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少齿差行星齿轮传动的设计计算与计算机辅助设计

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摘要　阐述了以少齿差行星齿轮传动的设计计算方法及计算机辅助设计方法。内容包括工作原理、参数选择、几何计算、流程框图以及变位系数选择表等。文中根据所设计的程序, 计算了 284 种少齿差内啮合齿轮副的几何参数并附有计算实例。实践表明, 文中给出的设计计算方法是正确的, 可供少齿差传动设计参考。

关键词: 少齿差; 变位系数; 齿廓重迭干涉; 重合度

1　引　言

少齿差行星齿轮传动是以齿数差相差甚少的圆柱内齿轮副为传动元件的一种行星传动。它具有传动比大、重量轻、结构简单、效率高、寿命长等特点。因此, 广泛应用于起重、运输、矿山、冶金、造船、建筑、农机、水利、轻工仪表、食品化工以及国防工业等部门。但少齿差行星轮传动, 由于内齿轮与外齿轮齿数相差甚少, 在传动过程中易产生干涉, 且计算比较复杂, 参数选择过程繁锁, 因此有待开发新的设计计算方法。为此, 本文采用 CAD 方法, 设计了少齿差传动的计算机程序, 计算了齿数差 $Z_2 - Z_1 = 1 \sim 4$ 的内啮齿轮副的变位系数, 并列出了变位系数选择表。根据该表可方便地进行少齿差传动计算。实践表明文中给出的设计方法是正确的, 计算数据是可靠的, 可满足传动比 $i = 30 \sim 100$ 和齿数差 $Z_2 - Z_1 = 1 \sim 4$ 范围内的 Z-X-V 型少齿差行星齿轮传动的设计计算要求, 可供少齿差传动设计参考。

2　工作原理

少齿差行星齿轮传动的型式有 N 型内啮合齿轮传动(Z-X-V 型) 和 NN 型双联行星轮内啮合齿轮传动(2Z-X 型) 两种。其工作原理与传动比计算公式示于表 1。其中, Z-X-V 型应用较多, 它是由一组内啮齿轮副组成的, 并需采用输出机构将其行星轮自身回转运动以 1∶1 的传动比传输给输出轴, 其传动比一般 $i \leq 100$。2Z-X 型是由双联行星轮内啮齿轮副组成的, 它无

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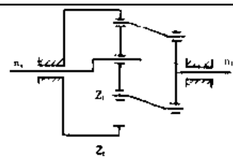
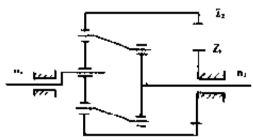
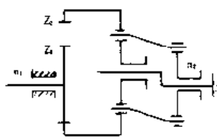
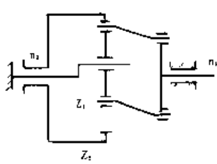
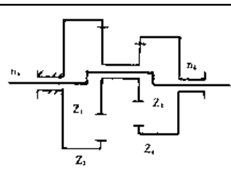
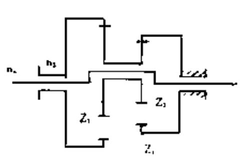
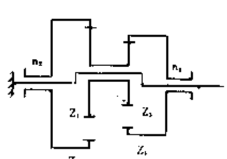
需采用输出机构,可由内齿轮或行星架直接输出,当 $Z_3 = Z_4$ 时,则 2Z-X 型少齿差传动即变为具有零齿差输出机构的 Z-X-V 型少齿差传动。表中各符号意义如下:

Table 1　Types of planetary gear drive of the few difference in number of teeth

type of drive	fixed parts	operating principle	transmission ratio
N (Z-X-V)	internal gear Z_2 is fixed		$i_{x-1} = \frac{n_x}{n_1} = \frac{Z_1}{Z_1 - Z_2}$
	external gear Z_1 is fixed		$i_{x-2} = \frac{n_x}{n_2} = \frac{Z_2}{Z_2 - Z_1}$
	planet carrier is fixed	 	$i_{1-2} = \frac{n_1}{n_2} = \frac{Z_2}{Z_1}$ $i_{2-1} = \frac{n_2}{n_1} = \frac{Z_1}{Z_2}$
NN (2Z-X)	internal gear Z_1 is fixed		$i_{x-4} = \frac{n_x}{n_4} = \frac{Z_1Z_4}{Z_1Z_4 - Z_2Z_3}$ $i_{4-x} = \frac{n_4}{n_x} = 1 - \frac{Z_2Z_3}{Z_1Z_4}$
	internal gear Z_4 is fixed		$i_{x-2} = \frac{n_x}{n_2} = \frac{Z_2Z_3}{Z_2Z_3 - Z_1Z_4}$ $i_{2-x} = \frac{n_2}{n_x} = 1 - \frac{Z_1Z_4}{Z_2Z_3}$
	planet carrier is fixed		$i_{2-4} = \frac{n_2}{n_4} = \frac{Z_1Z_4}{Z_2Z_3}$ $i_{4-2} = \frac{n_4}{n_2} = \frac{Z_2Z_3}{Z_1Z_4}$

Z_1, Z_3—— 外齿轮齿数;

Z_2, Z_4—— 内齿轮齿数;

n_1, n_3—— 外齿轮 Z_1、Z_3 的转速;

n_2, n_4—— 内齿轮 Z_2、Z_4 的转速;

n_x—— 行星架转速;

i_{x-1}—— 由行星架到外齿轮 Z_1 的传动比;

i_{1-2}—— 由外齿轮 Z_1 到内齿轮 Z_2 的传动比(其它类推)。

3 参数选择

在少齿差内啮齿轮传动中,主要的干涉是发生在齿轮齿顶的齿廓重迭干涉。为避免干涉,可采用短齿和正变位齿轮来修正,通常是在保证重合度 $\epsilon_\alpha > 1$ 的条件下,合理选择齿顶高系数 h_α^* 和啮合角 α',然后选出最适宜的变位系数 x_1 和 x_2 来,从而保证齿廓重迭干涉度 G_s 达到理想的期望值 $[G_s] = 0.05$ mm。

3.1 重合度 ϵ_α

重合度 ϵ_α 是表征传动连续性的参数,必须保证 $\epsilon_\alpha > 1$。当变位系数选定后,需作重合度验算,若 $\epsilon_\alpha < 1$ 时,需减小外齿轮变位系数 x_1。

3.2 啮合角 α'

啮合角 α' 受齿数差 $Z_2 - Z_1$ 和变位系数差 $x_2 - x_1$ 的影响。当变位系数尚未确定之前,可根据齿数差按表 2 选取[3]。

Table 2 Basic parameter selection of internal gear pair of the few difference in number of teeth

difference in number of teeth	module	pressure angle	working pressure angle	centre distance	addendum coefficient	expectation of interference of profile	modification coefficient
$Z_2 - Z_1$	m	α	α'	a'	h_a^*	$[G_s]$	x_1
1	1	20°	55.9898°	0.840	0.75	0.05	$0.015Z_1$
2	1	20°	40.7279°	1.240	0.80	0.05	$0.015Z_1$
3	1	20°	30.7423°	1.640	0.75	0.05	$0.015Z_1$
4	1	20°	27.5630°	2.120	0.80	0.05	$0.007Z_1$

Note: When module is not equal to 1, must multiply centre distance a' by module m.

3.3 齿顶高系数 h_a^*

齿顶高系数可取 $h_a^* = 0.6 \sim 0.8$,取小值可避免齿廓重迭干涉,取大值可增加重合度 ϵ_α,通常按表 2 选取。

3.4 齿廓重迭干涉度 G_s

齿廓重迭干涉度系指外齿轮与内齿轮的齿啮合结束后,外齿轮齿顶退出内齿轮齿槽时,外齿轮齿顶与内齿轮齿顶所发生的重迭干涉(相碰)。当 $G_s < 0$ 时,表示有重迭干涉,当 $G_s > 0$ 时,表示无重迭干涉,即有间隙存在。通常规定齿廓重迭干涉度的期望值 $[G_s] \geq 0.05$ mm[2]。

3.5 外齿轮变位系数 x_1

外齿轮变位系数 x_1 可按表 2 的经验公式初选,然后以齿廓重迭干涉度期望值 $[G_s]$ 为目标,通过迭代计算求出最适宜的 x_1 来,可按下述迭代程序计算[3],式中(n)表示第 n 次迭代,具体计算过程见表 3。

$$X_1^{(n+1)} = x_1^{(n)} - \frac{G_s^{(n)} - [G_s]}{\left(\frac{dG_s}{dx_1}\right)^{(n)}}$$

$$\frac{dG_s}{dx_1} = \frac{2(\sin\alpha_1 - \sin\alpha_2)}{\cos\alpha} - 2(\delta_1 - \delta_2)$$

3.6 内齿轮变位系数 x_2

当外齿轮变位系数 x_1 求出后,根据无齿侧隙啮合方程即可求出内齿轮变位系数 x_2 来(表 3)。

Table 3 Geometrical calculation formulae and examples

No.	items	marks	calculation formulae	examples: inital values	examples: final values
1	module	m	$m = 1$	—	1
2	pressure angle	α	$\alpha = 20°$	—	20°
3	working pressure angle	α'	$\alpha' = 55.9898°$	—	55.9898°
4	number of teeth in external gear	Z_1	$Z_1 = Z_2 - \frac{Z_2}{i}$	—	49
5	number of teeth in internal gear	Z_2	$Z_2 = i(Z_2 - Z_1)$	—	50
6	addendum coefficient	h_a^*	$h_a^* = 0.75$	—	0.75
7	initial modification coefficient of external gear	x_1	$x_1 = 0.015Z_1$	0.7350	0.6693
8	modification coefficient of internal gear	x_2	$x_2 = \frac{Z_2 - Z_1}{2\tan\alpha}(inv\alpha' - inv\alpha) + x_1$	1.4085	1.3428
9	reference diameter of external gear	d_1	$d_1 = mZ_1$	—	49
10	reference diameter of internal gear	d_2	$d_2 = mZ_2$	—	50
11	reference centre distance	a	$a = \frac{m}{2}(Z_2 - Z_1)$	—	0.50
12	modification centre distance	a'	$a' = a\frac{\cos\alpha}{\cos\alpha'}$	—	0.84

Table 3 continued

No.	items	marks	calculation formulae	examples: initial values	examples: final values
13	centre distance modification coefficient	Y	$Y = \frac{a' - a}{m}$	—	0.34
14	addendum of external gear	h_{a1}	$h_{a1} = m(h_a^* + x_1)$	1.485	1.419
15	addendum of internal	h_{a2}	$h_{a2} = m(h_a^* - x_1 - y)$	−0.325	0.259
16	Tip diameter of external gear	d_{a1}	$d_{a1} = d_1 + 2h_{a1}$	51.97	51.839
17	tip diameter of internal gear	d_{a2}	$d_{a2} = d_2 - 2h_{a2}$	50.65	50.519
18	base diameter of external gear	d_{b1}	$d_{b1} = d_1\cos\alpha$	—	46.0449
19	base diameter of internal gear	d_{b2}	$d_{b2} = d_2\cos\alpha$	—	46.9846
20	tip pressure angle of external gear	α_{a1}	$\cos\alpha_{a1} = \frac{d_{b1}}{d_{a1}}$	27°37′34″	27°20′53″
21	tip pressure angle of internal gear	α_{a2}	$\cos\alpha_{a2} = \frac{d_{b2}}{d_{a2}}$	21°56′0″	21°33′30″
22	tip radius of external gear	r_{a1}	$r_{a1} = \frac{d_{a1}}{2}$	25.985	25.919
23	tip radius of internal gear	r_{a2}	$r_{a2} = \frac{d_{a2}}{2}$	25.325	25.259
24	expectation of interference of profile	$[G_s]$	$[G_s] = 0.05$	—	0.05
25	interference of profile	G_s	$G_s = Z_1(\mathrm{inv}\alpha_{a1} + \delta_1) - Z_2((\mathrm{inv}\alpha_{a2} + \delta_2) + (Z_2 - Z_1)\mathrm{inv}\alpha'$	0.5995	0.05012

Table 3 continued

No.	items	marks	calculation formulae	examples initial values	examples final values
26	intermediate prameter of external gear	δ_1	$\cos\delta_1 = \frac{r_{a2}^2 - a'^2 - r_{a1}^2}{2a' r_{a1}}$	2.48436	2.48439
27	intermediate parameter of internal gear	δ_2	$\cos\delta_2 = \frac{r_{a2}^2 + a'^2 - r_{a1}^2}{2a' r_{a2}}$	2.46409	2.46407
28	first alternation calculationof modification coefficient of external gear	$X_1^{(1)}$	$X_1^{(1)} = X_1 - \frac{G_s - [G_s]}{\frac{dG_s}{dx_1}}$	0.6693	—
29	first derivative of interference of profile	$\frac{dG_s}{dx_1}$	$\frac{dG_s}{dx_1} = \frac{2(\sin\alpha_{a1} - \sin\alpha_{a2})}{\cos\alpha} - 2(\delta_1 - \delta_2)$	0.151374	—
30	repeated calculation		The items 8- 27 are repeatealy calulated according to modification coefficient $X_1^{(1)}$. Modification coefficient $X_1^{(1)}$. when $G_s = [G_s] = 0.05 \sim 0.055$ is just right wanted. After that, the all parameters are calculated according to modification coefficient $X_1^{(n)}$.	—	—
31	checking calculation of contact ratio	ϵ_α	$\epsilon_\alpha = \frac{1}{2\pi}[Z_1(\tan\alpha_{a1} - \tan\alpha') - Z_2(\tan\alpha_{a2} - \tan\alpha')] \geq 1$	—	1.125
32	checking calculation of tip collision interference	G_a	$G_a = a' + r_{a2} - r_{a1} > 0$	—	0.180
33	base tangent length	W_1	$W_1 = m\cos\alpha[\pi(K_1 - 0.5) + Z_1 \mathrm{inv}\alpha] + 2x_1 m\sin\alpha$	—	17.381
34	spanned numbe of teeth of external gear	K_1	$K_1 = \frac{\alpha}{180°} Z_1 + 0.5 + \frac{2x_1}{\pi}\tan\alpha$	in round number	6
35	base tangent length	W_2	$W_2 = m\cos\alpha[\pi(K_2 - 0.5) + Z_2 \mathrm{inv}\alpha] + 2x_2 m\sin\alpha$	—	17.856
36	spanned number of teeth of internal gear	K_2	$K_2 = \frac{\alpha}{180°} Z_2 + 0.5 + \frac{2x_2}{\pi}\tan\alpha$	in round number	6

4　几何计算

少齿差行星齿轮传动的几何计算公式与变位系数的迭代计算列于表3。根据表2给出的基本参数，按照表3的计算公式，即可算出最适宜的变位系数 x_1 和 x_2 及内齿轮与外齿的全部几何尺寸。在表3中还给出了 Z-X-V 型少齿差行星齿轮减速器的计算实例，其结构形式是外齿轮固定，参数是 $i = 50$, $m = 1$, $\alpha = 20°$, $Z_1 = 49$, $Z_2 = 50$。

5　流程框图

为简化设计计算过程，文中采用 CAD 方法，给出了如图1所示的少齿差行星齿轮传动计算的流程框图，根据该图设计了计算机程序（从略）。图中各符号意义如下：

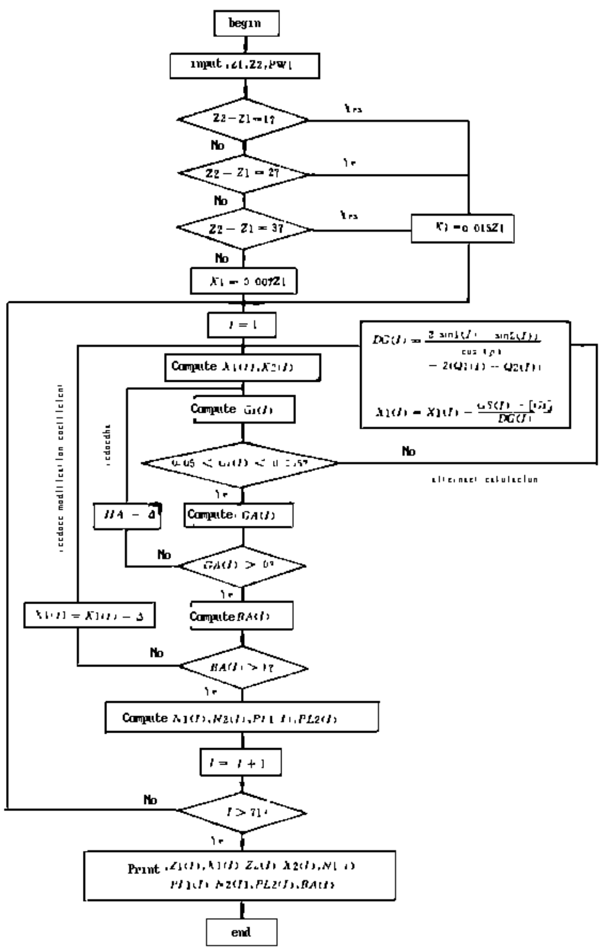


Fig. 1　Block diagram of driving calculation for the few difference in number of teeth

$Z1(I)$ —— 外齿轮齿数;
$Z2(I)$ —— 内齿轮齿数;
$X1(I)$ —— 外齿轮变位系数;
$X2(I)$ —— 内齿轮变位系数;
HA —— 齿顶高系数;
P —— 压力角的弧度值;
$PW1$ – 啮合角;
BA —— 重合度;
$\sin 1(I)$ ——外齿轮齿顶压力角的正弦值;
$\sin 2(I)$ ——内齿轮齿顶压力角的正弦值;
$GS(I)$ —— 齿廓重迭干涉度;
$DG(I)$ —— 齿廓重迭干涉度的一阶导数;
$GA(I)$ —— 齿顶相碰干步度;
$N1(I)$ —— 公法线测量跨齿数;
$N2(I)$ —— 公法线测量跨槽数;
$PL1(I)$ —— 外齿轮公法线测量长度;
$PL2(I)$ —— 内齿轮公法线测量长度;
$Q1(I)$ —— 外齿轮参变量;
$Q2(I)$ —— 内齿轮参变量;
Δ—— 参数的增量;
I—— 参数的循环变量。

6　变位系数选择表

根据所设计的程序, 本文计算了一齿差、二齿差、三齿差和四齿差(三齿差和四齿差限于篇幅从略) 的284种内啮齿轮副的变位系数 x_1、x_2 , 公法线测量长度 W_1、W_2 以及重合度 ϵ_α 等参数并列于表4。其中公法线测量长度是 $m=1$ 时的长度, 当 $m \neq 1$ 时, 表中数值应乘以模数 m 。表中给出的数据足可满足少齿差行星齿轮传动设计的要求。

Table 4　Modification coefficient selection of internal gear pair of the few difference in number of teeth

external gear				internal gear				contact ratio
number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	
Z_1	X_1	K_1	W_1	Z_2	X_2	K_2	W_2	ϵ_α
difference 1 in mumber of teeth								
30	0.3937806	4	11.01665	31	1.065659	4	11.4900	1.123361
31	0.4105069	4	11.04207	32	1.082385	4	11.51542	1.122764
32	0.4272364	4	11.06749	33	1.099114	4	11.54085	1.122238
33	0.4440330	4	11.09296	34	1.115911	5	14.51714	1.121756
34	0.4607991	4	11.11841	35	1.132677	5	14.54259	1.121336
35	0.4777127	4	11.14396	36	1.149591	5	14.56813	1.120931
36	0.4946450	5	14.12034	37	1.166523	5	14.59370	1.120559
37	0.5116061	5	14.14592	38	1.183484	5	14.61928	1.120225
38	0.5285712	5	14.17151	39	1.200449	5	14.64486	1.119923
39	0.5455941	5	14.19713	40	1.217472	5	14.67048	1.119634

Table 4　continued

external gear				internal gear				contact ratio
number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	
Z_1	X_1	K_1	W_1	Z_2	X_2	K_2	W_2	ϵ_α
difference 1 in number of teeth								
40	0.5626140	5	14.22275	41	1.234492	5	14.69610	1.119379
41	0.5796908	5	14.24841	42	1.251569	5	14.72177	1.119134
42	0.5967638	5	14.27407	43	1.268642	6	17.69825	1.11891
43	0.6138476	5	14.29973	44	1.285725	6	17.72391	1.118708
44	0.6310731	6	17.27632	45	1.302951	6	17.74967	1.118494
45	0.6481933	6	17.30201	46	1.320071	6	17.77538	1.118318
46	0.6652311	6	17.32764	47	1.337109	6	17.80100	1.118176
47	0.6825936	6	17.35350	48	1.354472	6	17.820685	1.117983
48	0.6996976	6	17.37918	49	1.371575	6	17.85253	1.117847
49	0.7168619	6	17.40490	50	1.388740	6	17.87825	1.117720
50	0.7341253	6	17.43069	51	1.406003	6	17.90404	1.117581
51	0.7512196	6	17.45636	52	1.423098	7	20.88053	1.117486
52	0.7686504	6	17.48226	53	1.440528	7	20.90644	1.117338
53	0.7858821	7	20.45885	54	1.457760	7	20.93220	1.117235
54	0.8033310	7	20.48476	55	1.475209	7	20.95812	1.117104
55	0.8205482	7	20.51052	56	1.492426	7	20.98387	1.117020
56	0.8377389	7	20.53626	57	1.509617	7	21.00961	1.116940
57	0.8550529	7	20.56208	58	1.526931	7	21.03548	1.116853
58	0.8723894	7	20.58792	59	1.544267	7	21.06127	1.116767
59	0.8896674	7	20.61371	60	1.561545	8	24.03789	1.116693
60	0.9069956	7	20.63954	61	1.578874	8	24.06373	1.116619
61	0.9244901	7	20.66549	62	1.596368	8	24.08967	1.116527
62	0.9398844	8	23.64083	63	1.611762	8	24.11418	1.116732
63	0.9571048	8	23.66659	64	1.628983	8	24.13994	1.116680
64	0.9745457	8	23.69249	65	1.646424	8	24.16585	1.116608
65	0.9919184	8	23.71836	66	1.663796	8	24.19171	1.116543
66	1.009238	8	23.74418	67	1.681116	8	24.21754	1.116490
67	1.026603	8	23.77004	68	1.698481	8	24.24339	1.116432
68	1.043870	8	23.79583	69	1.715748	9	27.22001	1.116393
69	1.061196	8	23.82166	70	1.733073	9	27.24584	1.116346
70	1.078573	9	26.79835	71	1.750451	9	27.27170	1.116298
71	1.096055	9	26.82429	72	1.767933	9	27.29764	1.116242
72	1.113347	9	26.85009	73	1.785225	9	27.32345	1.116205
73	1.130731	9	26.87596	74	1.802609	9	27.34932	1.116165
74	1.148113	9	26.90183	75	1.819991	9	27.37519	1.116125

Table 4　continued

external gear				internal gear				contact ratio
number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	
Z_1	X_1	K_1	W_1	Z_2	X_2	K_2	W_2	ϵ_α
difference 1 in number of teeth								
75	1. 165518	9	26. 92772	76	1. 837396	9	27. 40107	1. 116087
76	1. 183218	9	26. 9538	77	1. 855096	9	27. 42716	1. 116010
77	1. 200464	9	26. 97958	78	1. 872342	10	30. 40376	1. 115995
78	1. 217934	9	27. 00551	79	1. 889812	10	30. 42968	1. 115954
79	1. 235147	10	29. 98209	80	1. 907025	10	30. 45544	1. 115939
80	1. 252614	10	30. 00801	81	1. 924492	10	30. 48137	1. 115905
81	1. 269837	10	30. 03377	82	1. 941715	10	30. 50713	1. 115892
82	1. 287340	10	30. 05972	83	1. 959217	10	30. 53308	1. 115852
83	1. 30492	10	30. 08573	84	1. 976798	10	30. 55908	1. 115814
84	1. 32210	10	30. 11146	85	1. 993978	10	30. 58481	1. 115810
85	1. 339657	10	30. 13745	86	2. 011535	11	33. 56162	1. 115766
86	1. 357350	10	30. 16353	87	2. 029228	11	33. 58770	1. 115718
87	1. 374721	10	30. 18939	88	2. 046599	11	33. 61357	1. 115693
88	1. 397023	11	33. 16945	89	2. 068901	11	33. 64280	1. 115189
89	1. 414533	11	33. 19541	90	2. 086411	11	33. 66876	1. 115170
90	1. 426854	11	33. 21781	91	2. 098732	11	33. 69116	1. 115643
91	1. 449637	11	33. 24737	92	2. 121515	11	33. 72072	1. 115113
92	1. 467440	11	33. 27353	93	2. 139318	11	33. 74688	1. 115069
93	1. 484893	11	33. 29944	94	2. 156771	11	33. 77280	1. 115048
94	1. 501962	11	33. 32510	95	2. 17384	12	36. 74928	1. 115069
95	1. 514196	11	33. 34745	96	2. 186074	12	36. 77163	1. 115533
96	1. 537064	12	36. 32789	97	2. 208942	12	36. 80124	1. 115027
97	1. 548965	12	36. 35001	98	2. 220842	12	36. 82337	1. 115506
98	1. 572110	12	36. 37982	99	2. 243988	12	36. 85318	1. 114987
99	1. 589885	12	36. 40596	100	2. 261763	12	36. 87931	1. 114957
100	1. 601342	12	36. 42778	101	2. 273220	12	36. 90113	1. 115459

Table 4 continued

external gear				internal gear				contact ratio
number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	
Z_1	X_1	K_1	W_1	Z_2	X_2	K_2	W_2	ϵ_α
difference 2 in mumber of teeth								
30	0.4791342	4	11.07501	32	0.8502467	4	11.36671	1.261963
31	0.4957864	4	11.10038	33	0.8668989	4	11.38208	1.261229
32	0.5125598	4	11.12583	34	0.8836723	4	11.40753	1.260555
33	0.5295414	4	11.15143	35	0.9006539	5	14.38395	1.259900
34	0.5464967	4	11.17700	36	0.9176092	5	14.40953	1.259331
35	0.5633513	5	14.15333	37	0.9344638	5	14.43604	1.258859
36	0.5805663	5	14.17909	38	0.9516788	5	14.46079	1.258338
37	0.5976251	5	14.20474	39	0.9687377	5	14.48644	1.257921
38	0.6147976	5	14.23046	40	0.9859101	5	14.51216	1.257515
39	0.6318403	5	14.25610	41	1.0029530	5	14.53789	1.257190
40	0.6491367	5	14.28191	42	1.020249	5	14.56361	1.256833
41	0.6663479	5	14.30766	43	1.037460	6	17.54019	1.256533
42	0.6836409	5	14.33347	44	1.054753	6	17.56599	1.256242
43	0.7008012	5	14.35919	45	1.071914	6	17.59171	1.256013
44	0.7181575	6	17.33586	46	1.089270	6	17.61756	1.255760
45	0.7355456	6	17.36173	47	1.106658	6	17.64344	1.255522
46	0.7529494	6	17.38762	48	1.124062	6	17.66932	1.255308
47	0.7704609	6	17.41357	49	1.141573	6	17.69528	1.255084
48	0.7879581	6	17.43952	50	1.159071	6	17.72122	1.254882
49	0.8053678	6	17.46541	51	1.176480	6	17.74711	1.254714
50	0.8229018	6	17.49138	52	1.194014	7	20.72391	1.254539
51	0.8404332	6	17.51735	53	1.211548	7	20.74988	1.254376
52	0.8579483	6	17.54331	54	1.229061	7	20.77584	1.254228
53	0.8755552	7	20.52016	55	1.246668	7	20.80186	1.254076
54	0.8930579	7	20.54611	56	1.264170	7	20.82781	1.253958
55	0.9107571	7	20.57220	57	1.28187	7	20.85390	1.253806
56	0.9283258	7	20.59819	58	1.299438	7	20.87989	1.253692
57	0.9458125	7	20.62413	59	1.316925	7	20.90583	1.253604
58	0.9635381	7	20.65024	60	1.334651	7	20.93193	1.253487
59	0.9811604	7	20.67627	61	1.352273	8	23.90880	1.253377
60	0.9987344	7	20.70227	62	1.369847	8	23.93480	1.253295
61	1.016389	8	23.67915	63	1.387502	8	23.96085	1.253201
62	1.034118	8	23.70526	64	1.405230	8	23.98696	1.253104
63	1.051841	8	23.73136	65	1.422954	8	24.01306	1.253015
64	1.069476	8	23.75740	66	1.440589	8	24.03910	1.252941

Table 4　continued

external gear				internal gear				contact ratio
number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	number of teeth	modification coefficient	spanned number of teeth	base tangent lenght	
Z_1	X_1	K_1	W_1	Z_2	X_2	K_2	W_2	ϵ_α
difference 2 in mumber of teeth								
65	1.087235	8	23.78353	67	1.458348	8	24.06523	1.252853
66	1.104810	8	23.80953	68	1.475923	8	24.09123	1.252803
67	1.122727	8	23.83576	69	1.49384	9	27.06829	1.252703
68	1.140284	8	23.86175	70	1.511396	9	27.09428	1.252663
69	1.158097	8	23.88791	71	1.52921	8	27.12044	1.252583
70	1.175845	9	26.86486	72	1.546958	9	27.14656	1.252527
71	1.193682	9	26.89104	73	1.564795	9	27.17274	1.252457
72	1.211604	9	26.91727	74	1.582716	9	27.19897	1.252374
73	1.229099	9	26.94332	75	1.600212	9	27.22492	1.252358
74	1.247004	9	26.96945	76	1.618117	9	27.25115	1.252290
75	1.264804	9	26.99560	77	1.635917	9	27.27730	1.252235
76	1.282490	9	27.02168	78	1.653602	10	30.25421	1.252201
77	1.300229	9	27.04779	79	1.671342	10	30.28032	1.252161
78	1.318199	9	27.07406	80	1.689311	10	30.30659	1.252095
79	1.335851	10	30.05094	81	1.706963	10	30.33264	1.252070
80	1.353725	10	30.07714	82	1.724837	10	30.35885	1.252023
81	1.371448	10	30.10325	83	1.742561	10	30.38495	1.251991
82	1.389389	10	30.12950	84	1.760502	10	30.41120	1.25194
83	1.407165	10	30.15564	85	1.778278	10	30.43734	1.251908
84	1.424961	10	30.18179	86	1.796073	10	30.46349	1.251874
85	1.442575	10	30.20781	87	1.813687	11	33.44034	1.251869
86	1.460990	10	30.23439	88	1.832103	11	33.46692	1.251768
87	1.478818	11	33.21139	89	1.849931	11	33.46309	1.251733
88	1.496241	11	33.23728	90	1.867353	11	33.51898	1.251751
89	1.514270	11	33.26359	91	1.885382	11	33.54530	1.251702
90	1.531878	11	33.28962	92	1.902990	11	33.57132	1.251696
91	1.549890	11	33.31592	93	1.921003	11	33.59762	1.251653
92	1.567676	11	33.34206	94	1.938788	11	33.62376	1.251635
93	1.585439	11	33.36819	95	1.956552	12	36.60072	1.251610
94	1.603175	11	33.39430	96	1.974288	12	36.62682	1.251605
95	1.621099	11	33.42054	97	1.992212	12	36.65307	1.251574
96	1.639433	12	36.39788	98	2.010546	12	36.67959	1.251498
97	1.657287	12	36.42407	99	2.02840	12	36.70578	1.251479
98	1.674872	12	36.45008	100	2.045985	12	36.73179	1.251487
99	1.692635	12	36.47621	101	2.063747	12	36.75791	1.251471
100	1.710576	12	36.50246	102	2.081689	12	36.78416	1.25144

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Design and Calculation of Planetary Gear Drive of the Few Difference in Number of Teeth and the CAD

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Abstract

This paper describes the method which is used for designing the drive of the few difference in number of teeth and the algorithm of the CAD. It consist of the operating principle, the parameter selection, the geometrical calculation, the computer block diagram and the tables of modification coefficient. According to given program, the geometrical parameters of 284 internal gear pairs have calculated by the computer and the calculation example has given in this paper. The practice result indicates that the method of the design and the calculation is correct and it is able to provide references.

Key words: The few difference in number of teeth, Modification coefficient, Interference of profile, Contact ratio

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