

# 渐开线少齿差内齿轮副的几何参数

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正确选择一对内齿轮副的几何参数,其计算方法很复杂,即使是熟练的工程师也需要用五、六天的时间,才能算出一对内齿轮副的几何参数。笔者利用电子计算机,按模数 $m=1$ ,并取外齿轮的变位系数为较小值(包括不变位),作成齿数差 $Z_2-Z_1=1\sim 4$ 的几何参数表;设计者选用时,只要用几分钟的时间,就可以选出合适的内齿轮副的几何参数。

## 一、选择外齿轮变位系数的原则

目前国内许多学者(1)、(2)为了避免内齿轮副的齿廓重叠干涉,往往设法采用较大的外齿轮变位系数,以便使啮合角减小,并认为外齿轮变位系数大了轮齿的弯曲强度将增大。笔者则采用较小的外齿轮变位系数,这样不仅可使啮合角较小、重合度 $\epsilon_\alpha$ 较大( $\epsilon_\alpha > 1.1$ ),并可避免径隙过小。现将其原理讨论如下:

### (一)重合度和变位系数、齿顶高系数间的关系

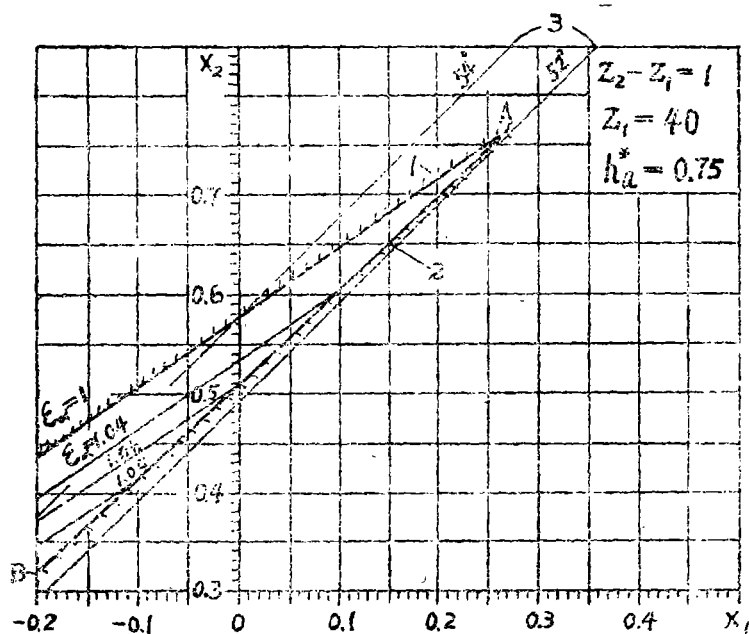


图 1

图1是少齿差的“封闭图”,图中曲线1是表示重合度 $\epsilon_\alpha=1$ 的曲线,若所述内齿轮副的

变位系数在此曲线以下, 则重合度  $\varepsilon_{\alpha} \geq 1$ ; 图中曲线2是避免齿廓重迭干涉的曲线, 只要所选内齿轮副的变位系数在此曲线以上就不会产生齿廓重迭干涉; 曲线3是等压力角线。从图中可知, 若选用的变位系数在曲线2上, 并愈接近A点, 即外齿轮的变位系数较大时, 可使啮合角最小, 但重合度  $\varepsilon_{\alpha} = 1$ ; 若考虑内、外齿轮的齿顶圆的制造公差, 则实际重合度往往小于1, 因此设计时应使重合度  $\varepsilon_{\alpha} \geq 1.1$ 。若选用的变位系数在曲线2上, 并向B点接近, 这时外齿轮的变位系数较小, 而重合度增大 ( $\varepsilon_{\alpha} > 1.1$ ), 但啮合角也稍增大, 不过啮合角的增量很小。

从图中可看出, 当外齿轮变位系数  $X_1 \geq 0$  时, 其重合度  $\varepsilon_{\alpha} < 1.1$ ; 若要使  $X_1 \geq 0$  并且  $\varepsilon_{\alpha} \geq 1.1$ , 则只有加大齿顶高系数  $h_a^* = 0.8$ , 才能实现; 但这时的啮合角比  $h_a^* = 0.75$  取  $X_1 < 0$  时的大, 如表1所示。

齿顶高系数和外齿轮变位系数对啮合角的影响

表 1

| 齿顶高系数<br>$h_a^*$ | 外齿轮变位系数<br>$x_1$ | 重合度<br>$\varepsilon_{\alpha}$ | 啮 合 角<br>$\alpha'$ | 中心距  |
|------------------|------------------|-------------------------------|--------------------|------|
| 0.75             | -0.2             | 1.11                          | 52.960385°         | 0.78 |
| 0.80             | 0                | 1.09                          | 54.0338°           | 0.80 |

注: 该表是按  $Z_1=40$ 、 $Z_2=41$ 、 $\alpha=20^\circ$  计算的。

因此在设计中, 如采用小的外齿轮变位系数, 不仅可使重合度增大, 并可使啮合角减小。

## (二) 外齿轮变位系数与弯曲强度的关系

在渐开线少齿差内齿轮副中的主要薄弱环节是轮齿的弯曲强度。一般认为外齿轮的变位系数愈大, 齿形系数愈小, 因此弯曲强度增大。但没有考虑到齿根处应力集中系数也随着增加, 所以在理论上, 外齿轮除齿数较少的以外, 正变位齿轮的齿根强度几乎不变<sup>[3]</sup>。现就正常齿高的滚刀加工齿顶高系数  $h_a^* = 0.75$  的圆柱外齿轮, 按  $30^\circ$  切线法计算的齿形系数、齿根圆角半径、应力集中系数、综合齿形系数和变位系数的关系, 列于表2中。

由表2可知, 齿形系数和齿根圆角半径随着变位系数增大而减小, 但应力集中系数随着变位系数增大, 所以综合齿形系数  $Y_{Fs} = Y_{Fa} \times Y_{sa}$ <sup>[4]</sup>, 与变位系数有关, 但影响不大; 因此为了考虑降低齿顶高系数和增大重合度的关系, 不仿取外齿轮的变位系数为  $X_1 = -0.2 \sim 0$ 。

## (三) 外齿轮变位系数大了易引起顶隙减小

因渐开线少齿差内齿轮副都采用正传动, 所以当外齿轮变位系数较大时, 则内齿轮变位系数更大。若内齿轮的变位系数  $X_2$  与内齿轮插齿刀变位系数  $X_0$  的差较大 (即  $X_2 - X_0$  较大), 则内齿轮与外齿轮装配后, 内齿轮齿根与外齿轮齿顶间的顶隙就显著减小, 甚至会产生负值。

齿形系数、应力集中系数与变位系数的关系 ( $\alpha=20^\circ$ )

表 2

| 齿数        | 变位系数 $x_1$       | -0.6   | -0.4   | -0.2   | 0      | 0.2    | 0.4    | 0.6    | 0.8    | 1.0    |
|-----------|------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| $z_1=30$  | 齿形系数 $Y_{Fa}$    | 3.017  | 2.669  | 2.369  | 2.178  | 2.005  | 1.868  | 1.760  | 1.677  | 1.617  |
|           | 齿根圆角半径 $\rho/m$  | 0.7751 | 0.6937 | 0.6180 | 0.5491 | 0.4884 | 0.4381 | 0.4011 | 0.3816 | 0.3861 |
|           | 应力集中系数 $Y_{Sa}$  | 1.442  | 1.539  | 1.645  | 1.758  | 1.876  | 1.991  | 2.092  | 2.159  | 2.169  |
|           | 综合齿形系数 $Y_{F_s}$ | 4.349  | 4.107  | 3.940  | 3.830  | 3.762  | 3.720  | 3.682  | 3.622  | 3.508  |
| $z_1=60$  | 齿形系数 $Y_{Fa}$    | 2.318  | 2.178  | 2.059  | 1.958  | 1.874  | 1.804  | 1.748  | 1.703  | 1.669  |
|           | 齿根圆角半径 $\rho/m$  | 0.6778 | 0.6129 | 0.5536 | 0.5009 | 0.4558 | 0.4195 | 0.3939 | 0.3810 | 0.3837 |
|           | 应力集中系数 $Y_{Sa}$  | 1.618  | 1.706  | 1.798  | 1.892  | 1.984  | 2.070  | 2.139  | 2.182  | 2.188  |
|           | 综合齿形系数 $Y_{F_s}$ | 3.751  | 3.714  | 3.701  | 3.705  | 3.719  | 3.735  | 3.739  | 3.716  | 3.652  |
| $z_1=100$ | 齿形系数 $Y_{Fa}$    | 2.081  | 2.003  | 1.935  | 1.876  | 1.826  | 1.783  | 1.748  | 1.720  | 1.698  |
|           | 齿根圆角半径 $\rho/m$  | 0.6026 | 0.5520 | 0.5065 | 0.4668 | 0.4335 | 0.4074 | 0.3894 | 0.3807 | 0.3824 |
|           | 应力集中系数 $Y_{Sa}$  | 1.744  | 1.821  | 1.899  | 1.975  | 2.048  | 2.111  | 2.160  | 2.189  | 2.193  |
|           | 综合齿形系数 $Y_{F_s}$ | 3.629  | 3.647  | 3.674  | 3.706  | 3.739  | 3.764  | 3.776  | 3.765  | 3.724  |

例如, 一对内齿轮副的模数  $m=2\text{mm}$ , 齿顶高系数  $h_a^*=0.75$ , 外齿轮的齿数  $Z_1=40$ , 变位系数  $X_1=1.00$ , 内齿轮的齿数  $Z_2=44$ , 变位系数  $X_2=1.081$ , 若采用内齿轮插齿刀齿数  $Z_0=38$ , 变位系数  $X_0=-0.315$  加工内齿轮, 则装配后内齿轮齿根与外齿轮齿顶间顶隙  $C=-0.047\text{mm}$ ①。

若将这对齿轮的齿顶高系数改为  $h_a^*=0.65$ , 内、外齿轮的变位系数分别改为  $X_1=0$ ,  $X_2=0.091$ , 则其顶隙  $C>1\text{mm}$ , 即顶隙系数  $C^*>0.5$ 。

由上可知, 在设计时, 如取外齿轮的变位系数为较小值, 将会使设计和制造比较方便。

## 二、渐开线少齿差内齿轮副几何参数表

### (一) 主要术语、代号和计算公式

本文所采用的主要术语、代号和计算公式见表3, 其中齿顶高的计算方法是采用DIN的公式(6), 其它有关公式的推导详文献(7)。

-----①顶隙的计算公式详文献(5)

主要术语、代号和计算公式

表 3

| 述 语      | 代号            | 计 算 公 式   |
|----------|---------------|---|
| 模 数      | $m$           |   |
| 原始齿形角    | $\alpha$      |   |
| 外齿轮齿数    | $Z_1$         |   |
| 内齿轮齿数    | $Z_2$         |   |
| 齿顶高系数    | $h_a^*$       |   |
| 外齿轮变位系数  | $X_1$         |   |
| 内齿轮变位系数  | $X_2$         |   |
| 啮合角      | $\alpha'$     | $\text{inv}\alpha' = \text{inv}\alpha + \frac{X_2 - X_1}{Z_2 - Z_1} 2\text{tg}\alpha$   |
| 中心距      | $a'$          | $a' = \frac{m(Z_2 - Z_1)\cos\alpha}{2\cos\alpha'}$  |
| 外齿轮分度圆半径 | $r_1$         | $r_1 = mz_1/2$  |
| 内齿轮分度圆半径 | $r_2$         | $r_2 = mz_2/2$  |
| 外齿轮基圆半径  | $r_{b1}$      | $r_{b1} = r_1 \cos\alpha$   |
| 内齿轮基圆半径  | $r_{b2}$      | $r_{b2} = r_2 \cos\alpha$   |
| 外齿轮齿顶圆半径 | $r_{a1}$      | $r_{a1} = m \left( \frac{Z_1}{2} + x_1 + h_a^* \right)$   |
| 内齿轮齿顶圆半径 | $r_{a2}$      | $r_{a2} = m \left( \frac{Z_2}{2} + x_2 - h_a^* \right)$   |
| 外齿轮齿顶压力角 | $\alpha_{a1}$ | $\cos\alpha_{a1} = \frac{r_{b1}}{r_{a1}}$   |
| 内齿轮齿顶压力角 | $\alpha_{a2}$ | $\cos\alpha_{a2} = \frac{r_{b2}}{r_{a2}}$   |
| 重合度      | $\epsilon_a$  | $\epsilon_a = \frac{1}{2\pi} [ (Z_2 - Z_1)\text{tg}\alpha' + Z_1\text{tg}\alpha_{a1} - Z_2\text{tg}\alpha_{a2} ]$   |
| 齿廓重迭干涉验算 | $G_s$         | $G_s = Z_1(\text{inv}\alpha_{a1} + \delta_1) + (Z_2 - Z_1)\text{inv}\alpha' - Z_2(\text{inv}\alpha_{a2} + \delta_2)$ <p>式中 <math>\cos\delta_1 = \frac{r_{a2}^2 - r_{a1}^2 - a'^2}{2a' r_{a1}}</math></p> <p><math>\cos\delta_2 = \frac{r_{a2}^2 - r_{a1}^2 + a'^2}{2a' r_{a2}}</math></p> |
| 外齿轮跨齿数   | $K_1$         | $K_1 = 0.5 + \frac{1}{\pi} [ Z_1(\text{tg}\alpha_m - \text{inv}\alpha) - 2x_1\text{tg}\alpha ]$ <p>式中 <math>\alpha_m = \cos^{-1} \frac{r_{b1}}{r_{a1} - h_a^* m}</math></p>   |
| 外齿轮公法线长度 | $W_{k1}$      | $W_{k1} = m\cos\alpha [ Z_1\text{inv}\alpha + (K_1 - 0.5)\pi + 2x_1\text{tg}\alpha ]$   |
| 内齿轮跨齿沟数  | $K_2$         | $K_2 = 0.5 + \frac{1}{\pi} [ Z_2(\text{tg}\alpha_m - \text{inv}\alpha) - 2x_2\text{tg}\alpha ]$   |

(续)

| 述 语      | 代号        | 计 算 公 式   |
|----------|-----------|---|
| 内齿轮公法线长度 | $W_{k_2}$ | 式中 $\alpha_{m_2} = \cos^{-1} \frac{\gamma_{b_2}}{\gamma_{a_2} + h_a^* m}$<br>$W_{k_2} = m \cos \alpha [z_2 \operatorname{inv} \alpha + (k_2 - 0.5) \pi + 2x_2 \operatorname{tg} \alpha]$  |
| 量棒值      | $d_{p_2}$ | $d_{p_2} = m z_2 \cos \alpha \left( \frac{\pi}{2z_2} + \frac{2x_2 \operatorname{tg} \alpha}{z_2} + \operatorname{inv} \alpha - \operatorname{inv} \alpha_p \right)$   |
| 跨棒距      | $M_2$     | 式中 $\alpha_p = \operatorname{tg} \alpha_{m_2} - \frac{\pi}{2z_2} - \operatorname{inv} \alpha - \frac{2x_2 \operatorname{tg} \alpha}{z_2}$<br>$\alpha_{m_2} = \cos^{-1} \frac{\gamma_{b_2}}{\gamma_{a_2} + h_a^* m}$<br>偶数齿<br>$M_2 = D_p - d_{p_2}$<br>奇数齿<br>$M_2 = D_p \cos \frac{90^\circ}{z_2} - d_{p_2}$<br>式中 $D_p = \frac{2 \gamma_2 \cos \alpha}{\cos \alpha'_p}$ ; $\operatorname{inv} \alpha'_p = \frac{1}{z_2} \left( \frac{\pi}{2} + 2x_2 \operatorname{tg} \alpha - \frac{d_{p_2}}{m \cos \alpha} \right) + \operatorname{inv} \alpha$ |

## (二) 内齿轮副的几何参数表

现将渐开线少齿差内齿轮副的几何参数,就齿数差 $Z_2 - Z_1 = 1 \sim 4$ 分别列于表4~7中,这些表中的参数是按模数 $m=1$ 作出的,当模数 $m \neq 1$ 时,需将表中的内、外齿顶圆直径 $d_{a_2}$ 、 $d_{a_1}$ ,内、外齿轮的公法线长度 $W_{k_2}$ 、 $W_{k_1}$ ,量棒直径 $d_{p_2}$ ,跨棒距 $M_2$ 乘以模数 $m$ 。

利用表中的几何参数,可使内齿轮副的重合度大于1.1,不发生齿廓重叠干涉,外齿轮和内齿轮的齿顶厚系数大于0.4,不发生节节点对面齿顶相互抵触干涉。

一齿差内齿轮副几何参数

表 4

| 共同参数 | 齿数差         | 模 数 | 压力角        | 啮 合 角             | 中心距  | 齿顶高系数  |
|------|-------------|-----|------------|-------------------|------|--------|
|      | $Z_2 - Z_1$ | $m$ | $\alpha$   | $\alpha'$         | $a'$ | $ha^*$ |
|      | 1           | 1   | $20^\circ$ | $52.930385^\circ$ | 0.78 | 0.75   |

(毫米)

| 外 齿 轮 |       |        |       |          | 内 齿 轮 |       |        |       |          |       |         |               | 重 合 度               | 齿 干 涉 验 算 |
|-------|-------|--------|-------|----------|-------|-------|--------|-------|----------|-------|---------|---------------|---------------------|-----------|
| 齿数    | 变位系数  | 齿顶圆直径  | 跨齿数   | 公法线长度    | 齿数    | 变位系数  | 齿顶圆直径  | 跨齿数   | 公法线长度    | 量棒直径  | 跨棒距     |               | $\varepsilon\alpha$ | $G_s$     |
| $Z_1$ | $X_1$ | $da_1$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $da_2$ | $K_2$ | $W_{k2}$ | $d_p$ | $M$     | $\sin\alpha'$ | $\varepsilon\alpha$ | $G_s$     |
| 30    | -0.2  | 31.10  | 3     | 7.6637   | 31    | 0.33  | 30.16  | 4     | 10.9924  | 1.7   | 29.2655 | 0.3421        | 1.11                | 0.129     |
| 31    | -0.2  | 32.10  | 4     | 10.6298  | 32    | 0.33  | 31.16  | 5     | 13.9585  | 1.7   | 30.3053 | 0.3421        | 1.11                | 0.129     |
| 32    | -0.2  | 33.10  | 4     | 10.6438  | 33    | 0.33  | 32.16  | 5     | 13.9725  | 1.7   | 31.2679 | 0.3421        | 1.11                | 0.129     |
| 33    | -0.2  | 34.10  | 4     | 10.6578  | 34    | 0.33  | 33.16  | 5     | 13.9865  | 1.7   | 32.3053 | 0.3421        | 1.11                | 0.129     |
| 34    | -0.2  | 35.10  | 4     | 10.6718  | 35    | 0.33  | 34.16  | 5     | 14.0005  | 1.7   | 33.2700 | 0.3421        | 1.11                | 0.129     |
| 35    | -0.2  | 36.10  | 4     | 10.6858  | 36    | 0.33  | 35.16  | 5     | 14.0145  | 1.7   | 34.3053 | 0.3421        | 1.11                | 0.129     |
| 36    | -0.2  | 37.10  | 4     | 10.6999  | 37    | 0.33  | 36.16  | 5     | 14.0285  | 1.7   | 35.2719 | 0.3421        | 1.11                | 0.129     |
| 37    | -0.2  | 38.10  | 4     | 10.7139  | 38    | 0.33  | 37.16  | 5     | 14.0425  | 1.7   | 36.3053 | 0.3421        | 1.11                | 0.129     |
| 38    | -0.2  | 39.10  | 4     | 10.7279  | 39    | 0.33  | 38.16  | 5     | 14.0565  | 1.7   | 37.2736 | 0.3421        | 1.11                | 0.128     |
| 39    | -0.2  | 40.10  | 4     | 10.7419  | 40    | 0.33  | 39.16  | 5     | 14.0705  | 1.7   | 38.3053 | 0.3421        | 1.11                | 0.128     |
| 40    | -0.2  | 41.10  | 4     | 13.7080  | 41    | 0.33  | 40.16  | 6     | 17.0367  | 1.7   | 39.2752 | 0.3421        | 1.11                | 0.128     |
| 41    | -0.20 | 42.10  | 5     | 13.7220  | 42    | 0.33  | 41.16  | 6     | 17.0507  | 1.7   | 40.3053 | 0.3421        | 1.11                | 0.128     |
| 42    | -0.20 | 43.10  | 5     | 13.7360  | 43    | 0.33  | 42.16  | 6     | 17.0647  | 1.7   | 41.2766 | 0.3421        | 1.11                | 0.128     |
| 43    | -0.20 | 44.10  | 5     | 13.7500  | 44    | 0.33  | 43.16  | 6     | 17.0787  | 1.7   | 42.3053 | 0.3421        | 1.11                | 0.128     |
| 44    | -0.20 | 45.10  | 5     | 13.7640  | 45    | 0.33  | 44.16  | 6     | 17.0927  | 1.7   | 43.2778 | 0.3421        | 1.11                | 0.128     |
| 45    | -0.20 | 46.10  | 5     | 13.7780  | 46    | 0.33  | 45.16  | 6     | 17.1067  | 1.7   | 44.3053 | 0.3421        | 1.11                | 0.128     |
| 46    | -0.20 | 47.10  | 5     | 13.7920  | 47    | 0.33  | 46.16  | 6     | 17.1207  | 1.7   | 45.2790 | 0.3421        | 1.11                | 0.128     |
| 47    | -0.20 | 48.10  | 5     | 13.8060  | 48    | 0.33  | 47.16  | 6     | 17.1347  | 1.7   | 46.3053 | 0.3421        | 1.11                | 0.127     |
| 48    | -0.20 | 49.10  | 5     | 13.8200  | 49    | 0.33  | 48.16  | 6     | 17.1487  | 1.7   | 47.2801 | 0.3421        | 1.11                | 0.127     |
| 49    | -0.20 | 50.10  | 6     | 16.7862  | 50    | 0.33  | 49.16  | 7     | 20.1149  | 1.7   | 48.3053 | 0.3421        | 1.11                | 0.127     |
| 50    | -0.20 | 51.10  | 6     | 16.8002  | 51    | 0.33  | 50.16  | 7     | 20.1289  | 1.7   | 49.2811 | 0.3421        | 1.11                | 0.127     |
| 51    | -0.20 | 52.10  | 6     | 16.8142  | 52    | 0.33  | 51.16  | 7     | 20.1429  | 1.7   | 50.3053 | 0.3421        | 1.11                | 0.127     |
| 52    | -0.20 | 53.10  | 6     | 16.8282  | 53    | 0.33  | 52.16  | 7     | 20.1569  | 1.7   | 51.2820 | 0.3421        | 1.11                | 0.127     |
| 53    | -0.20 | 54.10  | 6     | 16.8422  | 54    | 0.33  | 53.16  | 7     | 20.1709  | 1.7   | 52.3053 | 0.3421        | 1.11                | 0.127     |
| 54    | -0.20 | 55.10  | 6     | 16.8562  | 55    | 0.33  | 54.16  | 7     | 20.1849  | 1.7   | 53.2828 | 0.3421        | 1.11                | 0.127     |
| 55    | -0.20 | 56.10  | 6     | 16.8702  | 56    | 0.33  | 55.16  | 7     | 20.1989  | 1.7   | 54.3053 | 0.3421        | 1.11                | 0.127     |
| 56    | -0.20 | 57.10  | 6     | 16.8842  | 57    | 0.33  | 56.16  | 7     | 20.2129  | 1.7   | 55.2836 | 0.3421        | 1.11                | 0.127     |
| 57    | -0.20 | 58.10  | 6     | 16.8982  | 58    | 0.33  | 57.16  | 7     | 20.2269  | 1.7   | 56.3053 | 0.3421        | 1.11                | 0.127     |

(续)

| $Z_1$ | $X_1$ | $d_{a1}$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $d_{a2}$ | $K_2$ | $W_{k2}$ | $d_p$ | $M$     | $\sin\alpha'$ | $\varepsilon_\alpha$ | $G_s$ |
|-------|-------|----------|-------|----------|-------|-------|----------|-------|----------|-------|---------|---------------|----------------------|-------|
| 58    | -0.20 | 59.10    | 7     | 19.8644  | 59    | 0.33  | 58.16    | 8     | 23.1930  | 1.7   | 57.2843 | 0.3421        | 1.11                 | 0.126 |
| 59    | -0.20 | 60.10    | 7     | 19.8784  | 60    | 0.33  | 59.16    | 8     | 23.2071  | 1.7   | 58.3053 | 0.3421        | 1.11                 | 0.126 |
| 60    | -0.20 | 61.10    | 7     | 19.8924  | 61    | 0.33  | 60.16    | 8     | 23.2211  | 1.7   | 59.2850 | 0.3421        | 1.11                 | 0.126 |
| 61    | -0.20 | 62.10    | 7     | 19.9064  | 62    | 0.33  | 61.16    | 8     | 23.2351  | 1.7   | 60.3053 | 0.3421        | 1.11                 | 0.126 |
| 62    | -0.20 | 63.10    | 7     | 19.9204  | 63    | 0.33  | 62.16    | 8     | 23.2491  | 1.7   | 61.2857 | 0.3421        | 1.11                 | 0.126 |
| 63    | -0.20 | 64.10    | 7     | 19.9344  | 64    | 0.33  | 63.16    | 8     | 23.2631  | 1.7   | 62.3053 | 0.3421        | 1.11                 | 0.126 |
| 64    | -0.20 | 65.10    | 7     | 19.9484  | 65    | 0.33  | 64.16    | 8     | 23.2771  | 1.7   | 63.2863 | 0.3421        | 1.11                 | 0.126 |
| 65    | -0.20 | 66.10    | 7     | 19.9624  | 66    | 0.33  | 65.16    | 8     | 23.2911  | 1.7   | 64.8053 | 0.3421        | 1.11                 | 0.126 |
| 66    | -0.20 | 67.10    | 7     | 19.9764  | 67    | 0.33  | 66.16    | 8     | 23.3051  | 1.7   | 65.2868 | 0.3421        | 1.11                 | 0.126 |
| 67    | -0.20 | 68.10    | 8     | 22.9425  | 68    | 0.33  | 67.16    | 9     | 26.2712  | 1.7   | 66.3053 | 0.3421        | 1.11                 | 0.126 |
| 68    | -0.20 | 69.10    | 8     | 22.9566  | 69    | 0.33  | 68.16    | 9     | 26.2852  | 1.7   | 67.2874 | 0.3421        | 1.11                 | 0.126 |
| 69    | -0.20 | 70.10    | 8     | 22.9706  | 70    | 0.33  | 69.16    | 9     | 26.2992  | 1.7   | 68.3053 | 0.3421        | 1.11                 | 0.126 |
| 70    | -0.20 | 71.10    | 8     | 22.9846  | 71    | 0.33  | 70.16    | 9     | 26.3132  | 1.7   | 69.2879 | 0.3421        | 1.11                 | 0.126 |
| 71    | -0.20 | 72.10    | 8     | 22.9986  | 72    | 0.33  | 71.16    | 9     | 26.3272  | 1.7   | 70.3053 | 0.3421        | 1.11                 | 0.125 |
| 72    | -0.20 | 73.10    | 8     | 23.0126  | 73    | 0.33  | 72.16    | 9     | 26.3413  | 1.7   | 71.2884 | 0.3421        | 1.11                 | 0.125 |
| 73    | -0.20 | 74.10    | 8     | 23.0266  | 74    | 0.33  | 73.16    | 9     | 26.3553  | 1.7   | 72.3053 | 0.3421        | 1.11                 | 0.125 |
| 74    | -0.20 | 75.10    | 8     | 23.0406  | 75    | 0.33  | 74.16    | 9     | 26.3693  | 1.7   | 73.2888 | 0.3421        | 1.11                 | 0.125 |
| 75    | -0.20 | 76.10    | 8     | 23.0546  | 76    | 0.33  | 75.16    | 10    | 29.3354  | 1.7   | 74.3053 | 0.3421        | 1.11                 | 0.125 |
| 76    | -0.20 | 77.10    | 9     | 26.0207  | 77    | 0.33  | 76.16    | 10    | 29.3494  | 1.7   | 75.2892 | 0.3421        | 1.11                 | 0.125 |
| 77    | -0.20 | 78.10    | 9     | 26.0347  | 78    | 0.33  | 77.16    | 10    | 29.3634  | 1.7   | 76.3053 | 0.3421        | 1.11                 | 0.125 |
| 78    | -0.20 | 79.10    | 9     | 26.0487  | 79    | 0.33  | 78.16    | 10    | 29.3774  | 1.7   | 77.2896 | 0.3421        | 1.11                 | 0.125 |
| 79    | -0.20 | 80.10    | 9     | 26.0627  | 80    | 0.33  | 79.16    | 10    | 29.3914  | 1.7   | 78.3053 | 0.3421        | 1.11                 | 0.125 |
| 80    | -0.20 | 81.10    | 9     | 26.0768  | 81    | 0.33  | 80.16    | 10    | 29.4054  | 1.7   | 79.2900 | 0.3421        | 1.11                 | 0.125 |
| 81    | -0.20 | 82.10    | 9     | 26.0908  | 82    | 0.33  | 81.16    | 10    | 29.4194  | 1.7   | 80.3053 | 0.3421        | 1.11                 | 0.125 |
| 82    | -0.20 | 83.10    | 9     | 26.1048  | 83    | 0.33  | 82.16    | 10    | 29.4334  | 1.7   | 81.2904 | 0.3421        | 1.11                 | 0.125 |
| 83    | -0.20 | 84.10    | 9     | 26.1188  | 84    | 0.33  | 83.16    | 10    | 29.4474  | 1.7   | 82.3053 | 0.3421        | 1.11                 | 0.125 |
| 84    | -0.20 | 85.10    | 9     | 26.1328  | 85    | 0.33  | 84.16    | 11    | 32.4136  | 1.7   | 83.2907 | 0.3421        | 1.11                 | 0.125 |
| 85    | -0.20 | 86.10    | 10    | 29.0989  | 86    | 0.33  | 85.16    | 11    | 32.4276  | 1.7   | 84.3053 | 0.3421        | 1.11                 | 0.125 |
| 86    | -0.20 | 87.10    | 10    | 29.1129  | 87    | 0.33  | 86.16    | 11    | 32.4416  | 1.7   | 85.2911 | 0.3421        | 1.11                 | 0.125 |
| 87    | -0.20 | 88.10    | 10    | 29.1269  | 88    | 0.33  | 87.16    | 11    | 32.4556  | 1.7   | 86.3053 | 0.3421        | 1.11                 | 0.125 |
| 88    | -0.20 | 89.10    | 10    | 29.1409  | 89    | 0.33  | 88.16    | 11    | 32.4696  | 1.7   | 87.2914 | 0.3421        | 1.11                 | 0.125 |
| 89    | -0.20 | 90.10    | 10    | 29.1549  | 90    | 0.33  | 89.16    | 11    | 32.4836  | 1.7   | 88.3053 | 0.3421        | 1.11                 | 0.124 |
| 90    | -0.20 | 91.10    | 10    | 29.1689  | 91    | 0.33  | 90.16    | 11    | 32.4976  | 1.7   | 89.2917 | 0.3421        | 1.11                 | 0.124 |
| 91    | -0.20 | 92.10    | 10    | 29.1829  | 92    | 0.33  | 91.16    | 11    | 32.5116  | 1.7   | 90.3053 | 0.3421        | 1.11                 | 0.124 |

(续)

| $Z_1$ | $X_1$ | $d_{a1}$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $d_{a2}$ | $K_2$ | $W_{k2}$ | $d_p$ | $M$     | $\sin\alpha'$ | $\varepsilon_\alpha$ | $G_s$ |
|-------|-------|----------|-------|----------|-------|-------|----------|-------|----------|-------|---------|---------------|----------------------|-------|
| 92    | -0.20 | 93.10    | 10    | 29.1969  | 93    | 0.33  | 92.16    | 11    | 32.5256  | 1.7   | 91.2920 | 0.342         | 1.11                 | 0.124 |
| 93    | -0.20 | 94.10    | 10    | 29.2110  | 94    | 0.33  | 93.16    | 12    | 35.4918  | 1.7   | 92.3053 | 0.342         | 1.11                 | 0.124 |
| 94    | -0.20 | 95.10    | 11    | 32.1771  | 95    | 0.33  | 94.16    | 12    | 35.5058  | 1.7   | 93.2923 | 0.342         | 1.11                 | 0.124 |
| 95    | -0.20 | 96.10    | 11    | 32.1911  | 96    | 0.33  | 95.16    | 12    | 35.5198  | 1.7   | 94.3053 | 0.342         | 1.11                 | 0.124 |
| 96    | -0.20 | 97.10    | 11    | 32.2051  | 97    | 0.33  | 96.16    | 12    | 35.5338  | 1.7   | 95.2925 | 0.342         | 1.11                 | 0.124 |
| 97    | -0.20 | 98.10    | 11    | 32.2191  | 98    | 0.33  | 97.16    | 12    | 35.5478  | 1.7   | 96.3053 | 0.342         | 1.11                 | 0.124 |
| 98    | -0.20 | 99.10    | 11    | 32.2331  | 99    | 0.33  | 98.16    | 12    | 35.5618  | 1.7   | 97.2928 | 0.342         | 1.11                 | 0.124 |
| 99    | -0.20 | 100.10   | 11    | 32.2471  | 100   | 0.33  | 99.16    | 12    | 35.5758  | 1.7   | 98.3053 | 0.342         | 1.11                 | 0.124 |
| 100   | -0.20 | 101.10   | 11    | 32.2611  | 101   | 0.33  | 100.16   | 12    | 35.5898  | 1.7   | 99.2930 | 0.342         | 1.11                 | 0.124 |

二齿差齿轮副几何参数

表 5

| 共同参数 | 齿数差         | 模数  | 压力角        | 啮合角               | 中心距  | 齿顶高系数   |
|------|-------------|-----|------------|-------------------|------|---------|
|      | $Z_2 - Z_1$ | $m$ | $\alpha$   | $\alpha'$         | $a'$ | $h_a^*$ |
|      | 2           | 1   | $20^\circ$ | $36.567448^\circ$ | 1.17 | 0.65    |

(毫米)

| 外 齿 轮 |       |          |       |          | 内 齿 轮 |       |          |       |          |       |         |                | 重 合 度                | 干涉 验算 |
|-------|-------|----------|-------|----------|-------|-------|----------|-------|----------|-------|---------|----------------|----------------------|-------|
| 齿数    | 变位系数  | 齿顶圆直径    | 跨齿数   | 公法线长度    | 齿数    | 变位系数  | 齿顶圆直径    | 跨槽齿数  | 公法线长度    | 量棒直径  | 跨棒距     |                | $\varepsilon_\alpha$ | $G_s$ |
| $Z_1$ | $X_1$ | $d_{a1}$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $d_{a2}$ | $K_2$ | $W_{k2}$ | $d_p$ | $M$     | $\sin\alpha_p$ | $\varepsilon_\alpha$ | $G_s$ |
| 30    | 0     | 31.30    | 4     | 10.7526  | 32    | 0.244 | 31.188   | 4     | 10.9475  | 1.7   | 30.1298 | 0.328          | 1.14                 | 0.065 |
| 31    | 0     | 32.30    | 4     | 10.7666  | 33    | 0.244 | 32.188   | 5     | 13.9137  | 1.7   | 31.0927 | 0.328          | 1.14                 | 0.065 |
| 32    | 0     | 33.30    | 4     | 10.7806  | 34    | 0.244 | 33.188   | 5     | 13.9277  | 1.7   | 32.1300 | 0.329          | 1.14                 | 0.064 |
| 33    | 0     | 34.30    | 4     | 10.7946  | 35    | 0.244 | 34.188   | 5     | 13.9417  | 1.7   | 33.0950 | 0.329          | 1.14                 | 0.064 |
| 34    | 0     | 35.30    | 4     | 10.8086  | 36    | 0.244 | 35.188   | 5     | 13.9557  | 1.7   | 34.1302 | 0.330          | 1.14                 | 0.064 |
| 35    | 0     | 36.30    | 4     | 10.8227  | 37    | 0.244 | 36.188   | 5     | 13.9697  | 1.7   | 35.0971 | 0.330          | 1.14                 | 0.063 |
| 36    | 0     | 37.30    | 4     | 10.8367  | 38    | 0.244 | 37.188   | 5     | 13.9837  | 1.7   | 36.1304 | 0.330          | 1.14                 | 0.063 |
| 37    | 0     | 38.30    | 5     | 13.8028  | 39    | 0.244 | 38.188   | 5     | 13.9977  | 1.7   | 37.0989 | 0.331          | 1.14                 | 0.063 |
| 38    | 0     | 39.30    | 5     | 13.8168  | 40    | 0.244 | 39.188   | 5     | 14.0117  | 1.7   | 38.1305 | 0.331          | 1.14                 | 0.062 |
| 39    | 0     | 40.30    | 5     | 13.8308  | 41    | 0.244 | 40.188   | 5     | 14.0257  | 1.7   | 39.1006 | 0.331          | 1.14                 | 0.062 |
| 40    | 0     | 41.30    | 5     | 13.8448  | 42    | 0.244 | 41.188   | 6     | 16.9919  | 1.7   | 40.1306 | 0.331          | 1.14                 | 0.062 |



(续)

| $Z_1$ | $X_1$ | $da_1$ | $K_1$ | $Wk_1$  | $Z_2$ | $X_2$ | $da_2$ | $K_2$ | $Wk_2$  | $d_p$ | $M$     | $\sin \alpha_p$ | $\varepsilon_\alpha$ | $G_s$ |
|-------|-------|--------|-------|---------|-------|-------|--------|-------|---------|-------|---------|-----------------|----------------------|-------|
| 41    | 0     | 42.30  | 5     | 13.8588 | 43    | 0.244 | 42.188 | 6     | 17.0059 | 1.7   | 41.1021 | 0.332           | 1.14                 | 0.061 |
| 42    | 0     | 43.30  | 5     | 13.8777 | 44    | 0.244 | 43.188 | 6     | 17.0199 | 1.7   | 42.1308 | 0.332           | 1.14                 | 0.061 |
| 43    | 0     | 44.30  | 5     | 13.8868 | 45    | 0.244 | 44.188 | 6     | 17.0339 | 1.7   | 43.1035 | 0.332           | 1.14                 | 0.061 |
| 44    | 0     | 45.30  | 5     | 13.9008 | 46    | 0.244 | 45.188 | 6     | 17.0479 | 1.7   | 44.1309 | 0.332           | 1.14                 | 0.061 |
| 45    | 0     | 46.30  | 5     | 13.9148 | 47    | 0.244 | 46.188 | 6     | 17.0619 | 1.7   | 45.1048 | 0.333           | 1.14                 | 0.060 |
| 46    | 0     | 47.30  | 6     | 16.8810 | 48    | 0.244 | 47.188 | 6     | 17.0759 | 1.7   | 46.1310 | 0.333           | 1.14                 | 0.060 |
| 47    | 0     | 48.30  | 6     | 16.8950 | 49    | 0.244 | 48.188 | 6     | 17.0899 | 1.7   | 47.1059 | 0.333           | 1.14                 | 0.060 |
| 48    | 0     | 49.30  | 6     | 16.9090 | 50    | 0.244 | 49.188 | 6     | 17.1039 | 1.7   | 48.1311 | 0.333           | 1.14                 | 0.060 |
| 49    | 0     | 50.30  | 6     | 16.9230 | 51    | 0.244 | 50.188 | 7     | 20.0700 | 1.7   | 49.1070 | 0.333           | 1.14                 | 0.060 |
| 50    | 0     | 51.30  | 6     | 16.9370 | 52    | 0.244 | 51.188 | 7     | 20.0840 | 1.7   | 50.1312 | 0.333           | 1.14                 | 0.059 |
| 51    | 0     | 52.30  | 6     | 16.9510 | 53    | 0.244 | 52.188 | 7     | 20.0981 | 1.7   | 51.1080 | 0.334           | 1.14                 | 0.059 |
| 52    | 0     | 53.30  | 6     | 16.9650 | 54    | 0.244 | 53.188 | 7     | 20.1121 | 1.7   | 52.1312 | 0.334           | 1.14                 | 0.059 |
| 53    | 0     | 54.30  | 6     | 16.9790 | 55    | 0.244 | 54.188 | 7     | 20.1261 | 1.7   | 53.1089 | 0.334           | 1.14                 | 0.059 |
| 54    | 0     | 55.30  | 6     | 16.9930 | 56    | 0.244 | 55.188 | 7     | 20.1401 | 1.7   | 54.1313 | 0.334           | 1.14                 | 0.059 |
| 55    | 0     | 56.30  | 7     | 19.9592 | 57    | 0.244 | 56.188 | 7     | 20.1541 | 1.7   | 55.1098 | 0.334           | 1.14                 | 0.058 |
| 56    | 0     | 57.30  | 7     | 19.9732 | 58    | 0.244 | 57.188 | 7     | 20.1681 | 1.7   | 56.1314 | 0.334           | 1.14                 | 0.058 |
| 57    | 0     | 58.30  | 7     | 19.9872 | 59    | 0.244 | 58.188 | 7     | 20.1821 | 1.7   | 57.1106 | 0.335           | 1.14                 | 0.058 |
| 58    | 0     | 59.30  | 7     | 20.0012 | 60    | 0.244 | 59.188 | 8     | 23.1482 | 1.7   | 58.1315 | 0.335           | 1.14                 | 0.058 |
| 59    | 0     | 60.30  | 7     | 20.0152 | 61    | 0.244 | 60.188 | 8     | 23.1622 | 1.7   | 59.1113 | 0.335           | 1.14                 | 0.058 |
| 60    | 0     | 61.30  | 7     | 20.0292 | 62    | 0.244 | 61.188 | 8     | 23.1762 | 1.7   | 60.1315 | 0.335           | 1.14                 | 0.058 |
| 61    | 0     | 62.30  | 7     | 20.0432 | 63    | 0.244 | 62.188 | 8     | 23.1902 | 1.7   | 61.1120 | 0.335           | 1.14                 | 0.057 |
| 62    | 0     | 63.30  | 7     | 20.0572 | 64    | 0.244 | 63.188 | 8     | 23.2042 | 1.7   | 62.1316 | 0.335           | 1.14                 | 0.057 |
| 63    | 0     | 64.30  | 7     | 20.0712 | 65    | 0.244 | 64.188 | 8     | 23.2183 | 1.7   | 63.1127 | 0.335           | 1.14                 | 0.057 |
| 64    | 0     | 65.30  | 8     | 23.0373 | 66    | 0.244 | 65.188 | 8     | 23.2323 | 1.7   | 64.1316 | 0.335           | 1.14                 | 0.057 |
| 65    | 0     | 66.30  | 8     | 23.0513 | 67    | 0.244 | 66.188 | 8     | 23.2463 | 1.7   | 65.1133 | 0.335           | 1.15                 | 0.057 |
| 66    | 0     | 67.30  | 8     | 23.0654 | 68    | 0.244 | 67.188 | 8     | 23.2603 | 1.7   | 66.1317 | 0.336           | 1.15                 | 0.057 |
| 67    | 0     | 68.30  | 8     | 23.0794 | 69    | 0.244 | 68.188 | 9     | 26.2264 | 1.7   | 67.1139 | 0.336           | 1.15                 | 0.057 |
| 68    | 0     | 69.30  | 8     | 23.0934 | 70    | 0.244 | 69.188 | 9     | 26.2404 | 1.7   | 68.1317 | 0.336           | 1.15                 | 0.056 |
| 69    | 0     | 70.30  | 8     | 23.1074 | 71    | 0.244 | 70.188 | 9     | 26.2544 | 1.7   | 69.1144 | 0.336           | 1.15                 | 0.056 |
| 70    | 0     | 71.30  | 8     | 23.1214 | 72    | 0.244 | 71.188 | 9     | 26.2684 | 1.7   | 70.1318 | 0.336           | 1.15                 | 0.056 |
| 71    | 0     | 72.30  | 8     | 23.1354 | 73    | 0.244 | 72.188 | 9     | 26.2824 | 1.7   | 71.1149 | 0.336           | 1.15                 | 0.056 |
| 72    | 0     | 73.30  | 8     | 23.1494 | 74    | 0.244 | 73.188 | 9     | 26.2964 | 1.7   | 72.1318 | 0.336           | 1.15                 | 0.056 |
| 73    | 0     | 74.30  | 9     | 26.1155 | 75    | 0.244 | 74.188 | 9     | 26.3104 | 1.7   | 73.1154 | 0.336           | 1.15                 | 0.056 |
| 74    | 0     | 75.30  | 9     | 26.1295 | 76    | 0.244 | 75.188 | 9     | 26.3244 | 1.7   | 74.1318 | 0.336           | 1.15                 | 0.056 |

(续)

| $Z_1$ | $X_1$ | $d_{a1}$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $d_{a2}$ | $K_2$ | $W_{k2}$ | $d_p$ | $M$      | $\sin\alpha_p$ | $\varepsilon_a$ | $G_s$ |
|-------|-------|----------|-------|----------|-------|-------|----------|-------|----------|-------|----------|----------------|-----------------|-------|
| 75    | 0     | 76.30    | 9     | 26.1435  | 77    | 0.244 | 76.188   | 9     | 26.3384  | 1.7   | 75.1159  | 0.336          | 1.15            | 0.056 |
| 76    | 0     | 77.30    | 9     | 26.1575  | 78    | 0.244 | 77.188   | 10    | 29.3046  | 1.7   | 76.1319  | 0.336          | 1.15            | 0.056 |
| 77    | 0     | 78.30    | 9     | 26.1715  | 79    | 0.244 | 78.188   | 10    | 29.3186  | 1.7   | 77.1163  | 0.336          | 1.15            | 0.055 |
| 78    | 0     | 79.30    | 9     | 26.1855  | 80    | 0.244 | 79.188   | 10    | 29.3326  | 1.7   | 78.1319  | 0.337          | 1.15            | 0.055 |
| 79    | 0     | 80.30    | 9     | 26.1996  | 81    | 0.244 | 80.188   | 10    | 29.3466  | 1.7   | 79.1167  | 0.337          | 1.15            | 0.055 |
| 80    | 0     | 81.30    | 9     | 26.2136  | 82    | 0.244 | 81.188   | 10    | 29.3606  | 1.7   | 80.1320  | 0.337          | 1.15            | 0.055 |
| 81    | 0     | 82.30    | 9     | 26.2276  | 83    | 0.244 | 82.188   | 10    | 29.3746  | 1.7   | 81.1171  | 0.337          | 1.15            | 0.055 |
| 82    | 0     | 83.30    | 10    | 29.1937  | 84    | 0.244 | 83.188   | 10    | 29.8386  | 1.7   | 82.1320  | 0.337          | 1.15            | 0.055 |
| 83    | 0     | 84.30    | 10    | 29.2077  | 85    | 0.244 | 84.188   | 10    | 29.4026  | 1.7   | 83.1175  | 0.337          | 1.15            | 0.055 |
| 84    | 0     | 85.30    | 10    | 29.2217  | 86    | 0.244 | 85.188   | 10    | 29.4166  | 1.7   | 84.1320  | 0.337          | 1.15            | 0.055 |
| 85    | 0     | 86.30    | 10    | 29.2357  | 87    | 0.244 | 86.188   | 11    | 32.3828  | 1.7   | 85.1179  | 0.337          | 1.15            | 0.055 |
| 86    | 0     | 87.30    | 10    | 29.2497  | 88    | 0.244 | 87.188   | 11    | 32.3968  | 1.7   | 86.1320  | 0.337          | 1.15            | 0.055 |
| 87    | 0     | 88.30    | 10    | 29.2637  | 89    | 0.244 | 88.188   | 11    | 32.4108  | 1.7   | 87.1182  | 0.337          | 1.15            | 0.054 |
| 88    | 0     | 89.30    | 10    | 29.2777  | 90    | 0.244 | 89.188   | 11    | 32.4248  | 1.7   | 88.1321  | 0.337          | 1.15            | 0.054 |
| 89    | 0     | 90.30    | 10    | 29.2917  | 91    | 0.244 | 90.188   | 11    | 32.4388  | 1.7   | 89.1186  | 0.337          | 1.15            | 0.054 |
| 90    | 0     | 91.30    | 10    | 29.3057  | 92    | 0.244 | 91.188   | 11    | 32.4528  | 1.7   | 90.1321  | 0.337          | 1.15            | 0.054 |
| 91    | 0     | 92.30    | 11    | 32.2719  | 93    | 0.244 | 92.188   | 11    | 32.4668  | 1.7   | 91.1189  | 0.337          | 1.15            | 0.054 |
| 92    | 0     | 93.30    | 11    | 32.2859  | 94    | 0.244 | 93.188   | 11    | 32.4808  | 1.7   | 92.1321  | 0.337          | 1.15            | 0.054 |
| 93    | 0     | 94.30    | 11    | 32.2999  | 95    | 0.244 | 94.188   | 11    | 32.4948  | 1.7   | 93.1192  | 0.337          | 1.15            | 0.054 |
| 94    | 0     | 95.30    | 11    | 32.3139  | 96    | 0.244 | 95.188   | 12    | 35.4609  | 1.7   | 94.1321  | 0.337          | 1.15            | 0.054 |
| 95    | 0     | 96.30    | 11    | 32.3279  | 97    | 0.244 | 96.188   | 12    | 35.4750  | 1.7   | 95.1195  | 0.338          | 1.15            | 0.054 |
| 96    | 0     | 97.30    | 11    | 32.3419  | 98    | 0.244 | 97.188   | 12    | 35.4890  | 1.7   | 96.1322  | 0.338          | 1.15            | 0.054 |
| 97    | 0     | 98.30    | 11    | 32.3559  | 99    | 0.244 | 98.188   | 12    | 35.5030  | 1.7   | 97.1197  | 0.338          | 1.15            | 0.054 |
| 98    | 0     | 99.30    | 11    | 32.3699  | 100   | 0.244 | 99.188   | 12    | 35.5170  | 1.7   | 98.1322  | 0.338          | 1.15            | 0.054 |
| 99    | 0     | 100.30   | 11    | 32.3839  | 101   | 0.244 | 100.188  | 12    | 35.5310  | 1.7   | 99.1200  | 0.338          | 1.15            | 0.054 |
| 100   | 0     | 101.30   | 12    | 35.3501  | 102   | 0.244 | 101.188  | 12    | 35.5450  | 1.7   | 100.1322 | 0.338          | 1.15            | 0.053 |

三齿差内齿轮副几何参数

表 6

| 共同参数 | 齿 数 差       | 模 数 | 压力角        | 啮 合 角             | 中心距  | 齿顶高系数 |
|------|-------------|-----|------------|-------------------|------|-------|
|      | $Z_2 - Z_1$ | $m$ | $\alpha$   | $\alpha'$         | $a'$ | $ha$  |
|      | 3           | 1   | $20^\circ$ | $29.531393^\circ$ | 1.62 | 0.65  |

(毫米)

| 外 齿 轮  |                  |                       |             |                       | 内 齿 轮  |                  |                       |                  |                       |                  |             |                 | 重<br>合<br>度          | 齿<br>干<br>涉<br>重<br>验<br>算 |
|--------|------------------|-----------------------|-------------|-----------------------|--------|------------------|-----------------------|------------------|-----------------------|------------------|-------------|-----------------|----------------------|----------------------------|
| 齿<br>数 | 变<br>位<br>系<br>数 | 齿<br>顶<br>圆<br>直<br>径 | 跨<br>齿<br>数 | 公<br>法<br>线<br>长<br>度 | 齿<br>数 | 变<br>位<br>系<br>数 | 齿<br>顶<br>圆<br>直<br>径 | 跨<br>齿<br>槽<br>数 | 公<br>法<br>线<br>长<br>度 | 量<br>棒<br>直<br>径 | 跨<br>棒<br>距 |                 |                      |                            |
| $Z_1$  | $X_1$            | $d_{a1}$              | $K_1$       | $W_{k1}$              | $Z_2$  | $X_2$            | $d_{a2}$              | $K_2$            | $W_{k2}$              | $d_n$            | $M$         | $\sin \alpha_p$ | $\varepsilon_\alpha$ | $G_s$                      |
| 30     | 0                | 31.30                 | 4           | 10.7526               | 33     | 0.149            | 31.998                | 4                | 10.8966               | 1.7              | 30.8897     | 0.311           | 1.24                 | 0.056                      |
| 31     | 0                | 32.30                 | 4           | 10.7666               | 34     | 0.149            | 32.998                | 5                | 13.8627               | 1.7              | 31.9272     | 0.312           | 1.24                 | 0.056                      |
| 32     | 0                | 33.30                 | 4           | 10.7806               | 35     | 0.149            | 33.998                | 5                | 13.8767               | 1.7              | 32.8928     | 0.313           | 1.23                 | 0.056                      |
| 33     | 0                | 34.30                 | 4           | 10.7946               | 36     | 0.149            | 34.998                | 5                | 13.8907               | 1.7              | 33.9282     | 0.314           | 1.23                 | 0.056                      |
| 34     | 0                | 35.30                 | 4           | 10.8086               | 37     | 0.149            | 35.998                | 5                | 13.9047               | 1.7              | 34.8957     | 0.315           | 1.23                 | 0.056                      |
| 35     | 0                | 36.30                 | 4           | 10.8227               | 38     | 0.149            | 36.998                | 5                | 13.9187               | 1.7              | 35.9291     | 0.315           | 1.23                 | 0.056                      |
| 36     | 0                | 37.30                 | 4           | 10.8367               | 39     | 0.149            | 37.998                | 5                | 13.9327               | 1.7              | 36.8982     | 0.316           | 1.23                 | 0.056                      |
| 37     | 0                | 38.30                 | 5           | 13.8028               | 40     | 0.149            | 38.998                | 5                | 13.9467               | 1.7              | 37.9299     | 0.317           | 1.23                 | 0.055                      |
| 38     | 0                | 39.30                 | 5           | 13.8168               | 41     | 0.149            | 39.998                | 5                | 13.9607               | 1.7              | 38.9004     | 0.318           | 1.23                 | 0.056                      |
| 39     | 0                | 40.30                 | 5           | 13.8308               | 42     | 0.149            | 40.998                | 5                | 13.9747               | 1.7              | 39.9306     | 0.318           | 1.23                 | 0.056                      |
| 40     | 0                | 41.30                 | 5           | 13.8448               | 43     | 0.149            | 41.998                | 6                | 16.9409               | 1.7              | 40.9025     | 0.319           | 1.23                 | 0.056                      |
| 41     | 0                | 42.30                 | 5           | 13.8588               | 44     | 0.149            | 42.998                | 6                | 16.9549               | 1.7              | 41.9312     | 0.319           | 1.23                 | 0.056                      |
| 42     | 0                | 43.30                 | 5           | 13.8728               | 45     | 0.149            | 43.998                | 6                | 16.9689               | 1.7              | 42.9043     | 0.320           | 1.23                 | 0.056                      |
| 43     | 0                | 44.30                 | 5           | 13.8868               | 46     | 0.149            | 44.998                | 6                | 16.9829               | 1.7              | 43.9318     | 0.320           | 1.23                 | 0.056                      |
| 44     | 0                | 45.30                 | 5           | 13.9008               | 47     | 0.149            | 45.998                | 6                | 16.9969               | 1.7              | 44.9060     | 0.321           | 1.23                 | 0.055                      |
| 45     | 0                | 46.30                 | 5           | 13.9148               | 48     | 0.149            | 46.998                | 6                | 17.0109               | 1.7              | 45.9323     | 0.321           | 1.23                 | 0.055                      |
| 46     | 0                | 47.30                 | 6           | 16.8810               | 49     | 0.149            | 47.998                | 6                | 17.0249               | 1.7              | 46.9076     | 0.322           | 1.23                 | 0.055                      |
| 47     | 0                | 48.30                 | 6           | 16.8950               | 50     | 0.149            | 48.998                | 6                | 17.0389               | 1.7              | 47.9328     | 0.322           | 1.23                 | 0.055                      |
| 48     | 0                | 49.30                 | 6           | 16.9090               | 51     | 0.149            | 49.998                | 6                | 17.0529               | 1.7              | 48.9090     | 0.323           | 1.23                 | 0.055                      |
| 49     | 0                | 50.30                 | 6           | 16.9230               | 52     | 0.149            | 50.998                | 7                | 20.0191               | 1.7              | 49.9332     | 0.323           | 1.23                 | 0.055                      |
| 50     | 0                | 51.30                 | 6           | 16.9370               | 53     | 0.149            | 51.998                | 7                | 20.0331               | 1.7              | 50.9105     | 0.323           | 1.23                 | 0.055                      |
| 51     | 0                | 52.30                 | 6           | 16.9510               | 54     | 0.149            | 52.998                | 7                | 20.0471               | 1.7              | 51.9336     | 0.324           | 1.23                 | 0.055                      |
| 52     | 0                | 53.30                 | 6           | 16.9950               | 55     | 0.149            | 53.998                | 7                | 20.0611               | 1.7              | 52.9116     | 0.324           | 1.23                 | 0.055                      |
| 53     | 0                | 54.30                 | 6           | 16.9790               | 56     | 0.149            | 54.998                | 7                | 20.0751               | 1.7              | 53.9340     | 0.325           | 1.23                 | 0.055                      |
| 54     | 0                | 55.30                 | 6           | 16.9930               | 57     | 0.149            | 55.998                | 7                | 20.0891               | 1.7              | 54.9127     | 0.325           | 1.23                 | 0.055                      |
| 55     | 0                | 56.30                 | 7           | 19.9592               | 58     | 0.149            | 56.998                | 7                | 20.1031               | 1.7              | 55.9344     | 0.325           | 1.23                 | 0.055                      |
| 56     | 0                | 57.30                 | 7           | 19.9732               | 59     | 0.149            | 57.998                | 7                | 20.1171               | 1.7              | 56.9137     | 0.325           | 1.23                 | 0.055                      |
| 57     | 0                | 58.30                 | 7           | 19.9872               | 60     | 0.149            | 58.998                | 7                | 20.1311               | 1.7              | 57.9347     | 0.326           | 1.23                 | 0.055                      |

(续)

| $Z_1$ | $X_1$ | $d_{a1}$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $d_{a2}$ | $K_2$ | $W_{k2}$ | $d_p$ | $M$     | $\sin \alpha_p$ | $\varepsilon_\alpha$ | $G_s$ |
|-------|-------|----------|-------|----------|-------|-------|----------|-------|----------|-------|---------|-----------------|----------------------|-------|
| 58    | 0     | 59.30    | 7     | 20.0012  | 61    | 0.149 | 59.998   | 8     | 23.0972  | 1.7   | 58.9147 | 0.326           | 1.23                 | 0.055 |
| 59    | 0     | 60.30    | 7     | 20.0152  | 62    | 0.149 | 60.998   | 8     | 23.1113  | 1.7   | 59.9350 | 0.326           | 1.23                 | 0.055 |
| 60    | 0     | 61.30    | 7     | 20.0292  | 63    | 0.149 | 61.998   | 8     | 23.1253  | 1.7   | 60.9156 | 0.327           | 1.23                 | 0.056 |
| 61    | 0     | 62.30    | 7     | 20.0432  | 64    | 0.149 | 62.998   | 8     | 23.1393  | 1.7   | 61.9353 | 0.327           | 1.23                 | 0.055 |
| 62    | 0     | 63.30    | 7     | 20.0572  | 65    | 0.149 | 63.998   | 8     | 23.1533  | 1.7   | 62.9165 | 0.327           | 1.23                 | 0.055 |
| 63    | 0     | 64.30    | 7     | 20.0712  | 66    | 0.149 | 64.998   | 8     | 23.1673  | 1.7   | 63.9355 | 0.327           | 1.23                 | 0.055 |
| 64    | 0     | 65.30    | 8     | 23.0373  | 67    | 0.149 | 65.998   | 8     | 23.1813  | 1.7   | 64.9173 | 0.328           | 1.23                 | 0.054 |
| 65    | 0     | 66.30    | 8     | 23.0513  | 68    | 0.149 | 66.998   | 8     | 23.1953  | 1.7   | 65.9358 | 0.328           | 1.23                 | 0.054 |
| 66    | 0     | 67.30    | 8     | 23.0654  | 69    | 0.149 | 67.998   | 8     | 23.2093  | 1.7   | 66.9181 | 0.328           | 1.23                 | 0.054 |
| 67    | 0     | 68.30    | 8     | 23.0794  | 70    | 0.149 | 68.998   | 9     | 26.1754  | 1.7   | 67.9360 | 0.328           | 1.23                 | 0.054 |
| 68    | 0     | 69.30    | 8     | 23.0934  | 71    | 0.149 | 69.998   | 9     | 26.1894  | 1.7   | 68.9188 | 0.328           | 1.23                 | 0.054 |
| 69    | 0     | 70.30    | 8     | 23.1074  | 72    | 0.149 | 70.998   | 9     | 26.2034  | 1.7   | 69.9362 | 0.329           | 1.23                 | 0.054 |
| 70    | 0     | 71.30    | 8     | 23.1214  | 73    | 0.149 | 71.998   | 9     | 26.2174  | 1.7   | 70.9195 | 0.329           | 1.23                 | 0.054 |
| 71    | 0     | 72.30    | 8     | 23.1354  | 74    | 0.149 | 72.998   | 9     | 26.2314  | 1.7   | 71.9364 | 0.329           | 1.23                 | 0.054 |
| 72    | 0     | 73.30    | 8     | 23.1494  | 75    | 0.149 | 73.998   | 9     | 26.2455  | 1.7   | 72.9201 | 0.329           | 1.23                 | 0.054 |
| 73    | 0     | 74.30    | 9     | 26.1155  | 76    | 0.149 | 74.998   | 9     | 26.2595  | 1.7   | 73.9366 | 0.329           | 1.23                 | 0.054 |
| 74    | 0     | 75.30    | 9     | 26.1295  | 77    | 0.149 | 75.998   | 9     | 26.2735  | 1.7   | 74.9207 | 0.330           | 1.23                 | 0.054 |
| 75    | 0     | 76.30    | 9     | 26.1435  | 78    | 0.149 | 76.998   | 9     | 26.2875  | 1.7   | 75.9368 | 0.330           | 1.23                 | 0.054 |
| 76    | 0     | 77.30    | 9     | 26.1575  | 79    | 0.149 | 77.998   | 10    | 29.2536  | 1.7   | 76.9213 | 0.330           | 1.23                 | 0.054 |
| 77    | 0     | 78.30    | 9     | 26.1715  | 80    | 0.149 | 78.998   | 10    | 29.2676  | 1.7   | 77.9369 | 0.330           | 1.23                 | 0.054 |
| 78    | 0     | 79.30    | 9     | 26.1855  | 81    | 0.149 | 79.998   | 10    | 29.2816  | 1.7   | 78.9219 | 0.330           | 1.23                 | 0.054 |
| 79    | 0     | 80.30    | 9     | 26.1996  | 82    | 0.149 | 80.998   | 10    | 29.2956  | 1.7   | 79.9371 | 0.330           | 1.23                 | 0.054 |
| 80    | 0     | 81.30    | 9     | 26.2136  | 83    | 0.149 | 81.998   | 10    | 29.3096  | 1.7   | 80.9224 | 0.330           | 1.23                 | 0.054 |
| 81    | 0     | 82.30    | 9     | 26.2276  | 84    | 0.149 | 82.998   | 10    | 29.3236  | 1.7   | 81.9373 | 0.331           | 1.23                 | 0.054 |
| 82    | 0     | 83.30    | 10    | 29.1937  | 85    | 0.149 | 83.998   | 10    | 29.3376  | 1.7   | 82.9229 | 0.331           | 1.23                 | 0.054 |
| 83    | 0     | 84.30    | 10    | 29.2077  | 86    | 0.149 | 84.998   | 10    | 29.3516  | 1.7   | 83.9374 | 0.331           | 1.23                 | 0.054 |
| 84    | 0     | 85.30    | 10    | 29.2217  | 87    | 0.149 | 85.998   | 10    | 29.3657  | 1.7   | 84.9234 | 0.331           | 1.23                 | 0.054 |
| 85    | 0     | 86.30    | 10    | 29.2357  | 88    | 0.149 | 86.998   | 11    | 32.3318  | 1.7   | 85.9375 | 0.331           | 1.23                 | 0.054 |
| 86    | 0     | 87.30    | 10    | 29.2497  | 89    | 0.149 | 87.998   | 11    | 32.3458  | 1.7   | 86.9238 | 0.331           | 1.23                 | 0.054 |
| 87    | 0     | 88.30    | 10    | 29.2637  | 90    | 0.149 | 88.998   | 11    | 32.3598  | 1.7   | 87.9377 | 0.331           | 1.23                 | 0.054 |
| 88    | 0     | 89.30    | 10    | 29.2777  | 91    | 0.149 | 89.998   | 11    | 32.3738  | 1.7   | 88.9242 | 0.332           | 1.23                 | 0.053 |
| 89    | 0     | 90.30    | 10    | 29.2917  | 92    | 0.149 | 90.998   | 11    | 32.3878  | 1.7   | 89.9378 | 0.332           | 1.23                 | 0.053 |
| 90    | 0     | 91.30    | 11    | 32.3057  | 93    | 0.149 | 91.998   | 11    | 32.4018  | 1.7   | 90.9246 | 0.332           | 1.23                 | 0.053 |
| 91    | 0     | 92.30    | 11    | 32.2719  | 94    | 0.149 | 92.998   | 11    | 32.4158  | 1.7   | 91.9379 | 0.332           | 1.23                 | 0.053 |

(续)

| $Z_1$ | $X_1$ | $d_{a1}$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $d_{a2}$ | $K_2$ | $W_{k2}$ | $d_p$ | $M$      | $\sin \alpha_p$ | $\varepsilon \alpha$ | $G_s$ |
|-------|-------|----------|-------|----------|-------|-------|----------|-------|----------|-------|----------|-----------------|----------------------|-------|
| 92    | 0     | 93.30    | 11    | 32.2859  | 95    | 0.149 | 93.998   | 11    | 32.4298  | 1.7   | 92.9250  | 0.332           | 1.23                 | 0.053 |
| 93    | 0     | 94.30    | 11    | 32.2999  | 96    | 0.149 | 94.998   | 11    | 32.4438  | 1.7   | 93.9380  | 0.332           | 1.23                 | 0.053 |
| 94    | 0     | 95.30    | 11    | 32.3139  | 97    | 0.149 | 95.998   | 12    | 35.4100  | 1.7   | 94.9254  | 0.332           | 1.23                 | 0.053 |
| 95    | 0     | 96.30    | 11    | 32.3279  | 98    | 0.149 | 96.998   | 12    | 35.4240  | 1.7   | 95.9382  | 0.332           | 1.23                 | 0.053 |
| 96    | 0     | 97.30    | 11    | 32.3419  | 99    | 0.149 | 97.998   | 12    | 35.4380  | 1.7   | 96.9258  | 0.332           | 1.23                 | 0.053 |
| 97    | 0     | 98.30    | 11    | 32.3559  | 100   | 0.149 | 98.998   | 12    | 35.4520  | 1.7   | 97.9383  | 0.332           | 1.23                 | 0.053 |
| 98    | 0     | 99.30    | 11    | 32.3699  | 101   | 0.149 | 99.998   | 12    | 35.4660  | 1.7   | 98.9261  | 0.333           | 1.23                 | 0.053 |
| 99    | 0     | 100.30   | 11    | 32.3839  | 102   | 0.149 | 100.998  | 12    | 35.4800  | 1.7   | 99.9334  | 0.333           | 1.23                 | 0.053 |
| 100   | 0     | 101.30   | 12    | 35.3501  | 103   | 0.149 | 101.998  | 12    | 35.4940  | 1.7   | 100.9265 | 0.333           | 1.23                 | 0.053 |

四齿差内齿轮副几何参数

表 7

| 共同参数 | 齿数差         | 模数  | 压力角        | 啮合角               | 中心距  | 齿顶高系数 |
|------|-------------|-----|------------|-------------------|------|-------|
|      | $Z_2 - Z_1$ | $m$ | $\alpha$   | $\alpha'$         | $a'$ | $ha$  |
|      | 4           | 1   | $20^\circ$ | $25.371225^\circ$ | 2.08 | 0.65  |

(毫米)

| 外 齿 轮 |       |          |       |          | 内 齿 轮 |       |          |       |          |       |         |                 | 重 合 度                | 齿 干 涉 验 算 |
|-------|-------|----------|-------|----------|-------|-------|----------|-------|----------|-------|---------|-----------------|----------------------|-----------|
| 齿数    | 变位系数  | 齿顶圆直径    | 跨齿数   | 公法线长度    | 齿数    | 变位系数  | 齿顶圆直径    | 跨齿数   | 公法线长度    | 量棒直径  | 跨棒距     |                 |                      |           |
| $Z_1$ | $x_1$ | $d_{a1}$ | $k_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $d_{a2}$ | $k_2$ | $W_{k2}$ | $d_p$ | $M$     | $\sin \alpha_p$ | $\varepsilon \alpha$ | $G_s$     |
| 30    | 0     | 31.30    | 4     | 10.7526  | 34    | 0.091 | 32.832   | 4     | 10.8709  | 1.7   | 31.7976 | 0.300           | 1.29                 | 0.070     |
| 31    | 0     | 32.30    | 4     | 10.7636  | 35    | 0.091 | 33.882   | 5     | 13.8370  | 1.7   | 32.7639 | 0.302           | 1.29                 | 0.071     |
| 32    | 0     | 33.30    | 4     | 10.7806  | 36    | 0.091 | 34.882   | 5     | 13.8510  | 1.7   | 33.7996 | 0.303           | 1.28                 | 0.071     |
| 33    | 0     | 34.30    | 4     | 10.7948  | 37    | 0.091 | 35.882   | 5     | 13.8650  | 1.7   | 34.7676 | 0.304           | 1.28                 | 0.071     |
| 34    | 0     | 35.30    | 4     | 10.8086  | 38    | 0.091 | 36.882   | 5     | 13.8790  | 1.7   | 35.8013 | 0.306           | 1.23                 | 0.071     |
| 35    | 0     | 36.30    | 4     | 10.8227  | 39    | 0.091 | 37.882   | 5     | 13.8931  | 1.7   | 36.7709 | 0.307           | 1.23                 | 0.071     |
| 36    | 0     | 37.30    | 4     | 10.8367  | 40    | 0.091 | 38.882   | 5     | 13.9071  | 1.7   | 37.8028 | 0.308           | 1.23                 | 0.072     |
| 37    | 0     | 38.30    | 5     | 13.8028  | 41    | 0.091 | 39.882   | 5     | 13.9211  | 1.7   | 38.7738 | 0.309           | 1.23                 | 0.072     |
| 38    | 0     | 39.30    | 5     | 13.8168  | 42    | 0.091 | 40.882   | 5     | 13.9351  | 1.7   | 39.8042 | 0.309           | 1.23                 | 0.072     |
| 39    | 0     | 40.30    | 5     | 13.8308  | 43    | 0.091 | 41.882   | 5     | 13.9491  | 1.7   | 40.7764 | 0.310           | 1.23                 | 0.072     |
| 40    | 0     | 41.30    | 5     | 13.8448  | 44    | 0.091 | 42.882   | 6     | 16.9152  | 1.7   | 41.8054 | 0.311           | 1.27                 | 0.072     |

(续)

| $Z_1$ | $X_1$ | $da_1$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $da_2$ | $k_2$ | $W_{k2}$ | $d_p$ | $M$     | $\sin \alpha_p$ | $\varepsilon_\alpha$ | $G_s$ |
|-------|-------|--------|-------|----------|-------|-------|--------|-------|----------|-------|---------|-----------------|----------------------|-------|
| 41    | 0     | 42.30  | 5     | 13.8588  | 45    | 0.091 | 43.882 | 6     | 16.9292  | 1.7   | 42.7788 | 0.312           | 1.27                 | 0.072 |
| 42    | 0     | 43.30  | 5     | 13.8728  | 46    | 0.091 | 44.882 | 6     | 16.9432  | 1.7   | 43.8065 | 0.313           | 1.27                 | 0.072 |
| 43    | 0     | 44.30  | 5     | 13.8868  | 47    | 0.091 | 45.882 | 6     | 16.9572  | 1.7   | 44.7810 | 0.313           | 1.27                 | 0.072 |
| 44    | 0     | 45.30  | 5     | 13.9008  | 48    | 0.091 | 46.882 | 6     | 16.9712  | 1.7   | 45.8074 | 0.314           | 1.27                 | 0.072 |
| 45    | 0     | 46.30  | 5     | 13.9148  | 49    | 0.091 | 47.882 | 6     | 16.9852  | 1.7   | 46.7830 | 0.315           | 1.27                 | 0.072 |
| 46    | 0     | 47.30  | 6     | 16.8810  | 50    | 0.091 | 48.882 | 6     | 16.9992  | 1.7   | 47.8083 | 0.315           | 1.27                 | 0.072 |
| 47    | 0     | 48.30  | 6     | 16.8950  | 51    | 0.091 | 49.882 | 6     | 17.0133  | 1.7   | 48.7848 | 0.316           | 1.27                 | 0.072 |
| 48    | 0     | 49.30  | 6     | 16.9090  | 52    | 0.091 | 50.882 | 6     | 17.0273  | 1.7   | 49.8092 | 0.316           | 1.27                 | 0.072 |
| 49    | 0     | 50.30  | 6     | 16.9230  | 53    | 0.091 | 51.882 | 7     | 19.9934  | 1.7   | 50.7865 | 0.317           | 1.27                 | 0.073 |
| 50    | 0     | 51.30  | 6     | 16.9370  | 54    | 0.091 | 52.882 | 7     | 20.0074  | 1.7   | 51.8099 | 0.317           | 1.27                 | 0.073 |
| 51    | 0     | 52.30  | 6     | 16.9510  | 55    | 0.091 | 53.882 | 7     | 20.0214  | 1.7   | 52.7880 | 0.318           | 1.27                 | 0.073 |
| 52    | 0     | 53.30  | 6     | 16.9650  | 56    | 0.091 | 54.882 | 7     | 20.0354  | 1.7   | 53.8106 | 0.318           | 1.27                 | 0.073 |
| 53    | 0     | 54.30  | 6     | 16.9790  | 57    | 0.091 | 55.882 | 7     | 20.0494  | 1.7   | 54.7895 | 0.319           | 1.27                 | 0.073 |
| 54    | 0     | 55.30  | 6     | 16.9930  | 58    | 0.091 | 56.882 | 7     | 20.0634  | 1.7   | 55.8112 | 0.319           | 1.27                 | 0.073 |
| 55    | 0     | 56.30  | 7     | 19.9592  | 59    | 0.091 | 57.882 | 7     | 20.0774  | 1.7   | 56.7908 | 0.320           | 1.27                 | 0.073 |
| 56    | 0     | 57.30  | 7     | 19.9732  | 60    | 0.091 | 58.882 | 7     | 20.0914  | 1.7   | 57.8118 | 0.320           | 1.27                 | 0.073 |
| 57    | 0     | 58.30  | 7     | 19.9872  | 61    | 0.091 | 59.882 | 7     | 20.1054  | 1.7   | 58.7920 | 0.320           | 1.27                 | 0.073 |
| 58    | 0     | 59.30  | 7     | 20.0012  | 62    | 0.091 | 60.882 | 8     | 23.0716  | 1.7   | 59.8124 | 0.321           | 1.27                 | 0.073 |
| 59    | 0     | 60.30  | 7     | 20.0152  | 63    | 0.091 | 61.882 | 8     | 23.0856  | 1.7   | 60.7932 | 0.321           | 1.27                 | 0.073 |
| 60    | 0     | 61.30  | 7     | 20.0292  | 64    | 0.091 | 62.882 | 8     | 23.0996  | 1.7   | 61.8129 | 0.322           | 1.27                 | 0.073 |
| 61    | 0     | 62.30  | 7     | 20.0432  | 65    | 0.091 | 63.882 | 8     | 23.1136  | 1.7   | 62.7943 | 0.322           | 1.27                 | 0.073 |
| 62    | 0     | 63.30  | 7     | 20.0572  | 66    | 0.091 | 64.882 | 8     | 23.1276  | 1.7   | 63.8133 | 0.322           | 1.27                 | 0.073 |
| 63    | 0     | 64.30  | 7     | 20.0712  | 67    | 0.091 | 65.882 | 8     | 23.1416  | 1.7   | 64.7953 | 0.323           | 1.27                 | 0.073 |
| 64    | 0     | 65.30  | 8     | 23.0373  | 68    | 0.091 | 66.882 | 8     | 23.1556  | 1.7   | 65.8138 | 0.323           | 1.27                 | 0.073 |
| 65    | 0     | 66.30  | 8     | 23.0513  | 69    | 0.091 | 67.882 | 8     | 23.1696  | 1.7   | 66.7963 | 0.323           | 1.27                 | 0.073 |
| 66    | 0     | 67.30  | 8     | 23.0654  | 70    | 0.091 | 68.882 | 8     | 23.1836  | 1.7   | 67.8142 | 0.323           | 1.27                 | 0.073 |
| 67    | 0     | 68.30  | 8     | 23.0794  | 71    | 0.091 | 69.882 | 9     | 26.1498  | 1.7   | 68.7972 | 0.324           | 1.27                 | 0.073 |
| 68    | 0     | 69.30  | 8     | 23.0934  | 72    | 0.091 | 70.882 | 9     | 26.1638  | 1.7   | 69.8146 | 0.324           | 1.27                 | 0.073 |
| 69    | 0     | 70.30  | 8     | 23.1074  | 73    | 0.091 | 71.882 | 9     | 26.1778  | 1.7   | 70.7980 | 0.324           | 1.26                 | 0.073 |
| 70    | 0     | 71.30  | 8     | 23.1214  | 74    | 0.091 | 72.882 | 9     | 26.1918  | 1.7   | 71.8150 | 0.324           | 1.26                 | 0.073 |
| 71    | 0     | 72.30  | 8     | 23.1354  | 75    | 0.091 | 73.882 | 9     | 26.2058  | 1.7   | 72.7988 | 0.325           | 1.26                 | 0.073 |
| 72    | 0     | 73.30  | 8     | 23.1494  | 76    | 0.091 | 74.882 | 9     | 26.2198  | 1.7   | 73.8153 | 0.325           | 1.26                 | 0.073 |
| 73    | 0     | 74.30  | 9     | 26.1155  | 77    | 0.091 | 75.882 | 9     | 26.2338  | 1.7   | 74.7996 | 0.325           | 1.26                 | 0.073 |
| 74    | 0     | 75.30  | 9     | 26.1295  | 78    | 0.091 | 76.882 | 9     | 26.2478  | 1.7   | 75.8157 | 0.325           | 1.26                 | 0.073 |

(续)

| $Z_1$ | $X_1$ | $d_{a1}$ | $K_1$ | $W_{k1}$ | $Z_2$ | $X_2$ | $d_{a2}$ | $K_2$ | $W_{k2}$ | $d_p$ | $M$      | $\sin \alpha_p$ | $\varepsilon \alpha$ | $G_s$ |
|-------|-------|----------|-------|----------|-------|-------|----------|-------|----------|-------|----------|-----------------|----------------------|-------|
| 75    | 0     | 76.30    | 9     | 26.1435  | 79    | 0.091 | 77.882   | 9     | 26.2618  | 1.7   | 76.8003  | 0.326           | 1.26                 | 0.073 |
| 76    | 0     | 77.30    | 9     | 26.1575  | 80    | 0.091 | 78.882   | 10    | 29.2279  | 1.7   | 77.8160  | 0.326           | 1.26                 | 0.073 |
| 77    | 0     | 78.30    | 9     | 26.1715  | 81    | 0.091 | 79.882   | 10    | 29.2419  | 1.7   | 78.8010  | 0.326           | 1.26                 | 0.073 |
| 78    | 0     | 79.30    | 9     | 26.1855  | 82    | 0.091 | 80.882   | 10    | 29.2560  | 1.7   | 79.8163  | 0.326           | 1.26                 | 0.073 |
| 79    | 0     | 80.30    | 9     | 26.1996  | 83    | 0.091 | 81.882   | 10    | 29.2700  | 1.7   | 80.8016  | 0.326           | 1.26                 | 0.073 |
| 80    | 0     | 81.30    | 9     | 26.2136  | 84    | 0.091 | 82.882   | 10    | 29.2840  | 1.7   | 81.8165  | 0.327           | 1.26                 | 0.073 |
| 81    | 0     | 82.30    | 9     | 26.2276  | 85    | 0.091 | 83.882   | 10    | 29.2980  | 1.7   | 82.8022  | 0.327           | 1.26                 | 0.073 |
| 82    | 0     | 83.30    | 10    | 29.1937  | 86    | 0.091 | 84.882   | 10    | 29.3120  | 1.7   | 83.8168  | 0.327           | 1.26                 | 0.073 |
| 83    | 0     | 84.30    | 10    | 29.2077  | 87    | 0.091 | 85.882   | 10    | 29.3260  | 1.7   | 84.8028  | 0.327           | 1.26                 | 0.073 |
| 84    | 0     | 85.30    | 10    | 29.2217  | 88    | 0.091 | 86.882   | 10    | 29.3400  | 1.7   | 85.8171  | 0.327           | 1.26                 | 0.073 |
| 85    | 0     | 86.30    | 10    | 29.2357  | 89    | 0.091 | 87.882   | 11    | 32.3061  | 1.7   | 86.8034  | 0.328           | 1.26                 | 0.073 |
| 86    | 0     | 87.30    | 10    | 29.2497  | 90    | 0.091 | 88.882   | 11    | 32.3201  | 1.7   | 87.8173  | 0.328           | 1.26                 | 0.073 |
| 87    | 0     | 88.30    | 10    | 29.2637  | 91    | 0.091 | 89.882   | 11    | 32.3341  | 1.7   | 88.8039  | 0.328           | 1.26                 | 0.073 |
| 88    | 0     | 89.30    | 10    | 29.2777  | 92    | 0.091 | 90.882   | 11    | 32.3481  | 1.7   | 89.8175  | 0.328           | 1.26                 | 0.073 |
| 89    | 0     | 90.30    | 10    | 29.2917  | 93    | 0.091 | 91.882   | 11    | 32.3621  | 1.7   | 90.8044  | 0.328           | 1.26                 | 0.073 |
| 90    | 0     | 91.30    | 10    | 29.3057  | 94    | 0.091 | 92.882   | 11    | 32.3761  | 1.7   | 91.8177  | 0.328           | 1.26                 | 0.073 |
| 91    | 0     | 92.30    | 11    | 32.2719  | 95    | 0.091 | 93.882   | 11    | 32.3902  | 1.7   | 92.8049  | 0.329           | 1.26                 | 0.073 |
| 92    | 0     | 93.30    | 11    | 32.2859  | 96    | 0.091 | 94.882   | 11    | 32.4042  | 1.7   | 93.8180  | 0.329           | 1.26                 | 0.073 |
| 93    | 0     | 94.30    | 11    | 32.2999  | 97    | 0.091 | 95.882   | 11    | 32.4182  | 1.7   | 94.8054  | 0.329           | 1.26                 | 0.073 |
| 94    | 0     | 95.30    | 11    | 32.3139  | 98    | 0.091 | 96.882   | 12    | 35.3843  | 1.7   | 95.8182  | 0.329           | 1.26                 | 0.073 |
| 95    | 0     | 96.30    | 11    | 32.3279  | 99    | 0.091 | 97.882   | 12    | 35.3983  | 1.7   | 96.8059  | 0.329           | 1.26                 | 0.073 |
| 96    | 0     | 97.30    | 11    | 32.3419  | 100   | 0.091 | 98.882   | 12    | 35.4123  | 1.7   | 97.8184  | 0.329           | 1.26                 | 0.072 |
| 97    | 0     | 98.30    | 11    | 32.3559  | 101   | 0.091 | 99.882   | 12    | 35.4263  | 1.7   | 98.8063  | 0.329           | 1.26                 | 0.072 |
| 98    | 0     | 99.30    | 11    | 32.3699  | 102   | 0.091 | 100.882  | 12    | 35.4403  | 1.7   | 99.8185  | 0.330           | 1.26                 | 0.072 |
| 99    | 0     | 100.30   | 11    | 32.3839  | 103   | 0.091 | 101.882  | 12    | 35.4543  | 1.7   | 100.8067 | 0.330           | 1.26                 | 0.072 |
| 100   | 0     | 101.30   | 12    | 35.3501  | 104   | 0.091 | 102.882  | 12    | 35.4683  | 1.7   | 101.8187 | 0.330           | 1.26                 | 0.072 |

### 三、结 束 语

由于本文中采用小的外齿轮变位系数和短的齿顶高系数相结合的方法, 不仅能使重合度增大, 并能使啮合角显著降低; 现以一齿差来比较, 表4中的啮合角比日本两角宗晴〔6〕的小 $8^{\circ}$ 多, 比机械工程手册〔9〕中的数据小 $3^{\circ}$ 。从而可降低转臂轴承上的载荷, 提高转臂轴承的寿命。

在拟订参数表时, 为了便于偏心轴的制造和适用于N-N型减速器, 在表4~7中分别采用同一的中心距; 因此表中采用的啮合角并非最小值, 但所增大的量不大, 对转臂轴承上作用力的影响不大。

由于选择的外齿轮变位系数较小, 可避免内齿轮齿根和外齿轮齿顶间顶隙的过小, 所以在设计少齿差内齿轮副和选用正常齿高的内齿轮插齿刀时, 不需进行顶隙的验算工作。

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