

Gear Navigation System

0. Abstract

In some cases, a dress gear with dimensions that differ from those of the work gear, or a dress gear modified with a complicated process such as bias correction, may be used in a honing operation.

However, in reality, the degree of machining accuracy can be judged only by checking the actual machined gears.

The Gear Navigation System solves these problems simply.

1. Introduction

Gear Navigation System software simulates gear cutting by hob, pinion cutter, shaving cutter, and honing, and analyzes it. Then, it is possible to simulate the gear meshing.

In addition, it is possible to search the tool database for a desired tool with the tool management function. In honing, modifications of the tooth profile and tooth trace and tooth form after tooth surface modifications will be calculated and displayed graphically.

A Gear Navigation System window is shown in Fig. 1.1.

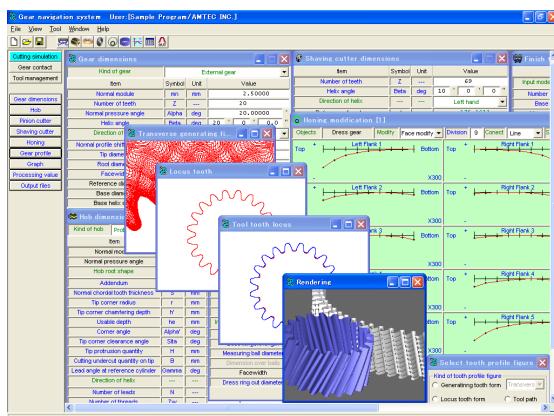


Fig. 1.1 Gear Navigation System

2. The Application Gear

- Spur and Helical Gears (Involute)
- External and Internal Gears

3. The Tool

3.1 Hob

- (1) Standard hob
- (2) Semi-topping hob (Bottom form is R or C)
- (3) Protuberance hob
- (4) Protuberance semi-topping hob
- (5) Tooth profile shift hob
- (6) Tooth modification hob

3.2 Pinion Cutter

- (1) Standard pinion cutter
- (2) Semi-topping pinion cutter (Bottom form is R or C)
- (3) Protuberance pinion cutter
- (4) Protuberance semi-topping pinion cutter
- (5) The pinion cutter is applied to external gears and internal gears.

3.3 Shaving cutter

3.4 Honing

For dress gear, profile modification, tooth trace modification and tooth surface modification can be analyzed. And, it is possible to set the dress gear dimensions different from that of the work gear.

4. Gear dimensions setting

The gear dimension input window is shown in Fig. 4.1.

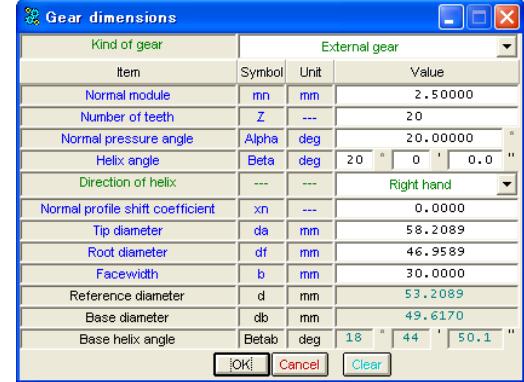


Fig. 4.1 Gear dimensions setting

5. Tool dimension setting

5.1 Hob dimension

The hob setting is shown in Figs 5.1-5.4. It is possible to set the hob dimension for up to 3 processes.

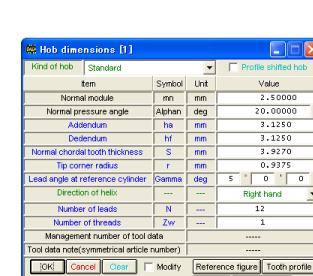


Fig. 5.1 Standard hob

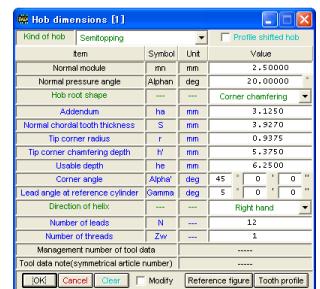


Fig. 5.2 Semi-topping hob

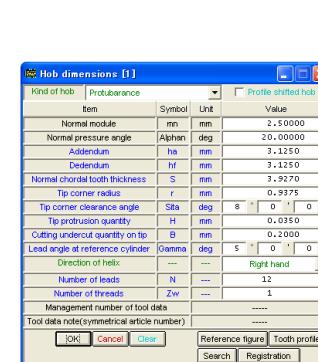


Fig. 5.3 Protuberance Hob

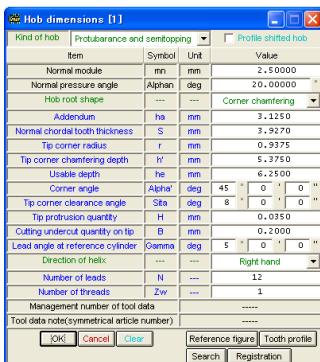


Fig. 5.4 Protuberance semi-topping Hob

5.2 Pinion cutter dimensions

The pinion cutter setting are shown in Fig.5.5-5.8.

The pinion cutter dimension can be set for up to 3 processes.

Item	Symbol	Unit	Value
Number of teeth	Zc	---	69
Tip diameter	ds	mm	189.8207
Reference diameter	d	mm	183.5707
Root diameter	df	mm	141.8565
Input mode of tooth thickness	---	---	Chordal tooth thickness
Chordal height	hj	mm	3.1436
Chordal tooth thickness	sj	mm	3.9268
Number of teeth spanned	zm	---	10
Base tangent length	VW	mm	72.9974
Tip corner radius	r	mm	0.9375
Management number of tool data	----	----	----
Tool data note(symmetrical article number)	-----	-----	-----

Buttons: OK, Cancel, Clear, Reference figure, Tooth profile, Search, Registration.

Fig. 5.5 Standard pinion cutter

Item	Symbol	Unit	Value
Number of teeth	Zc	---	69
Tip diameter	ds	mm	189.8207
Reference diameter	d	mm	183.5707
Root diameter	df	mm	141.8565
Input mode of tooth thickness	---	---	Chordal tooth thickness
Chordal height	hj	mm	3.1436
Chordal tooth thickness	sj	mm	3.9268
Number of teeth spanned	zm	---	10
Base tangent length	VW	mm	72.9974
Tip corner radius	r	mm	0.9375
Root corner chamfering height	hc	mm	5.3750
Tooth thickness at chamfering	sc	mm	2.6631
Chamfering angle	Sita	deg	45° 0' 0"
Management number of tool data	----	----	----
Tool data note(symmetrical article number)	-----	-----	-----

Buttons: OK, Cancel, Clear, Reference figure, Tooth profile, Search, Registration.

Fig. 5.6 Semi-topping pinion cutter

Item	Symbol	Unit	Value
Number of teeth	Zc	---	69
Tip diameter	ds	mm	189.8207
Reference diameter	d	mm	183.5707
Root diameter	df	mm	141.8565
Input mode of tooth thickness	---	---	Chordal tooth thickness
Chordal height	hj	mm	3.1436
Chordal tooth thickness	sj	mm	3.9268
Number of teeth spanned	zm	---	10
Base tangent length	VW	mm	72.9974
Tip corner radius	r	mm	0.9375
Cutting undercut quantity on tip	E	mm	0.0250
Management number of tool data	----	----	----
Tool data note(symmetrical article number)	-----	-----	-----

Buttons: OK, Cancel, Clear, Reference figure, Tooth profile, Search, Registration.

Fig. 5.7 Protuberance pinion cutter

Item	Symbol	Unit	Value
Number of teeth	Zc	---	69
Tip diameter	ds	mm	189.8207
Reference diameter	d	mm	183.5707
Root diameter	df	mm	141.8565
Input mode of tooth thickness	---	---	Chordal tooth thickness
Chordal height	hj	mm	3.1436
Chordal tooth thickness	sj	mm	3.9268
Number of teeth spanned	zm	---	10
Base tangent length	VW	mm	72.9974
Tip corner radius	r	mm	0.9375
Root corner chamfering height	hc	mm	5.3750
Tooth thickness at chamfering	sc	mm	2.6631
Chamfering angle	Sita	deg	45° 0' 0"
Cutting undercut quantity on tip	E	mm	0.0250
Management number of tool data	----	----	----
Tool data note(symmetrical article number)	-----	-----	-----

Buttons: OK, Cancel, Clear, Reference figure, Tooth profile, Search, Registration.

Fig. 5.8 Protuberance semi-topping pinion cutter

5.3 Shaving cutter

The settings for the shaving cutter are shown in Fig. 5.9.

Item	Symbol	Unit	Value
Number of teeth	Z	---	69
Helix angle	Beta	deg	10° 0' 0"
Direction of helix	---	---	Left hand
Reference diameter	d	mm	175.1611
Tip diameter	da	mm	180.1611
Input mode of depth	---	---	Any input
Usable depth	he	mm	7.9310
Base diameter	db	mm	164.2991
Number of teeth spanned	zm	---	8
Base tangent length	VW	mm	57.8763
Facewidth	b	mm	30.0000
Setting angle	Sita	deg	-9.99999
Management number of tool data	----	----	----
Tool data note(symmetrical article number)	-----	-----	-----

Buttons: OK, Cancel, Clear, Reference figure, Tooth profile, Search, Registration.

Fig. 5.9 Shaving cutter

5.4 Honing

The honing dimension setting sets dress gear dimension and honing grinding stone dimension. The honing dress gear and grinding stone dimensions can be set for up to 2 processes.

The following are shown in Figs 5.10 to 5.13: Dressing gear dimension, dressing gear modification setting, dressing gear modification topography, and honing grinding stone dimension.

Item	Symbol	Unit	Value
Number of teeth	Z	---	20
Helix angle	Beta	deg	20° 0' 0.0"
Direction of helix	---	---	Right hand
Reference diameter	d	mm	53.2089
Base diameter	db	mm	49.6370
Tip diameter	da	mm	59.4589
Root diameter	df	mm	45.7089
Input mode of tooth thickness	---	---	Base tangent length
Number of teeth spanned	zm	---	3
Base tangent length	VW	mm	19.28684
Measuring ball diameter	dp	mm	4.2800
Dimension over balls	dm	mm	59.06991
Facewidth	b	mm	30.0000
Dress ring out diameter	iD	mm	59.4589

Buttons: OK, Cancel, Clear, Modify.

Fig. 5.10 Dressing gear dimension

Object	Dress gear	Modify	Face modify	Division	9	Connect	Line	Scale	300
Top	Left Flank 1	Bottom	X300	-	-	-	-	-	-
Top	Right Flank 1	Bottom	X300	-	-	-	-	-	-
Top	Left Flank 2	Bottom	X300	-	-	-	-	-	-
Top	Right Flank 2	Bottom	X300	-	-	-	-	-	-
Top	Left Flank 3	Bottom	X300	-	-	-	-	-	-
Top	Right Flank 3	Bottom	X300	-	-	-	-	-	-
Top	Left Flank 4	Bottom	X300	-	-	-	-	-	-
Top	Right Flank 4	Bottom	X300	-	-	-	-	-	-
Top	Left Flank 5	Bottom	X300	-	-	-	-	-	-
Top	Right Flank 5	Bottom	X300	-	-	-	-	-	-

Buttons: Modify mode, Lead, Clear, TopoGraphy.

Fig. 5.11 Dressing gear modification on flank

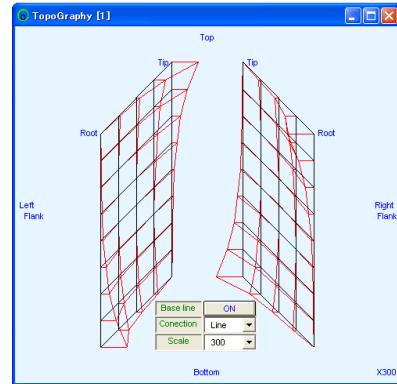


Fig. 5.12 Topography of modified dressing gear

Input mode	Input Axes angle/Centre distance		
Item	Symbol	Unit	Value
Number of teeth	Z	---	131
Helix angle	Beta	deg	10° 0' 0.0"
Direction of helix	---	---	Right hand
Shaft crossed axes angle(Dress gear)	SigmaD	deg	-10° 0' 0.0"
Centre distance(Dress gear)	aD	mm	139.6717
Centre distance(Dress ring)	aR	mm	134.7000
Shaft crossed axes angle(Work)	Sigma	deg	-10° 0' 0.0"
Centre distance(Work)	a	mm	139.6717
Reference diameter	d	mm	332.5522
Tip diameter	da	mm	328.8589
Root diameter	df	mm	338.8023
Base diameter	db	mm	311.9301
Spacewidth	Sn	mm	3.9270
Tooth thickness at tip	S	mm	2.6111
Normal profile shifted coefficient	xn	---	0.00002
Interference(Dress gear)	---	---	Not arise
Clearance(Dress gear root)	---	mm	1.9033
Clearance(Work tip)	---	mm	0.6250
Clearance(Work root)	---	mm	1.2783

Buttons: OK, Cancel, Clear.

Fig. 5.13 Honing dimension

6. Setting of finishing gear tooth thickness

For measurement of thickness of tooth finished by hobbing, shaving, or honing, you can select either of the following methods: base tangent length, dimension over balls, circular thickness. Fig. 6.1 shows the window for the finished gear tooth thickness setting. In this example, hobbing, shaving, and honing are carried out once.

The rough cutting of the gear by hob with target base tangentlength of W1=19.350 mm and the honing procedure for finishing target base tangent length of W3=19.287 mm are shown.

Item	Symbol	Unit	Pinion cutter [1]	Shaving cutter	Honing [1]
Input mode of tooth thickness	---	---	Base	xnc=0.03694	Base tangent I
Number of teeth spanned	Zm	---	3	3	3
Base tangent length	VW	mm	19.35000	19.32000	19.28684
Measuring ball diameter	dp	mm	4.2800	4.2800	4.2800
Dimension over balls	dm	mm	59.22616	59.15220	59.06992
Normal tooth thickness	Sn	mm	3.99421	3.96228	3.92699
Difference of base tangent length	DeltaW	mm	-----	-0.0300	-0.0332
Amount of change of the dimension	Deltadm	mm	-----	-0.0740	-0.0823

Fig. 6.1 Setting window for finishing tooth thickness of work gear

7. Gear tooth profile by processing

The gear shape, when dimension and machining condition are set, is displayed. It is possible that it superimpose tooth form shape processed by each tool and easily confirm diameters and depth measurement and machined gear tooth profile. The tooth form selection window is shown in Fig. 7.1 and the gear tooth form after analysis is shown in Figs 7.2 to 7.9.



Fig. 7.1 Tooth form selection window

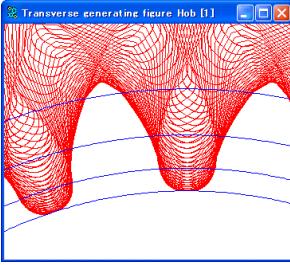


Fig. 7.2 Tooth generation

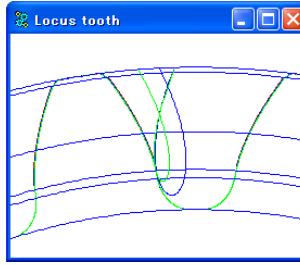


Fig. 7.3 Tooth profile

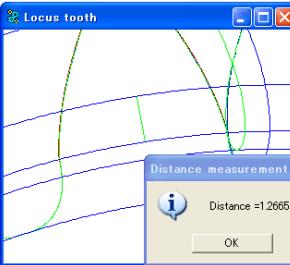


Fig. 7.4 Measurement

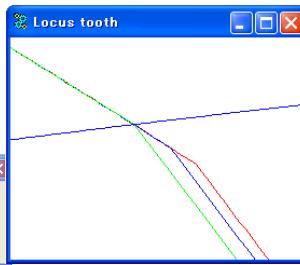


Fig. 7.5 Partial extension

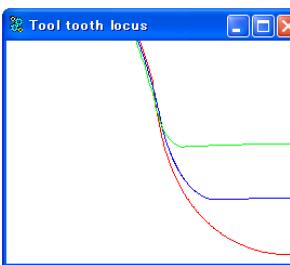


Fig. 7.6 Tool path line

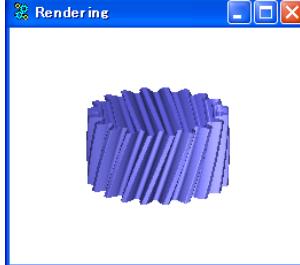


Fig. 7.7 Rendering

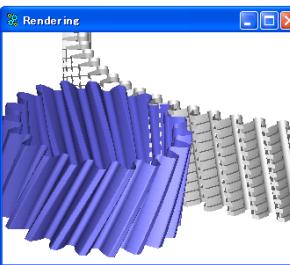


Fig. 7.8 Contact between shaving cutter and work gear

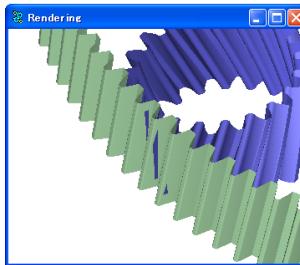


Fig. 7.9 Contact between grinding stone and work gear in honing

8. Processing value

The processing value of each tool is shown in Figs 8.1 to 8.4. It is possible to confirm detailed values such as chamfering length, face diameter, and gear volume with these tables.

Processing value			
Kind of tool	Hob [1]	Symbol	Unit
Radius of the tip corner	hp	mm	0.2609
Tip corner length	hk	mm	0.1660
Tip form diameter	dh	mm	57.6970
Residual tooth thickness at tip	Sc	mm	1.6750
Root form diameter	fd	mm	50.7979
Rolling length(d=fd)	Rd	mm	57.2689
Working depth	he	mm	3.4446
Volume of gear	V	mm ³	66103.0833
Tip diameter	ds	mm	58.2069
Root diameter	dt	mm	47.1436
Cutting depth	h	mm	5.5227
Hob setting angle	Betas	deg	-15.0000
Tooth surface polygon error	Dotes	mm	0.0014

Fig. 8.1 Hobbing processing value

Processing value			
Kind of tool	Pinion cutter [1]	Symbol	Unit
Radius of the tip corner	hp	mm	0.0838
Tip corner length	hk	mm	0.0631
Tip form diameter	dh	mm	58.0412
Residual tooth thickness at tip	Sc	mm	1.8809
Root form diameter	fd	mm	50.4930
Rolling length(d=fd)	Rd	mm	50.3754
Working depth	he	mm	3.7741
Volume of gear	V	mm ³	66218.0293
Tip diameter	ds	mm	58.2089
Root diameter	dt	mm	47.1431
Cutting depth	h	mm	5.5229

Fig. 8.2 Shaping processing value

Processing value			
Kind of tool	Shaving cutter	Symbol	Unit
Radius of the tip corner	hp	mm	0.2321
Tip corner length	hk	mm	0.1474
Tip form diameter	dh	mm	57.7446
Residual tooth thickness at tip	Sc	mm	1.6750
Root form diameter	fd	mm	50.6212
Rolling length(d=fd)	Rd	mm	57.7534
Working depth	he	mm	3.6167
Volume of gear	V	mm ³	66030.5601
Centre distance	a	mm	114.2333
Processing minimum diameter	TC	mm	50.6212
Clearance of Tool tip and gear root	C	mm	0.5810
Working normal pressure angle	Alpha	deg	20.0631
Contact ratio	Epsilon	---	1.6896

Fig. 8.3 Shaving processing value

Processing value			
Kind of tool	Honing [1]	Symbol	Unit
Radius of the tip corner	hp	mm	0.1279
Tip corner length	hk	mm	0.1474
Tip form diameter	dh	mm	57.7531
Residual tooth thickness at tip	Sc	mm	1.6750
Root form diameter	fd	mm	50.6111
Rolling length(d=fd)	Rd	mm	57.7873
Working depth	he	mm	3.5710
Volume of gear	V	mm ³	66015.2754
Processing minimum diameter	TC	mm	50.6033

Fig. 8.4 Honing processing value

9. Deviation graph

Fig. 9.1 shows the profile deviation graph after the processing. This system has rich functions. The topography shows the tendency in the whole tooth form, modifying value at each diameter and graph scaling, etc.

These functions facilitate verifying whether the proper tooth form is obtained by machining when using a dress gear with dimensions different from those of the work gear or a dress gear modified with a complicated process such as bias correction. Figure 9.2 shows honed gear helix deviation graph. Figure 9.3 shows the topography of tooth profile and tooth trace shape.

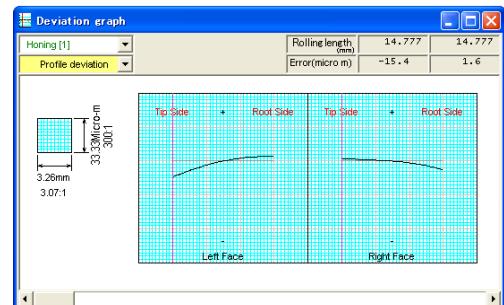


Fig. 9.1 An example of honed gear profile deviation graph

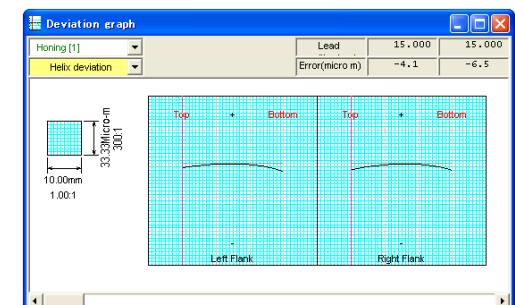


Fig. 9.2 Honed gear helix deviation graph

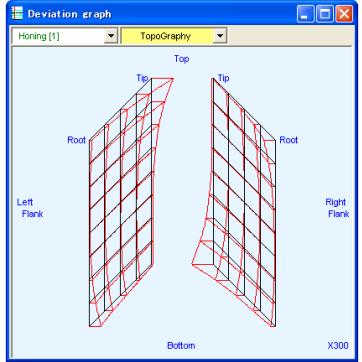


Fig. 9.3 Topography

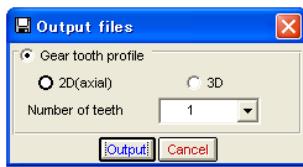


Fig. 10.1 Output tooth form coordinates file

10. Outputting tooth form coordinate file

It is possible to output tooth form coordinate value after the processing as a CAD data file and the file types DXF and IGES are supported. A tooth form coordinates file output window is shown in Fig. 10.1.

11. Gear contacting

Using stored cutting simulation data, it is possible to do a meshing simulation.

The meshing simulation window is shown in Fig. 11.1.

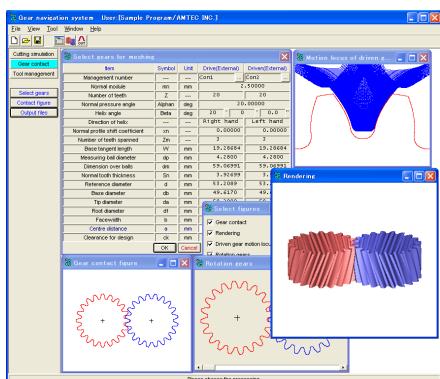


Fig. 11.1 Gear contact simulation

12. Selecting gear data for contact simulation

Select the data of gear to be contacted from the registered gear data and configure the setting. The data setting window is shown in Fig. 12.1.

Item	Symbol	Unit	Drive(External)	Driven(External)
Management number	---	---	Con1	... Con2 ...
Normal module	mn	mm		2.50000
Number of teeth	Z	---	20	20
Normal pressure angle	Alpha	deg		20.00000
Helix angle	Beta	deg	20 ° 0' 0.0"	
Direction of helix	---	---	Right hand	Left hand
Normal profile shift coefficient	xn	---	0.00000	0.00000
Number of teeth spanned	Zm	---	3	3
Base tangent length	W	mm	19.28684	19.28684
Measuring ball diameter	dp	mm	4.2800	4.2800
Dimension over balls	dm	mm	59.06991	59.06991
Normal tooth thickness	Sn	mm	3.92699	3.92699
Reference diameter	d	mm	53.2089	53.2089
Base diameter	db	mm	49.6170	49.6170
Tip diameter	da	mm	58.2089	58.2089
Root diameter	df	mm	46.9589	46.9589
Facewidth	b	mm	30.0000	30.0000
Centre distance	a	mm	53.5000	
Clearance for design	ck	mm	0.9161	0.9161

Fig. 12.1 Gear setting window for meshing simulation.

13. Gear contact

Fig. 13.1 shows the tooth form selection window. You can display the gear selected at (12) in 2D gear meshing, 3D meshing model, rotary motion locus of the driven gear, and/or continuous rotation. The 2D gear meshing figure supports partial extension, distance measuring function and drawing function of the circle, and it is possible to confirm the meshing conditions in detail. Gear contacting windows and motion locus windows are shown in Figs 13.2 to 13.8.



Fig. 13.1 Tooth form selection window

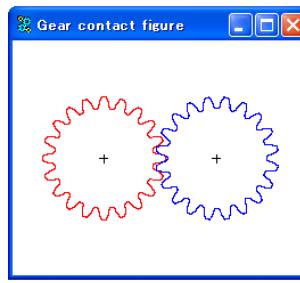


Fig. 13.2 Gear contacting

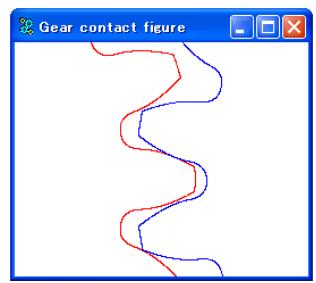


Fig. 13.3 Extension

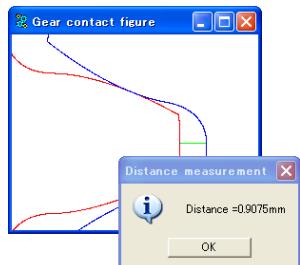


Fig. 13.4 Measurement
(Top clearance measurement)

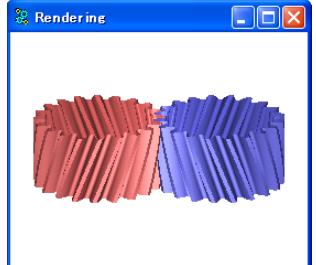


Fig. 13.5 Rendering

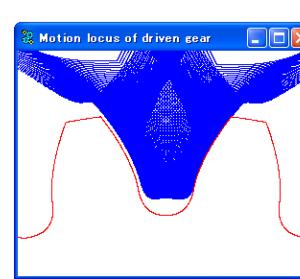


Fig. 13.6 Rotary motion locus of the driven gear

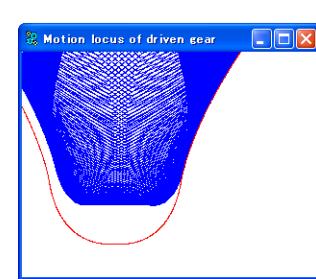


Fig. 13.7 Part extension

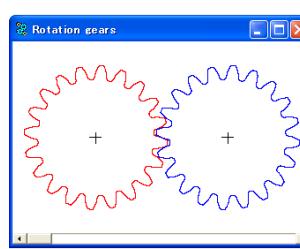


Fig. 13.8 Continuous rotation

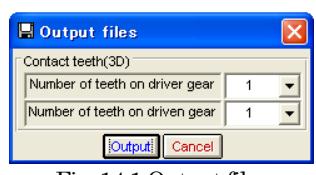


Fig. 14.1 Output files
in contacting

14. Output files in contacting gear data

It is possible to output the tooth data of contacting gear into DXF and IGES file format as a CAD data. The Output files window is shown in Fig. 14.1.

15. Tool management

By registering the retention tool dimension in the database, **Gear Navigation System** can search for the tool suitable for common use calculation and conditions such as chamfering length after the processing and effective tooth surface length in the processing simulation. The setting items for tool management are shown in Figs 15.1 to 15.5.

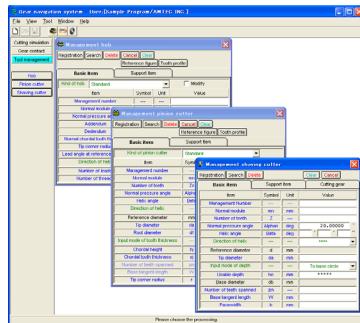


Fig. 15.1 Tool management window

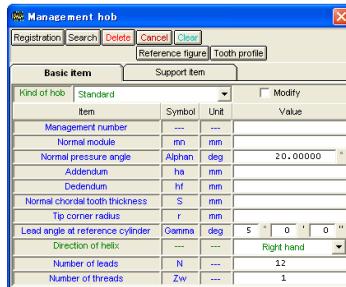


Fig. 15.2 Hob dimension

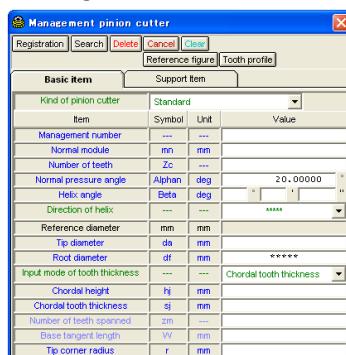


Fig. 15.3 Pinion shape cutter dimension



Fig. 15.4 Shaving cutter dimension

Management base circle board				
Item	Symbol	Unit	Value	
Management number	---	---		
Out diameter	D	mm		
Inside diameter	d	mm		
Thickness	t	mm		

Fig. 15.5 Base disk dimension

16. Other functions

Hob setting angle calculation

Setting angle of the profile shifted hob is calculated.

Hob setting angle				
Item	Symbol	Unit	Work gear	Hob
Normal module	mn	mm	1.00000	0.97061
Number of teeth/threads	Z,Zw	---	20	1
Normal pressure angle	Alphan	deg	20.00000	14.50000
Helix/Lead angle	Beta/Gamma	deg	5 ° 0' 0.0"	3 ° 0' 0.0"
Direction of helix	---	---	Right hand	Left hand
Setting angle	BetaS	deg	-7 ° 51' 9.670"	

Fig. 16.1 Hob setting angle calculation

17. System requirements

① Operating system

Windows 2000, Windows XP

② Hardware

Personal computer with Pentium processor 800 MHz or above running Windows

③ CD-ROM drive

④ Display resolution 1024×768 or higher

⑤ At least 1 GB physical RAM

⑥ Hard disk area 2 GB up

⑦ Mouse or other pointing device

⑧ Printer