[21] L-Hypoid Gear Design System

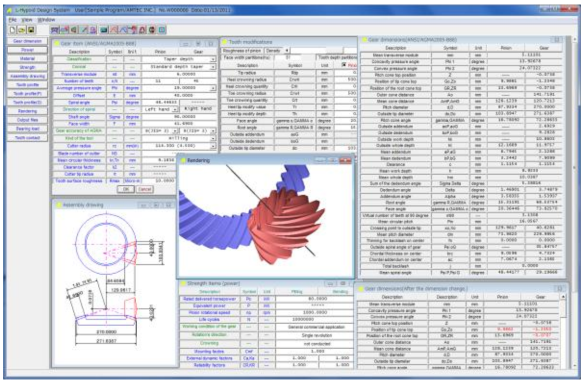


図 21.1 L-Hypoid Gear Design System

21.1 Foreword

L-Hypoid Gear Design System can design the gear dimension, the tooth profile and strength calculation in the total and so on. A general hypoid gear is formed from the bevel gear generating machine. Therefore, a tooth profile is decided by the exercise of the tool and the machine. However, this software gives the offset to the spiral bevel gear with spherical involute tooth profile, it analyzes and decides the tooth profile of the pinion. The screen of L-Hypoid Gear Design software is shown in Fig. 21.1.

21.2 Gear dimensions

The dimension setting screen is shown in Fig.21.2. It is possible to input the standard value, when numerical value is uncertain, and it is possible that spiral angles, tooth thickness, offset and tool radii, etc. are freely set.

Gear item (ANSI/AGMA2005-B88)

Description	Symbol	Unit	Pinion	Gear
Classification	---	---	Taper depth	
Conical	---	---	Standard depth taper	
Transverse module	mt	mm	6.00000	
Number of teeth	n,N	---	11	45
Average pressure angle	Phi	degree	19.00000	
Offset	E	mm	40.0000	
Spiral angle	Psi	degree	48.44633	-----
Direction of spiral	---	---	Left hand	Right hand
Shaft angle	Sigma	degree	90.00000	
Face width	F	mm	41.6900	
Gear accuracy of AGMA	---	---	9(JIS= 3)	9(JIS= 3)
Kind of the tool	---	---	Milling	
Cutter radius	rc	mm(in)	114.300 (4.500)	
Blade number of cutter	NS	---	-----	
Mean circular thickness	tn,Tn	mm	9.1836	4.8331
Clearance factor	k2	---	-----	0.1250
Cutter tip radius	rt	mm	-----	0.7200
Tooth surface roughness	Rmax	Micro-m	10.0000	10.0000

OK　Cancel

Fig21.2 Gear dimensions

21.3 Dimension calculation result

Each part dimension of the hypoid gears is calculated based on the AGMA2005-B88 standard. The dimension result is shown in Fig. 21.3.

Gear dimensions(ANSI/AGMA2005-B88)

Description	Symbol	Unit	Pinion	Gear
Mean transverse module	mm	mm	5.11101	
Concavity pressure angle	Phi 1	degree	13.92678	
Convex pressure angle	Phi 2	degree	24.07322	
Pitch cone top position	Z	mm	-----	-0.0738
Position of tip cone top	Go,Zo	mm	9.9861	-1.2348
Position of the root cone top	GR,ZR	mm	13.6969	-0.0738
Outer cone distance	Ao	mm	-----	141.7191
Mean cone distance	AmP,AmG	mm	128.1239	120.7213
Pitch diameter	d,D	mm	87.9334	270.0000
Outside tip diameter	do,Do	mm	103.8947	271.6387
Pitch cone angle	gamma,GAMMA	degree	16.78092	72.28633
Outside addendum	aoP,aoG	mm	-----	2.6929
Outside dedendum	boP,boG	mm	-----	9.2828
Outside work depth	hk	mm	-----	10.8603
Outside whole depth	ht	mm	12.1669	11.9757
Mean addendum	aP,aG	mm	6.7945	2.1288
Mean dedendum	bP,bG	mm	3.2442	7.9099
Clearance	c	mm	1.1154	1.1154
Mean work depth	h	mm	8.9233	
Mean whole depth	hm	mm	10.0387	
Sum of the dedendum angle	Sigma Delta	degree	5.28816	
Dedendum angle	Delta	degree	1.46901	3.74879
Addendum angle	Alpha	degree	3.58355	1.53937
Root angle	gamma R,GAMMA	degree	15.31191	68.53754
Face angle	gamma o,GAMMA o	degree	20.36446	73.82570
Virtual number of teeth at 90 degree	m90	---	3.1308	
Mean circular pitch	Pm	mm	16.0567	
Crossing point to outside tip	xo,Xo	mm	129.9617	40.6281
Mean pitch diameter	dm	mm	73.9820	229.9956
Thinning for backlash on center	fn	mm	0.0000	0.0000
Outside spiral angle of gear	Psi oG	degree	-----	35.84757
Chordal thickness on center	tnc	mm	9.0596	4.7324
Chordal addendum on center	ac	mm	7.0674	2.1365
Total backlash	j	mm	0.0000	
Mean spiral angle	Psi P,Psi G	degree	48.44177	29.19668

Fig21.3 Dimensions result (Standard value)

Analysis accuracy, crowning and tip relief of the tooth profile are set in Fig. 21.4 in the modified gear dimension input screen. Reference figure of crowning and tip relief is shown in Fig.21.5 (a) and 21.5 (b). When adjusting a tooth contact pattern, it adjusts Crt and Crwt in Fig. 21.4 (a.)

Tooth modifications

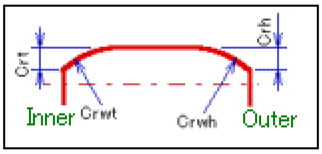
Roughness of pinion | Density | Coarse

Face width partitions(hu) 55　Tooth depth partitions(vu) 55

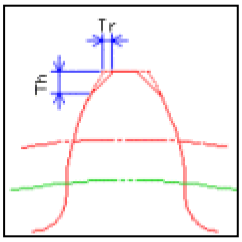
Description	Symbol	Unit	Pinion	Gear
Tip radius	Rtip	mm	0.6000	0.6000
Heel crowning radius	Crwh	mm	500.0000	270.0000
Heel crowning quantity	Crh	mm	0.1000	0.0000
Toe crowning radius	Crwt	mm	500.0000	270.0000
Toe crowning quantity	Crt	mm	0.0300	0.0000
Heel tip modify value	Tr	mm	0.0000	0.0000
Heel tip modify depth	Th	mm	0.0000	0.0000
Face angle	gamma o,GAMMA o	degree	20.36446	73.82570
Root angle	gamma R,GAMMA R	degree	15.31191	68.53754
Outside addendum	aoG	mm	---	2.6929
Outside dedendum	boG	mm	---	9.2828
Outside tip diameter	do	mm	103.8947	---

Reference figure　OK　Cancel　Reset

Fig.21.4 Modified gear dimension input screen



(a) Crowning

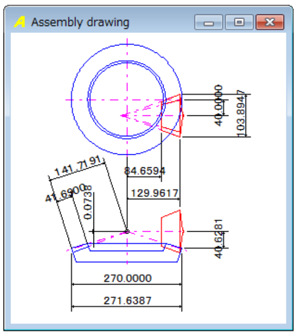


(b) Tip relief

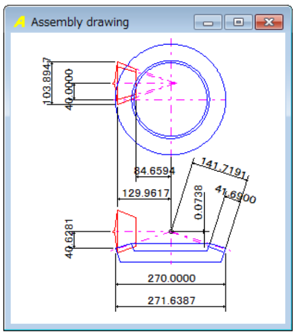
Fig.21.5 Crowning and tip relief

21.4 Assembly drawing

The hypoid gear dimension and position are shown in Fig. 21.6.



(a) Right position



(b) Left position

Fig.21.6 Position of Hypoid gear

21.5 Gear strength

21.5.1 Power setting

The strength calculation of the hypoid gear is based on the ANSI / AGMA 2003-A86 standard. Power specification setting is shown in Fig. 21.7. Also, Life Factor graph is shown in Fig. 21.8 and Fig. 21.9.

Strength items (power)

Description	Symbol	Unit	Pitting	Bending
Rated delivered horsepower	Po	kW	60.0000	
Equivalent power	P	kW	*****	
Pinion rotational speed	np	rpm	1000.0000	
Life cycles	N	---	10000000	
Working condition of the gear	---	---	General commercial application	
Rotation's direction	---	---	Single revolution	
Crowning	---	---	not conducted	
Mounting factos	Cmf	---	1.000	
External dynamic factors	Ca,Ka	---	1.000	1.000
Reliability factors	CR,KR	---	1.000	1.000
Temperature factoes	CT,KT	---	1.000	1.000
Frequency of pinion overload/minute		---	1	
Frequency of gear overload/minute		---	1	

☐ Life Factor CL ☐ Life Factor KL [OK] [Cancel] [Geometry factor]

図 21.7 Setting of power

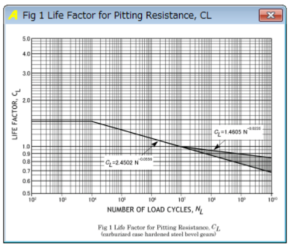


図 21.8 Life Factor (C_L)

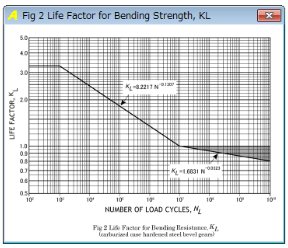


図 21.9 Life Factor (K_L)

21.5.2 Geometry factor

The standard value of geometry factor (I , J) are shown in Fig. 21.10, but the graph of Fig.21.11 and Fig.21.12 can be freely changed by consulting.

Geometry factor I,J

Description	Symbol	Pinion	Gear
Geometry factor I	I	0.18698	
Geometry factor J	JP,JG	0.25438	0.31609
Offset coefficient	E/D	0.15	

☐ Graph of geometry factor I ☐ Graph of geometry factor J

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Fig.21.10 Geometry factor (Standard value)

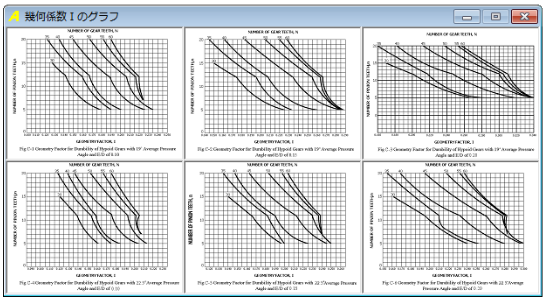

Fig.21.11 Geometry factor (I)

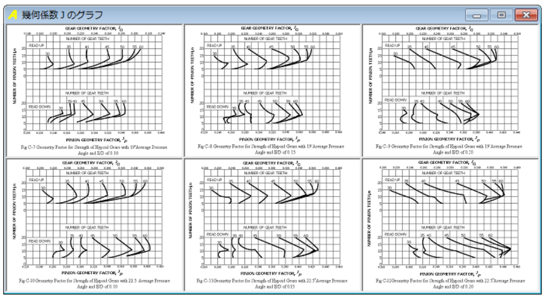

Fig.21.12 Geometry factor (J)

21.5.3 Material

The setting screen of the material, heat-treatment, hardness and the permissible stress number are shown in Fig.21.13.

Strength item (materials)

Pinion material		Gear material	
Material name	Steel	Material name	Steel
Material symbol	aaa	Material symbol	bbb
Heat treatment	Carburized & hardened	Heat treatment	Carburized & hardened
Hardness(HRC)	60	Hardness(HRC)	55
Allowable contact stress (MPa)	1240.0	Allowable contact stress (MPa)	1240.0
Allowable bending stress(MPa)	380.0	Allowable bending stress (MPa)	380.0

☐ Reference table [OK] [Cancel] [Elastic modulus]

Fig.21.13 Setting of material

21.5.4 Gear strength value

The strength result of the hypoid gear is shown in Fig. 21.14.

Strength result(ANSI/AGMA2003-A86)

Description	Symbol	Unit	Pinion	Gear
Gear ratio	mG	--	4.091	
Tangential velocity at outer pitch circle	Vt	m/s	4.604	
Efficiency	Zeta	%	96.379	
Design pinion torque	TD	N m	572.983	
Operating pinion torque	TP	N m	572.983	
Contact strength				
Stress adjustment factor	Cb	--	0.634	
Internal dynamic factor	Cv	--	0.928	
U coefficient	U	--	0.239	
Approximate internal dynamic factor	Cvmin	--	0.238	
Face contact ratio	mF	--	2.760	
Size factor	Cs	--	1.000	
Load distribution factor	Cm	--	1.200	
Crowning factor	Cxc	--	1.000	
Surface condition factor	Cf	--	1.000	
Geometry factor	I	--	0.187	
Life factor	CL	--	1.000	
Hardness ratio factor	CH	--	1.000	
Allowable contact stress number	Sac	MPa	1240.000	1240.000
Calculated contact stress number	Sc	MPa	597.278	575.652
Allowable transmitted power	Pac	kW	258.621	249.257
Allowances rate of the contact strength	SFc	--	4.310	4.154
Bending strength				
Internal dynamic factor	Kv	--	0.928	
Size factor	Ks	--	1.000	1.000
Load distribution factor	Km	--	1.200	
Lengthwise curvature factor	Kx	--	1.061	
Geometry factor	J	--	0.254	0.316
Life factor	KL	--	1.000	
Allowable bending stress number	Sat	MPa	380.000	380.000
Calculated bending stress number	St	MPa	249.677	270.818
Allowable transmitted power	Pat	kW	91.323	104.197
Allowances rate of the bending strength	SFt	--	1.522	1.737

Fig.21.14 Gear strength value (Bending, Pitting)

21.5.5 Lifetime of the gear

The gear lifetime calculation result is shown in Fig. 21.15..

Result of life

Life of pitting resistance	Symbol	Unit	Pinion	Gear
Prediction life factor	CL'	---	0.482	0.482
Prediction life load frequency	Nc	cycs	3.161E+20	3.161E+20
Prediction lifetime	Lc	hrs	8.781E+16	3.592E+17
Life of bending resistance	**Symbol**	**Unit**	**Pinion**	**Gear**
Prediction life factor	KL'	---	0.657	0.713
Prediction life load frequency	Nt	cycs	1.000E+07	1.000E+07
Prediction lifetime	Lt	hrs	2.778E+03	1.136E+04

Fig.21.15 Lifetime of the gear

21.6 Tooth rendering

The analysis of the tooth profile is based on the distribution number to the direction of the face width and the direction of the tooth height. A tooth rendering is shown in Fig. 21.16 and Fig. 21.17. The tooth profile rendering which is shown in Fig.21.18 is the figure which piled Fig.21.17 with the cutting cutter.

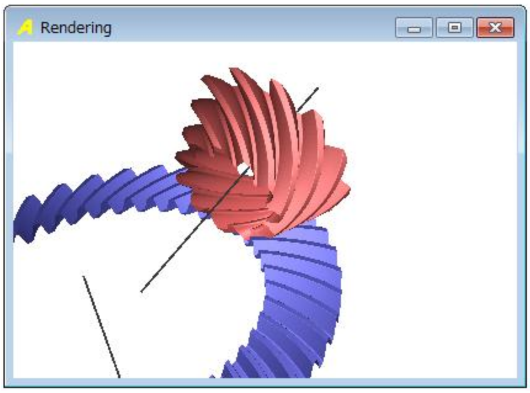

Fig.21.16 Tooth rendering-1

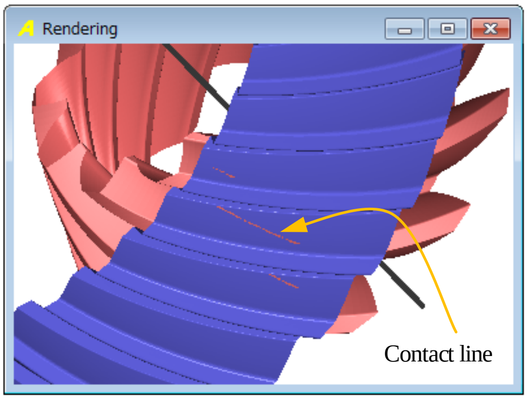

Fig.21.17 Tooth rendering-2

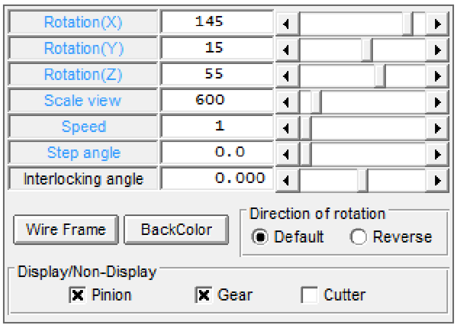

Fig.21.17a Control form

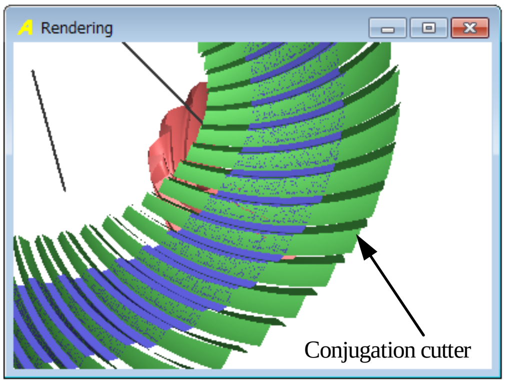

Fig.21.18 Tooth rendering-3 (+Conjugation cutter)

The generation procedure of the tooth profile of both gear is shown below.

(1) The tooth profile of the gear is a spherical involute curve.

(2) The spiral curve of the gear is decided at the tool radius in Fig. 21.2.

(3) The tooth profile of the pinion considers an offset and is generating the tooth profile which meshes with the gear.

21.7 CAD file

The tooth profile of the pinion and the gear can be output in DXF and the IGES file. A file output form is shown in Fig. 21.19. Then, CAD drawing a figure example is shown in Fig. 21.20 and Fig. 21.21.

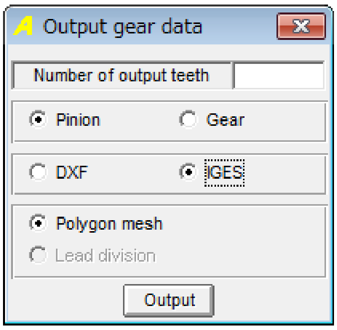

Fig.21.19 Output form of CAD data

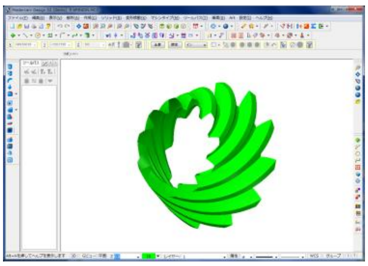

Fig.21.20 CAD- drawing example (Pinion-3D-IGES)

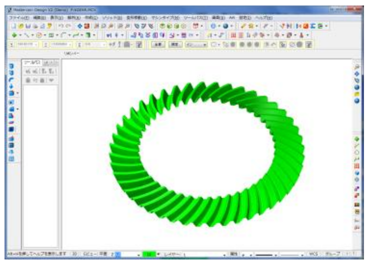

Fig.21.21 CAD- drawing example (Gear-3D-IGES)

21.8 Analysis of tooth contact pattern（Optional）

Analysis setting and an analysis sample of tooth contact pattern are shown in Fig. 21.22 and Fig. 21.23. Also, contact value is shown in Fig. 21.24.

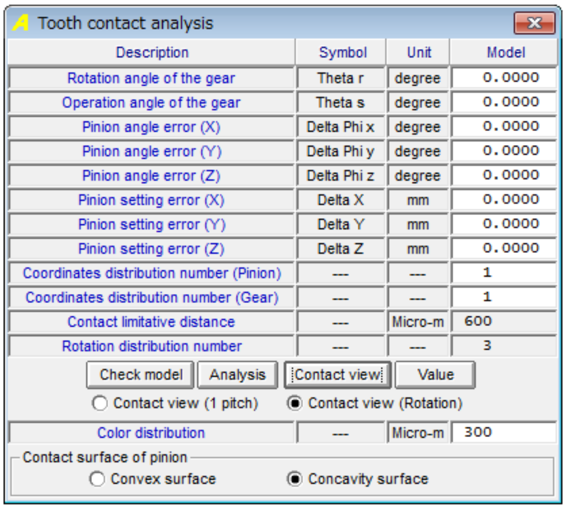

Fig.21.22 Setting of tooth contact pattern

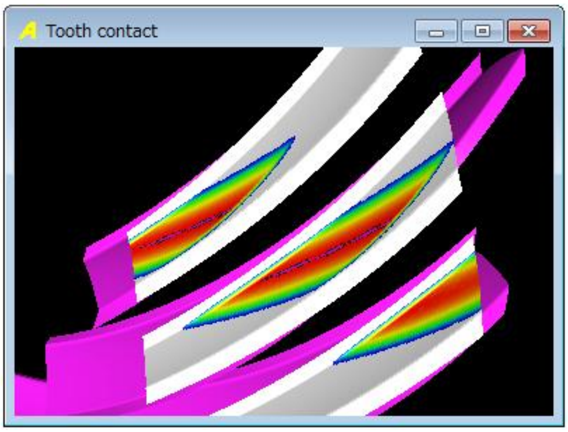

Fig.21.23 Contact pattern of teeth

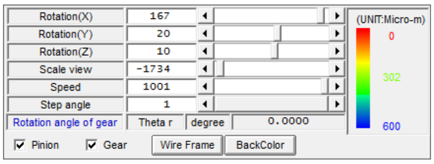

Fig.21.23a Control form

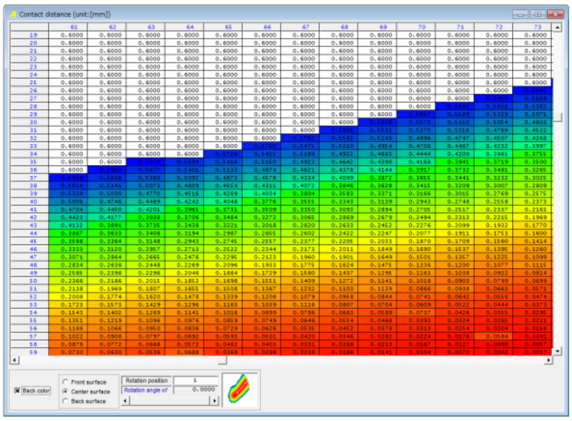

Fig.21.24 Contact pattern of teeth (Value)

21.9 Bearing load

The setting of bearing computation and the calculation example of the bearing load are shown in Fig. 21.25 and Fig. 21.26.

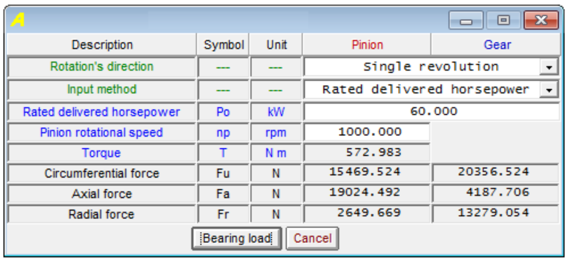

Fig.21.25 Setting of bearing load-1

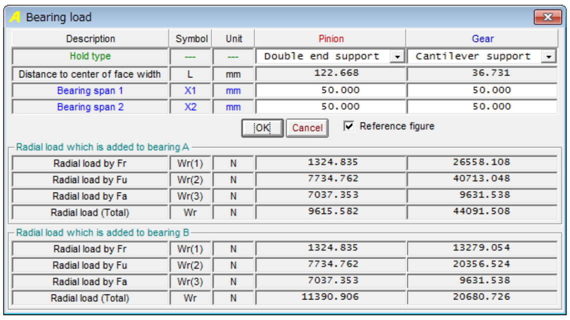

Fig.21.26 Setting of bearing load-2

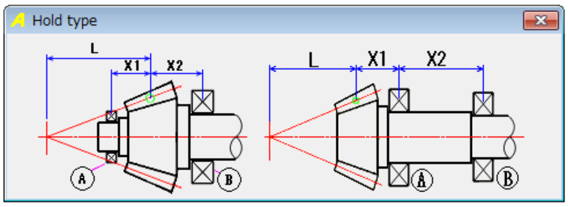

Fig.21.26a Bearing support example

21.10 Required System Configuration

(1) Operating system

Windows XP or Windows 7

(2) Computer

Personal computer with Pentium 1 GHz or faster capable of running Windows

(3) CD-ROM drive

(4) Windows-compatible monitor with 1024 × 768 or higher resolution

(5) 1GMB or more of available memory space

(6) 1GB or more of available hard disk space

(7) Windows-compatible mouse or other pointing device

(8) Windows-compatible printer