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弧齿锥齿轮在土机床及洋机床 加工的两种调整计算卡介绍

上海第一机床厂资料室

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Y3150 弧齿锥齿轮在土磨齿机
(螺旋伞齿轮铣具) 加工计算书

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计算项目：

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2. 刀盘参数的计算
3. 刀盘调整座标位置计算
4. 测量齿规尺寸的计算
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Y3150-500 滚齿机弧齿锥齿轮主要参数表

零件号	模数	齿数	螺旋角	螺旋方向	压力角	节锥角	齿根角	外 径	节径	备注
31232	3.5	24	35°	右	20°	45°	3°26'	88.06	84	
31213	3.5	24	35°	左	20°	45°	3°26'	88.06	84	
52205	3.5	17	35°	左	20°	45°	4°51'	63.56	59.5	
31208	3.5	17	35°	右	20°	45°	4°51'	63.56	59.5	
31210	3.5	20	35°	右	20°	45°	4°8'	74.06	70	
31202	3.5	20	35°	左	20°	45°	4°8'	74.06	70	

Y3150 滚齿机用螺旋伞齿轮铣刀盘数据

刀具编号	零件号	用途	刀盘块 体厚度		刀垫厚度		基淮距离		形成直径		刀 刃 角		刀顶 距 W	刀尖 宽 f	备 注
			A	K	Be	Bi	be	bi	De	Dj	α_e	α_i			
Y3150-Cl-6	31212右	粗切	126	4.69	4.005		4.92		153.23		18°		0.83	0.51	右旋 刀盘
	31213左					2.035		6.06		151.57		22°			
Y3150-Cl-7	31212右	精切	126	4.69	4.38		4.92		153.98		18°		1.58	1.02	左旋 刀盘
	31212左					1.66		6.06		150.82		22°			
Y3150-Cl-8 Y3150-Cl-9	31212右	精切	126	4.69	2.045		4.92		149.31		18°			0.51	右旋 刀盘
	31208左					3.995		6.06		155.49		22°			
Y3150-Cl-10	52205右	粗切	66	2.38	5.00		4.48		89.72		17°10'		0.82	0.51	右旋 刀盘
	31208左					3.42		5.24		88.08		22°50'			
Y3150-Cl-11	52205右	精切	66	2.38	5.375		4.48		90.47		17°10'		1.57	1.02	左旋 刀盘
	31208左					3.045		5.24		87.33		22°50'			
Y3150-Cl-12 Y3150-Cl-13	31208右	精切	66	2.38	1.31		4.48		82.34		17°10'			0.51	右旋 刀盘
	31202左					7.11		5.24		95.46		22°50'			
Y3150-Cl-14	31210右	粗切	66	2.38	5.025		4.48		89.77		17°35'		0.87	0.51	右旋 刀盘
	31202左					3.395		5.24		88.03		22°25'			
Y3150-Cl-15	31210右	精切	66	2.38	5.40		4.48		90.52		17°35'		1.62	1.02	左旋 刀盘
	31202左					3.02		5.24		87.28		22°25'			
Y3150-Cl-16 Y3150-Cl-17	31202右	精切	66	2.38	1.835		4.48		83.39		17°35'			0.51	右旋 刀盘
	31202左					6.585		5.24		94.41		22°25'			

Y3150-500 毫米滚齿机所用垫圈 (理论计算)

件 号	α	安装距 L_1	齿轮基距 L_2	垫圈厚度 H	对刀架垫圈厚度 L_4
Y3150-31212	45°	124.94	53	71.24	76.20
Y3150-31213	45°	124.94	53	72.26/71.62	76.20
Y3150-52205	45°	124.94	45	79.94	76.20
Y3150-31208	45°	124.94	52.5	73.333/71.633	76.20
Y3150-31210	45°	124.94	50	74.94	76.20
Y3150-31202	45°	124.94	50	76.56/73.32	76.20

变换齿轮 标准件 D521 $M = 2.25$ $d_A = 30$
 $Z = *34, *35, *38, *39, *40, *43, 45, *50, *50, *55, *60, *62,$
 $65, 65, *70, *74, *80, 80, 85, 92, 98, *100$

需新添者 $Z^* = *75, *60, *71$

以上齿轮齿数凡标有符号 * 者, 为本产品所需要齿轮, 必须据此整理制造

螺伞齿铣齿心轴编号:

Y3150-B1-11	Y3150-31212
Y3150-B1-12	Y3150-31213
Y3150-B1-13	Y3150-52205
Y3150-B1-14	Y3150-31208
Y3150-B1-15	Y3150-31210
Y3150-B1-16	Y3150-31202

计算举例：3150 < $\frac{52205}{31208}$ 弧齿锥齿轮切削刀盘的计算

(一) 齿轮几何参数的计算

1. 小齿轮齿数 $z_{\text{III}} = 17$ Y3150-31208 左
2. 大齿轮齿数 $z_K = 17$ Y3150-52205 右
3. 传动比 $i = \frac{z_K}{z_{\text{III}}} = 1$
4. 高度修正系数 $\xi = 0$ (表一)
5. 切向修正系数 $\tau = 0$ (表四)
6. 径向间隙系数 $K_c = 0.2$ 齿高系数 $f = 0.82$ (表十)
7. 啮合角 $\alpha = 20^\circ$
8. 螺旋角 $\beta = 35^\circ$
9. 轴间角 $\delta = 90^\circ$
10. 平齿轮齿数 $z_c = \sqrt{z_{\text{III}}^2 + z_K^2} = \sqrt{17^2 + 17^2} = 24.04163$
11. 齿厚系数 $C_s = 1.571 + 0.888\xi + \tau = 1.571$
12. 模数 $M = 3.5$
13. 节锥母线长度 $L_e = 0.5 m z_c = 0.5 \times 3.5 \times 24.04163 = 42.0729$
14. 轮缘宽度 $B = 15$
15. 工作深度 $h_3 = 1.64 m = 1.64 \times 3.5 = 5.74$
16. 径向间隙 $c = K_c m = 0.2 \times 3.5 = 0.7$
17. 齿高 $h = h_3 + c = 5.74 + 0.7 = 6.44$
18. 周节 $t = M\pi = 3.5 \times 3.1416 = 10.9956$
19. 节圆直径 $d_{\text{III}} = d_K = z_{\text{III}} m = 17 \times 3.5 = 59.5$
20. 齿顶高 $h_{\Gamma\text{III}} = h_{\Gamma K} = (0.82 + \xi) m = 0.82 \times 3.5 = 2.87$
21. 齿根高 $h_{H\text{III}} = h_{HK} = h - h_{\Gamma\text{III}} = 6.44 - 2.87 = 3.57$
22. 节锥角 $\varphi_{\text{III}} = \varphi_K = \text{tg}^{-1} \frac{z_{\text{III}}}{z_K} = \text{tg}^{-1} 1 = 45^\circ$
23. 节锥角的三角函数 $\sin \varphi_{\text{III}} = \cos \varphi_K = \sin 45^\circ = 0.70711$

24. 齿根角 $\gamma_{\text{III}} = \gamma_K = \text{tg}^{-1} \frac{h_{\text{HIII}}}{L_e} = \text{tg}^{-1} \frac{3.57}{42.0729} = 4^\circ 51'$
25. 外锥角 $\varphi_{e\text{III}} = \varphi_{eK} = 45^\circ + 4^\circ 51' = 49^\circ 51'$
26. 内锥角 $\varphi_{i\text{III}} = \varphi_{iK} = 45^\circ - 4^\circ 51' = 40^\circ 09'$
27. 外径 $d_{e\text{III}} = d_{eK} = d_{\text{III}} + 2h_{\text{rIII}} \cos \varphi_{\text{III}}$
 $= 59.5 + 2 \times 2.87 \times 0.70711 = 63.5588$
28. 锥顶至轮缘距离 $A'_{\text{MIII}} = A'_{\text{MK}} = 0.5d_K - h_{\text{rIII}} \sin \varphi_{\text{III}}$
 $= 0.5 \times 59.5 - 2.87 \times 0.70711 = 27.7206$
29. 齿弧厚 $S_{\text{III}} = m C_s = 1.571 \times 3.5 = 5.4985$ $S_K = 5.4171$

(二) 刀盘参数计算

1. 刀盘名义直径 据表值, 选取 $r = 44.45$ ($3\frac{1}{2}$ 刀盘) $D = 88.9$
2. 大小轮齿根角和 $\gamma_{\text{III}} + \gamma_K = 4^\circ 51' + 4^\circ 51' = 9^\circ 42' = 582'$
3. 理论刀号 $N_o = \frac{\gamma_{\text{III}} + \gamma_K}{20} \sin \beta = \frac{582}{20} \times 0.57358$
 $= 16.69$ 取 $N_o = 17$
4. 平均节锥距 $L = 42.0729 - \frac{15}{2} = 34.5729$
5. 精切大轮刀顶距 $W_K = \frac{L}{L_e} (S_{\text{III}} \cos \beta - 2 h_{\text{HK}} \text{tg} \alpha)$
 $= \frac{34.5729}{42.0729} (5.4985 \times 0.81915 - 2 \times 3.57 \times 0.36397)$
 $= 1.5657$ 取 1.57
6. 粗切大轮刀顶距 $W_K' = W_K - 0.75 = 1.57 - 0.75 = 0.82$
7. 大轮精刀尖宽度 取表值 $= 1.02$
8. 大轮粗刀尖宽度 取表值 $= 0.51$
9. 大轮精切外刃 $D_{eK} = 2r + W_K = 88.9 + 1.57 = 90.47$
10. 大轮精切内刃 $D_{iK} = 2r - W_K = 88.9 - 1.57 = 87.33$
11. 大小轮粗切外刃 $D_e = 2r + W_K' = 88.9 + 0.82 = 89.72$

12. 大小轮粗切内刃 $D_i = 2r - W_K' = 88.9 - 0.82 = 88.08$

13. 刀片外刃压力角 $\alpha_e = \alpha - 10' N_0 = 20^\circ - 170' = 20^\circ - 2^\circ 50' = 17^\circ 10'$

14. 刀片内刃压力角 $\alpha_i = \alpha + 10' N_0 = 20^\circ + 170' = 20^\circ + 2^\circ 50' = 22^\circ 50'$

15. 后面辅助公式 $\Delta L = - \left(\frac{L}{\gamma} - \sin \beta \right) \frac{L \operatorname{tg} \alpha}{\cos \beta} (\operatorname{tg} \gamma_{III} + \operatorname{tg} \gamma_K)$

$$= - \left(\frac{34.5729}{44.45} - 0.57358 \right) \frac{34.5729 \times 0.36397}{0.81915^2} (0.08485 + 0.08485)$$

$$= - 0.64988$$

16. 同上 $\Delta r_1 = \left(\frac{r}{L} \right)^2 \Delta L \sin \beta$

$$= \left(\frac{44.45}{34.5729} \right)^2 \times (-0.64988) \times 0.57358 = -0.61617$$

17. 同上 $\Delta r_2 = 0.5 W_K + L \operatorname{tg} \alpha (\operatorname{tg} \gamma_{III} + \operatorname{tg} \gamma_K)$

$$= 0.5 \times 1.57 + 34.5729 \times 0.36397 (0.08485 + 0.08485) = 2.92042$$

18. 同上 $\Delta r_3 = 0.064 \left(\frac{\gamma \cos \beta}{F \cdot b} \right)^2 = 0.064 \left(\frac{44.45 \times 0.81915}{0.6 \times 15} \right)^2$

$$= 1.04755$$

19. 同上 $\Delta r = \Delta r_1 + \Delta r_3 - \Delta r_2 = -0.61617 + 1.04755 - 2.92042$

$$= -2.48904$$

20. 小轮精切外刃 $D_{eIII} = 88.9 + 2(-2.48904) = 83.922$

21. 小轮精切内刃 $D_{iIII} = 88.9 - 2(-2.48904) = 93.878$

22. 小轮精切刀尖
宽度 取 0.51

刀 盘 座 标 位 置 计 算

1. 大轮水平座标 $H_K = L - r \sin \beta = 34.573 - 44.45 \times 0.57358 = 9.077$
2. 大轮垂直座标 $V_K = r \cos \beta = 44.45 \times 0.81915 = 36.411$
3. 大轮辐向座标 $S_{K0} = \sqrt{H_K^2 + V_K^2} = \sqrt{9.077^2 + 36.411^2} = 37.525$
4. 后面辅助公式 $\Delta S_r = (B18) + (B16) - r \operatorname{tg} \alpha (\operatorname{tg} \gamma_{III} + \operatorname{tg} \gamma_K) \sin \beta$
 $= 1.04755 + (-0.61617) - 44.45 \times 0.36397 \times 0.16970 \times 0.57358$
 $= -1.14342$
5. 同 上 $\Delta V = (B4) \cos \beta = (-1.14342)(0.81915) = -0.93663$
6. 同 上 $\Delta H = (B15) - r \operatorname{tg} \alpha (\operatorname{tg} \gamma_{III} + \operatorname{tg} \gamma_K) - (B4) \sin \beta$
 $= (-0.64988) - 44.45 \times 0.36397 \times 0.16970 - (-1.14342) \times 0.57358$
 $= -2.74144$
7. 小轮水平座标 $H_{III} = (B1) \pm (B6)$
 外刃 $H_{III} = 9.077 + (-2.74144) = 6.3356$
 内刃 $H_{III} = 9.077 - (-2.74144) = 11.8184$
8. 小轮垂直座标 $V_{III} = (B2) \pm (B5)$
 外刃 $V_{III} = 36.411 + (-0.93663) = 35.4744$
 内刃 $V_{III} = 36.411 - (-0.93663) = 37.3476$
9. 小轮外刃辐向座标 $S_{IIIe} = \sqrt{H_{III}^2 + V_{III}^2} = \sqrt{6.34^2 + 35.47^2}$
 $= \sqrt{40.196 + 1258.120} = \sqrt{1298.316} = 36.032$
10. 小轮内刃辐向座标 $S_{IIIi} = \sqrt{H_{III}^2 + V_{III}^2} = \sqrt{11.82^2 + 37.35^2}$
 $= \sqrt{139.712 + 1395.022} = \sqrt{1534.734} = 39.176$

注：① 大轮粗（精）切座标用第(1)、(2)、(3)项

② 小轮粗切座标用第(1)、(2)、(3)项与大轮相同

③ 切小轮凹面用外刃刀座标定位

切小轮凸面用内刃刀座标定位

齿 规 尺 寸 计 算

1. 外距处螺旋角 $\sin \beta_e = \frac{1}{2r} \left(L_e + \frac{L(2r \sin \beta - L)}{L_e} \right)$
 $= \frac{1}{2 \times 44.45} 42.0729 + \frac{34.5729(2 \times 44.45 \times 0.57358 - 34.5729)}{42.0729}$
 $= 0.625019$
 $\beta_e = 38^\circ 41' \quad \sin 38^\circ 41' = 0.625015$
2. β_e 的余弦 $\cos \beta_e = \cos 38^\circ 41' = 0.78061$
3. 小轮大端弦齿厚 $S_{mnx} = (B5) + 1.96 h_{HK} \cdot \operatorname{tg} \alpha$
 $= 1.57 + 1.96 \times 3.57 \times 0.36397$
 $= 4.117$
4. 小轮大端弧齿厚 $S_{III} = \frac{(\Gamma 3)}{0.98(\Gamma 2)} = \frac{4.117}{0.98 \times 0.78061} = 5.382$
5. 大轮大端弧齿厚 $S_{K'} = t - (\Gamma 4) = 10.9956 - 5.382$
 $= 5.6136 \quad \text{取 } 5.61$
6. 大量齿宽之平均锥距 $L_{III} = L_e - \frac{1}{2} \sin \beta_e \cos \beta_e (\Gamma 4)$
 $= 42.0729 - \frac{1}{2} \times 0.62501 \times 0.78061 \times 5.382$
 $= 40.76$
7. 同 上 $L_{Km} = L_e - \frac{1}{2} (\Gamma 1) (\Gamma 2) (\Gamma 5)$
 $= 42.0729 - \frac{1}{2} \times 0.62501 \times 0.78061 \times 5.61$
 $= 40.70435$
8. 大轮大端弦齿厚 $S_{Knx} = \frac{(\Gamma 7)}{L_e} (\Gamma 5) (\Gamma 2)$
 $= \frac{40.7044}{42.0729} \times 5.61 \times 0.78061 = 4.237$
9. 后面用辅助公式 $0.25 \cos^4 \beta_e = 0.25 \times 0.78061^4 = 0.092828$
10. 同 上 $\frac{(\Gamma 9) (\Gamma 5)^2 \cos \varphi_K}{d_K}$
 $= \frac{0.092828 \times (5.61)^2 \times 0.70711}{59.5} = 0.03472$
11. 同 上 $\frac{(\Gamma 9) (\Gamma 4)^2 \cos \varphi_{III}}{d_{III}}$
 $= \frac{0.092828 \times (5.38)^2 \times 0.70711}{59.5} = 0.03193$

12. 小轮大端
弦齿高

$$\begin{aligned} h_{mn} &= \frac{(\Gamma 6)}{L_e} (h_{2m} + (\Gamma 11)) \\ &= (2.87 + 0.03193) \\ &= 2.8114 \end{aligned}$$

13. 大轮大端
弦齿高

$$\begin{aligned} h_{kn} &= \frac{(\Gamma 7)}{L_e} (h_{2K} + (\Gamma 10)) \\ &= \frac{40.7044}{42.0729} (2.87 + 0.03472) \\ &= 2.8102 \end{aligned}$$

- 注： ① 本表的计算公式只适用本例切削法切齿时计算齿规尺寸。
- ② 在实际生产，大轮按表值切出；小轮则根据与大轮相配合而保持所要求的间隙即可，小轮往往不进行齿规测量。

滚动比挂轮的计算

1. 大轮粗(精)切 $\frac{a}{b} \cdot \frac{c}{d} \cdot \frac{e}{f} = \frac{1}{2.7 \sin \varphi_{\text{III}}} = \frac{1}{2.7 \times 0.70711} = 0.52378$

$$\frac{a}{b} \cdot \frac{c}{d} \cdot \frac{e}{f} = \frac{50}{60} \times \frac{40}{50} \times \frac{55}{70}$$

2. 小轮内刃精切 $\frac{a}{b} \cdot \frac{c}{d} \cdot \frac{e}{f} = \frac{1}{2.7 \sin \varphi_{\text{III}}} - \frac{[B15]}{L} \cdot \left(\frac{1}{2.7 \sin \varphi_{\text{III}}} \right)$

$$= 0.52378 - \frac{-0.64988}{34.5729} \times 0.52378$$

$$\frac{a}{b} \cdot \frac{c}{d} \cdot \frac{e}{f} = \frac{34 \times 50 \times 39}{35 \times 71 \times 50} = 0.533626$$

3. 小轮外刃精切 $\frac{a}{b} \cdot \frac{c}{d} \cdot \frac{e}{f} = \frac{1}{2.7 \sin \varphi_{\text{III}}} + \frac{[B15]}{L} \cdot \left(\frac{1}{2.7 \sin \varphi_{\text{III}}} \right)$

$$= 0.52378 + 0.0098455$$

$$= 0.513934 \text{ (理论)}$$

$$0.51389 = \frac{74}{80} \times \frac{40}{60} \times \frac{50}{60}$$

因交换齿轮没有，改为：

$$0.533333 \quad \frac{a}{b} \cdot \frac{c}{d} \cdot \frac{e}{f} = \frac{40 \times 80 \times 35}{60 \times 50 \times 70}$$

(误差为 0.000293)

$$\text{分度手柄转数 } n = \frac{40}{Z} = \frac{40}{17} = 2\frac{6}{17}$$

$$\text{节锥角 } \varphi = 45^\circ$$

$$\text{垫铁 } a = 45^\circ - 40^\circ 36' = 4^\circ 24'$$

$$\text{齿根角 } \gamma = 4^\circ 51'$$

$$\text{垫铁 } b = 4^\circ 51'$$

夹具摇架中心计算尺寸

大小轮相同：

$$EF = BD = CD \div \sin \alpha = 210 \div 0.70711 = 296.983$$

$$AF = BF \operatorname{tg} \alpha = 114 \cdot \operatorname{tg} 45^\circ = 114$$

$$L = AF + EF = 296.983 + 114 = 410.983$$

$$AB = BF \sec \alpha = 114 \cdot \sec \alpha = 114 / 0.70711 = 161.220$$

$$BC = CD \operatorname{tg} \alpha = 210 \cdot \operatorname{tg} 45^\circ = 210$$

$$L_3 = AB + BC - 95 = 161.220 + 210 - 95 = 276.220$$

$$L_4 = L_3 - 200 = 276.220 - 200 = 76.220$$

$$L_1 = L - 286 = 410.983 - 286 = 124.983 \text{ (安装距)}$$

$$C = D_1 - \text{小轮基距} = 106.29 - 52.5 = 53.79$$

$$\text{大轮粗精切} = C_K = 106.29 - 45 = 61.29$$

$$\text{小轮外刃光刀} = C_{III} = C + \frac{-\{E15\}}{\cos \varphi_{iIII}} = 53.79 + \frac{0.64988}{0.76436} = 54.64$$

$$\text{小轮内刃光刀} = C_{III} = C - \frac{\{E15\}}{\cos \varphi_{iIII}} = 53.79 - \frac{0.64988}{0.76436} = 52.94$$

在洋机床 Y225 弧齿锥齿轮铣齿机加工调整计算典型举例：

J31 - 31206,

J31 - 31202.

螺 伞 齿 几 何 计 算

1. $Z_{III} = 21$
2. $Z_K = 21$
3. $i = 1$
6. $\xi = 0$
7. $\tau = 0$
9. $K_C = 0.2$
10. $Z_C = 29.6984848$
11. $C_S = 1.571$
12. $m = 2.5$
13. $Le = 0.5 \cdot m \cdot Z_C$
 $= 0.5 \times 2.5 \times 29.69848$
 $= 37.1231$
14. $b = 12$
15. $h_3 = 1.64 \cdot m$
 $= 1.64 \times 2.5 = 4.1$
16. $C = K_C \cdot m = 0.2 \times 2.5 = 0.5$
17. $h = h_3 + C = 4.6$
18. $t = \pi m = 3.1416 \times 2.5 = 7.854$
19. $d_{III} = Z_{III} \cdot m = 21 \times 2.5 = 52.5$
20. 齿顶高: $h_{r_{III}} = 0.82 \times m = 0.82 \times 2.5 = 2.05$
 $h_{r_K} = h_3 - h_{r_{III}} = 4.1 - 2.05 = 2.05$
21. 齿根高: $h_{H_{III}} = h - h_{r_{III}} = 4.6 - 2.05 = 2.55$
 $h_{H_K} = h - h_{r_K} = 4.6 - 2.05 = 2.55$
22. 节锥角: $\varphi_{III} = \arctg \frac{Z_{III}}{Z_K} = 45^\circ$
23. 节锥角的三角函数:
 $\sin \varphi_{III} = 0.70711$
24. 齿根角:
 $\gamma_{III} = \arctg \frac{h_{H_{III}}}{Le} = \arctg \frac{2.55}{37.1231} = 3^\circ 56'$

$$25. \text{ 面锥角: } \varphi_{eIII} = \varphi_{III} + \gamma_K = 45^\circ + 3^\circ 56' = 48^\circ 56'$$

$$26. \text{ 内锥角: } \varphi_{iIII} = \varphi_{III} - \gamma_K = 45^\circ - 3^\circ 56' = 41^\circ 04'$$

$$27. \text{ 外 径: } d_{eIII} = d_{III} + 2h_{rIII} \cdot \cos \varphi_{III} \\ = 52.5 + 2 \times 2.05 \times 0.70711 = 55.4$$

28. 锥顶至轮缘的距离:

$$A_M' = 0.5 d_K - h_{rIII} \cdot \sin \varphi_{III} \\ = 0.5 \times 52.5 - 2.05 \times 0.70711 = 24.8$$

29. 弧齿厚:

$$S_{III} = C_{S_{III}} = 1.571 \times 2.5 = 3.9275$$

单号单面法

$$1. \gamma_{III} + \gamma_K = 3^\circ 56' + 3^\circ 56' = 236' + 236' = 472'$$

$$2. \operatorname{tg} \gamma_{III} + \operatorname{tg} \gamma_K = 0.06876 + 0.06876 = 0.13752$$

$$3. N_o = \frac{\gamma_{III} + \gamma_K}{20} \sin \beta = \frac{472'}{20} \cdot 0.57358$$

$$4. L = L_e - 0.5 b = 37.123 - 6 = 31.123$$

$$5. L_1 = L_e - b = 37.123 - 12 = 25.123$$

$$6. R_n = 44.45$$

7. 大轮垂直座标:

$$V = R_n \cos \beta = 44.45 \times 0.81915 = 36.411$$

8. 大轮水平座标:

$$\begin{aligned} H &= L - R_n \sin \beta \\ &= 31.12 - 44.45 \times 0.57358 \\ &= 5.627 \end{aligned}$$

9. 极角:

$$q = \operatorname{arc} \operatorname{tg} \frac{V}{H} = \operatorname{arc} \operatorname{tg} \frac{36.411}{5.627} = 81^\circ 13'$$

$$11. J = q - \beta = 81^\circ 13' - 35^\circ = 46^\circ 13'$$

12. 齿宽系数:

$$K_b = \frac{b}{L_e} = \frac{12}{37.123} = 0.32$$

$$13. r_1' = \cos \beta \cdot e$$

$$\sin \beta_e = \frac{1}{2R_n} (L_e + \frac{L}{Le} (2R_n \sin \beta_e - L))$$

$$= \frac{1}{2 \times 44.45} (37.123 + \frac{31.123}{37.123} (2 \times 44.45 \times 0.57358 + 31.123))$$

$$= 0.60503$$

$$\beta_e = 37^\circ 14'$$

$$\Gamma_1' = \cos \beta_e = 0.79618$$

$$14. \quad \Gamma_1'' = 0.25 \sin 2\beta_e \\ = 0.25 \sin 74^\circ 28' = 0.25 \times 0.96347 = 0.24087$$

$$15. \quad \Gamma_1''' = 0.25 \cos^2 \beta_e = 0.25 \times 0.79618^2 = 0.10046$$

$$16. \quad \sin \beta_i = \frac{1}{2R_n} \left(Li + \frac{L}{Li} (2R_n \sin \beta_c - L) \right) \\ = \frac{1}{2 \times 44.45} \left(25.123 + \frac{31.123}{25.123} (2 \times 44.45 \times 0.57358 - 31.123) \right) \\ = 0.55952$$

$$\beta_i = 34^\circ 01'$$

$$T_2 = \cos \beta_i = 0.82887$$

$$17. \quad (16) \cdot S_{III} = 0.82887 \times 3.9275 = 3.255$$

$$18. \quad (16) \cdot S_K = 0.82887 \times 3.9275 = 3.255$$

$$19. \quad 2h_{HIII} \operatorname{tg} \alpha = 2 \times 2.55 \times 0.36397 = 1.856$$

$$20. \quad 2h_{HK} \operatorname{tg} \alpha = 2 \times 2.55 \times 0.36397 = 1.856$$

$$21. \quad 1 - K_b = 1 - (12) = 1 - 0.32 = 0.68$$

$$22. \quad (18) - (19) = 3.255 - 1.856 = 1.399$$

$$23. \quad (17) - (20) = 3.255 - 1.856 = 1.399$$

$$24. \quad (7) - H \operatorname{tg} \beta = 36.411 - 5.627 \times 0.70021 = 32.471$$

$$25. \quad \frac{L \cdot \sin \beta \cdot \operatorname{tg} \alpha}{(9)} = \frac{31.623 \times 0.57358 \times 0.36397}{6.4720} \\ = 0.20877 \times 5.3213 = 1.1109$$

$$26. \frac{R_n \cdot \operatorname{tg} \alpha \cdot \operatorname{tg} \alpha_{III}}{\cos \beta} = \frac{44.45 \times 0.36397 \times 1}{0.81915}$$

$$= 19.7503$$

$$27. N_{\Phi} = 7.5$$

$$28. \Delta N = 7.5 - 13.5 = -6$$

$$29. W_{III} \leq (21)(22) - \Delta W \leq 0.68 \times 1.399 - 0.5 \leq 0.45$$

$$\text{取 } 0.50$$

$$30. W_K \leq (21)(23) - \Delta W \leq 0.68 \times 1.399 - 0.5 \leq 0.45$$

$$\text{取 } 0.50$$

$$31. K = -0.01892$$

$$K = \frac{\Delta N \cdot \operatorname{tg} \alpha}{172 \cdot \cos^2 \beta} = \frac{(-6) \times 0.36397}{172 \times 0.81915^2} = 0.01892$$

$$32. \cos (q - \beta) = \cos 46^{\circ}13' = 0.69193$$

$$33. \Delta S = (26)(31)(32) = -19.7503 \times 0.01892 \times 0.69193 = -0.25853$$

$$34. V^2 = (7)^2 = 36.411^2 = 1325.7600$$

$$35. H^2 = (8)^2 = 5.627^2 = 31.6631$$

$$36. S = \sqrt{(34) + (35)} = \sqrt{1325.76 + 31.66} = 36.843$$

$$37. \frac{W_{III} + W_K}{2R_n}(24) = \frac{0.50}{44.45} 32.471 = 0.36530$$

$$38. dV = (37) - (2)(25) = 0.36530 - 0.13752 \times 1.1109 = 0.22724$$

$$39. [(7) + (38)]^2 = [36.411 + 0.227]^2 = 1342.34$$

$$40. [(7) - (38)]^2 = [36.411 - 0.227]^2 = 1309.28$$

$$41. (35) + (39) = 31.66 + 1342.34 = 1374.00$$

$$42. (35) + (40) = 31.66 + 1309.28 = 1340.94$$