determine the safety. Please see spec for details.

Plastic gear strength calculation example is shown in Fig.1.22, strength geometry is shown in Fig 1.23, bending stress is shown in Fig. 1.24, spur gear equivalent value is shown in Fig.1.25, coefficient and safety factor are shown in Fig.1.26.

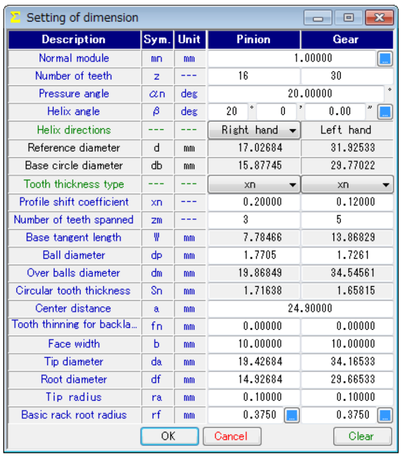


Fig.1.22 Gear geometry

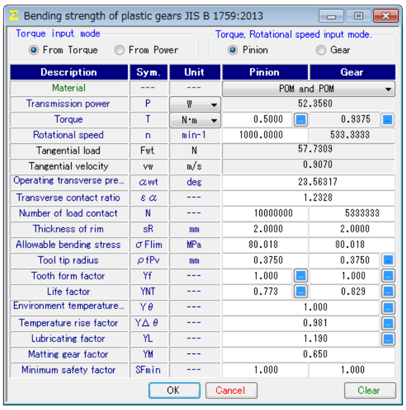


Fig.1.23 Strength geometry

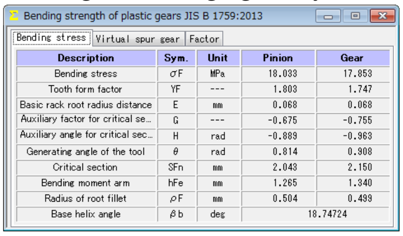


Fig.1.24 Root bending

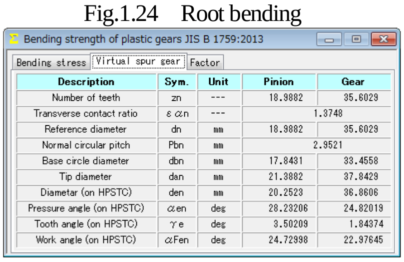


Fig.1.25 Equivalent spur gear

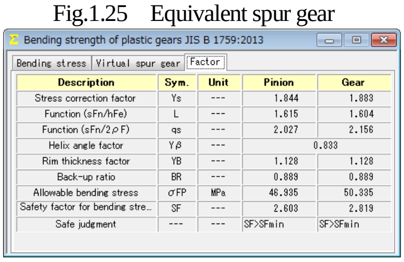


Fig.1.26 Coefficient

1.11 Bearing load

Gear load and bearing load are calculated. Types of loads are tangential force, normal force and 20 loads on bearings are calculated as shown in Fig.1.27.

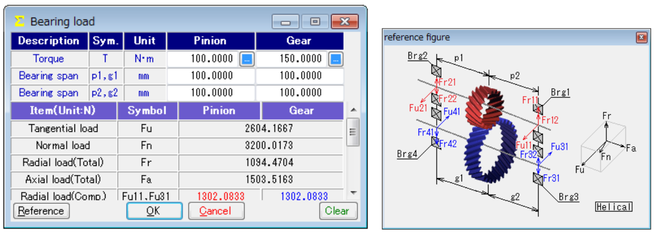


Fig.1.27 Bearing load

1.12 Gear surface evaluation

In surface evaluation, sliding ratio, Hertzian stress, film thickness, contact temperature, sliding speed, sliding speed drawing (PV value) are displayed. These are not used for tooth surface modification. Also, film thickness, contact temperature (gear temperature + flash temperature) are based on AGMA2001-C95, Annex A. Thus, for analysis by considering surface medication amount and load sharing, **[45]CT-FEM Opera iii** should be used. Oil types in Fig.1.28 can be Mineral oil, synthetic oil and ISO grade (customized setting is possible). In addition, the friction coefficient can be selected from a fixed value, ISO, AGMA method. Fig. 1.29 to 1.34 show the sliding ratio, Hertz stress graph, etc., but the horizontal scale can be switched between roll angle and line of action length.

Probability of occurrence of wear can be calculated from the oil film thickness in Fig.1.31, and the probability of scuffing from the contact temperature can be calculated as shown in Fig.1.32.

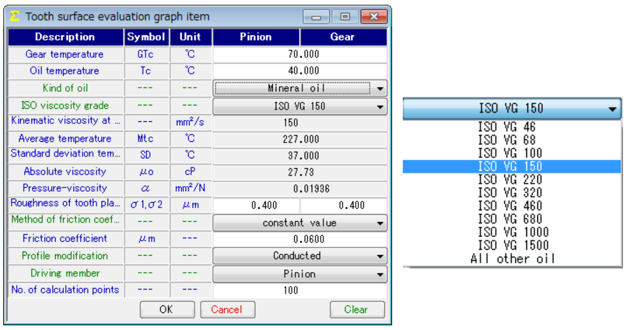


Fig.1.28 Surface evaluation（setup）

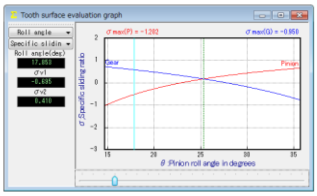


Fig.1.29 sliding ratio

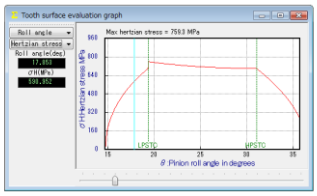


Fig.1.30 Hertz stress

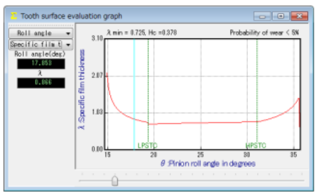


Fig 1.31 Film thickness

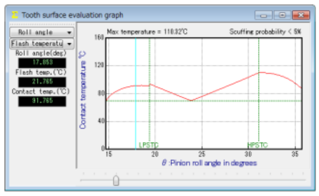


Fig 1.32 Flash temperature

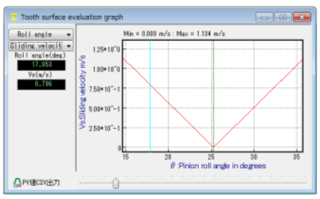


Fig.1.33 Sliding velocity

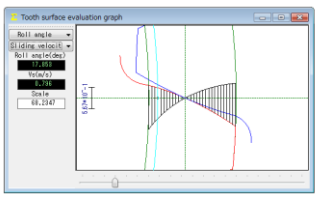
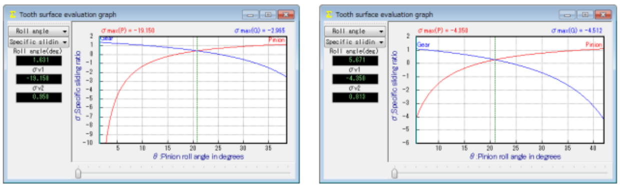


Fig.1.34 Sliding velocity drawing

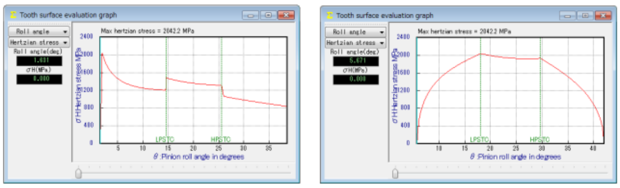
1.12a Sliding ratio and Hertz stress graph

As involute tooth form, meshing pitch circle will be rolling motion, but others will involve slip motion. The example gear (m_n=2, z_1=15, z_2=24, α=20° normal spur gear) in Fig.1.35 (left column) has sliding ratio, Hertzian stress, tooth surface contact temperature (gear temperature + flash temperature) and oil film thickness graph. Large Hertz stress change is observed in early meshing cycle due to pinion root sliding ratio. In this case, accuracy improvement would not help. In addition to contact ratio, sliding ratio and Hertz stress changes must be considered in design. To smooth out Hertz stress changes, shift coefficient medication may easily solve the challenge. It is important to consider sliding heat when designing resin gears.

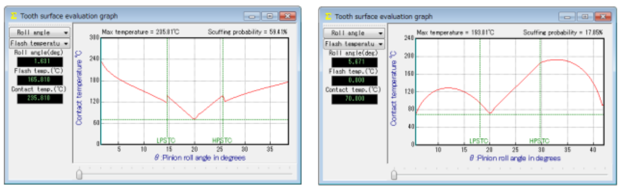
When tooth modification (Smooth meshing) is carried out by using shift coefficient of x_{n1}=0.24, x_{n2}=-0.24 without changing center distance, sliding ratio, Hertz stress and tooth surface contact temperature changes are shown in Fig.1.36. As a result, scuffing probability is reduced from 59.4% in Fig.1.35(c) to 17.9% in Fig.1.36(c), while wear probability is reduced from 36% to 32%.



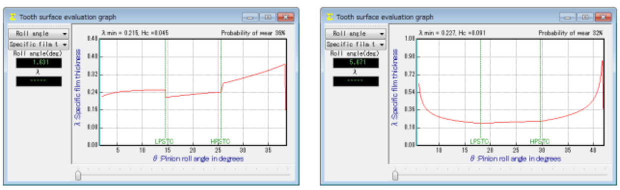
(a) Sliding ratio



(b) Hertz stress



(c)Tooth surface contact temperature (flash temperature)



(d) Oil thickness

Fig.1.35 Normal gear Fig.1.36 Shift coefficient

1.12b O class grade gear

Involute surface is as important as root shape. Involute testing result (both flank meshing) is shown in Fig.1.37 by connecting root curve with specific R. Also, theoretical trochoid curve involute test result is shown in Fig.1.38. Considering the creation motion as the basis, the root shape is a quasi-trochoid curve determined by (1) pressure angle, (2) basic rack root height, (3) basic rack root R, (4) shift amount, (5) number of teeth. involuteΣiii (spur and helical) can output theoretical involute curve. Please see Appendix [D] for the effect of stress on the root shape.

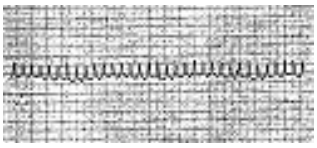


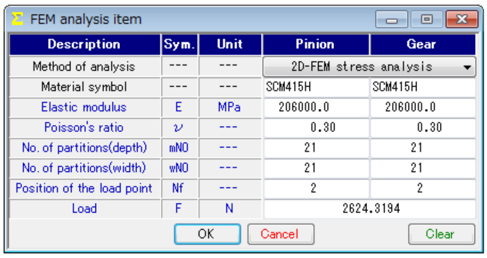
Fig.1.37 Gear test (specific R)

Fig.1.38 Gear test (theoretical involute)

1.13 FEM (Tooth profile stress analysis)

After strength analysis, clicking [FEM] icon allows the users to carry out stress analysis. FEM analysis setup screen is shown in Fig.1.39. By providing longitudinal elastic modulus, Poisson's ratio, number of partitions and load point position and load (changeable), stress (σ_x ,σ_y ,shear stress τ, main stress σ_1, σ_2) can be analyzed. Gear strength reliability can be improved by evaluating both gear strength and actual stress on teeth. Pinion max main stress σ_1 distribution is shown in Fig. 1.40. Tooth profile displacement (contour display is possible) and involute modification amount is shown in Fig.1.41.

Tooth profile modification is a useful method for improving driving performance of gears, so even if the gears are accurate, the difference in normal pitch occurs between the teeth of the drive and the driven gears due to deflection of teeth at the time of meshing. Mismatch due to this difference in normal pitch causes [vibration] and [sound]. Tooth profile modification is one way to solve this. Since displacement of small elastic modulus like resin material increases, it can be said that the tooth profile modification effect is even greater. As shown in Fig.41, it is possible to know the amount of deflection of teeth when determining tooth tip modification by 2D-FEM, determination of 3D tooth surface modification requires [45] CT - FEM Opera iii.



FEM analysis item

Description	Sym.	Unit	Pinion	Gear
Method of analysis	---	---	2D-FEM stress analysis	
Material symbol	---	---	SCM415H	SCM415H
Elastic modulus	E	MPa	206000.0	206000.0
Poisson's ratio	ν	---	0.30	0.30
No. of partitions(depth)	mNO	---	21	21
No. of partitions(width)	wNO	---	21	21
Position of the load point	Nf	---	2	2
Load	F	N	2624.3194	

OK Cancel Clear

Fig.1.39 FEM setup（2D）

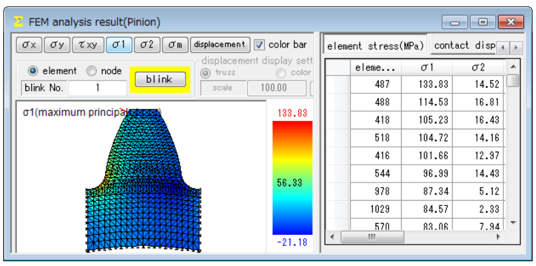


Fig.1.40 Max main stress σ_1（Pinion）

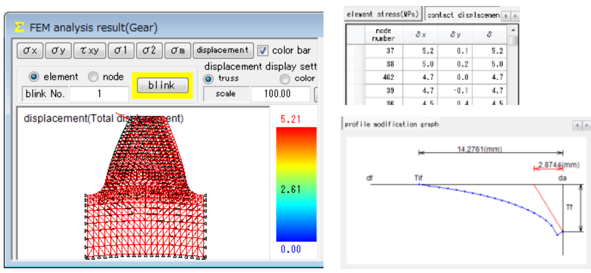
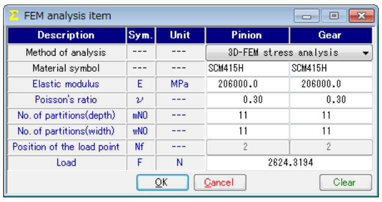


Fig.1.41 Tooth displacement & graph（Gear）

Fig.1.42 shows 3D-FEM analysis condition setting screen. Fig.1.43 shows pinion and gear stress distribution, and Fig.1.44 shows pinion and gear displacement. Also, observation angle can be changed by vertical rotation and horizontal rotation function with the scroll bar at the top of the screen in Fig.1.43 and Fig.1.44, and the figure can be enlarged or reduced with zoom function.

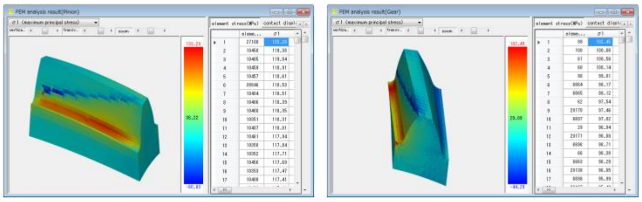
In this software, stress and displacement of the tooth is calculated when a load acts on one tooth. However, stress, tooth displacement, axial angle error, tooth profile error, pitch error, and tooth surface modification need to be considered when load is applied to multiple simultaneous meshing teeth, please use **[45]CT-FEM Opera ⅲ**.



Description	Sym.	Unit	Pinion	Gear
Method of analysis	---	---	3D-FEM stress analysis	
Material symbol	---	---	SCM415H	SCM415H
Elastic modulus	E	MPa	206000.0	206000.0
Poisson's ratio	ν	---	0.30	0.30
No. of partitions(depth)	mNO	---	11	11
No. of partitions(width)	wNO	---	11	11
Position of the load point	Nf	---	2	2
Load	F	N	2624.3194	

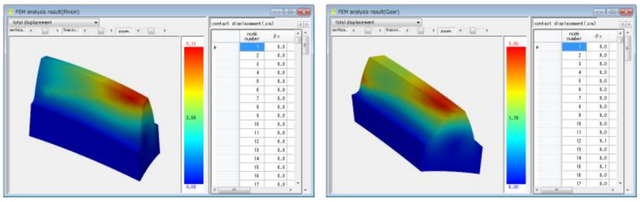
OK Cancel Clear

Fig.1.42 FEM setup（3D）



(a)Pinion (b)Gear

Fig.1.43 Max main stress σ_1



(a)Pinion (b)Gear

Fig.1.44 Tooth displacement

1.14 Gear modification（involute, lead, bias）

Fig.1.45 shows an example of giving tooth surface modification. In order to obtain this tooth form, it is possible to give tooth profile modification by numerical input as shown in Fig.1.46, or it can be done by inputting a numerical value to patterned tooth form as shown on the right side. Likewise, lead modification can also be set as shown in Fig. 1.47.

The tooth profile modification and lead modification represented in Fig.1.48 can be copied on the opposite tooth surface for identical tooth profile as shown in Fig.1.45. In addition, "involute", "lead", "involute/lead" in the combo box at the top of the screen in Fig.1.48 can be selected, and involute height direction can be assigned by line of action or diameter. In addition, the magnification of tooth profile modification can be set up to 1000 times.

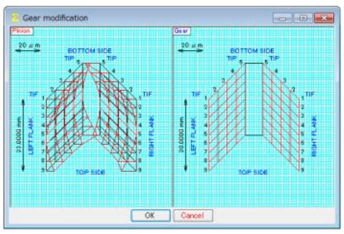


Fig.1.45 Tooth surface modification（Topo graph）

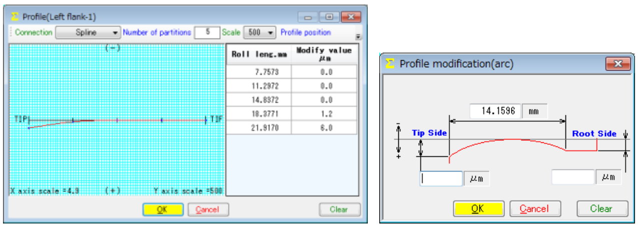


Fig.1.46 Involute modification

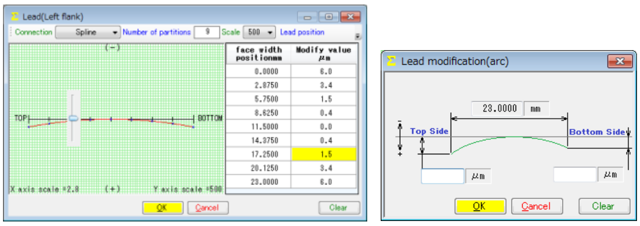


Fig.1.47 Lead modification

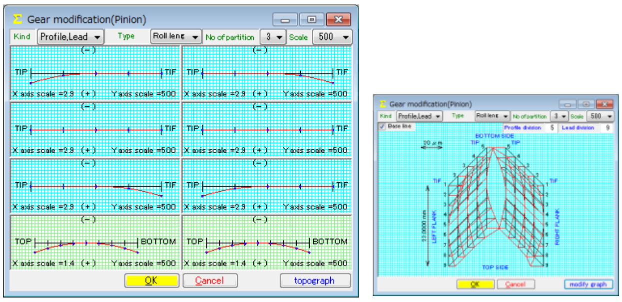
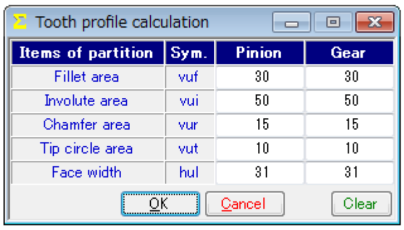


Fig.1.48 Involute ＆ Lead modification & Topo graph

Modified tooth profile can be set with the tooth profile calculation data in Fig.1.49. The tooth profile calculation conditions set here are valid for the tooth form shown in Fig.1.10 to 1.14 and can be superimposed on the tooth form rendering of Fig.1.14, so it can be displayed as shown in Fig. 1.50. Here, since tooth surface modification is given to Pinion, a yellow tooth surface appears within the red tooth surface in the figure (Gear is unmodified).



Items of partition	Sym.	Pinion	Gear
Fillet area	vuf	30	30
Involute area	vui	50	50
Chamfer area	vur	15	15
Tip circle area	vut	10	10
Face width	hul	31	31

OK Cancel Clear

Fig.1.49 Tooth calculation dimension

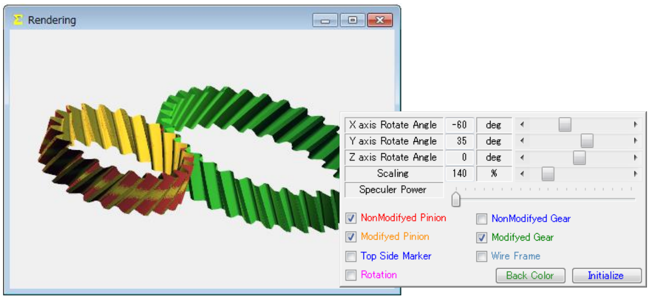


Fig.1.50 Tooth rendering（tooth modification）

1.15 Contact pattern

It is possible to check the tooth contact by setting the tooth contact condition in Fig.1.51 on the gear given the tooth surface modification (Fig.1.45). Here, the tooth contact is shown in Fig.1.52 and Fig.1.53

when parallelism error and discrepancy error are 0 and the contact maximum clearance is 2.0 μm.

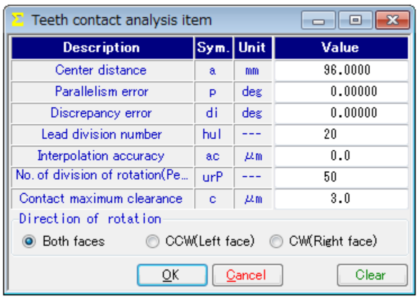


Fig.1.51 Contact setup

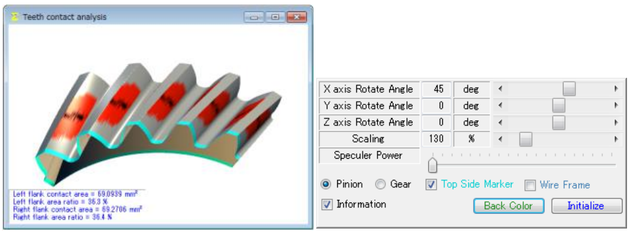


Fig.1.52 Contact pattern（Pinion）

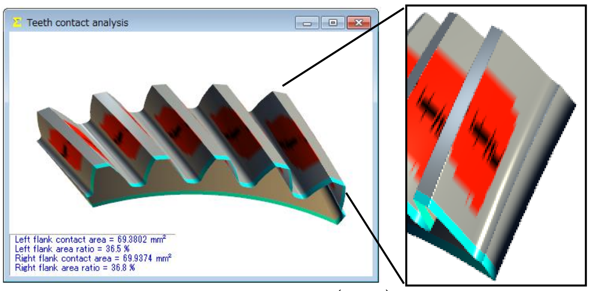
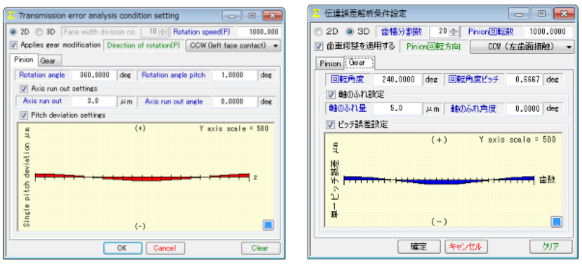


Fig.1.53 Contact pattern（Gear） & magnified

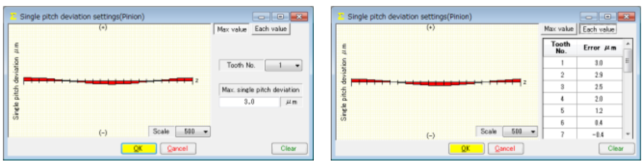
1.16 Transmission error (TE) analysis

In TE analysis, it is possible to perform a rotation transmission error test under no load with a non-modified tooth profile or the tooth profile given in Fig.1.45. The TE setting is shown in Fig.1.54. In this case, 2D analysis or 3D analysis can be selected, and axis runout and rotation speed can be set. As for pitch error, maximum value or pitch error of all teeth can be set as shown in Fig.1.55. TE analysis, wow flutter (rotation irregularity) and Fourier analysis results are shown in Fig. 1.56 to 1.58. In Fig. 1.57 [Sound] [Sound] can be heard.



(a)Pinion (b)Gear

Fig.1.54 TE setup



(a) Max value setup (b) All teeth setup

Fig.1.55 Pitch error setup

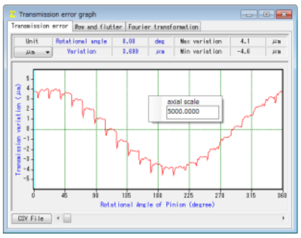


Fig.1.56 TE result

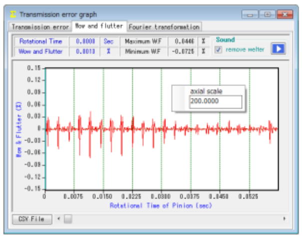


Fig.1.57 Wow flutter

TE analysis, Wow flutter, Fourier analysis results can be output to csv file (361 pieces of data in this example) as shown in Fig.1.59 in the lower left corner of Fig .1.56 ~ 1.58 [CSV File].

This software is a TE analysis test with no load. For TE analysis corresponding to load and shaft angle error, please use **[45]CT-FEM Operaⅲ**.

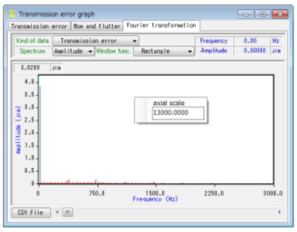


Fig.1.58 Fourier analysis

	A	B
1	0	3.698569
2	1	3.752178
3	2	3.806162
4	3	3.79174
5	4	3.660432
6	5	3.748919
7	6	3.077734
8	7	3.55005
9	8	3.731161

Fig.1.59 csv file example

1.17 Tooth profile output

The generated tooth profile can be output in the tooth profile file format shown in Fig.1.60. In the case of 3D-IGES, it is possible to select integrated type and separated type of tooth profile,

In the case of a separated type, it is split into a root fillet part, involute tooth surface, tooth tip R, and a tooth tip, and then output as shown in Fig. 1.61. In the coordinate correction setting shown in Fig.1.62, it is possible to output tooth profile considering the module shrinkage rate, pressure angle correction, helix angle correction, and discharge gap in consideration of use for molds. As an example, Fig.1.63 shows a tooth profile (2D) considering the module shrinkage factor of 20/1000. Also, it is possible to output the tooth profile coordinate value as a text file as shown in Fig.1.64.

(arc or line)

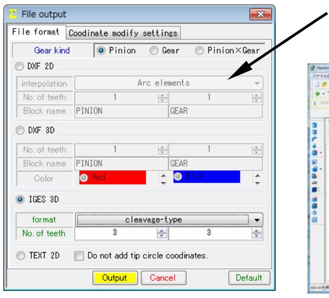


Fig.1.60 Tooth file format

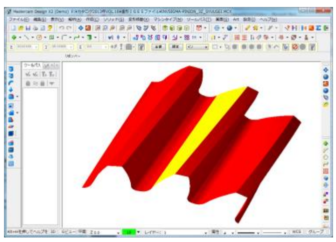


Fig.1.61 CAD sample

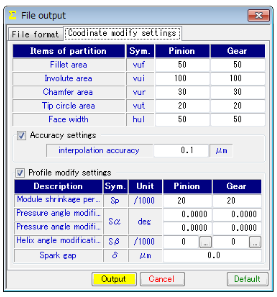


Fig.1.62 Coordinate correction setup

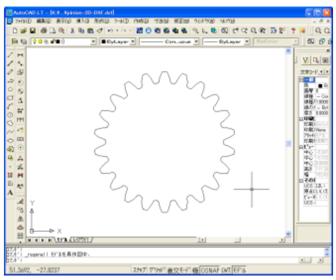


Fig.1.63 CAD sample

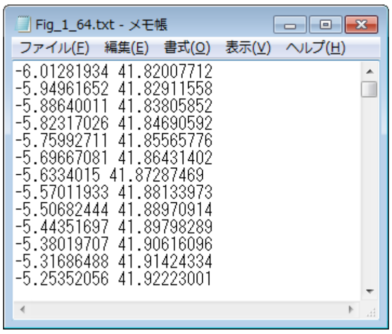
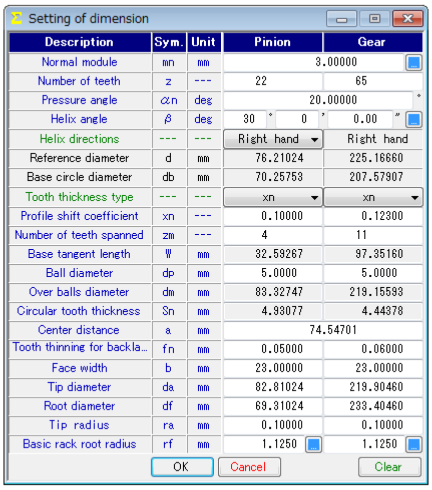


Fig.1.64 Text file (.txt)

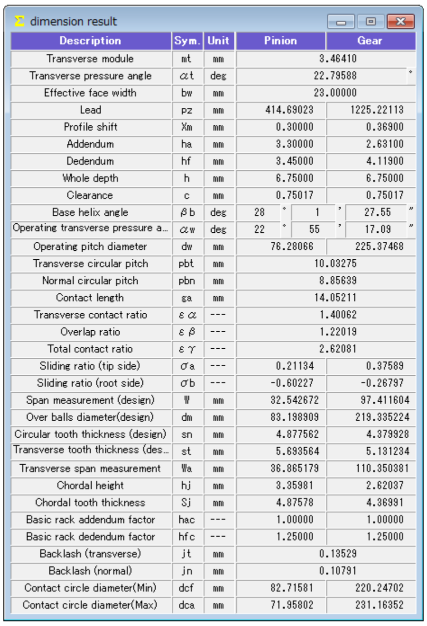
1.18 Internal gear

Internal gear can be calculated like External gear by selecting "External gear × Internal gear" in Fig.1.3. Fig.1.65 shows concept dimensions, while Fig.1.66 shows detail dimensions. Fig.1.67 shows tooth profile rendering while Fig.168 shows tooth contact pattern. In addition, Pinion that meshes with Gear in Fig.1.68 is given the same tooth surface modification as Fig.1.45. Strength calculation, TE analysis, FEM analysis and tooth profile output are the same as "External gear x External gear".



Description	Sym.	Unit	Pinion	Gear
Normal module	mn	mm	3.00000	
Number of teeth	z	---	22	65
Pressure angle	αn	deg	20.00000 °	
Helix angle	β	deg	30 ° 0 ′ 0.00 ″	
Helix directions	---	---	Right hand	Right hand
Reference diameter	d	mm	76.21024	225.16660
Base circle diameter	db	mm	70.25753	207.57907
Tooth thickness type	---	---	xn	xn
Profile shift coefficient	xn	---	0.10000	0.12300
Number of teeth spanned	zm	---	4	11
Base tangent length	W	mm	32.59267	97.35160
Ball diameter	dp	mm	5.0000	5.0000
Over balls diameter	dm	mm	83.32747	219.15593
Circular tooth thickness	Sn	mm	4.93077	4.44378
Center distance	a	mm	74.54701	
Tooth thinning for backla...	fn	mm	0.05000	0.06000
Face width	b	mm	23.00000	23.00000
Tip diameter	da	mm	82.81024	219.90460
Root diameter	df	mm	69.31024	233.40460
Tip radius	ra	mm	0.10000	0.10000
Basic rack root radius	rf	mm	1.1250	1.1250

Fig.1.65 Concept dimension（Internal gear）



Description	Sym.	Unit	Pinion	Gear
Transverse module	mt	mm	3.46410	
Transverse pressure angle	αt	deg	22.79588 °	
Effective face width	bw	mm	23.00000	
Lead	pz	mm	414.69023	1225.22113
Profile shift	Xm	mm	0.30000	0.36900
Addendum	ha	mm	3.30000	2.63100
Dedendum	hf	mm	3.45000	4.11900
Whole depth	h	mm	6.75000	6.75000
Clearance	c	mm	0.75017	0.75017
Base helix angle	βb	deg	28 ° 1 ′ 27.55 ″	
Operating transverse pressure a...	αw	deg	22 ° 55 ′ 17.09 ″	
Operating pitch diameter	dw	mm	76.28066	225.37468
Transverse circular pitch	pbt	mm	10.03275	
Normal circular pitch	pbn	mm	8.85639	
Contact length	ga	mm	14.05211	
Transverse contact ratio	εα	---	1.40062	
Overlap ratio	εβ	---	1.22019	
Total contact ratio	εγ	---	2.62081	
Sliding ratio (tip side)	σa	---	0.21134	0.37589
Sliding ratio (root side)	σb	---	-0.60227	-0.26797
Span measurement (design)	W	mm	32.542672	97.411604
Over balls diameter(design)	dm	mm	83.198909	219.335224
Circular tooth thickness (design)	sn	mm	4.877562	4.379928
Transverse tooth thickness (des...	st	mm	5.693564	5.131234
Transverse span measurement	Wa	mm	36.865179	110.350381
Chordal height	hj	mm	3.35981	2.62037
Chordal tooth thickness	Sj	mm	4.87578	4.36991
Basic rack addendum factor	hac	---	1.00000	1.00000
Basic rack dedendum factor	hfc	---	1.25000	1.25000
Backlash (transverse)	jt	mm	0.13529	
Backlash (normal)	jn	mm	0.10791	
Contact circle diameter(Min)	dcf	mm	82.71581	220.24702
Contact circle diameter(Max)	dca	mm	71.95802	231.16352

Fig.1.66 Detail dimension（internal gear）

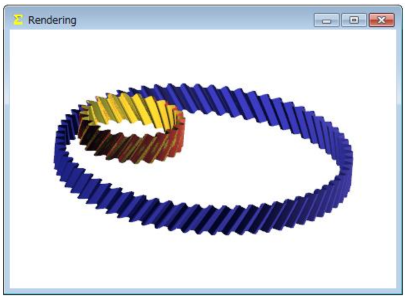


Fig.1.67 Rendering

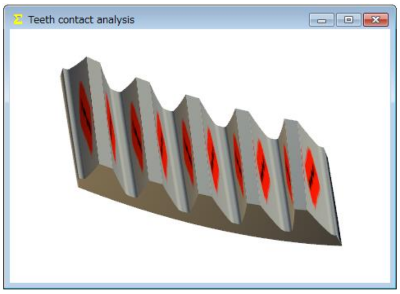


Fig.1.68 Contact pattern（Gear）

1.19 HELP feature

[HELP] function can be used to understand the operation method. For example, if the user wants to know about gear accuracy, by activating the "Precision" form and press the [F1] key, the explanation about accuracy is displayed as shown in Fig.1.69.

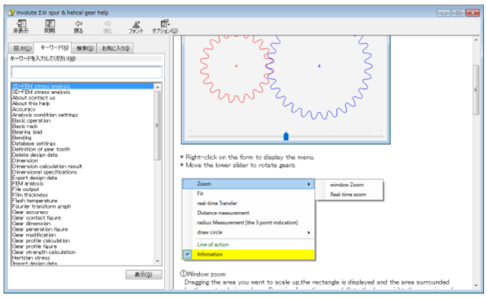


Fig.1.69 HELP function

1.20 Design data management（Saving / Loading）

The design data can be saved and loaded as shown in Fig.1.70. In addition to the control number and the title, users can also retrieve the data from the gear specification (module, number of teeth, pressure angle, helix angle).

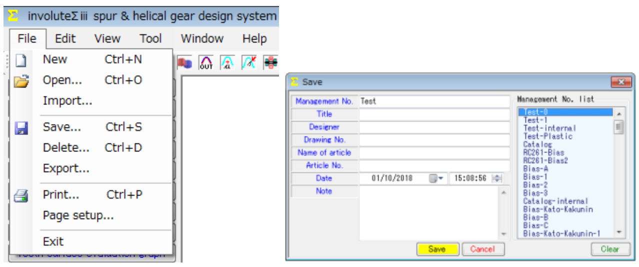


Fig.1.70 Data saving, loading