(1) During the designing process of V-Belt, why should we limit d_{min}(minimum shaft diameter) and v_{max}(maximum belt speed) ?

The reason for limiting d_{min}

We should make sure that $d_{d1} \geq d_{min}$ to avoid the over stress of bending, which would reduce the life of the belt.

The reason for limiting v_{max}

If the belt speed is too large, the following problems will occur:

1) The centrifugal force will be too large and the friction force between the shaft and the belt will be reduced. Creep may occur.
2) The bending numbers will increase, reducing the belt's life.

So we should limit v_{max} to avoid these problems.

(2) During the designing process of belt drive, why should we limit the number of belts(z)? If z>10, how to handle it?

The reason for limiting the number of belts(z)

The number of belts should be lower than 10 to make the stress uniform.

If $z > 10$, belt model or the diameter of the large wheel should be changed and conduct recalculation.

(3) Please design an ordinary v-belt drive for lathes. The following parameters are known: rated power $P = 3.2\ kW$, $rotational\ speed\ of\ small\ pulley\ n_1 = 1460\ r/min$, $transmission\ ratio\ i = 3.6$, $daily\ working\ time = 16\ hours$. The structure should be as compact as possible.

Step 1 Determine calculated power P_c

The working machine: lathes

Daily working time = 16hours

From table 13-9 on the Chinese text book:

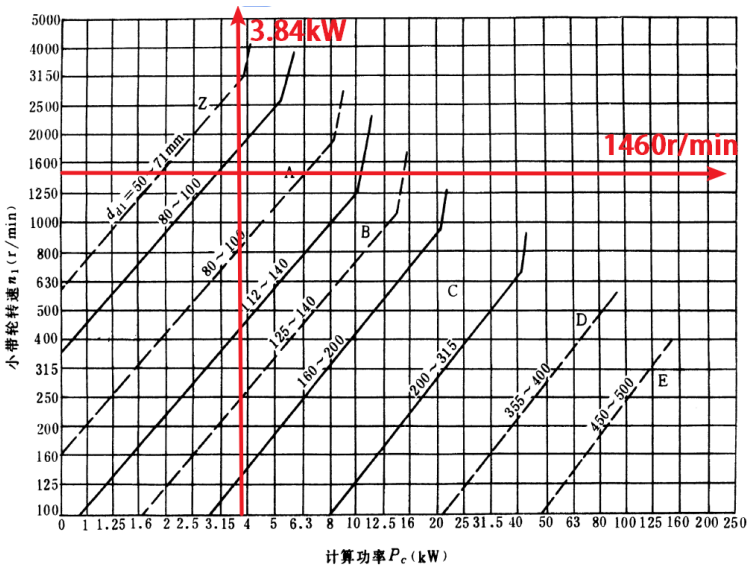
$$K_A = 1.2$$

$$P_c = K_A P = 1.2 \times 3.2 = 3.84\ kW$$

载荷性质	工作机	原动机					
		电动机(交流起动、三角起动、直流并励)、四缸以上的内燃机			电动机(联机交流起动、直流复励或串励)、四缸以下的内燃机		
		每天工作小时数/h					
		<10	10～16	>16	<10	10～16	>16
载荷变动很小	液体搅拌机、通风机和鼓风机(≤7.5 kW)、离心式水泵和压缩机、轻负荷输送机	1.0	1.1	1.2	1.1	1.2	1.3
载荷变动较小	带式输送机(不均匀负荷)、通风机(>7.5 kW)，旋转式水泵和压缩机(非离心式)、发电机、金属切削机床、印刷机、旋转筛、锯木机和木工机械	1.1	1.2	1.3	1.2	1.3	1.4

Table 13-9 on text book

Step 2 Select V-belt model



choose Type A

$d_1 = 80{\sim}100mm$

Step 3 Select shaft diameters d_{d1}, d_{d2}

型号	Y	Z	A	B	C	D	E
最小直径 d_{min}	20	50	75	125	200	355	500
基准直径系列	20, 22.4, 25, 28, 31.5, 35.5, 40, 45, 50, 56, 63, 71, 75, 80, 90, 95, 100, 106, 112, 118, 125, 132, 140, 150, 160, 170, 180, 200, 212, 224, 236, 250, 265, 280, 300, 315, 355, 375, 400, 425, 450, 475, 500, 530, 560, 600, 630, 670, 710, 750, 800, 900, 1000						

$$d_{d1} \geq d_{min} = 75mm$$
$$since \text{ type A } d_1 = 80\sim100mm$$
$$\therefore choose\ d_{d1} = 100mm$$
$$d_{d2} \approx id_{d1} = 3.6 \times 100 = 360mm$$
$$\therefore choose\ d_{d2} = 375mm$$

Step4 Verify the speed of the belt (V)

$$v = \frac{\pi d_{d1} n_1}{60 \times 1000} = \frac{\pi \times 100 \times 1460}{60 \times 1000} = 7.64m/s \in (5m/s\ ,25m/s)$$

Step 5 Verify rotational speed error

Actual rotational speed of the follower:

$$n_2' \approx \frac{n_1 d_{d1}}{d_{d2}} = \frac{1460 \times 100}{375} = 389.3r/min$$

Theoretical rotational speed of the follower:

$$n_2 = \frac{n_1}{i} = \frac{1460}{3.6} = 405.6r/min$$

Rotational speed error:

$$\left|\frac{n_2' - n_2}{n_2}\right| = \left|\frac{389.3 - 405.6}{405.6}\right| = 0.04018 < 5\%$$

Step 6 Determine central distance (a) and belt length (L)

1) Determine initial central distance

$$a_0 = 1.5(d_{d1} + d_{d2}) = 1.5 \times (100 + 375) = 712.5mm$$
$$choose\ a_0 = 750mm$$
$$which \in (0.7(d_{d1} + d_{d2}), 2(d_{d1} + d_{d2}))$$

2) Determine the belt length

$$L_0 \approx 2a_0 + \frac{\pi}{2}(d_{d1} + d_{d2}) + \frac{(d_{d2} - d_{d1})^2}{4a_0} = 2 \times 750 + \frac{\pi}{2}(100 + 375) + \frac{(375 - 100)^2}{4 \times 750} = 2271mm$$

表 13-2 V 带基准长度 L_d 和带长修正系数 K_L

Z 型		A 型		B 型		C 型	
L_d/mm	K_L	L_d/mm	K_L	L_d/mm	K_L	L_d/mm	K_L
405	0.87	630	0.81	930	0.83	1 565	0.82
475	0.90	700	0.83	1 000	0.84	1 760	0.85
530	0.93	790	0.85	1 100	0.86	1 950	0.87
625	0.96	890	0.87	1 210	0.87	2 195	0.90
700	0.99	990	0.89	1 370	0.90	2 420	0.92
780	1.00	1 100	0.91	1 560	0.92	2 715	0.94
920	1.04	1 250	0.93	1 760	0.94	2 880	0.95
1 080	1.07	1 430	0.96	1 950	0.97	3 080	0.97
1 330	1.13	1 550	0.98	2 180	0.99	3 520	0.99
1 420	1.44	1 640	0.99	2 300	1.01	4 060	1.02
1 540	1.54	1 750	1.00	2 500	1.03	4 600	1.05
		1 940	1.02	2 700	1.04	5 380	1.08
		2 050	1.04	2 870	1.05	6 100	1.11
		2 200	1.06	3 200	1.07	6 815	1.14
		2 300	1.07	3 600	1.09	7 600	1.17
		2 480	1.09	4 060	1.13	9 100	1.21
		2 700	1.10	4 430	1.15	10 700	1.24
				4 820	1.17		
				5 370	1.20		
				6 070	1.24		

From the table: $L_d = 2300mm$

3) Calculate the actual central distance a

$$a \approx a_0 + \frac{L_d - L_0}{2} = 750 + \frac{2300 - 2271}{2} = 764.5mm$$

4) Adjust range of central distance

$$a_{min} = a - 0.015L_d = 764.5 - 0.015 \times 2300 = 730mm$$
$$a_{max} = a + 0.03L_d = 764.5 + 0.03 \times 2300 = 833.5mm$$

Step 7 Verify the contact angle

$$\alpha_1 = 180° - \frac{d_{d2} - d_{d1}}{a} \times 57.3° = 180° - \frac{375 - 100}{764.5} \times 57.3° = 159.4°$$

Step 8 Determine number of belts (z)

$$z \geq \frac{P_c}{(P_0 + \Delta P_0)K_\alpha K_L}$$

表 13-2 V 带基准长度 L_d 和带长修正系数 K_L

Z 型		A 型		B 型		C 型	
L_d/mm	K_L	L_d/mm	K_L	L_d/mm	K_L	L_d/mm	K_L
405	0.87	630	0.81	930	0.83	1 565	0.82
475	0.90	700	0.83	1 000	0.84	1 760	0.85
530	0.93	790	0.85	1 100	0.86	1 950	0.87
625	0.96	890	0.87	1 210	0.87	2 195	0.90
700	0.99	990	0.89	1 370	0.90	2 420	0.92
780	1.00	1 100	0.91	1 560	0.92	2 715	0.94
920	1.04	1 250	0.93	1 760	0.94	2 880	0.95
1 080	1.07	1 430	0.96	1 950	0.97	3 080	0.97
1 330	1.13	1 550	0.98	2 180	0.99	3 520	0.99
1 420	1.44	1 640	0.99	2 300	1.01	4 060	1.02
1 540	1.54	1 750	1.00	2 500	1.03	4 600	1.05
		1 940	1.02	2 700	1.04	5 380	1.08
		2 050	1.04	2 870	1.05	6 100	1.11
		2 200	1.06	3 200	1.07	6 815	1.14
		2 300	1.07	3 600	1.09	7 600	1.17
		2 480	1.09	4 060	1.13	9 100	1.21
		2 700	1.10	4 430	1.15	10 700	1.24
				4 820	1.17		
				5 370	1.20		
				6 070	1.24		

$$K_L = 1.07$$

型号	小带轮基准直径 d_1/mm	小带轮转速 n_1/（r/min）										
		400	730	800	980	1200	1460	1600	2000	2400	2800	3200
Z	50	0.06	0.09	0.10	0.12	0.14	0.16	0.17	0.20	0.22	0.26	0.28
	63	0.08	0.13	0.15	0.18	0.22	0.25	0.27	0.32	0.37	0.41	0.45
	71	0.09	0.17	0.20	0.23	0.27	0.31	0.33	0.39	0.46	0.50	0.54
	80	0.14	0.20	0.22	0.26	0.30	0.36	0.39	0.44	0.50	0.56	0.61
	90	0.14	0.22	0.24	0.28	0.33	0.37	0.40	0.48	0.54	0.60	0.64
A	75	0.27	0.42	0.45	0.52	0.60	0.68	0.73	0.84	0.92	1.00	1.04
	90	0.39	0.63	0.68	0.79	0.93	1.07	1.15	1.34	1.50	1.64	1.75
	100	0.47	0.77	0.83	0.97	1.14	1.32	1.42	1.66	1.87	2.05	2.19
	125	0.67	1.11	1.19	1.40	1.66	1.93	2.07	2.44	2.74	2.98	3.16
	160	0.94	1.56	1.69	2.00	2.36	2.74	2.94	3.42	3.80	4.06	4.19
B	125	0.84	1.34	1.44	1.67	1.93	2.20	2.33	2.50	2.64	2.76	2.85
	160	1.32	2.16	2.32	2.72	3.17	3.64	3.86	4.15	4.40	4.60	4.75
	200	1.85	3.06	3.30	3.86	4.50	5.15	5.46	6.13	6.47	6.43	5.95
	250	2.50	4.14	4.46	5.22	6.04	6.85	7.20	7.87	7.89	7.14	5.60
	280	2.89	4.77	5.13	5.93	6.90	7.78	8.13	8.60	8.22	6.80	4.26

$$P_0 = 1.32kW$$

带型	小带轮转速 n（r/min）	传动比 i									
		1.00～1.01	1.02～1.04	1.05～1.08	1.09～1.12	1.13～1.18	1.19～1.24	1.25～1.34	1.35～1.51	1.52～1.99	≥2.0
A型	200	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03
	400	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05
	700	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
	950	0.00	0.01	0.03	0.04	0.05	0.06	0.07	0.8	0.10	0.11
	1450	0.00	0.02	0.04	0.06	0.08	0.09	0.11	0.13	0.15	0.17
	2800	0.00	0.04	0.08	0.11	0.15	0.19	0.23	0.26	0.30	0.34
	4000	0.00	0.02	0.04	0.06	0.08	0.09	0.11	0.13	0.15	0.17
	5000	0.00	0.05	0.11	0.16	0.22	0.27	0.32	0.38	0.43	0.48

$$\Delta P_0 = 0.17 + \frac{1460 - 1450}{2800 - 1450} \times (0.34 - 0.17) = 0.171kW$$

小带轮包角	180^0	170^0	160^0	150^0	140^0	130^0	120^0
K_α	1.00	0.98	0.95	0.92	0.89	0.86	0.82

$$K_\alpha = 0.95$$

$$z \geq \frac{P_c}{(P_0 + \Delta P_0)K_\alpha K_L} = \frac{3.84}{(1.32 + 0.171) \times 0.95 \times 1.07} = 2.5$$

$$\therefore choose\ z = 3$$

Step 9 Determine initial tension

带 型	Z	A	B	C	D	E
q/(kg/m)	0.06	0.10	0.17	0.30	0.62	0.90

$$F_0 = \frac{500P_c}{zv}\left(\frac{2.5}{K_\alpha} - 1\right) + qv^2 = \frac{500 \times 3.84}{3 \times 7.64} \times \left(\frac{2.5}{0.95} - 1\right) + 0.10 \times 7.64^2 = 143N$$

Step 10 Determine force on shafts

$$F = 2zF_0 sin\frac{\alpha_1}{2} = 2 \times 3 \times 143 \times sin\frac{159.4°}{2} = 844.2N$$