[35] K-H-V Differential gear design system

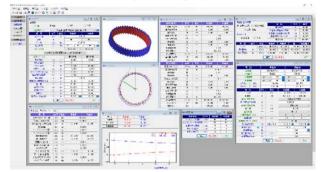


Fig. 35.1 K-H-V Differential gear design system

35.1 Abstract

The K-H-V Differential gear design system is the reduction gear shown in Figure 35.2. The software is a differential reduction (acceleration) mechanism design (three types of gear difference 0, 1 and 2) software for involute gears, and can perform tooth profile design, tooth meshing, sliding ratio, and gear strength calculation. If the difference in the number of teeth is small, involute interference etc. will occur if it is designed with a standard gear with a profile shift of 0. However, with this software, it is possible to calculate gears with combinations of profile shift factor that have a contact ratio of 1 or more and do not generate interference. Please see catalog [34] for differential gear software with trochoid curve.

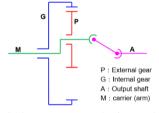
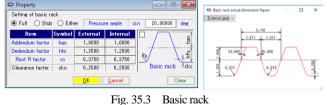


Fig. 35.2 KH-V type reduction mechanism

35.2 Propaty (Basic rack)

As shown in Figure 35.3, set the basic rack and display the actual dimensions of the basic rack set as an auxiliary function.

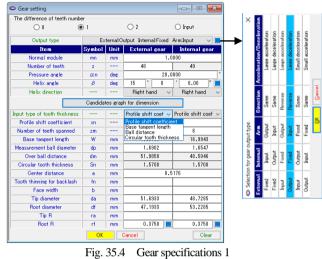


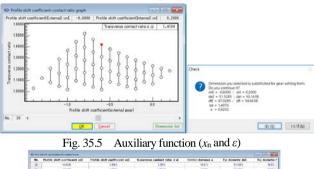
Basic rack

35.2 Gear dimension setting

As shown in Fig. 35.4, select the difference in number of teeth (one tooth difference, two teeth difference, zero tooth difference), and then select the combination (arm fixed / input / output). When the difference in the number of teeth is 0, the tooth shape is drawn with the arm fixed.

After inputting mn, z, α n, β in Fig. 35.4, set the profile shift factor (xn). However, there are innumerable ways of giving profile shift factor, so use the auxiliary function shown in Figure 35.3 to determine combinations with an contact ratio of 1.0 or more and no involute interference. In the case of this example, 55 pieces are displayed. If the profile shift factor No.26 ($x_{n1} = -0.6$, \bigcirc circle in the figure) is selected from these, the specifications will be determined as shown in Fig. 35.7. The profile shift factor, contact ratio and gear dimensions can be confirmed and selected in the table in Figure 35.6.





28	-6408	O FINE	1.0631	18815	61.1215	56.90
21	-6.508	0.536.0	1.8528	08392	ALCONS.	41.41
-	-6108	02981	8.0079	10014	81,2203	92.01
21	-6.708	0.2001	12001	16910	\$1,285	96.60
24	-6.528	CANES -	1.12/3	18.830	512015	96.902
3	-6.128	CSND	1.1078	18815	11.003	96.75
31	-6408	03007	0.007	2690	11585	91.15
20	-64,08	03061	139GF	283/8	415265	9.81
78	-41608	0.4961	1.2004	18.019	817,915	56.84
25	-6.9006	CONT	1.002	10420	\$12815	96.70
	-168	0.001	1361	1001	61.095	10.41
81	-45/0	0.39819	LIND	28.963	81,7765	98.85
20	-6608	C.RHE	1,2404	20014	81,7265	96.60
=	-1108	0584	13818	188(6	\$1,795	94.75
ж	-4308	0.506.8	1.17/8	11421	81.7713	56 ML
18	-6.4098	CANEL	13457	26362	110013	96.90
ж	-6408	0.044	1283	1994	Stimi.	14 No.
30	-6408	0.0001	LIND	18819	111255	16.85-
н	-0+006	0.714.1	13858	10420	810013	\$1.15
č.	-110	(1180.5	1979	16.00	41.000	41.

Fig. 35.6 Auxiliary function ((No. 27, x_n and ε)

The difference of teeth numb	er				_		
00	1		O 2		0	Input	
Output type	E>	ternal:0	utput Inte	rnal:Fixed	Arm	Input	\sim
Item	Symbol	Unit	Exterr	al gear	I	nternal e	ear
Normal module	mn	mm		1.0	0000		
Number of teeth	z		49			50	
Pressure angle	an	deg		20.0	0000		
Helix angle	β	deg	15	* 0	1.	0.00	"
Helix direction			Right	hand \checkmark		Right hand	1
	Candida	tes grap	h for dime	nsion			
Input type of tooth thickness			Profile sh	hift coef \sim	Pro	file shift o	oef
Profile shift coefficient	xn		-0.6000		Γ	0.2000	
Number of teeth spanned	zm		5			7	
Base tangent length	W	mm	13	.6318	20.0987		
Measurement ball diameter	dp	mm	1.6536			1.673	8
Over ball distance	dm	mm	51.6378			49.908	5
Circular tooth thickness	Sn	mm	1.1340		1.4252		
Center distance	a	mm		0.9	9202		
Tooth thinning for backlash	fn	mm	0	.1000	0.0000		
Face width	b	mm	10	.0000		10.000	0
Tip diameter	da	mm	51	.5285		50.163	8
Root diameter	df	mm	47	.0285		54.6638	
Tip R	ra	mm	0	.0500		0.050	0
Root R	rf	mm	0	.3750 📃		0.375	0
	OK		Cancel			0	ear

Fig. 35.7 Gear specifications 2

When the gear specifications in Fig. 35.7 are confirmed, dimensions and interference calculation results are displayed as in Fig. 35.8 to Fig. 35.10. In the case of this example, although the trimming has occurred, the calculation will proceed as it is because there is no influence on the mesh.

Dimension Contact Interference					
Item	Symbol	Unit	External gear	Internal gear	
Transverse module	mt	mm	1	.0353	
Transverse pressure angle	αt	deg	20	.6469	
Reference diameter	d	mm	49.6933	50.7285	
Base diameter	db	mm	46.5015	47.4703	
Base cylindrical helix angle	βb	deg	14.0761		
Lead	pz	mm	582.6327	594.7709	
Maximum effective diameter	dh	mm	51.4712	54.2727	
Minimum effective diameter(TIF)	dt	mm	47.8675	50.2310	
Cutting profile shift coefficient	xnc		-0.7462	0.2000	
Tooth depth	h	mm	2.2500	2.2500	
Design normal circular tooth thickness	sn'	mm	1.0276	1.4252	
Design over ball distance	dm'	mm	50.2857	48.8479	
Design base tangent length	W	mm	13.5163	20.0833	

Result of dimension					
Dimension Contact Interference					
Item	Symbol	Unit	External gear	Internal gear	
Transverse contact pressure angle	aw	deg	58	.2376	
Contact helix angle	βw	deg	25	.4699	
Contact pitch diameter	dw	mm	88.3392	90.1796	
Effective face width	bw	mm	10	.0000	
Clearance(large diameter)	ckh	mm	0	.6474	
Clearance(small diameter)	ckt	mm	0.6474		
Maximum contact diameter	dja	mm	51.4723	53.0278	
Minimum contact diameter	djf	mm	48.8185	50.2319	
Transverse contact ratio	εα		1	.1840	
Overlap contact ratio	εβ		0	.8238	
Total contact ratio	εγ		2	.0078	
Sliding ratio(large diameter)	σa		-0.0491	0.0468	
Sliding ratio(small diameter)	σf		-0.0827	0.0764	
Transverse backlash	jnt	mm	0	.1031	
Backlash angle	jσ	deg	0.2542	0.2490	

Fig. 35.9 Gear contact dimensions

Symbol	Unit	External(Output)	Internal(Fixed)	Arm(Input)		
Vhi		-0.0208	0.0000	1.0000		
Uhi		-48.0000	0.0000	1.0000		
		occurs(Attention)				
			doesn't occur(Safety)			
		doesn't occur(Safety)				
			doesn't occur(Safety)			
	Vhi Uhi 	Vhi Uhi	Uhi48.0000 	Vhi -0.0208 0.0000 Uhi -48.0000 0.0000 occurs(Attention) doesn't occur(Safety) doesn't occur(Safety)		

Fig. 35.10 Gear interference

35.4 Tooth profile

The tooth profile of the gear specifications (Fig. 35.7) can be drawn as shown in Fig. 35.11. Figure 34.12 shows a close-up view of the tooth profile (A) and (B). Also, distance measurement is possible as shown in Figure 34.12 (b). Figure 35.14 shows teeth rendering.

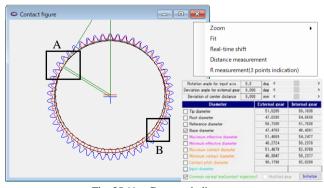


Fig. 35.11 Gear mesh diagram

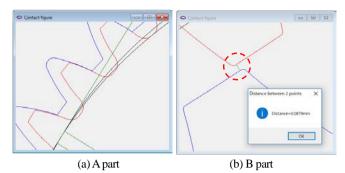


Fig. 35.12 Gear mesh diagram, distance measurement

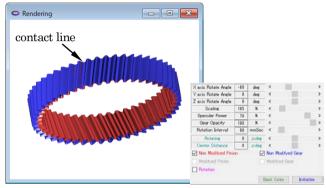


Fig. 35.13 Tooth rendering, tooth profile, rotation

35.5 Tooth profile / tooth lead modification (option)

When modifying tooth profile and tooth lead, you can apply modifications as shown in Fig. $35.149 \sim 35.16$. In Figure 35.16, you can enter a specified number of points (maximum = 50) to be modified, and you can also enter an arc pattern. Then, the contact of the modified tooth profile can be confirmed as shown in Figure 35.17.

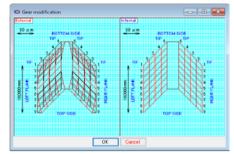


Fig. 35.14 Tooth rendering, tooth profile and topo-graph

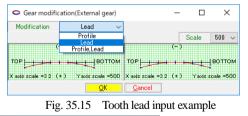




Fig. 35.16 Tooth lead input and arc input example

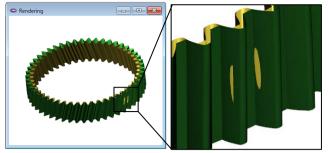


Fig. 35.17 Tooth rendering, modified tooth form

35.6 Sliding ratio

The sliding ratio of this example gear is shown in the dimension calculation result of Fig. 35.9, and the change of the sliding ratio at the tooth profile position (roll angle) is shown in Fig. 35.18.

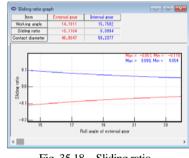


Fig. 35.18 Sliding ratio

35.7 Gear strength

For gear strength calculation, enter the coefficient of friction, torque and rotational speed on the strength setting screen as shown in Figure 35.19. In this example, when the coefficient of friction is 0.10, the input torque of the arm is 1 (Nm), and the rotational speed is 1000 min-1, the torque and rotational speed of the pinion and gear are displayed with the **[OK]** button.



Fig. 35.19 Gear strength calculation specification setting

The input screen of gear strength specifications (materials, factors) is shown in Figure 35.21. Material selection can be made from the table in



Fig. 35.20 Selection of material

Figure 35.20, but you can also input σ_{Flim} and σ_{Hlim} directly. Figure 35.22 shows the gear strength results.

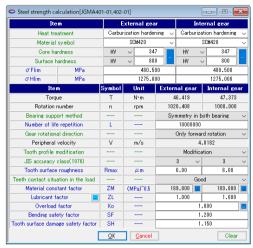


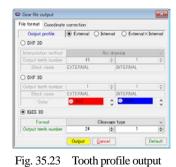
Fig. 35.21 Gear strength calculation (strength specification)

 Result of strength calculation[JGM. 	A401-01,40	i2-01j			
Item(Bending)	Symbol	Unit	External gear	Internal gear	
Allowable bending stress	σFlim	MPa	480.500	480.500	
Bending effective face width	Ь'	mm	10.000	10.000	
Tooth profile factor	YF		3.067	2.065	
Load distribution factor	Yε		0.749		
Helix angle factor	Yβ		0	.875	
Life factor	KL		1.000	1.000	
Dimension factor	KFx		1.000	1.000	
Dynamic load factor	Kv		1	.145	
Circumference force	Ft	N	1029.488		
Allowable circumference force	Ftlim	N	1739.948	2584.003	
Root bending stress	σF	MPa	284.301	187.606	
Bending strength	Sft		1.690	2.561	
Item(Pitting)	Symbol	Unit	External gear	Internal gear	
Allowable hertzian stress	σHlim	MPa	1275.000	1275.000	
Surface pressure effective face width			10.000		
process	bw	mm	10	.000	
Zone factor	ZH	mm 		.000	
Zone factor	ZH		1.000	. 171	
Zone factor Life factor	ZH		1.000	.171	
Zone factor Life factor Contact ratio factor	ZH KHL Ζε		1.000	.171 1.000 .890	
Zone factor Life factor Contact ratio factor Roughness factor	ZH KHL Z & ZR		1 1.000 0 0.842	.171 1.000 .890 0.842	
Zone factor Life factor Contact ratio factor Roughness factor Lubrication speed factor	ZH KHL Z & ZR ZV		1.000 0.842 0.984 1.000	.171 1.000 .890 0.842 0.984	
Zone factor Life factor Contact ratio factor Roughness factor Lubrication speed factor Hardness ratio factor	ZH KHL Z & ZR ZV ZW		1.000 0.842 0.984 1.000	.171 1.000 .890 0.842 0.984 1.000	
Zone factor Life factor Contact ratio factor Roughness factor Lubrication speed factor Hardness ratio factor Load distribution factor	ZH KHL Z & ZR ZV ZW KH Ø		1.000 0.842 0.984 1.000	.171 1.000 .890 0.842 0.384 1.000 .000 .086	
Zone factor Life factor Contact ratio factor Roughness factor Lubrication speed factor Hardness ratio factor Lead distribution factor Dynamic lead factor	ZH KHL Z & ZR ZV ZW KH Ø Kv		1 1.000 0.842 0.384 1.000 1 1	.171 1.000 .890 0.842 0.384 1.000 .000 .086	
Zone factor Life factor Contact ratio factor Roughness factor Lubrication speato factor Hardness ratio factor Load distribution factor Dynamic load factor Circumference force	ZH KHL Z & ZR ZV ZW KH & Kv Fc	 N	1.000 0.842 0.984 1.000 1 1 1830	.171 1.000 .890 0.842 0.384 1.000 .000 .086 .110	

Fig. 35.22 Gear strength result

35.8 Tooth profile output

The generated tooth profile can be output as CAD data. Figures 35.24 and 35.25 show examples of drawing CAD data output by the tooth profile output function shown in Figure 35.23.



Tig. 55.25 Tooth prome outpe

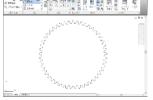


Fig. 35.24 CAD example (2D) Fig. 35.25 CAD example (3D)

35.9 Design example of the difference in number of teeth 0

An example of the gear mechanism (K-H-V) connected in two stages is shown in Figure 35.26. The 1st gear is an external and internal gear with one tooth gap (internal gear fixed, external gear output, arm input). The 2nd stage (follower side) is an external / internal gear with a zerotooth difference. By connecting the 1st stage external gear and the 2nd stage internal gear, output can be made on the same axis as the input axis.

In Figure 35.26, none of the external gear, internal gear and arms in the second step, with 0-tooth difference, is fixed. The rotation ratio of the driven side of the green (differential external gear + internal gear with zero tooth difference) and the external gear (red) of the red is the same. Therefore, it is possible to take out the reduction ratio of the differential gear coaxially. The following is a design example of a zero-tooth differential gear.

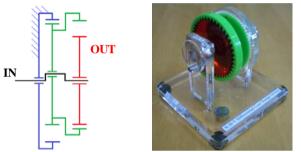


Fig. 35.26 Mechanism (1st stage differential, 2nd stage $z_1=z_2$), model

In Fig. 35.27, select 0 in gear number difference, and set the module, number of teeth, pressure angle and helix angle. Next, select No. 25 out of 25 items that fit in the auxiliary function (Fig. 35. 28). The dimensions of this gear are shown in Fig. 35.29 and in Fig. 35.30. Also, Fig. 35.31

The difference of teeth number	er						
• • C) 1		O 2		Oŀ	nput	
Output type	E>	cternal:Ir	nput Interna	al:Output a	Arm:Fi	×ed	~
Item	Symbol	Unit	Externa	al gear	In	ternal g	ear
Normal module	mn	mm		1.5	000		
Number of teeth	z		30	30			
Pressure angle	an	deg		20.0	000		
Helix angle	β	deg	0 *	0	1	0.00	"
Helix direction			****	ek 🗸		****	
	Candida	ites grap	oh for dimer	ision			
Input type of tooth thickness			Profile shift coef \lor Pr			le shift c	oef
Profile shift coefficient	xn		-0.3000		1.4937		
Number of teeth spanned	zm		3		6		
Base tangent length	W	mm	11.	3929	26.5180		
Measurement ball diameter	dp	mm	2.4766			2.366	1
Over ball distance	dm	mm	47.3424		45.9286		6
Circular tooth thickness	Sn	mm	2.0286			0.7252	
Center distance	a	mm		0.9	202		
Tooth thinning for backlash	fn	mm	0.	1000		0.000	0
Face width	ь	mm	15.	0000		15.000	0
Tip diameter	da	mm	48.	2570		44.097	4
Root diameter	df	mm	41.	5070		50.847	4
Tip R	ra	mm	0.	0500		0.050	0
Root R	rf	mm	0.	5625 📃		0.562	5

Fig. 35.27 Gear specification setting

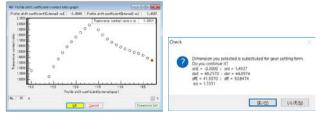
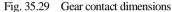


Fig. 35.28 Auxiliary function (*x*_n and contact ratio)

shows an enlarged view of the meshing parts C and D in Fig. 35.30. Teeth rendering is shown in Figure 35.32.

Dimension Contact Interference							
Item	Symbol	Unit	External gear	Internal gea			
Transverse contact pressure angle	aw	deg	90.0000				
Contact helix angle	βw	deg		-			
Contact pitch diameter	dw	mm					
Effective face width	bw	mm	15	.0000			
Clearance(large diameter)	ckh	mm	0.3750				
Clearance(small diameter)	ckt	mm					
Maximum contact diameter	dja	mm	48.2048	49.1149			
Minimum contact diameter	djf	mm	43.6726	44.1686			
Transverse contact ratio	εα		1	2972			
Overlap contact ratio	εβ		0	.0000			
Total contact ratio	εγ		1	2972			
Sliding ratio(large diameter)	σa		-0.0795	0.0737			
Sliding ratio(small diameter)	σf		-0.1686	0.1443			
Transverse backlash	jnt	mm	0	.1000			
Backlash angle	iσ	deg	0.2711	0.2711			



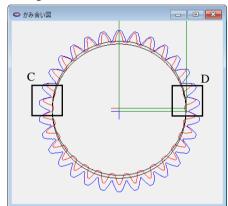


Fig. 35.30 Gear mesh diagram ($z_1=z_2$)

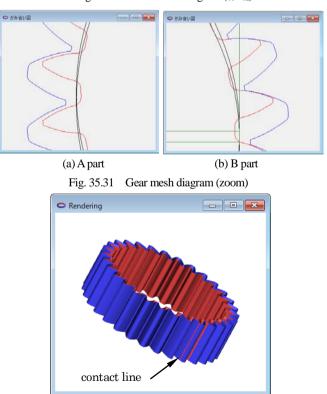


Fig. 35.32 Teeth rendering