[1] involute Σ (Spur and Helical Gear Design)

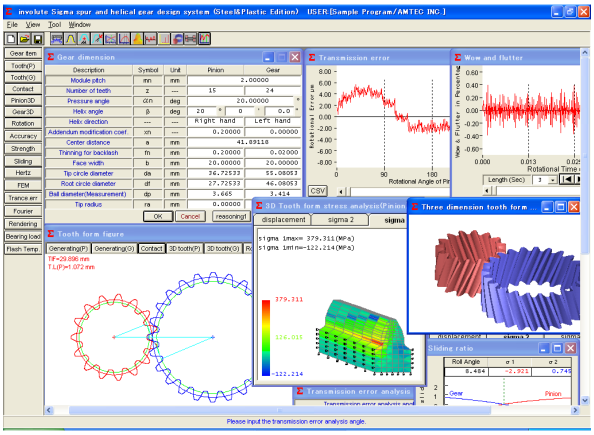


Fig..1.1 Calculation Result Screen

1.1 Introduction

involute Σ (Spur & Helical) adopted many customer requests from those who used conventional software, and the software was revised in May, 2000. In addition, 3D tooth form stress analysis software and 3D error analysis software was added in May, 2001. The latest ***involute Σ*** can output tooth form in 3D data, and it can observe the meshing line of contact of gear rotation continuously by tooth form rendering (see Fig. 1.1). Other new functions to obtain gear strength standards and infer optimum addendum modification coefficient were added. Please review the following content.

1.2 Software Composition

Software is classified into 3 types of [ST], [PL], [SP]. Please see Table 1.1.

Table 1.1 Software Composition

Items	Page	ST	PL	SP
1. Setting Basic Rack	1	○	○	○
2. Gear Dimension	1	○	○	○
3. Reasoning -1	2	○	○	○
4. Reasoning -2	2	○	○	○
5. Tooth Profile Generating Figure	2	○	○	○
6. Gear Meshing Figure	2	○	○	○
7. Meshing Continuation Rotation	2	○	○	○
8. Tooth Form DXF File Output	3	○	○	○
9. Tooth Form Rendering Figure	3	○	○	○
10. Gear Accuracy	3	○	○	○
11. Design Data Management	--	○	○	○
12. Steel Gear Strength	5	○	×	○
13. Plastic Gear Strength	5	×	○	○
14. Steel and Plastic Gear Strength	--	×	×	○
15. Sliding Ratio Graph	4	○	○	○
16. Hertz Stress Graph	4	○	○	○
17. Bearing Load	5	○	○	○
18. FEM Tooth Form Stress Analysis	6	◎	◎	◎
19. Transmission Error Analysis	6	◎	◎	◎
20. Fourier Analysis	7	◎	◎	◎
21.Tooth Form IGES File Output	3	◎	◎	◎
22.Flash Temperature	5	◎	◎	◎

Legend

ST: Steel Edition PL : Plastic Edition

SP: Steel & Plastic Edition

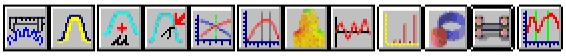
○: Included ◎::Optional

△: Conditionally Included ×: Not Included

1.3 Software Content

1.3.1 Icon Button

There are 12 icon buttons: [Dimension], [Tooth Form], [Accuracy], [Strength], [Sliding Graph], [Hertz Stress Graph], [FEM], [Transmission Error], [Fourier Analysis], [Tooth Form Rendering], [Load Bearing], and [Flash Temp.]. There is also a [Tool] button that sets initial values of basic rack, etc.



1.3.2 Gear Types.

・ Involute Spur Gear, Helical Gear

・ External Gear and Internal Gear

1.3.3 Setting of Basic Rack, etc.,

Basic rack settings screen is shown in Fig. 1.2.

Combination of Gears: External Gear／External Gear,
External Gear／Internal Gear

Basic Rack: Full Depth Tooth, Stub Gear Tooth, Special

1.3.4 Gear Dimensions

Dimension of each part of gear is used to calculate contact ratio, sliding ratio, tooth thickness, etc. The contact rate of the gear with the undercut is calculated on the basis of the TIF diameter. And, the contact ratio is calculated by containing R in the tip (TIF: True Involute Form).

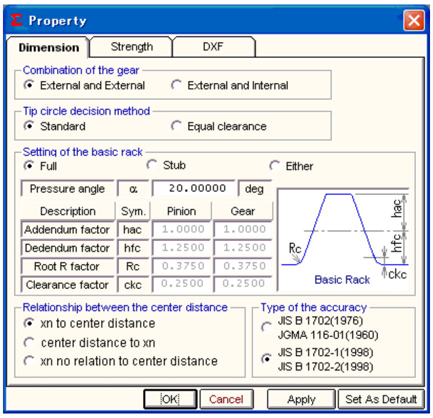


Fig. 1.2 Properties (Dimensions)

(1) Relation between addendum modification coefficient and center distance is the following 3 types.

<1>The addendum modification coefficient of each gear decides center distance.

<2>The decision of center distance gives the addendum modification coefficients for pinion and gear.

<3>The center distance disregards addendum modification coefficient, and it is optionally decided.

(2) Setting system of addendum modification coefficient are the following 4 types.

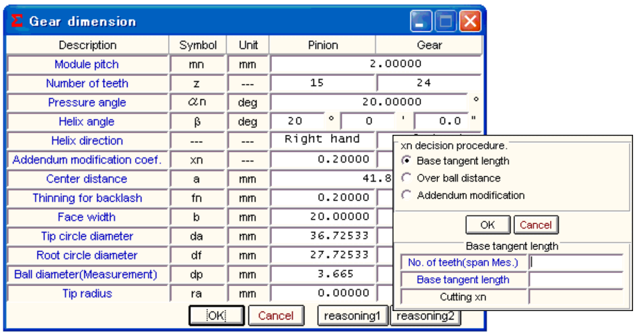
<1>The addendum modification coefficient is directly input.

<2>The addendum modification coefficient is decided by the input of base tangent length.

<3>The addendum modification coefficient is decided by the input of over ball distance.

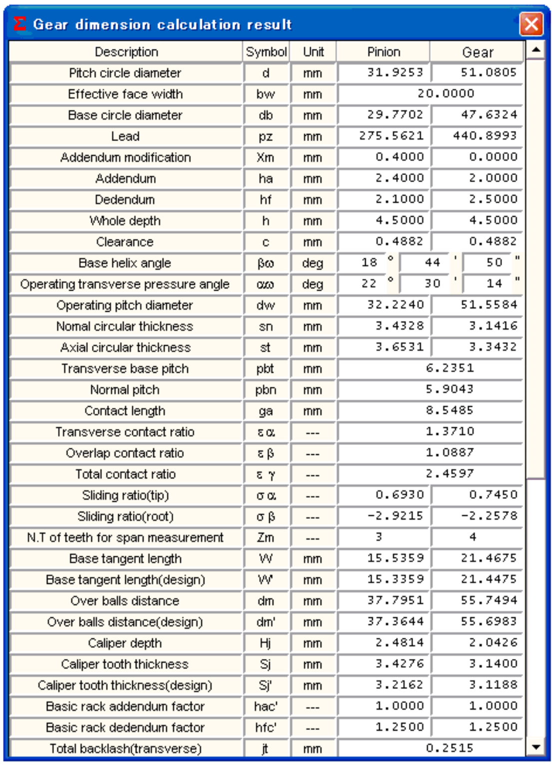
<4>The input of amount of addendum modification.

The dimensions setting screen and selection screen in the addendum modification coefficient input are shown in Fig.1.3. The dimension result screen is shown in Fig. 1.4.



Description	Symbol	Unit	Pinion	Gear
Module pitch	mn	mm	2.00000	
Number of teeth	z	---	15	24
Pressure angle	αn	deg	20.00000 °	
Helix angle	β	deg	20 ° 0 ' 0.0 "	
Helix direction	---	---	Right hand	
Addendum modification coef.	xn	---	0.20000	
Center distance	a	mm	41.8	
Thinning for backlash	fn	mm	0.20000	
Face width	b	mm	20.00000	
Tip circle diameter	da	mm	36.72533	
Root circle diameter	df	mm	27.72533	
Ball diameter(Measurement)	dp	mm	3.665	
Tip radius	ra	mm	0.00000	

Fig. 1.3 Dimensions Setting Screen

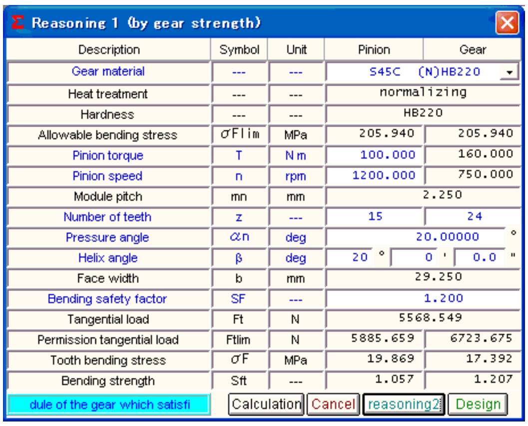


Description	Symbol	Unit	Pinion	Gear
Pitch circle diameter	d	mm	31.9253	51.0805
Effective face width	bw	mm	20.0000	
Base circle diameter	db	mm	29.7702	47.6324
Lead	pz	mm	275.5621	440.8993
Addendum modification	Xm	mm	0.4000	0.0000
Addendum	ha	mm	2.4000	2.0000
Dedendum	hf	mm	2.1000	2.5000
Whole depth	h	mm	4.5000	4.5000
Clearance	c	mm	0.4882	0.4882
Base helix angle	βo	deg	18 ° 44 ' 50 "	
Operating transverse pressure angle	αo	deg	22 ° 30 ' 14 "	
Operating pitch diameter	dw	mm	32.2240	51.5584
Nomal circular thickness	sn	mm	3.4328	3.1416
Axial circular thickness	st	mm	3.6531	3.3432
Transverse base pitch	pbt	mm	6.2351	
Normal pitch	pbn	mm	5.9043	
Contact length	ga	mm	8.5485	
Transverse contact ratio	εα	---	1.3710	
Overlap contact ratio	εβ	---	1.0887	
Total contact ratio	εγ	---	2.4597	
Sliding ratio(tip)	σα	---	0.6930	0.7450
Sliding ratio(root)	σβ	---	-2.9215	-2.2578
N.T of teeth for span measurement	Zm	---	3	4
Base tangent length	W	mm	15.5359	21.4675
Base tangent length(design)	W'	mm	15.3359	21.4475
Over balls distance	dm	mm	37.7951	55.7494
Over balls distance(design)	dm'	mm	37.3644	55.6983
Caliper depth	Hj	mm	2.4814	2.0426
Caliper tooth thickness	Sj	mm	3.4276	3.1400
Caliper tooth thickness(design)	Sj'	mm	3.2162	3.1188
Basic rack addendum factor	hac'	---	1.0000	1.0000
Basic rack dedendum factor	hfc'	---	1.2500	1.2500
Total backlash(transverse)	jt	mm	0.2515	

Fig. 1.4 Dimension Result Screen

1.3.5 Reasoning-1

Reasoning-1 decides module and face width with respect to bending strength. Here, inferential module and face width are indicated, then, it is possible to advance to the next design. There are various combinations of module, face width, and material that can satisfy strength requirements. So, this function is very effective in summarizing the gear on the basis of the reasoning result. The reasoning-1 screen is shown in Fig. 1.5.



Description	Symbol	Unit	Pinion	Gear
Gear material	---	---	S45C (N)HB220	
Heat treatment	---	---	normalizing	
Hardness	---	---	HB220	
Allowable bending stress	σFlim	MPa	205.940	205.940
Pinion torque	T	N m	100.000	160.000
Pinion speed	n	rpm	1200.000	750.000
Module pitch	mn	mm	2.250	
Number of teeth	z	---	15	24
Pressure angle	αn	deg	20.00000 °	
Helix angle	β	deg	20 ° 0 ' 0.0 "	
Face width	b	mm	29.250	
Bending safety factor	SF	---	1.200	
Tangential load	Ft	N	5568.549	
Permission tangential load	Ftlim	N	5885.659	6723.675
Tooth bending stress	σF	MPa	19.869	17.392
Bending strength	Sft	---	1.057	1.207

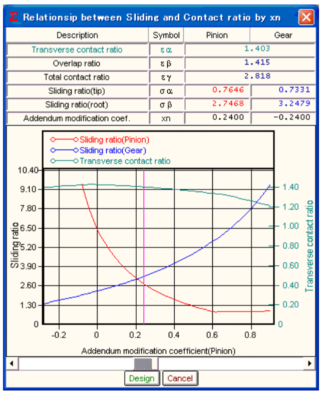
Fig. 1.5 Reasoning-1 Screen

1.3.6 Reasoning-2

The function of reasoning-2 decides the optimum addendum modification coefficient on the basis of specific sliding and meshing ratio. Fig. 1.6 graphs largest sliding ratio of pinion in red line, largest sliding ratio of gear in blue line, transverse contact ratio in green line. This case, an addendum modification coefficient of 0.2 of pinion is optimum tooth form, when it is judged from sliding ratio and contact ratio.

The decision reason of general addendum modification coefficients is undercut prevention, changes of center distance, adjustment of operating pressure angle, etc.

But, this reasoning function can decide the addendum modification coefficient based on the relationship between sliding ratio and contact ratio.



Description	Symbol	Pinion	Gear
Transverse contact ratio	εα	1.403	
Overlap ratio	εβ	1.415	
Total contact ratio	εγ	2.818	
Sliding ratio(tip)	σα	0.7646	0.7331
Sliding ratio(root)	σβ	2.7468	3.2479
Addendum modification coef.	xn	0.2400	-0.2400

Fig.1.6 Reasoning-2 Screen

1.3.7 Tooth Profile

(1) The type of the tooth profile figure.

- Tooth form generating
- Contact tooth profile
- 3D tooth profile
- Rotation tooth profile

(2) CAD file

- DXF file (2D, 3D)
- IGES file(3D)

The pinion tooth form generating profile is shown in Fig. 1.7,and the contact profile is shown in Fig. 1.8. Internal gear checks 3 kinds of interference (involute interference, trochoid interference, trimming). The 3D tooth form figure is shown in Fig. 1.9 and Fig. 1.10.

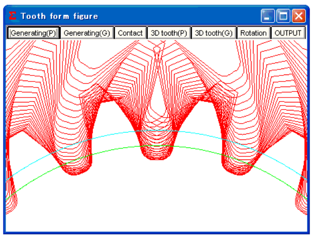


Fig. 1.7 Tooth Form Generating Figure (P)

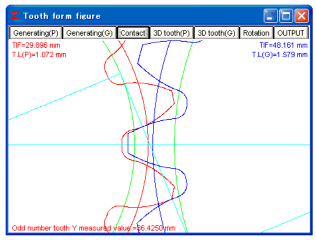


Fig.1.8 Tooth Form Meshing

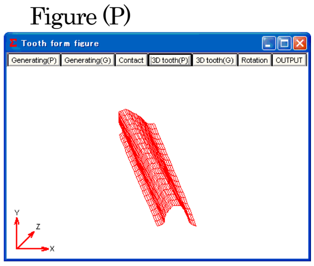


Fig. 1.9 3D Tooth Form (P)

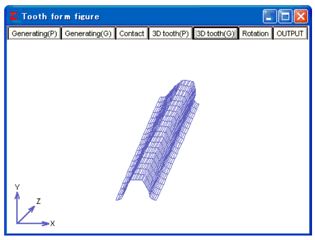


Fig. 1.10 3D Tooth Form (G)

1.3.8 DXF and IGES File Output of Tooth Profile

It is possible to output the gear tooth profile by 2D, 3D-DXF and 3D-IGES files.

(1) The tooth profile output gives module shrinkage percentage and pressure angle correction factor for metal molds.

(2) The output tooth numbers can be set manually .

(3) The coordinate value is output to 8 decimal places.

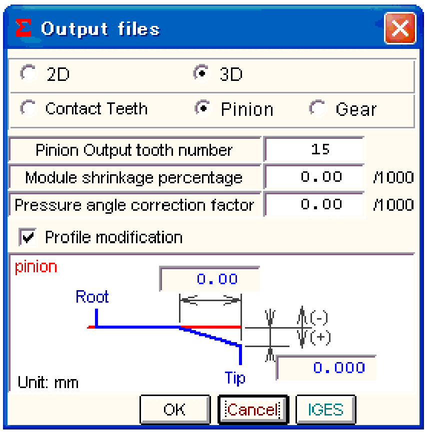


Fig. 1.11 Output File Setting Screen

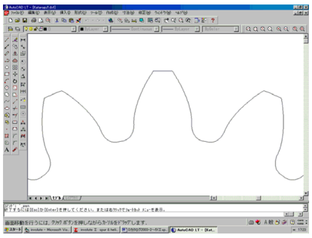


Fig. 1.11-a Drawing Sample (DXF)

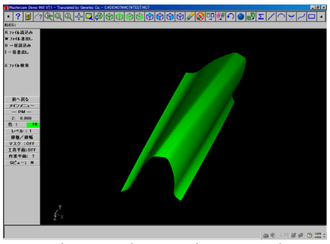


Fig. 1.11-b Drawing Sample (IGS)

1.3.9 Tooth Profile Rendering

3D tooth profile meshing can be drawn as in Fig. 1.12. The pinion rotates in 1 degree increments if the gear meshing step angle is 1; the pinion stands still if the gear meshing step angle is 0. The tooth profile direction can be freely changed, extended and reduced. Fig. 1.12 displays figure and setting screen from the gear side, and Fig. 1.13 displays figure from the pinion side. In meshing part of Fig. 1.12, line of contact can be observed.

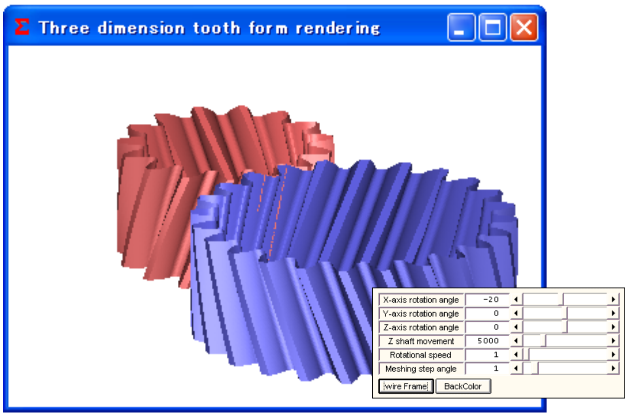


Fig. 1.12 Tooth Form Rendering Figure and Setting

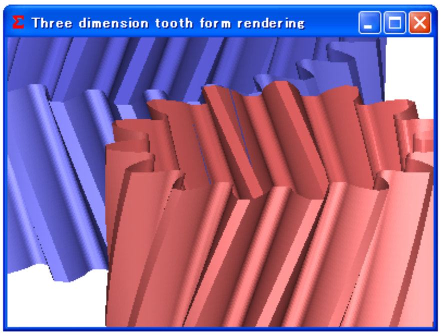
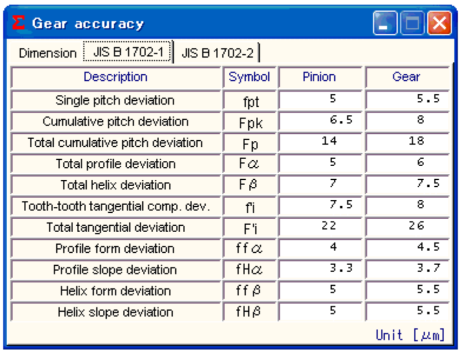


Fig. 1.13 Tooth Profile Rendering

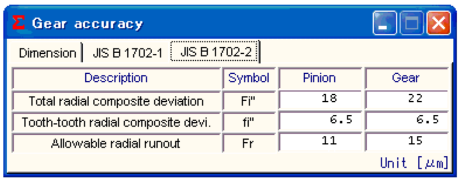
1.3.10 Gear Accuracy

The error tolerance (JIS B 1702-1 and JIS B 1702-2) of the new JIS is displayed in Fig. 1.14 and Fig. 1.15. The new JIS or old JIS may be chosen.



Description	Symbol	Pinion	Gear
Single pitch deviation	fpt	5	5.5
Cumulative pitch deviation	Fpk	6.5	8
Total cumulative pitch deviation	Fp	14	18
Total profile deviation	Fα	5	6
Total helix deviation	Fβ	7	7.5
Tooth-tooth tangential comp. dev.	fi'	7.5	8
Total tangential deviation	Fi'	22	26
Profile form deviation	ffα	4	4.5
Profile slope deviation	fHα	3.3	3.7
Helix form deviation	ffβ	5	5.5
Helix slope deviation	fHβ	5	5.5

Fig. 1.14 Gear Accuracy (JIS B 1702-1)



Description	Symbol	Pinion	Gear
Total radial composite deviation	Fi"	18	22
Tooth-tooth radial composite devi.	fi"	6.5	6.5
Allowable radial runout	Fr	11	15

Fig. 1.15 Gear Accuracy (JIS B 1702-2)

1.3.11 Noise Reduction (Specific Sliding and Hertz Stress Graph)

On the operating pitch circle, as a feature of the involute tooth form, contacting involute teeth make a rolling motion, while teeth of other kinds make a sliding motion.

The graph change of specific sliding and hertz stress of an example gear is displayed in Fig. 1.16 and Fig. 1.17 (standard spur gear of m_n=2, Z_1=15, Z_2=24, α=20°). And, rapid hertz stress modification in the first engagement is shown, because the dedendum specific sliding of the pinion is large. In this case, the problem is not solved, even if the accuracy is improved. Therefore, not only contact ratio but also considering design changes of specific sliding and Hertzian stress are necessary. There is a case in which a solution is reached by adjusting the transposition, in order to smooth the Hertzian stress. Plastic gear must be designed with highest attention as the heat caused by sliding motion considerably affects the gear. When the addendum modification coefficients are Xn1=0.24 and Xn2=-0.24 and the center distance is not changed, the curves of specific sliding ratio and Hertzian stress are shown in Fig. 1.18 and Fig. 1.19, respectively. When a profile modification is applied to the gear whose Hertzian stress is shown in Fig.1.19, the curve of Hertzian stress of the modified gear becomes smoother as shown in Fig. 1.20.

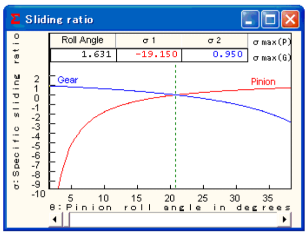


Fig.1.16 Sliding Ratio Graph-1

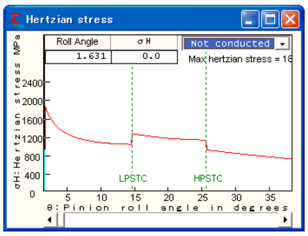


Fig. 1.17 Hertz Stress-1

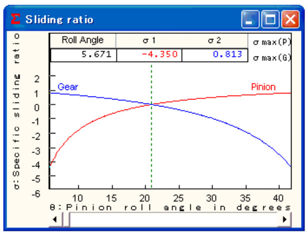


Fig.1.18 Sliding Ratio Graph-2

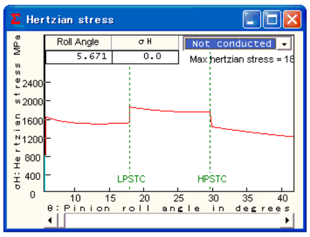


Fig. 1.19 Hertz Stress-2

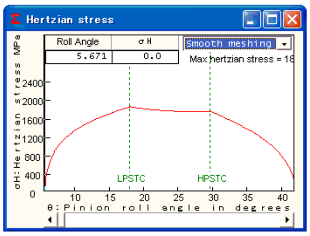


Fig. 1.20 Hertz Stress-3

1.3.12 Zero Class Gear

The involute plane of the gear tooth type is important, but the dedendum shape is important as well. The graph of Fig. 1.21 is a test result (both tooth surface meshing) of a tooth form that connected the root of tooth curve in optional R; Fig. 1.22 shows the test result of theoretical trochoid curve tooth form.

In the case of a basic generating motion, the tooth root shape is a semi-trochoid curve decided by ① pressure angle, ② basic rack dedendum, ③ dedendum R, ④ addendum modification, ⑤ teeth number. *involute Σ* outputs the theoretical tooth form curve.

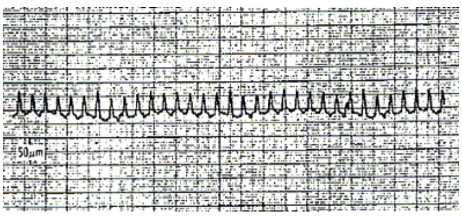


Fig. 1.21 Gear Test (optional dedendum R)

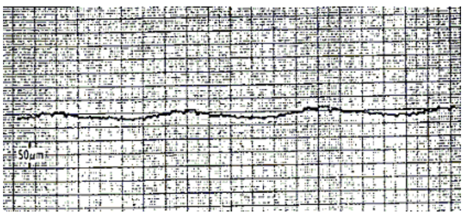
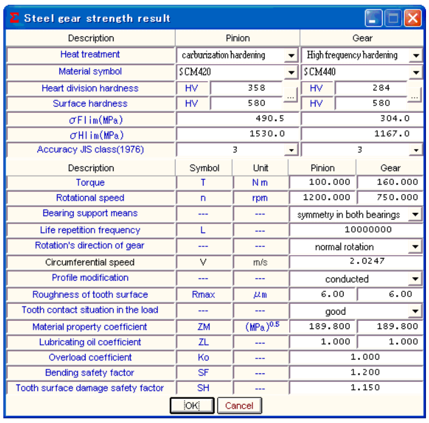


Fig. 1.22 Gear Test (theoretical tooth form)

1.3.13 Gear Strength Calculation (Steel)

The gear strength calculation is based on JGMA401-01, 402-02. SI unit system or MKS unit system can be chosen for designs. The strength setting screen is shown in Fig. 1.23. The material selection displays the material selection form adapted to "heat treatment," as shown in Fig. 1.24. The strength calculation result is shown in Fig. 1.25.



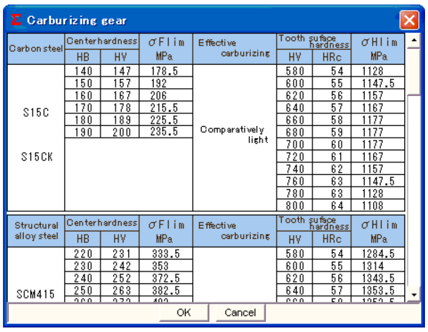
Steel gear strength result

Description	Pinion		Gear	
Heat treatment	carburization hardening		High frequency hardening	
Material symbol	SCM420		SCM440	
Heart division hardness	HV	358	HV	284
Surface hardness	HV	580	HV	580
σFlim(MPa)	490.5		304.0	
σHlim(MPa)	1530.0		1167.0	
Accuracy JIS class(1976)	3		3	

Description	Symbol	Unit	Pinion	Gear
Torque	T	N m	100.000	160.000
Rotational speed	n	rpm	1200.000	750.000
Bearing support means	---	---	symmetry in both bearings	
Life repetition frequency	L	---	10000000	
Rotation's direction of gear	---	---	normal rotation	
Circumferential speed	V	m/s	2.0247	
Profile modification	---	---	conducted	
Roughness of tooth surface	Rmax	μm	6.00	6.00
Tooth contact situation in the load	---	---	good	
Material property coefficient	ZM	$(MPa)^{0.5}$	189.800	189.800
Lubricating oil coefficient	ZL	---	1.000	1.000
Overload coefficient	Ko	---	1.000	
Bending safety factor	SF	---	1.200	
Tooth surface damage safety factor	SH	---	1.150	

OK Cancel

Fig. 1.23 Gear Strength Input Screen



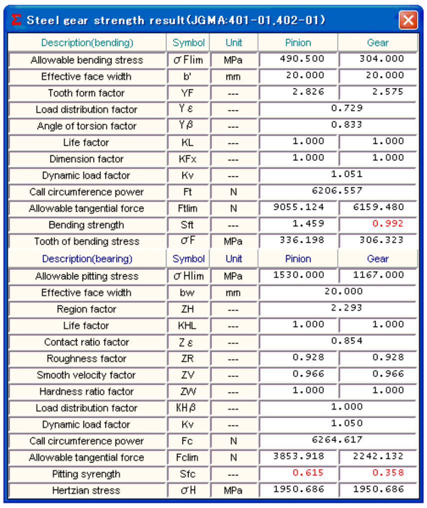
Carburizing gear

Carbon steel	Centerhardness HB	Centerhardness HV	σFlim MPa	Effective carburizing	Tooth suface hardness HV	Tooth suface hardness HRc	σHlim MPa
S15C	140	147	178.5	Comparatively light	580	54	1128
	150	157	192		600	55	1147.5
	160	167	206		620	56	1157
	170	178	215.5		640	57	1167
	180	189	225.5		660	58	1177
	190	200	235.5		680	59	1177
S15CK					700	60	1177
					720	61	1167
					740	62	1157
					760	63	1147.5
					780	63	1128
					800	64	1108

Structural alloy steel	Centerhardness HB	Centerhardness HV	σFlim MPa	Effective carburizing	Tooth suface hardness HV	Tooth suface hardness HRc	σHlim MPa
SCM415	220	231	333.5		580	54	1284.5
	230	242	353		600	55	1314
	240	252	372.5		620	56	1343.5
	250	263	382.5		640	57	1353.5

OK Cancel

Fig. 1.24 Material Selection



Steel gear strength result(JGMA:401-01,402-01)

Description(bending)	Symbol	Unit	Pinion	Gear
Allowable bending stress	σFlim	MPa	490.500	304.000
Effective face width	b'	mm	20.000	20.000
Tooth form factor	YF	---	2.826	2.575
Load distribution factor	Yε	---	0.729	
Angle of torsion factor	Yβ	---	0.833	
Life factor	KL	---	1.000	1.000
Dimension factor	KFx	---	1.000	1.000
Dynamic load factor	Kv	---	1.051	
Call circumference power	Ft	N	6206.557	
Allowable tangential force	Ftlim	N	9055.124	6159.480
Bending strength	Sft	---	1.459	0.992
Tooth of bending stress	σF	MPa	336.198	306.323
Description(bearing)	**Symbol**	**Unit**	**Pinion**	**Gear**
Allowable pitting stress	σHlim	MPa	1530.000	1167.000
Effective face width	bw	mm	20.000	
Region factor	ZH	---	2.293	
Life factor	KHL	---	1.000	1.000
Contact ratio factor	Zε	---	0.854	
Roughness factor	ZR	---	0.928	0.928
Smooth velocity factor	ZV	---	0.966	0.966
Hardness ratio factor	ZW	---	1.000	1.000
Load distribution factor	KHβ	---	1.000	
Dynamic load factor	Kv	---	1.050	
Call circumference power	Fc	N	6264.617	
Allowable tangential force	Fclim	N	3853.918	2242.132
Pitting syrength	Sfc	---	0.615	0.358
Hertzian stress	σH	MPa	1950.686	1950.686

Fig. 1.25 Strength Calculation Result

1.3.14 Gear Strength Calculation (Plastic)

The basis of the strength calculation of the plastic gear is an equation of Lewis, and the material allowable stress value adopts experimental values considering temperature and life. As a material combination, the strength calculation of [plastic × plastic] and [steel × plastic] is possible.

SI unit system or MKS unit system can be chosen for designs. Input screen of the plastic gear strength calculation is shown in Fig. 1.26. The tooth profile factor decides the tooth profile of gear dimension given in Fig. 1.3. The strength calculation result is shown in Fig. 1.27. The plastic material is polyacetal (M90, KT20, GH25) and polyamide (Nylon).

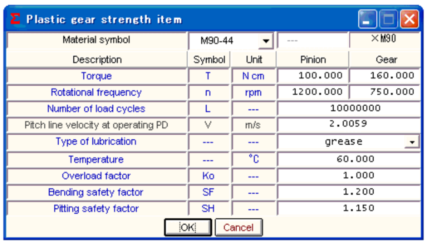


Fig. 1.26 Input Screen of Gear Strength

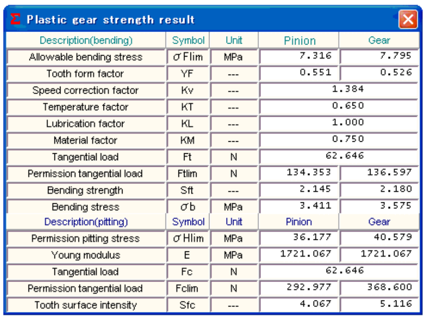


Fig. 1.27 Strength Calculation Result

1.3.15 Bearing Load

The load that affects the gear and the load that affects bearing are calculated. Twenty kinds of load affecting each bearing, such as contact force and normal force, are calculated. The calculation result is shown in Fig. 1.28.

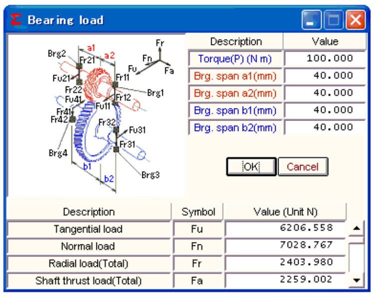


Fig. 1.28 Bearing Load

1.3.16 Flash Temperature

The flash temperature which arises on a tooth surface is calculated. The setting screen is shown in Fig. 1.29. Then, the flash temperature graph of the non-modified tooth profile is shown in Fig. 1.30.

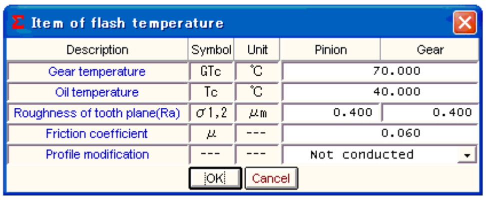


Fig. 1.29 Input Screen of Flash Temperature

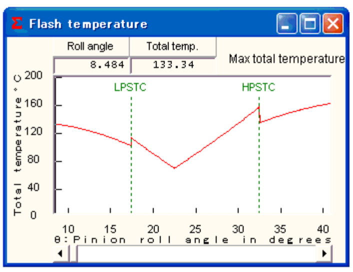


Fig. 1.30 Flash Temperature

[2] 2D Tooth Form Stress Analysis Software

2D tooth form stress analysis is optional ***involute Σ*** (Spur and Helical Gear Design) software. Please observe software composition (Table 1.1).

2.1 Operation

Stress analysis is simply accomplished by clicking the [FEM] icon after the strength calculation ends. Setting screen of FEM analysis is shown in Fig. 2.1. It is possible to change load and number of partitions and Poisson ratio and Young modulus.

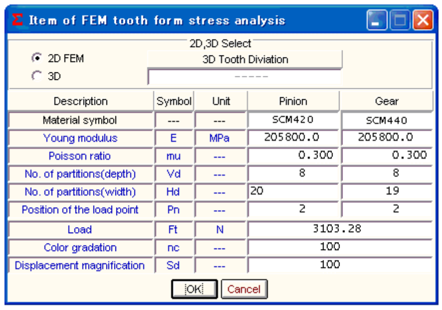


Fig. 2.1 FEM Analysis Setting Screen

2.2 Stress is Analyzed by Load that Affects the Tooth

This software calculates 5 kinds of stress (σ_x, σ_y, shearing stress τ, main stress σ_1, σ_2). Gear reliability can be enhanced by evaluating the actual stress that affects tooth and by calculating the gear strength. The maximum main stress σ_1 is shown in Fig. 2.2, the equality line of stress figure of the smallest main stress σ_2 is shown in Fig. 2.3.

2.3 Tooth Form Modification Quantity is Calculated by Displacement Quantity of Tooth Form

The tooth form modification is a useful method for improving gear running performance. Normal pitch difference arises by deflection of the tooth in the driving gear and tooth of driven gear, even if it is an accurate gear.

The improper contact of mating teeth caused by the difference in this normal pitch becomes a cause of vibration and noise. The tooth form modification is one method for solving this. The tooth form displacement figure is shown in Fig. 2.4, the graph of tooth form modification is shown in Fig. 2.5.

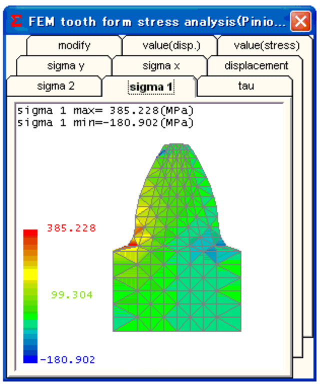


Fig.2.2 Maximum Principal Stress σ_1

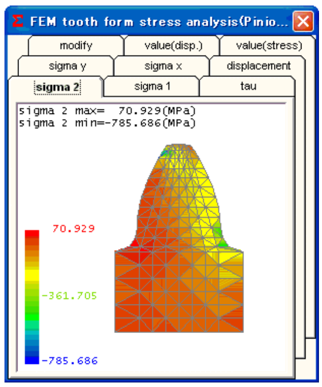


Fig.2.3 Smallest Principal Stress σ_2

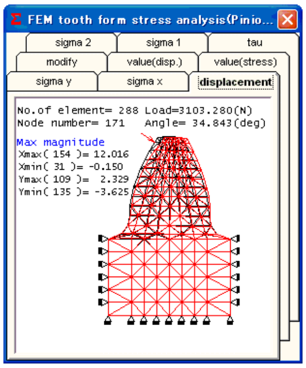


Fig.2.4 Tooth Form Displacement

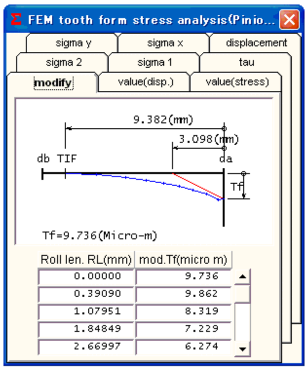


Fig. 2.5 Profile Modification Graph

[3] 3D Tooth Form Stress Analysis Software

3D tooth form stress analysis is optional ***involute Σ*** (Spur and Helical Gear Design) software. In the case of a helical gear, the number of partitions of the face width direction are decided according to the tooth form pitch number of partitions of initial stage setting screen Fig. 3.1. The division of the tooth depth direction is divided on basis of contact line. The smallest main stress, maximum principal stress and tooth form displacement figure are shown in Fig. 3.2 to Fig. 3.7.

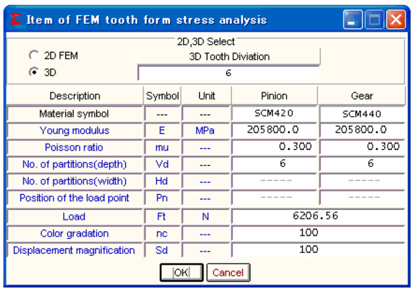


Fig.3.1 Initial Stage Setting Screen

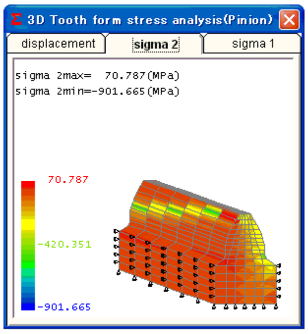


Fig.3.2 Smallest Principal Stress σ_2 (Helical Gear)

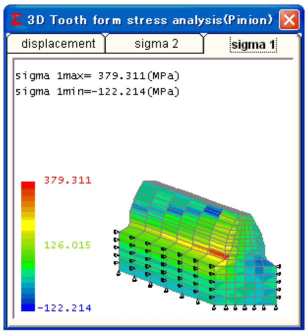


Fig 3.3 Maximum Principal Stress σ_1 (Helical Gear)

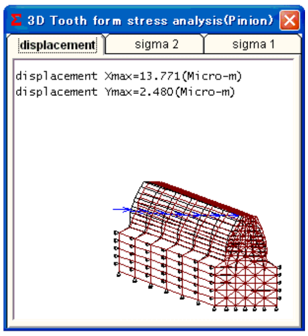


Fig.3.4 Tooth Form Displacement (Helical Gear)

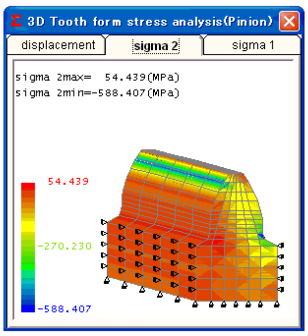


Fig.3.5 Smallest Principal Stress σ_2 (Spur Gear)

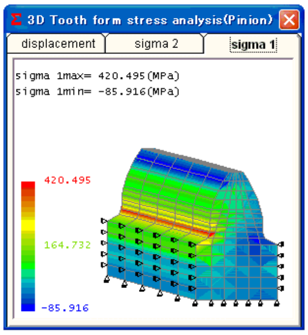


Fig 3.6 Maximum Principal Stress σ_1 (Spur Gear)

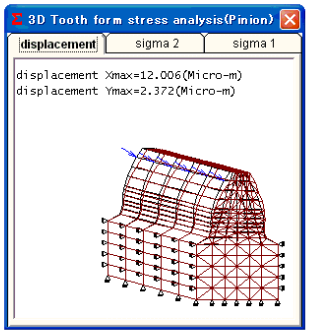


Fig 3.7 Tooth Form Displacement (Spur Gear)

[4] Transmission Error Analysis Software

Transmission error analysis software is optional for ***involute Σ*** (Spur & Helical). The transmission error analysis software requires FEM tooth form stress analysis software.

4.1 Rotation Transmission Error Analysis of Gear

The software uses the following five items as elements to analyze transmission error:

①Tooth profile error
②Pitch variation
③Deflection of tooth
④Runout of shaft
⑤Sliding speed

Gear rotation transmission error can be predicted at the gear design stage, verification by actual product test and measurement is not necessary

The object gear can be analyzed as a spur gear in case of 2D tooth form stress analysis. However, when 3D tooth form stress analysis is used, the transmission error analysis of spur gear and helical gear is possible. Setting screen of transmission error is shown in Fig. 4.1 and Fig. 4.2.

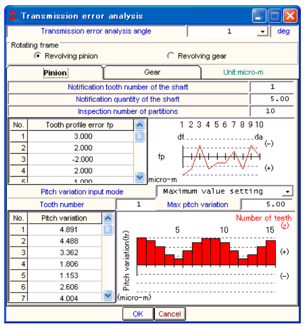


Fig.4.1 Transmission Error Setting Screen (P)

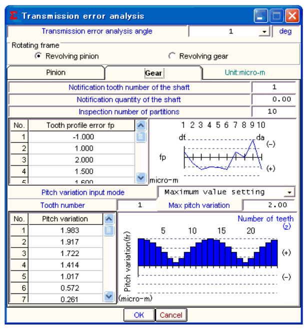


Fig.4.2 Transmission Error Setting Screen (G)

4.2 Evaluation of Transmission Error (1)

The rotation transmission error graph is shown in Fig. 4.3, the wow and flutter graph is shown in Fig. 4.4. And, it can be confirmed by the noise frequency.

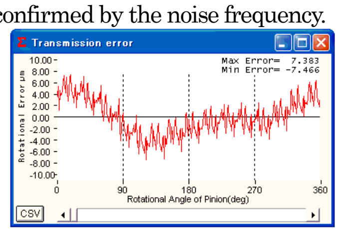


Fig.4.3 Transmission Error

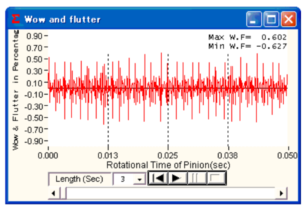


Fig. 4.4 Wow and Flutter

4.3 Evaluation of Transmission Error (2)

Transmission error analytical result and wow and flutter graph of a helical gear are shown in Fig. 4.5 and Fig. 4.6, respectively. The three-dimensional transmission error analysis also considers meshing plane and back interference.

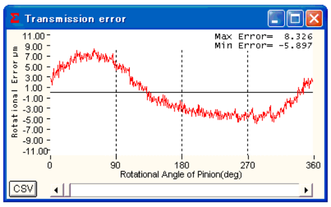


Fig.4.5 Transmission Error

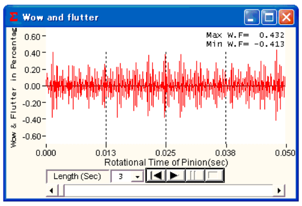


Fig 4.6 Wow and Flutter

[5] Fourier Analysis Software

Transmission error analysis of the spur gear (mn=2, Z1=Z2=40) is carried out, and the frequency analysis results are as follows.

The pinion tooth profile error is set to 10 μm, and shaft runout is set to 3μm. However, there is no pitch error of the pinion and tooth profile error of the gear and shaft runout of the gear. The setting screen is shown in Fig. 5.1. The transmission error graph for a pinion made to rotate at 1200 rpm is shown in Fig. 5.2.

The result of the frequency analysis is shown in Fig. 5.3. The frequency of 800 Hz (1200 min-1 × 40 Hz/60 sec) of the first frequency and the secondary 1600 Hz, third, fourth appeared clearly in the analytical result.

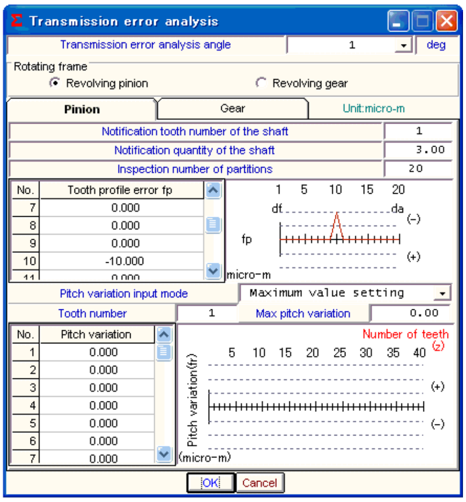


Fig.5.1 Transmission Error Setting Screen (P)

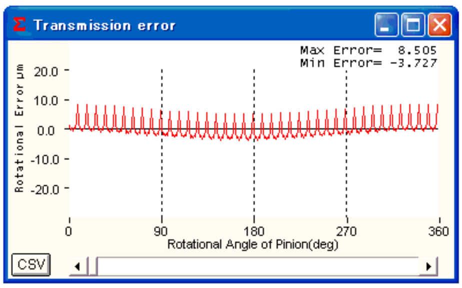


Fig 5.2 Transmission Error Analysis

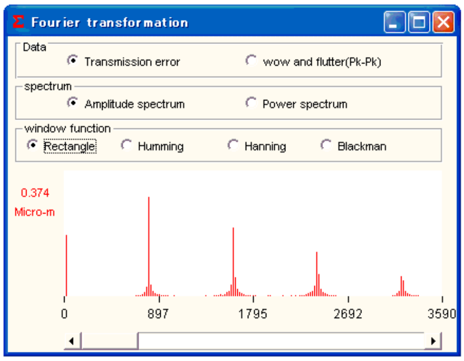


Fig 5.3 Frequency Analysis

[6] Transmission Error Analysis of Plastic Gears

The transmission error was measured by single tooth surface contact testing equipment, while the load was given by the drive of molding plastic helical gear (POM). The gear dimensions are shown in Table1.

Table 6.1

	Unit	Pinion	Gear
Module	mm	1	
Number of teeth	---	37	37
Pressure angle	deg	20	
Helix angle	deg	20	
Face width	mm	10	
Center distance	mm	39.47	
torque	Nm	9.8	
Rotational speed	min^{-1}	6	

A measurement result is shown in Fig. 6.1 and a frequency analysis is shown in Fig. 6.2. Analysis shows a similar corrugation figure and maximum value of the transmission error of 30μm are observed on both results of the actual measurement and the simulation.. And, the 3.7Hz frequency and the 7.4Hz have remarkably appeared, as shown in Fig.6.4.

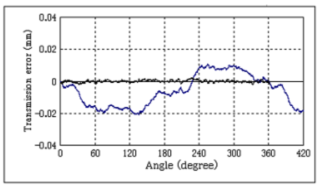


Fig.6.1 Transmission Error Experimental

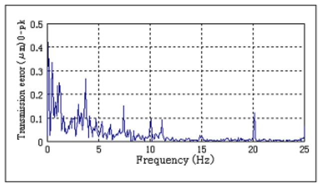


Fig.6.2 Frequency Analysis

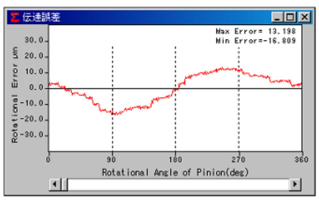


Fig.6.3 Transmission Error by Simulation

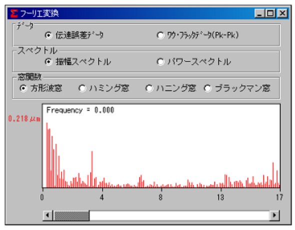


Fig.6.4 Frequency Analysis by Simulation