MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

KHARKIV NATIONAL AUTOMOBILE AND HIGHWAY UNIVERSITY

Guidelines

BY COURSE
"**MACHINE ELEMENTS**"

V-belt Drive Calculation

in English

2023

Guidelines intended for students studying the discipline "Machine Elements" Section: Belt Drive. V-belt Drive Calculation " in English.

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An important component of mechanical drives are belt transmissions (the term is belt drive often used). Studying the features of design and calculation of belt drives is an integral element of studying a full course of the family of disciplines ME (Machine Elements), ME and DP (Machine Elements and Design Principles), ME and LTE (Lifting and Transport Equipment), as well as AM (applied mechanics).

Belt drive is one of the oldest types of mechanical transmissions that have retained their importance to this day. It is used in almost all branches of mechanical engineering. The simplest belt drive consists of drive and driven pulleys and a belt, put on the pulleys with tension and transmits circumferential force using friction forces.

Transmissions with two or more driven pulleys are possible.

The purpose of these guidelines is to familiarize students with the main stages of calculating belt drives, as well as for course design. For serious commercial calculations, it is necessary to use only current standards.

BELT DRIVE. Brief Information

Contents

1. Application area

Belt drives are called flexible machine elements. They are used:

1) In conveying systems for transportation of coal, mineral ores etc. over a long distance;

2) for transmission of power. Mainly used for running of various industrial appliances using prime movers like electric motors, I.C. Engine etc.;

3) for replacement of rigid type power transmission system (A gear drive may be replaced by a belt transmission system.).

2. Advantages and disadvantages of belt drives

There are four basic advantages of belt drives:

a) distance between axes of driving and driven shafts is large;

b) belt drives operate smoothly and without knocking;

c) belt drives transmit only definite load which, if exceeded, will cause the belt to slip over the pulley (thus protect the other parts of the drive against overload);

d) simple design and rather low initial cost.

These are the disadvantages of belt drives:

a) large dimensions;

b) certain inconstancy of the velocity ratio because of belt slippage;

c) heavy loads on the shafts and bearings;

d) comparatively short service life of the belts.

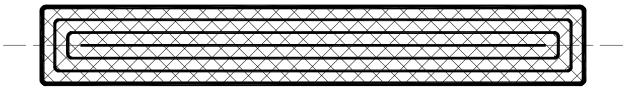
3. Belt materials, types of belts and structure of belt

Belt materials:

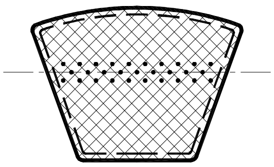
- Leather
  (Oak tanned or chrome tanned);
- Rubber
  (Canvas or cotton duck impregnated with rubber. For greater tensile strength, rubber belts are reinforced with steel cords or nylon cords);
- Plastics
  (Thin plastic sheets with rubber layers);
- Fabric
  (Canvas or woven cotton ducks. The belt thickness can be built up with a number of layers. The number of layers is known as ply.).

Types of belts:

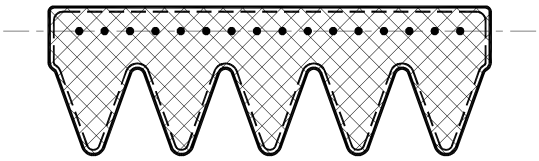
- Flat belt



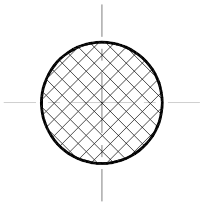
- V-belt



- V-ribbed belts (Poly-V-belt)

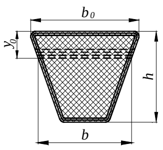
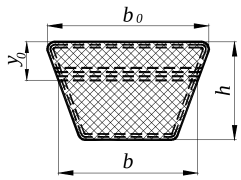
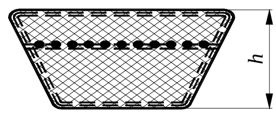


- Rope

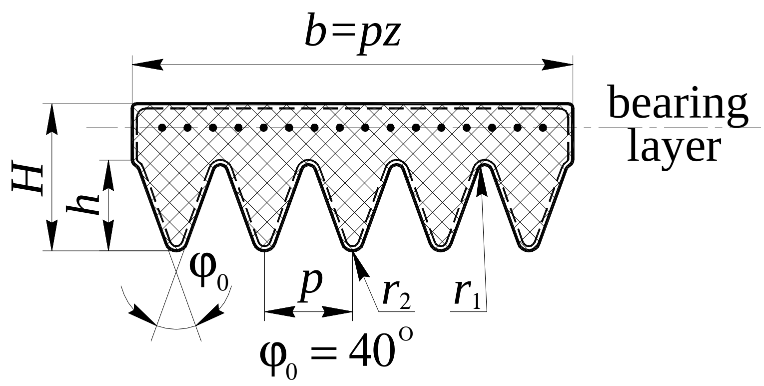


Types of V-belts Section

Section ISO	Section GOST
Z	O
A	A
B	Б
C	B
D	Г
E	Д
EO (F)	E

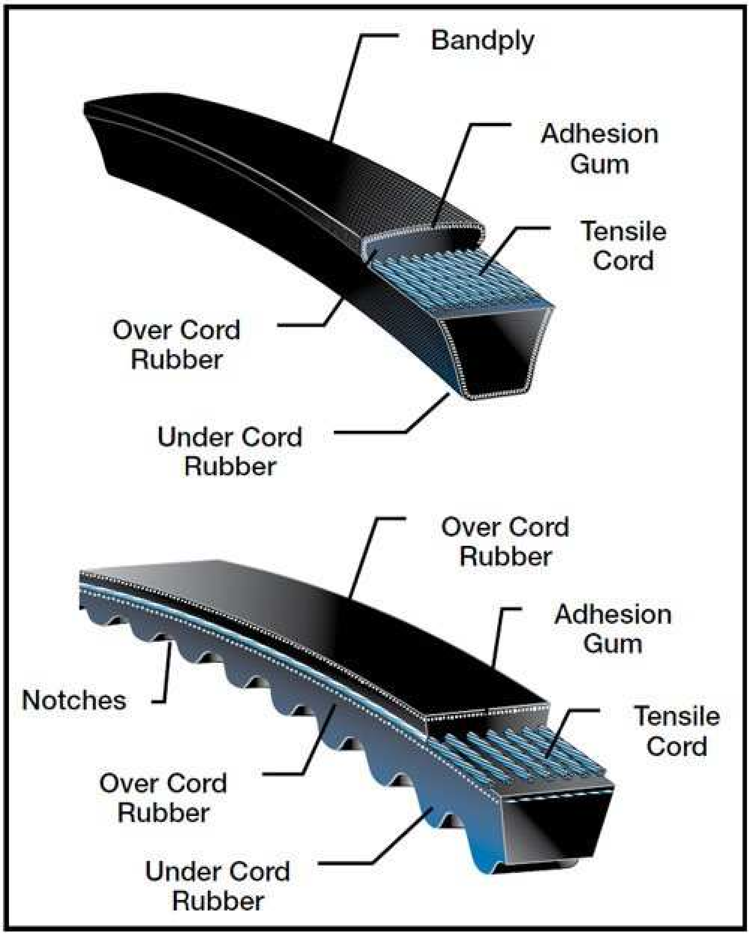
Narrow Belts	Classical (normal) Belt	Wide Belts (for variators)
$\frac{b_0}{h} = 1.2$	$\frac{b_0}{h} = 1.6$	$\frac{b_0}{h} = 2.5 - 3.5$
		

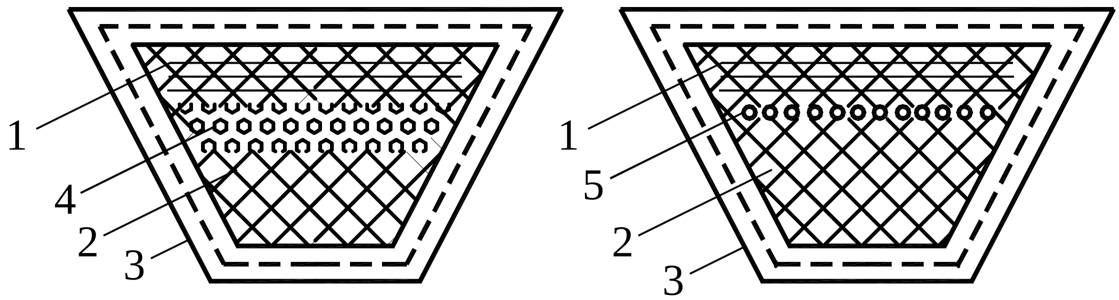
Section of Poly-V-belts (V-ribbed belts)



Poly-V-belts can be **К (K)**, **Л (L)**, **М (M)** (our standards)
PH, PJ, PK, PL, PM (foreign standards)
with number of edges z = 2 – 50
К – PJ; **Л – PL**; **М – PM (Analogues, not full compliance)**

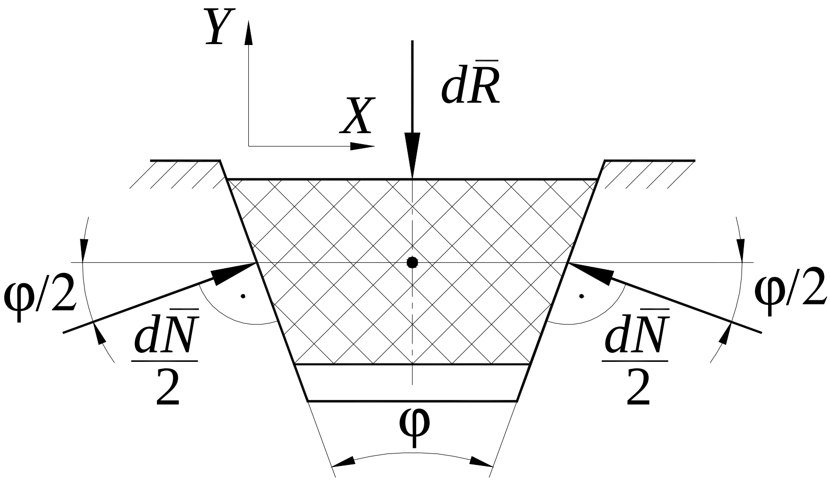
Structure of V-belt





1 – rubber layer for tension;
2 – rubber layer for compression (base rubber);
3 – a couple of wrapping rubberized fabric layers;
4 – multi-cord (e.g. rubber-fabric);
5 – single-cord.

Improved pulling capacity of V-belt

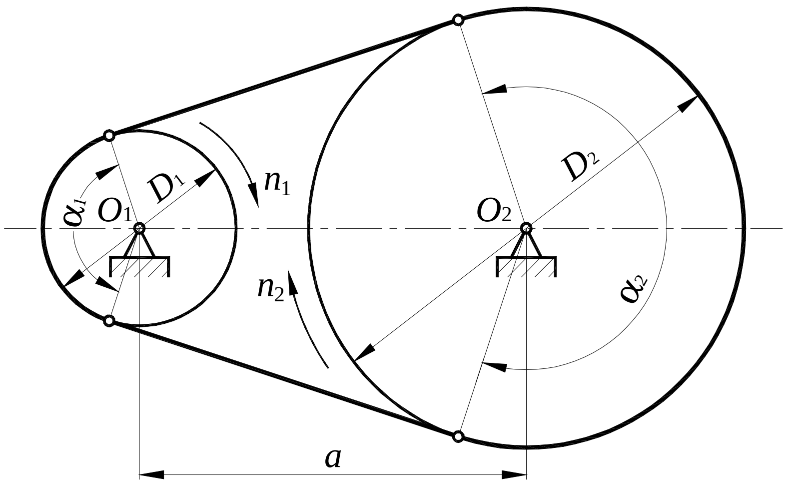


Superficial friction factor $f' = \frac{f}{\sin\varphi}$,

$$f' = \frac{f}{\sin 20^\circ} \approx 3 \cdot f,$$

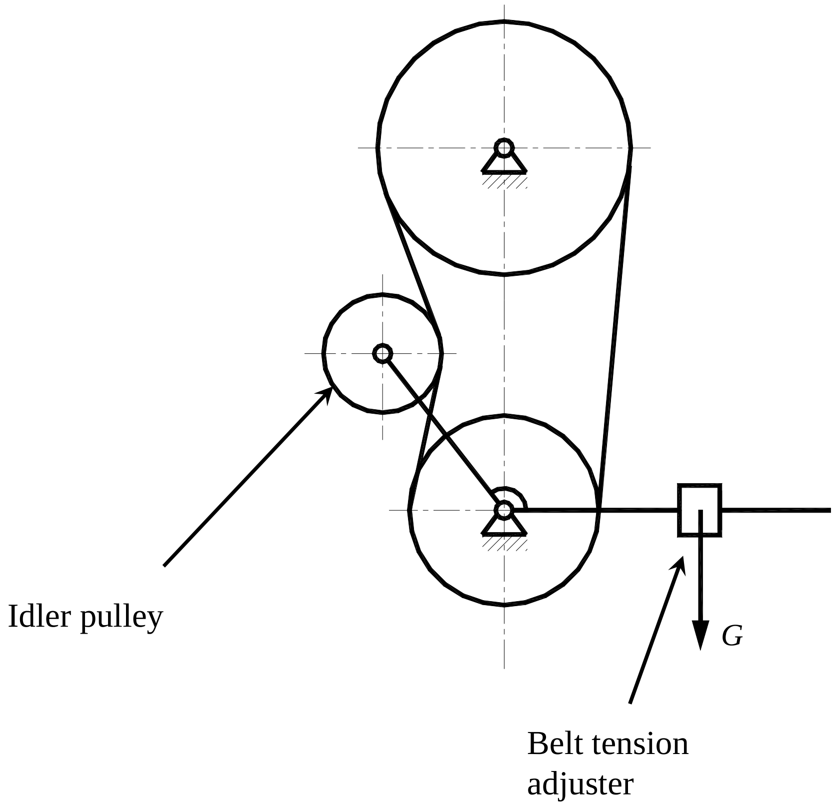
4. Parameters and geometry of belt drive

Simple belt drive

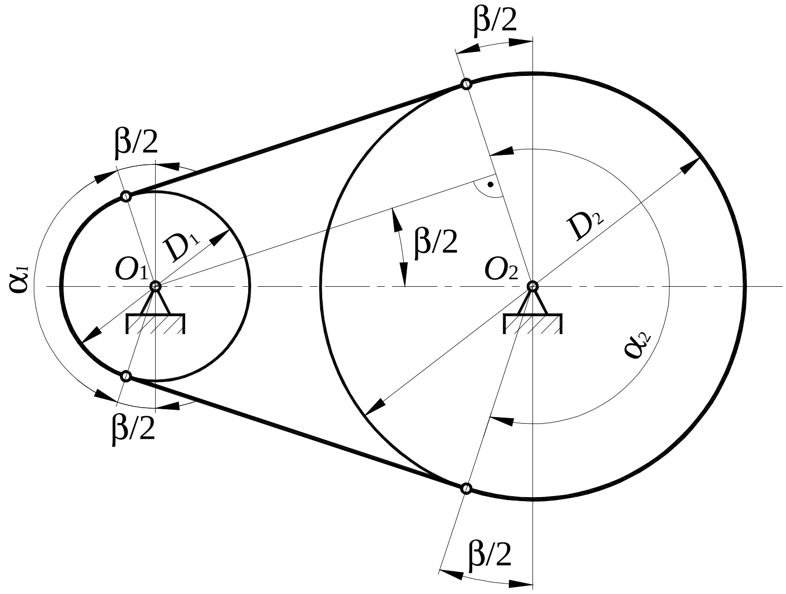


D_1 – diameter of the smaller pulley (driving pulley);
D_2 – diameter of the lager pulley (driven pulley);
α – angle of wrap;
a – center distance between the two pulleys.

Belt drive with tension adjuster



Belt drive geometry parameters

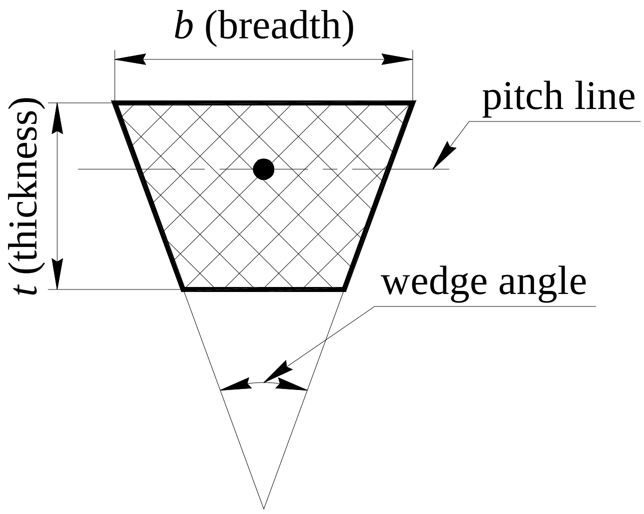


$$(\alpha \pm \beta) = 180°$$

$$(\alpha_1 + \beta) = 180°$$

$$(\alpha_2 - \beta) = 180°$$

Belt geometry parameters



Parameters of belt drive:

Angular speed ratio:

$$i \equiv u = \frac{n_1}{n_2} = \frac{D_2}{D_1(1-\xi)},$$

where

n_1, n_2 – rotating frequency;

$\xi = 0.01 \div 0.02$ – belt slip factor.

Angle of wrap:

$$\alpha_1 = 180° - \frac{D_2 - D_1}{a} \cdot 57°,$$

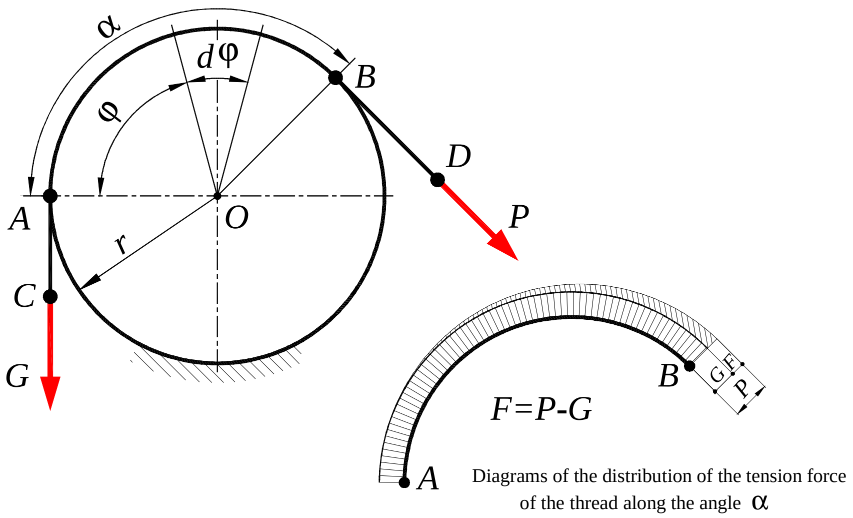
Length of the belt:

$$L = 2 \cdot a + \pi \cdot \frac{D_1 + D_2}{2} + \frac{1}{a} \cdot \left(\frac{D_2 - D_1}{2}\right)^2$$

Center distance between the two pulleys (exact center distance):

$$a_{ex} = 0.25\left(L_{st} - \pi \cdot \frac{D_1 + D_2}{2} + \sqrt{\left(L_{st} - \pi \cdot \frac{D_1 + D_2}{2}\right)^2 - 8 \cdot \left(\frac{D_2 - D_1}{2}\right)^2}\right)$$

Forces in belts



Scheme of a flexible cord winding on cylinder

The following relation was established by L. Euler 1775:

$$\frac{G}{P} = e^{f\alpha},$$

where
G, P – forces applied to the cord ends;
f – friction factor between the cord and the cylinder surface;
α – angle of contact arc between the cord and the cylinder.

There are four basic relations between forces in belt:

$$F_1 = F_t \frac{e^{f\alpha}}{e^{f\alpha} - 1}; \quad F_2 = F_t \frac{1}{e^{f\alpha} - 1};$$

$$F_1 + F_2 = F_0; \quad F_1 - F_2 = F_t,$$

where
F_1, F_2 – tensions in driving and driven sides of the belt;
F_0 – initial tension;
F_t – peripheral force.

Stresses in belts

Stress due to initial tension:

$$\sigma_0 = \frac{F_0}{A},$$

where A – area.

Stress due to peripheral force:

$$\sigma_t = \frac{F_t}{A},$$

Stress due to tension:

$$\sigma_1 = \frac{F_1}{A}; \ \sigma_2 = \frac{F_2}{A},$$

$$\sigma_1 = \sigma_0 + 0.5 \cdot \sigma_t; \ \sigma_2 = \sigma_0 - 0.5 \cdot \sigma_t,$$

Stress due to centrifugal force:

$$\sigma_c = \frac{\rho \cdot v_B{}^2}{10g} \approx \frac{v_B{}^2}{100},$$

where v_B is peripheral velocity of the belt.

Stress due to bending:

$$\sigma_b = E \cdot \varepsilon = E \cdot \frac{h}{D_1},$$

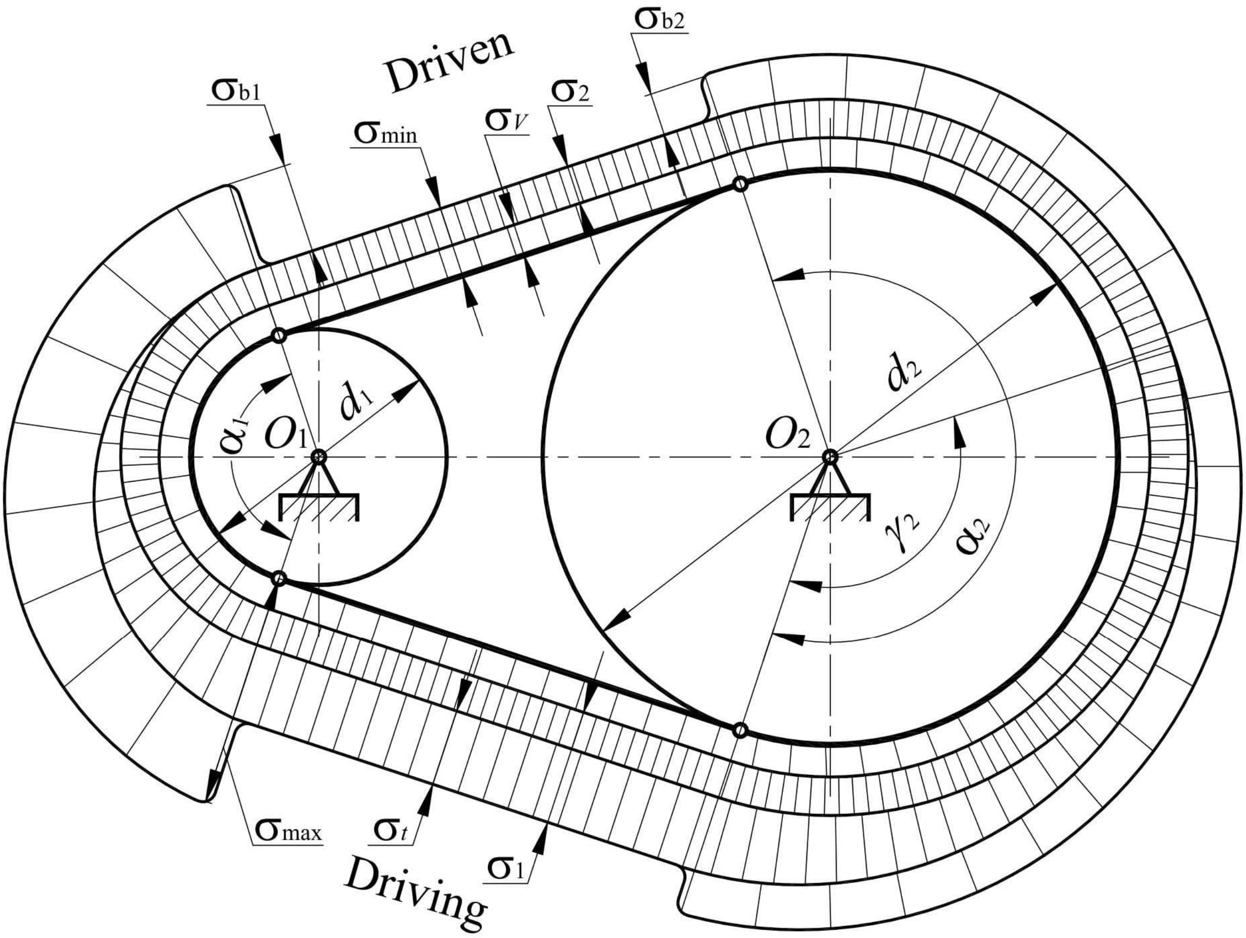
where E is Young's modulus;

$\varepsilon = \dfrac{h}{D_1}$ – strain.

Hence h is height of the belt, D_1 is diameter of smaller pulley.

The maximum stress is $\sigma_{\max} = \sigma_1 + \sigma_c + \sigma_b$,

and the minimum stress is $\sigma_{\min} = \sigma_2 + \sigma_c$.



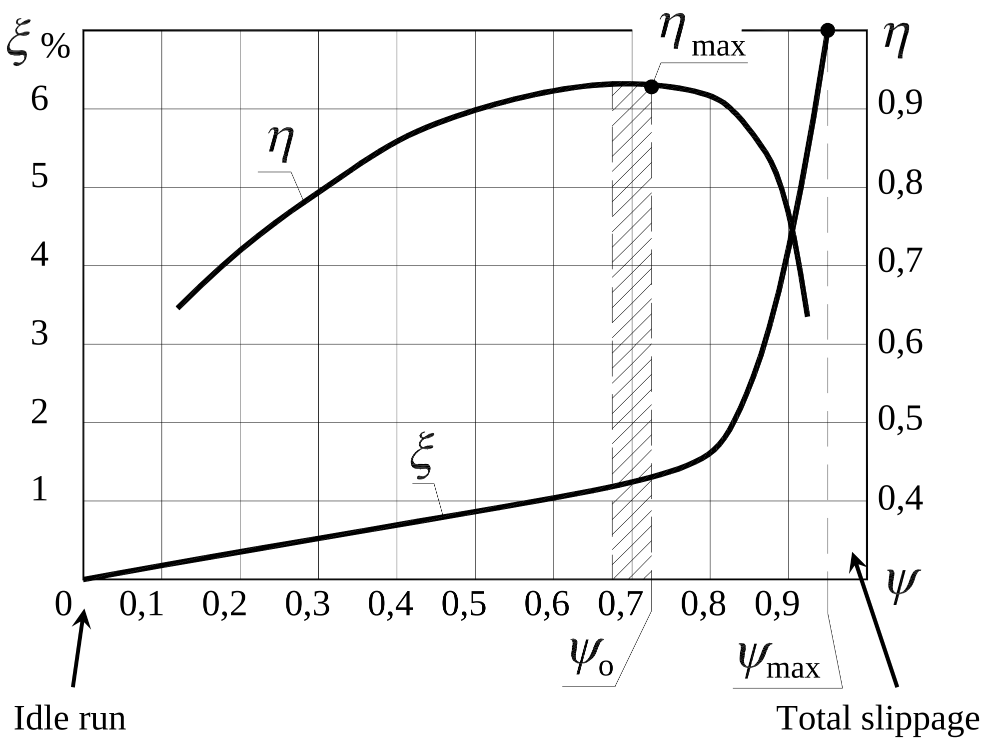
Scheme of the stresses in belt

Basic factors of a belt drive

Belt slip factor: $\xi = \dfrac{V_2 - V_1}{V_1} \cdot 100\%$.

Efficiency factor: $\eta = \dfrac{N_2}{N_1} \cdot 100\%$.

Pulling factor: $\psi = \dfrac{F_t}{F_1 + F_2} = \dfrac{F_t}{2F_0}$.



Relation between three basic factor of the belt drive

5. Steps for the design of a belt drive:

Calculation methods for different types of belt drives are similar. The simplest is the calculation of a belt drive with flat belts. However, V-belt and poly-V-belt transmissions are characterized by increased adhesion forces to the pulleys and, consequently, increased traction capacity. Therefore, next we will consider the features of V- belts drive calculating.

The initial stage of designing belt drives comes down to choosing the section and type of belt depending on the initial data (about the load, as well as the necessary parameters of transmitted power/torque and speed). The sections and types of belts are standardized, and to select them it is necessary to use the standards.

Next, it is necessary to calculate the geometry of the belt drive, and also take standard values for the diameters of the pulleys and the length of the belt.

Power calculations for V-belt drives usually come down to determining the permissible power per V-belt and finding the number of belts, as well as the pre-tensioning force of one V-belt and the forces acting on the V-belt drive shafts. Note that for a poly-V-ribbed transmission, instead of finding the number of belts, the required number of ribs of the poly-V-belt is determined. To perform calculations, you also need to know a number of parameters and coefficients contained in the reference literature (Directory).

Ukrainian students should focus on official domestic DSTU ISO standards. However, their use is not free of charge and it is advisable to use existing educational and methodological literature, as well as publicly available textbooks.

Foreign (english-speaking) students, it is advisable to focus on the originals of ISO standards in English, which are provided on a commercial basis and are more expensive than DSTU ISO standards. Even with their acquisition, there are legal issues (ownership) associated with the distribution and dissemination of the information found in these standards.

Steps for the design of a belt drive:

a. Select the types of the belt using initial data.

b. Determine diameters of pulleys and center distance.

c. Calculate peripheral velocity and angular speed ratio.

d. Find the length of the belt and decide on the standard belt size.

e. Calculate exact center distance using standard length.

f. Calculate modified power rating of a belt.

g. Determine the number of the belts.

If number of belts proves to be unsuitable for some reason or other (e.g. $z>8$) then repeat the calculations with another section of belt (not A – then B, C….)

h. Determine loads carried by drive shafts and other parameters.

V-belt Drive Calculation

It is required to calculate the belt drive given the following parameters:

Torque on driving shaft: $T_1 = 72.74$ Nm;

Motor **rotation frequency** (Rotation frequency on the input shaft of the belt drive and on the smaller pulley) $n_1 = 1460$ rpm

Belt drive **transmission ratio** (**angular velocity ratio**) $i_{BD} = i_{12} = 3.3$
Belt drive **efficiency** $\eta_{BD} = 0.95$

1. Select the types of the belt using initial data

Angular velocity on the motor:

$$\omega_1 = \frac{\pi \cdot n_1}{30} = \frac{3.14 \cdot 1460}{30} = 152.891 \text{ rad/s}$$

Transmitted power:

$$P_1 = T_1 \cdot \omega_1 = 72.74 \cdot 152.891 = 11121 \text{ W} = 11.121 \text{ kW}$$

Table 1– **Belt section parameters**

Section	b, mm	b_0, mm	h, mm	Cross-section area, sm^2	Weight q, kg/m	L	T_1	Minimum D_p
Z(O)	8.5	10	6,0	0.47	0.06 (0.07)	400-2500	<30	63
A	11.0	13	8,0	0.81	0.10	560-4000	15...60	90
B(Б)	14.0	17	10,5	1.38	0.18	800-6300	50...150	125
C(B)	19.0	22	13,5	2.30	0.30	1800-10000	120...600	200
D(Г)	27.0	32	19,0	4.76	0.60 (0.62)	3150-14000	450...2400	315
E(Д)	32.0	38	23,5	6.92	0.90	4500-18000	*1600...8000*	500
F(E)	42.0	50	30,0	11.72	1.52	6300-18000	*6000...3000*	800

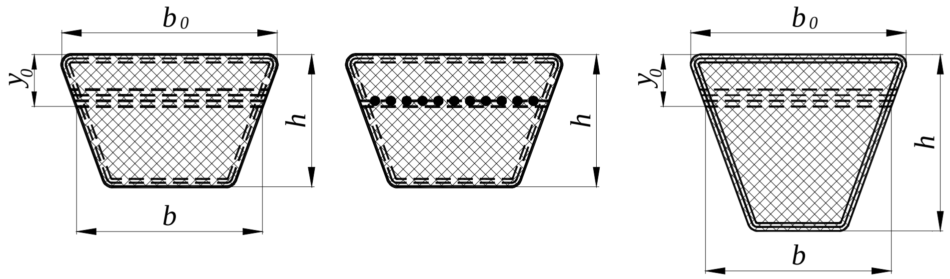


Fig. 1. V-Belt section

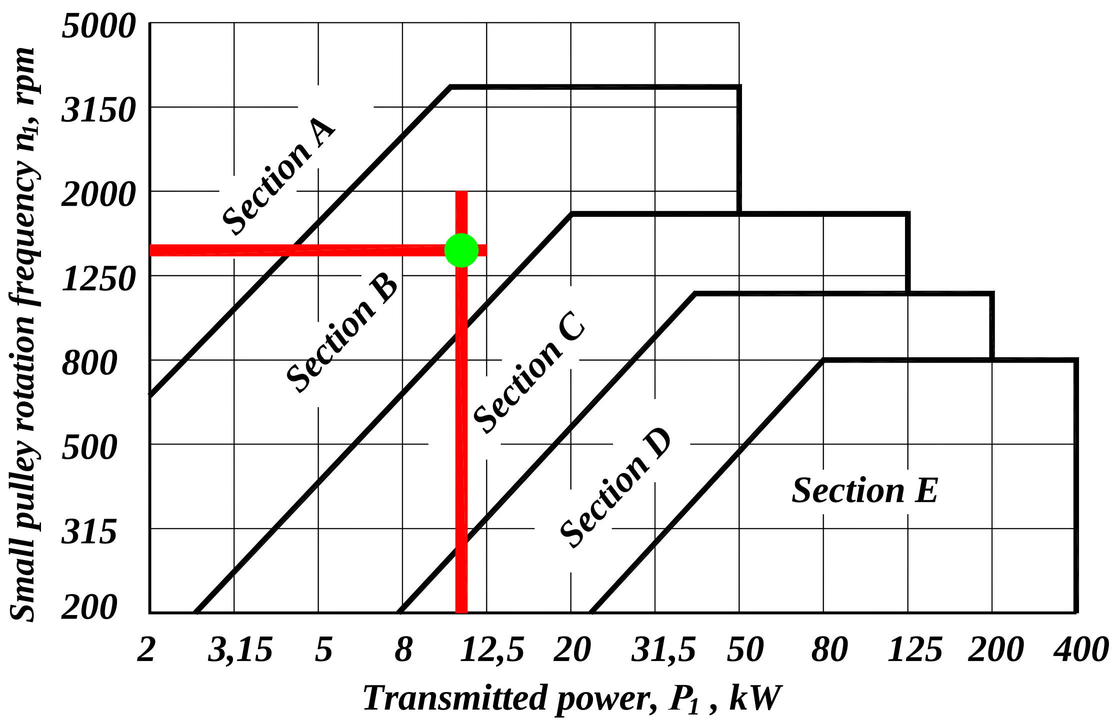


Fig. 2. Transmitted power for different section of V-Belts

For Torque $T_1 = 72.74$ Nm and Rotation Frequency $n_1 = 1460$ rpm we can use **section B** with the range of Torque 50...150 Nm (Tab. 1 or Fig. 2 for Power 11.121 kW)

2. Determine diameters of pulleys and center distance

The minimum diameter of the smaller pulley for **section B** V-Belt (Tab. 1) is 125 mm. We can use more or equal standard value from the next series of **Nominal design diameters**.

Let's take the **Diameter of smaller pulley** $D_1 = 200$ mm (200>125)

We can take **Belt Slip Factor** $\xi = 0.02$

Diameter of bigger (driven) pulley:

$$D_2 = D_1 \cdot i_{12} \cdot (1 - \xi) = 200 \cdot 3.3 \cdot (1 - 0.02) = 646.8 \text{ mm}$$

Standart Value of Diameter: $D_{2std} = 630$ mm (the nearest value from the next series of **Nominal design diameters**)

Nominal design diameters D_p of pulleys, mm:

50; (53); 56; (60); 63; (67); 71; (75); 80; (85); 90; (95); 100; (106); 112; (118); 125; (132); 140; (150); 160; (170); 180; (190); 200; (212); 224; (236); 250; (265); 280; (300); 315; (335); 355; (375); 400; (425); 450; 475; 500; (530); 560; (600); (620); 630; (670); 710; (750); 800; (850); 900; (950); 1000; (1060); 1120; (1180); 1250; (1320); 1400; (1500); 1600; (1700); 1800; (1900); 2000; (2120); 2240; (2360); 2500; (2650); (2800); (3000); (3150); (3550); (3750); (4000) mm.

Note. The dimensions given in round brackets are used in technically justified cases.

3. Calculate peripheral velocity and angular velocity ratio

Real angular velocity ratio:

$$i_{BDr} = \frac{D_{2std}}{D_1 \cdot (1-\xi)} = \frac{630}{200 \cdot (1-0.02)} = 3.214$$

Circumferential velocity (**peripheral velocity**):

$$v_B = \omega_1 \cdot \frac{D_1 \cdot 0.001}{2} = 152.891 \cdot \frac{200 \cdot 0.001}{2} = 15.29$$

Real rotation frequency of driven shaft

$$n_{2r} = \frac{D_1 \cdot (1-\xi)}{D_{2std}} \cdot n_1 = \frac{200 \cdot (1-0.02)}{630} \cdot 1460 = 454.2 \text{ rpm}$$

Center distance between the two pulleys

$$a = y \cdot D_{2std}$$

We can find parameter y using Tab. 2 (and interpolation method for exact calculation)

$x_1 = 3$	$y_1 = 1$
$x = i_{BDr} = 3.214$	$y = ?$
$x_2 = 4$	$y_2 = 0.95$

Linear interpolation formula:

$$y = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1) = 1 + \frac{0.95-1}{4-3}(3.214-3) = 1 - \frac{0.05}{1}0.214 = 0.9893$$

Center distance between the two pulleys

$$a = y \cdot D_{2std} = 0.9893 \cdot 630 = 623.259 \approx 623 \text{ mm}$$

Table 2 – **Center distance formula**

Transmission ratio, u	1	2	3	4	5	6.3
Center distance, a	$1.5d_2$	$1.2d_2$	d_2	$0.95d_2$	$0.9d_2$	$0.85d_2$

4. Find the **length** of the belt and accept **standard belt size**

Length of the belt:

$$L = 2 \cdot a + \pi \cdot \frac{D_1 + D_2}{2} + \frac{1}{a} \cdot \left(\frac{D_2 - D_1}{2} \right)^2 =$$

$$= 2 \cdot 623 + \pi \cdot \frac{200 + 630}{2} + \frac{1}{623} \cdot \left(\frac{630 - 200}{2} \right)^2 = 2623.96 \text{ mm}$$

Standard length of the belt: $L_{st} = 2800$ mm (the value from the next series of **Standard belt lengths** L_{st}).

The inequality $L_{st} > L$ must be satisfied.

Standard belt lengths L_{st}:

400, 450, 500, 560, 630, 710, 800, 900, 1000, 1120, 1250, 1400, 1600, 1800, 2000, 2240, 2500, 2800, 3150, 3550, 5000, 5000, 5000 , 5600, 6300, 7100, 8000, 9000, 10000, 11200, 12500, 14000, 16000, 18000.

In technically justified cases, intermediate L_{st} values are allowed:

425, 475, 530, 600, 670, 750, 850, 950, 1060, 1180, 1320, 1500, 1700, 1900, 2120, 2360, 2650, 3000, 3350, 3750, 4 , 4750, 5300, 6000, 6700, 7500, 8500, 9500, 10600, 11800, 13200, 15000, 17000.

5. Calculate **exact center distance** using standard length

Exact center distance between the two pulleys

$$a_{ex} = 0.25\left(L_{st} - \pi \cdot \frac{D_1 + D_2}{2} + \sqrt{\left(L_{st} - \pi \cdot \frac{D_1 + D_2}{2} \right)^2 - 8 \cdot \left(\frac{D_2 - D_1}{2} \right)^2} \right) =$$

$$= 0.25\left(2800 - \pi \cdot \frac{200 + 630}{2} + \sqrt{\left(2800 - \pi \cdot \frac{200 + 630}{2} \right)^2 - 8 \cdot \left(\frac{630 - 200}{2} \right)^2} \right) =$$

$$= 715.83\,\text{mm} \approx 716\,\text{mm}$$

Minimum center distance:

$$a_{\min} = a_{ex} - 0.01 \cdot L_{st} = 716 - 0.01 \cdot 2800 = 688\,\text{mm}$$

Maximum center distance:

$$a_{\max} = a_{ex} + 0.25 \cdot L_{st} = 716 + 0.25 \cdot 2800 = 786\,\text{mm}$$

Checking of calculation

$$U = \frac{v_B}{0.001 \cdot L_{st}} = \frac{15.29}{0.001 \cdot 2800} = 5.46 \le (8..10)$$

$$5.46 < 8 \text{ – It is OK}$$

Angle of wrap

$$\alpha_1 = 180° - \frac{D_2 - D_1}{a_{ex}} \cdot 57° = 180° - \frac{630 - 200}{716} \cdot 57° = 145.76° \ge (90°...120°)$$

It should be bigger then $90°, \alpha_1 > 90°$.

6. Calculate **modified rated power, transmitted by one V-belt**

Modified rated power P_b, transmitted by 1 V-belt:

$$P_b = P_0 \cdot C_\alpha \cdot C_L \cdot C_P$$

Rated power P_0, transmitted by one V-belt using Tab. 3.

Let us remind you in our case:

– We chose V-belt **section B**;

– Real angular velocity ratio**:** $i_{BDr} = 3.214$;

– Diameter of smaller pulley $D_1 = 200$ mm;

– Rotation Frequency $n_1 = 1460$ rpm.

There is no diameter of smaller pulley $D_1 = 200$ mm in Tab. 3, but there are 180 mm and 224 mm, so we need to perform an interpolation procedure on diameter $D_1 = 200$ mm and angular velocity ratio $i_{BDr} = 3.214$. Note that the rotation frequency is almost the same ($n_1 = 1460$ rpm – in our case and 1450 rpm in Table)

If $D_1 = 180$ mm and $i_{BDr} = 3.214$ ($i_{BD} \geq 3$) – $P_0 = 5.01$ kW

If $D_1 = 200$ mm and $i_{BDr} = 3.214$ ($i_{BD} \geq 3$) – $P_0 = ?$ kW

If $D_1 = 224$ mm and $i_{BDr} = 3.214$ ($i_{BD} \geq 3$) – $P_0 = 6.81$ kW

Rated power P_0, transmitted by one V-belt:

$$P_0 = 5.01 + \frac{6.81 - 5.01}{224 - 180}(200 - 180) = 5.8282 \text{ kW}$$

Example of interpolation for a more complex case:

– V-belt ***section A****;*

*– Real angular velocity ratio****:*** $i_{BDr} = 2.28$*;*

– Diameter of smaller pulley $D_1 = 125$ *mm;*

– Rotation Frequency $n_1 = 1760$ *rpm (In the USA, the power supply frequency is 60 Hz, so the synchronous frequency of an electric motor with 4 poles will be 1800 rpm, and the asynchronous one will be slightly less).*

For this case we should write down the following values from Table 3:

If $D_1 = 100$ *mm;* $n_1 = 1450$ *rpm ;* $i_{BD} = 1.5$ – $P_0 = 1.45$ *kW*

If $D_1 = 100$ *mm;* $n_1 = 1450$ *rpm ;* $i_{BD} \geq 3$ – $P_0 = 1.5$ *kW*

If $D_1 = 100$ *mm;* $n_1 = 2200$ *rpm ;* $i_{BD} = 1.5$ – $P_0 = 1.96$ *kW*

If $D_1 = 100$ *mm;* $n_1 = 2200$ *rpm ;* $i_{BD} \geq 3$ – $P_0 = 2.02$ *kW*

If $D_1 = 140$ *mm;* $n_1 = 1450$ *rpm ;* $i_{BD} = 1.5$ – $P_0 = 2.51$ *kW*

If $D_1 = 140$ *mm;* $n_1 = 1450$ *rpm ;* $i_{BD} \geq 3$ – $P_0 = 2.59$ *kW*

If $D_1 = 140$ *mm;* $n_1 = 2200$ *rpm ;* $i_{BD} = 1.5$ – $P_0 = 3.38$ *kW*

If $D_1 = 140$ *mm;* $n_1 = 2200$ *rpm ;* $i_{BD} \geq 3$ – $P_0 = 3.48$ *kW*

We need to perform an interpolation procedure on diameter $D_1 = 125$ *mm, rotation frequency* $n_1 = 1765$ *rpm and angular velocity ratio* $i_{BDr} = 2.28$ *(seven times):*

1) on angular velocity ratio $i_{BDr} = 2.28$ *(4 times)*

$$1.\ P_0 = 1.45 + \frac{1.5 - 1.45}{3 - 1.5}(2.28 - 1.5) = 1.476 \text{ kW}$$

$$2.\ P_0 = 1.96 + \frac{2.02 - 1.96}{3 - 1.5}(2.28 - 1.5) = 1.9912 \text{ kW}$$

$$3.\ P_0 = 2.51 + \frac{2.59 - 2.51}{3 - 1.5}(2.28 - 1.5) = 2.5516 \text{ kW}$$

$$4.\ P_0 = 3.38 + \frac{3.48 - 3.38}{3 - 1.5}(2.28 - 1.5) = 3.432 \text{ kW}$$

2) rotation frequency $n_1 = 1765$ *rpm (2 times)*

$$5.\ P_0 = 1.476 + \frac{1.9912 - 1.476}{2200 - 1450}(1760 - 1450) = 1.6889 \text{ kW}$$

$$6.\ P_0 = 2.5516 + \frac{3.432 - 2.5516}{2200 - 1450}(1760 - 1450) = 2.9155 \text{ kW}$$

2) diameter $D_1 = 125$ *mm (1 times)*

$$7.\ P_0 = 1.6889 + \frac{2.9155 - 1.6889}{140 - 100}(125 - 100) = 2.4555 \text{ kW}$$

In case if $D_1 = 125$ *mm;* $n_1 = 1760$ *rpm ;* $i_{BDr} = 2.28$ *the rated power* P_0, *transmitted by one* ***section A*** *V-belt will be* $P_0 = 2.4555$ *kW.*

Table 3 – **Rated power** P_0**, kW, transmitted by one V-belt**

Section and L, mm	D_1	i_{BD}	Smaller pulley rotation frequency, rpm							
			400	800	950	1200	1450	2200	2400	2800
Z (O) 1320	80	1,2	0,26	0,47	0,55	0,66	0,77	1,08	1,15	1,28
		1,5	0,27	0,49	0,56	0,68	0,80	1,11	1,18	1,32
		≥3	0,28	0,50	0,58	0,71	0,82	1,14	1,22	1,36
	≥112	1,2	0,42	0,76	0,88	1,07	1,25	1,72	1,84	2,04
		1,5	0,43	0,78	0,91	1,10	1,29	1,78	1,90	2,11
		≥3	0,44	0,81	0,94	1,14	1,33	1,84	1,96	2,17
A (A) 1700	100	1,2	0,50	0,88	1,01	1,22	1,41	1,90	2,01	2,19
		1,5	0,52	0,91	1,05	1,25	1,45	1,96	2,07	2,27
		≥3	0,53	0,94	1,08	1,30	1,50	2,02	2,14	2,34
	140	1,2	0,84	1,51	1,74	2,10	2,43	3,27	3,44	3,72
		1,5	0,86	1,56	1,79	2,17	2,51	3,38	3,56	3,85
		≥3	0,89	1,60	1,85	2,24	2,59	3,48	3,67	3,97
	≥180	1,2	1,16	2,10	2,43	2,93	3,38	4,43	4,62	4,85
		1,5	1,20	2,17	2,51	3,03	3,50	4,58	4,77	5,02
		≥3	1,24	2,24	2,59	3,12	3,61	4,72	4,92	5,18
B (Б) 2240	140	1,2	1,12	1,95	2,22	2,64	3,01	3,83	3,96	4,11
		1,5	1,16	2,01	2,30	2,72	3,10	3,95	4,09	4,25
		≥3	1,2	2,08	2,37	2,82	3,21	4,08	4,22	4,38
	180	1,2	1,70	3,01	3,45	4,11	4,70	5,91	6,07	6,16
		1,5	1,76	3,11	3,56	4,25	4,85	6,10	6,27	6,36
		≥3	1,81	3,21	3,67	4,38	5,01	6,29	6,47	6,56
	224	1,2	2,32	4,13	4,73	5,63	6,39	7,47	7,80	–
		1,5	2,40	4,27	4,89	5,81	6,60	8,00	8,08	–
		≥3	2,47	4;40	5,04	6,00	6,81	8,25	8,31	–
	≥280	1,2	3,09	5,49	6,26	7,42	8,30	9,12	–	–
		1,5	3,19	5,67	6,47	7,66	8,57	9,42	–	–
		≥3	3,29	5,85	6,67	7,91	8,84	9,72	–	–
C (B) 3750	250	1,2	3,87	6,66	7,58	8,78	9,67	10,29*1	–	–
		1,5	4,00	6,88	7,82	9,07	9,99	10,62*1	–	–
		≥3	4,12	7,10	8,07	9,36	10,69	10,96*1	–	–
	315	1,2	5,50	9,55	10,75	12,33	13,33	13,56*2	–	–
		1,5	5,68	9,86	11,10	12,73	13,76	14,00*2	–	–
		≥3	5,86	10,17	11,45	13,14	14,20	14,44*2	–	–
	≥450	1,2	8,77	14,76	16,29	17,75	17,90*3	–	–	–
		1,5	9,05	15,24	16,82	18,33	18,49*3	–	–	–
		≥3	9,34	15,72	17,35	18,91	19,07*3	–	–	–
*1 at 2000 rpm; *2 at 1800 rpm; *3 at 1300 rpm										

Table 3 – **Rated power P_0, kW, transmitted by one V-belt**

Section and L, mm	D_1	i_{BD}	Smaller pulley rotation frequency, rpm					
			200	400	600	750	950	1200
D (Г) 6000	400	1,2	6,98	12,25	16,50	19,01	21,46	22,68
		1,5	7,21	12,64	17,04	19,63	22,16	23,42
		≥3	7,48	13,04	17,57	20,25	22,86	24,16
	630	1,2	13,42	23,59	31,21	34,81	36,58	–
		1,5	13,85	24,36	32,23	36,45	37,78	–
		≥3	14,29	25,13	33,25	37,08	38,97	–
	≥800	1,2	17,93	31,12	39,73	40,81	–	–
		1,5	18,51	32,13	41,03	43,48	–	–
		≥3	19,10	33,15	42,33	44,85	–	–
E (Д) 7100	630	1,2	16,74	28,83	37,27	40,70	–	–
		1,5	17,28	29,77	38,49	42,03	–	–
		≥3	17,83	30,71	39,70	43,36	–	–
	800	1,2	23,21	39,64	49,49	51,33	–	–
		1,5	23,97	40,94	51,11	53,01	–	–
		≥3	24,73	42,23	52,73	54,68	–	–
	≥1000	1,2	30,52	50,84	59,38	–	–	–
		1,5	31,51	52,51	61,27	–	–	–
		≥3	32,51	54,17	63,21	–	–	–

Factor of the wrap angle

$$C_\alpha = 1 - 0.003 \cdot (180° - \alpha) = 1 - 0.003 \cdot (180° - 145.76°) = 0.8973$$

Factor of the load (depends on operating mode, load, etc.; range 0.5...1.0)

$$C_P = 0.75$$

Factor of the length (Tab. 4)

$$C_L = 1.05$$

Modified rated power P_b, transmitted by 1 V-belt:

$$P_b = P_0 \cdot C_\alpha \cdot C_L \cdot C_P = 5.8282 \cdot 0.8973 \cdot 0.75 \cdot 1.05 = 4.1183 \text{ kW}$$

Table 4 – **The value of the C_L coefficient for V-belts**

Lengh L, mm	Belt section						
	Z(O)	A(A)	B(Б)	C(B)	D(Г)	E(Д)	F(E)
400	0,79	–	–	–	–	–	–
450	0,80	–	–	–	–	–	–
50	0,81	–	–	–	–	–	–
560	0,82	0,79	–	–	–	–	–
630	0,84	0,81	–	–	–	–	–
710	0,86	0,83	–	–	–	–	–
800	0,90	0,85	–	–	–	–	–
900	0,92	0,87	0,82	–	–	–	–
1000	0,94	0,89	0,84	–	–	–	–
1120	0,95	0,91	0,86	–	–	–	–
1250	0,98	0,93	0,88	–	–	–	–
1400	1,01	0,96	0,90	–	–	–	–
1600	1,04	0,99	0,93	–	–	–	–
1800	1,06	1,01	0,95	0,86	–	–	–
2000	1,08	1,03	0,98	0,88	–	–	–
2240	1,10	1,06	1,00	0,91	–	–	–
2500	1,30	1,09	1,03	0,93	–	–	–
2800	–	1,11	1,05	0,95	–	–	–
315	–	1,13	1,07	0,97	0,86	–	–
3550	–	1,15	1,09	0,99	0,88	–	–
4000	–	1,17	1,13	1,02	0,91	–	–
4500	–	–	1,15	1,04	0,93	–	–
5000	–	–	1,18	1,07	0,96	0,92	–
5600	–	–	1,20	1,09	0,98	0,95	–
6300	–	–	1,23	1,12	1,01	0,97	0,92
7100	–	–	–	1,15	1,04	1,00	0,96
8000	–	–	–	1,18	1,06	1,02	0,98
9000	–	–	–	1,21	1,09	1,05	1,01
10000	–	–	–	1,23	1,11	1,07	1,03
12500	–	–	–	–	1,17	1,13	1,08
15000	–	–	–	–	1,20	1,17	1,11
18000	–	–	–	–	–	1,20	1,16

7. Determine the **number of the belts**

Number of belts:

$$z = \frac{P_1}{P_b \cdot C_z} = \frac{11.121}{4.1183 \cdot C_z}$$

Coefficient taking into account the influence of the **number of belts** operating simultaneously (Tab. 5)

$$C_z = 0.95$$

Table 5 – **Influence of the number of belts operating simultaneously**

z	2-3	4-6	≥6
C_z	0.95	0.9	0.85

where C_z – coefficient taking into account the influence of the number of belts operating simultaneously

Number of belts:

$$z = \frac{P_1}{P_b \cdot C_z} = \frac{11.121}{4.1183 \cdot 0.95} = 2.8425$$

We choose $z = 3$ **belts**

If number of belts proves unsuitable for some reason or other (e.g. z>8) then repeat the calculations with another ***section*** *of belt (not A – then B, C….)*

8. Determine loads carried by drive shafts and other parameters.

Belt pretension force:

$$F_0 = \frac{750 \cdot P_1}{v_B \cdot C_\alpha \cdot C_p \cdot z} + q \cdot v_B^{\,2}$$

Linear Weight for ***section*** B V-belt $q = 0.18$ kg/m (Tab. 6)

$$F_0 = \frac{750 \cdot P_1}{v_B C_\alpha C_p z} + q v_B^2 = \frac{750 \cdot 11.12}{15.29 \cdot 0.9 \cdot 0.75 \cdot 3} + 0.18 \cdot 15.29^2 = 311.44 \text{ kN}$$

Table 6 – **Linear weight (to find influence of centrifugal forces)**

Belt section	Z (0)	A	B (Б)	C (B)	D (Г)	E (Д)	F (E)
q $\{\theta\}$, kg/m	0.06	0.10	0.18	0.30	0.60	0.90	1.50

Note. For drives with automatic belt tension $q \cdot v_B{}^2 = 0$.

Force which applied to the shafts:

$$Q = 2 \cdot F_0 \cdot z \cdot \sin\left(\frac{\alpha}{2}\right) = 2 \cdot 311.44 \cdot 3 \cdot \sin\left(\frac{145.76^\circ}{2}\right) = 1785.84 \text{ kN}$$

Working life of the belt drive in hours:

For **number of cycles** $N_c = 5.7 \cdot 10^6$ (Tab. 7)

$$L_h = N_c \cdot \frac{L_{st}}{60 \cdot \pi \cdot D_1 \cdot n_1} = 5.7 \cdot 10^6 \cdot \frac{2800}{60 \cdot \pi \cdot 200 \cdot 1460} = 289.967 \approx 290 \text{ hours}$$

Table 7 – **Number of cycles N_c for V-belts with cord fabric (Class I)**

Belt section	Z (0), A	B (Б), C (B), D (Г)	E (Д), EO (E)
N_c	$5.6 \cdot 10^6$	$5.7 \cdot 10^6$	$2.5 \cdot 10^6$

Pulley rim dimensions (Tab. 8)**:**

$b_p = 14$ mm; $h_p = 10.8$ mm; $h_e = 4.2$ mm; $h_{1\min} = 8$ mm;

$e = 19 \pm 0.4$ mm; ($e_{\min} = 18.6$ mm; $e_{\max} = 19.4$ mm)

$f = 12.5^{+2}_{-1}$ mm; $r = 1$ mm; $\alpha_1 = 36°$ mm; $\alpha_2 = 40°$ mm;

Pulley outer diameters

$$d_{e1} = D_1 + 2 \cdot h_e = 200 + 2 \cdot 4.2 = 208.4 \text{ mm}$$

$$d_{e2} = D_{2st} + 2 \cdot h_e = 630 + 2 \cdot 4.2 = 638.4 \text{ mm}$$

Pulley rim width

$$B = (z - 1) \cdot e + 2 \cdot f = (3 - 1) \cdot 19 + 2 \cdot 12.5 = 63 \text{ mm}$$

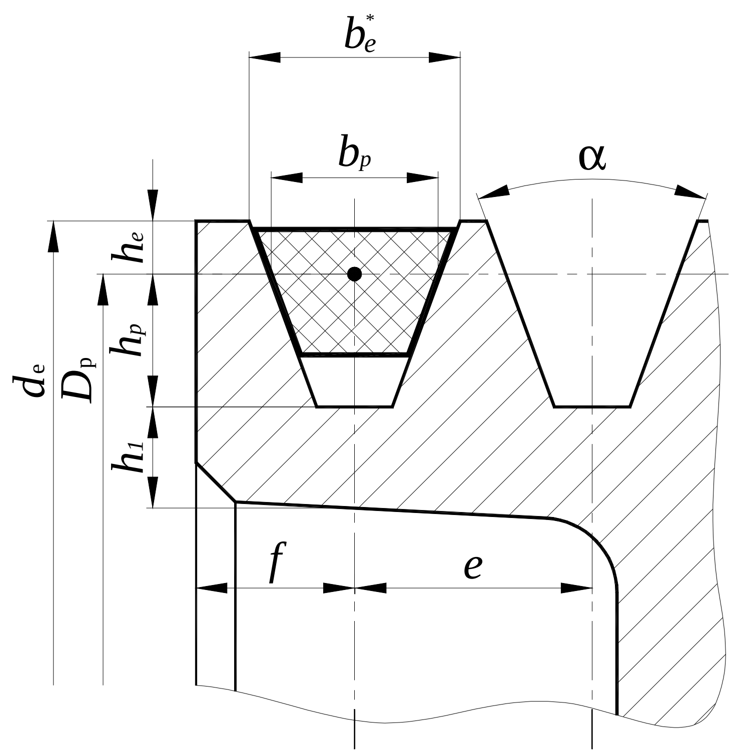
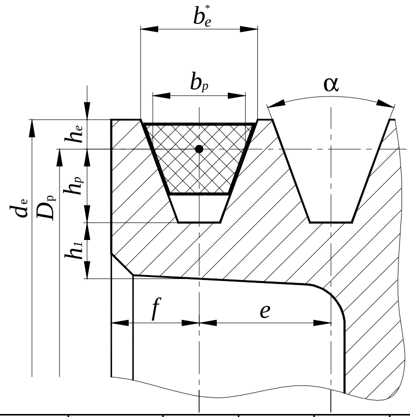


Fig. 3. Section of the Rim

Table 8 – **V-belt Rim parameters**



1) All linear dimensions are given in millimeters.

2) The maximum deviations b_e^* of the distance between the first and any other groove in a multi-groove pulley should not exceed the maximum deviations for size *e*

Section	b_p	h_p	h_e	h_1	r	e		f		D_p	b_e^*	α, deg
Z	8.5	7.0	2.5	6	0.5	12	±0.3	8.0	±1	63...71	10.0	34°
										80...100	10.1	36°
										112...160	10.2	38°
										180	10.3	40°
A	11	8.7	3.3	6	1.0	15	±0.3	10.0	+2 –1	90...112	13.1	34°
										125...160	13.3	36°
										140...400	13.4	38°
										450	13.5	40°
B	14	10.8	4.2	8	1.0	19	±0.4	12.5	+2 –1	125...160	17.0	34°
										180...224	17.2	36°
										250...500	17.4	38°
										560	17.6	40°
C	19	14.3	5.7	10	1.5	25.5	±0.5	17.0	+3 –1	200...315	22.9	36°
										355...630	23.1	38°
										710	23.3	40°
D	27	20.0	8.1	12	2.0	37.0	±0.6	24.0	+3 –1	315...450	32.5	36°
										500...900	32.8	38°
										1000	33.2	40°

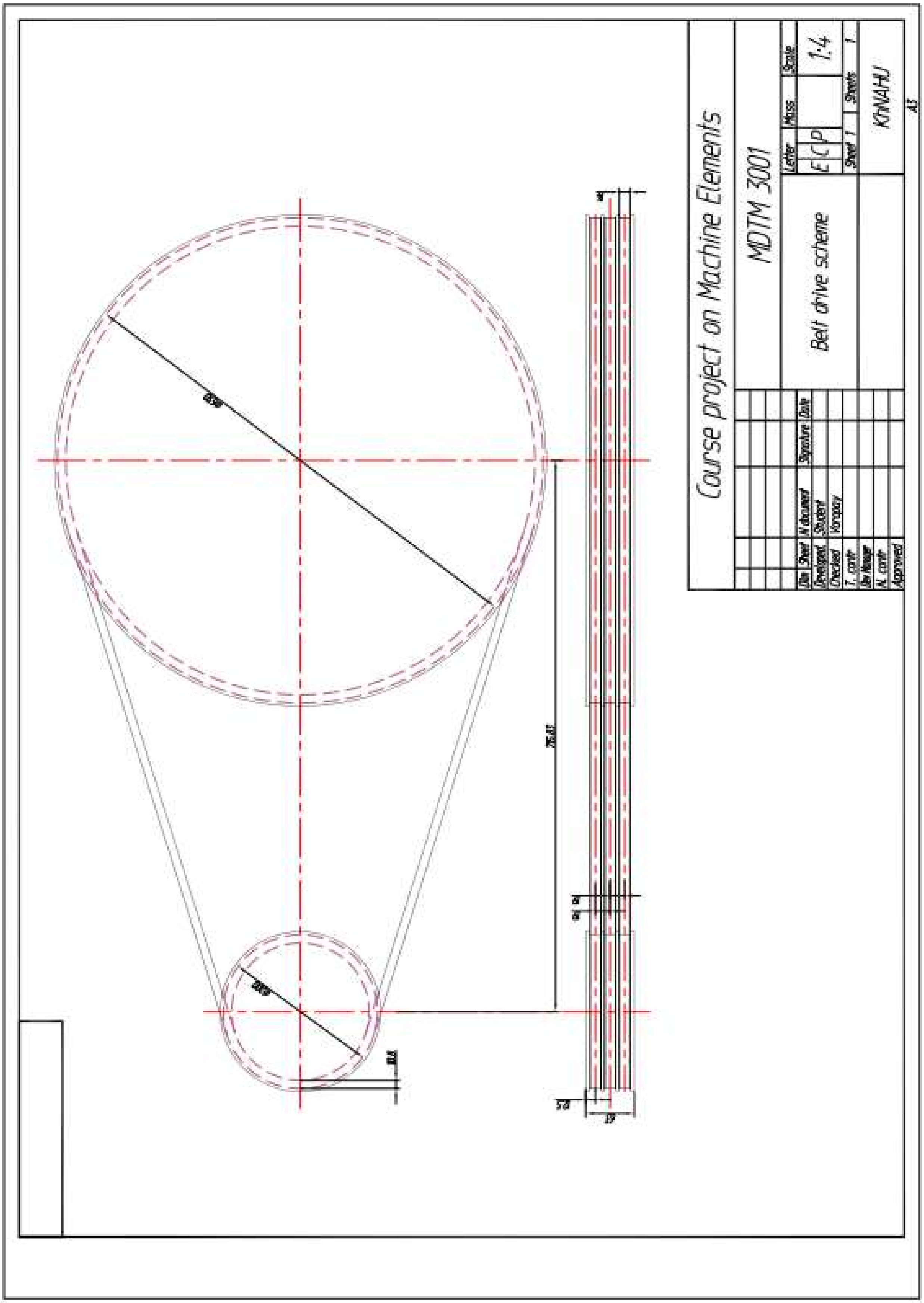


Fig. 4. Belt drive schema

Directory

Nominal design diameters D_p of pulleys, mm:

50; (53); 56; (60); 63; (67); 71; (75); 80; (85); 90; (95); 100; (106); 112; (118); 125; (132); 140; (150); 160; (170); 180; (190); 200; (212); 224; (236); 250; (265); 280; (300); 315; (335); 355; (375); 400; (425); 450; 475; 500; (530); 560; (600); (620); 630; (670); 710; (750); 800; (850); 900; (950); 1000; (1060); 1120; (1180); 1250; (1320); 1400; (1500); 1600; (1700); 1800; (1900); 2000; (2120); 2240; (2360); 2500; (2650); (2800); (3000); (3150); (3550); (3750); (4000) mm.

Note. The dimensions given in round brackets are used in technically justified cases.

Standard belt lengths *L*:

400, 450, 500, 560, 630, 710, 800, 900, 1000, 1120, 1250, 1400, 1600, 1800, 2000, 2240, 2500, 2800, 3150, 3550, 5000, 5000, 5000 , 5600, 6300, 7100, 8000, 9000, 10000, 11200, 12500, 14000, 16000, 18000.

In technically justified cases, intermediate ***L*** values are allowed:
425, 475, 530, 600, 670, 750, 850, 950, 1060, 1180, 1320, 1500, 1700, 1900, 2120, 2360, 2650, 3000, 3350, 3750, 4 , 4750, 5300, 6000, 6700, 7500, 8500, 9500, 10600, 11800, 13200, 15000, 17000.

Table 1– **Belt section parameters**

Section	b, mm	b_0, mm	h, mm	Cross-section area, sm^2	Weight q, kg/m	L	T_1	Minimum D_p
Z(O)	8.5	10	6,0	0.47	0.06 (0.07)	400-2500	<30	63
A	11.0	13	8,0	0.81	0.10	560-4000	15...60	90
B(Б)	14.0	17	10,5	1.38	0.18	800-6300	50...150	125
C(B)	19.0	22	13,5	2.30	0.30	1800-10000	120...600	200
D(Г)	27.0	32	19,0	4.76	0.60 (0.62)	3150-14000	450...2400	315
E(Д)	32.0	38	23,5	6.92	0.90	4500-18000	*1600...8000*	500
EO(E)	42.0	50	30,0	11.72	1.52	6300-18000	*6000...3000*	800

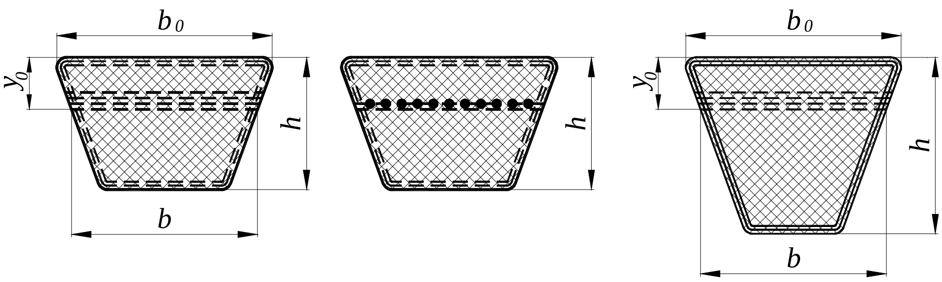


Fig. 1. V-Belt section

Table 2 – **Center distance formula**

Transmission ratio, u	1	2	3	4	5	6.3
Center distance, a	$1.5d_2$	$1.2d_2$	d_2	$0.95d_2$	$0.9d_2$	$0.85d_2$

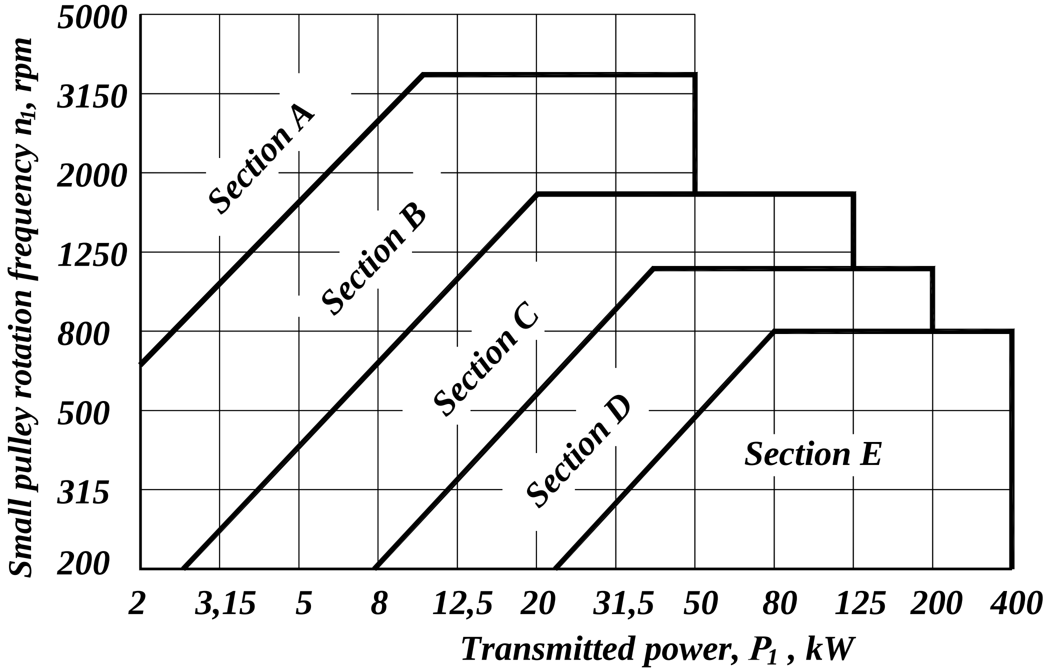


Fig. 2. Transmitted power for different ***section*** of V-Belts

Table 3 – **Rated power P_0, kW, transmitted by one V-belt**

Section and L, mm	D_1	i_{BD}	Smaller pulley rotation frequency, rpm							
			400	800	950	1200	1450	2200	2400	2800
Z (O) 1320	80	1,2	0,26	0,47	0,55	0,66	0,77	1,08	1,15	1,28
		1,5	0,27	0,49	0,56	0,68	0,80	1,11	1,18	1,32
		≥3	0,28	0,50	0,58	0,71	0,82	1,14	1,22	1,36
	≥112	1,2	0,42	0,76	0,88	1,07	1,25	1,72	1,84	2,04
		1,5	0,43	0,78	0,91	1,10	1,29	1,78	1,90	2,11
		≥3	0,44	0,81	0,94	1,14	1,33	1,84	1,96	2,17
A (A) 1700	100	1,2	0,50	0,88	1,01	1,22	1,41	1,90	2,01	2,19
		1,5	0,52	0,91	1,05	1,25	1,45	1,96	2,07	2,27
		≥3	0,53	0,94	1,08	1,30	1,50	2,02	2,14	2,34
	140	1,2	0,84	1,51	1,74	2,10	2,43	3,27	3,44	3,72
		1,5	0,86	1,56	1,79	2,17	2,51	3,38	3,56	3,85
		≥3	0,89	1,60	1,85	2,24	2,59	3,48	3,67	3,97
	≥180	1,2	1,16	2,10	2,43	2,93	3,38	4,43	4,62	4,85
		1,5	1,20	2,17	2,51	3,03	3,50	4,58	4,77	5,02
		≥3	1,24	2,24	2,59	3,12	3,61	4,72	4,92	5,18
B (Б) 2240	140	1,2	1,12	1,95	2,22	2,64	3,01	3,83	3,96	4,11
		1,5	1,16	2,01	2,30	2,72	3,10	3,95	4,09	4,25
		≥3	1,2	2,08	2,37	2,82	3,21	4,08	4,22	4,38
	180	1,2	1,70	3,01	3,45	4,11	4,70	5,91	6,07	6,16
		1,5	1,76	3,11	3,56	4,25	4,85	6,10	6,27	6,36
		≥3	1,81	3,21	3,67	4,38	5,01	6,29	6,47	6,56
	224	1,2	2,32	4,13	4,73	5,63	6,39	7,47	7,80	–
		1,5	2,40	4,27	4,89	5,81	6,60	8,00	8,08	–
		≥3	2,47	4;40	5,04	6,00	6,81	8,25	8,31	–
	≥280	1,2	3,09	5,49	6,26	7,42	8,30	9,12	–	–
		1,5	3,19	5,67	6,47	7,66	8,57	9,42	–	–
		≥3	3,29	5,85	6,67	7,91	8,84	9,72	–	–
C (B) 3750	250	1,2	3,87	6,66	7,58	8,78	9,67	10,29*1	–	–
		1,5	4,00	6,88	7,82	9,07	9,99	10,62*1	–	–
		≥3	4,12	7,10	8,07	9,36	10,69	10,96*1	–	–
	315	1,2	5,50	9,55	10,75	12,33	13,33	13,56*2	–	–
		1,5	5,68	9,86	11,10	12,73	13,76	14,00*2	–	–
		≥3	5,86	10,17	11,45	13,14	14,20	14,44*2	–	–
	≥450	1,2	8,77	14,76	16,29	17,75	17,90*3	–	–	–
		1,5	9,05	15,24	16,82	18,33	18,49*3	–	–	–
		≥3	9,34	15,72	17,35	18,91	19,07*3	–	–	–
*1 at 2000 rpm; *2 at 1800 rpm; *3 at 1300 rpm										

Table 3 – **Rated power P_0, kW, transmitted by one V-belt**

Section and L, mm	D_1	i_{BD}	Smaller pulley rotation frequency, rpm					
			200	400	600	750	950	1200
D (Г) 6000	400	1,2	6,98	12,25	16,50	19,01	21,46	22,68
		1,5	7,21	12,64	17,04	19,63	22,16	23,42
		≥3	7,48	13,04	17,57	20,25	22,86	24,16
	630	1,2	13,42	23,59	31,21	34,81	36,58	–
		1,5	13,85	24,36	32,23	36,45	37,78	–
		≥3	14,29	25,13	33,25	37,08	38,97	–
	≥800	1,2	17,93	31,12	39,73	40,81	–	–
		1,5	18,51	32,13	41,03	43,48	–	–
		≥3	19,10	33,15	42,33	44,85	–	–
E (Д) 7100	630	1,2	16,74	28,83	37,27	40,70	–	–
		1,5	17,28	29,77	38,49	42,03	–	–
		≥3	17,83	30,71	39,70	43,36	–	–
	800	1,2	23,21	39,64	49,49	51,33	–	–
		1,5	23,97	40,94	51,11	53,01	–	–
		≥3	24,73	42,23	52,73	54,68	–	–
	≥1000	1,2	30,52	50,84	59,38	–	–	–
		1,5	31,51	52,51	61,27	–	–	–
		≥3	32,51	54,17	63,21	–	–	–

Table 4 – **The value of the C_L coefficient for V-belts**

Lengh L, mm	Belt section						
	Z(O)	A(A)	B(Б)	C(B)	D(Г)	E(Д)	F(E)
400	0,79	–	–	–	–	–	–
450	0,80	–	–	–	–	–	–
50	0,81	–	–	–	–	–	–
560	0,82	0,79	–	–	–	–	–
630	0,84	0,81	–	–	–	–	–
710	0,86	0,83	–	–	–	–	–
800	0,90	0,85	–	–	–	–	–
900	0,92	0,87	0,82	–	–	–	–
1000	0,94	0,89	0,84	–	–	–	–
1120	0,95	0,91	0,86	–	–	–	–
1250	0,98	0,93	0,88	–	–	–	–
1400	1,01	0,96	0,90	–	–	–	–
1600	1,04	0,99	0,93	–	–	–	–
1800	1,06	1,01	0,95	0,86	–	–	–
2000	1,08	1,03	0,98	0,88	–	–	–
2240	1,10	1,06	1,00	0,91	–	–	–
2500	1,30	1,09	1,03	0,93	–	–	–
2800	–	1,11	1,05	0,95	–	–	–
315	–	1,13	1,07	0,97	0,86	–	–
3550	–	1,15	1,09	0,99	0,88	–	–
4000	–	1,17	1,13	1,02	0,91	–	–
4500	–	–	1,15	1,04	0,93	–	–
5000	–	–	1,18	1,07	0,96	0,92	–
5600	–	–	1,20	1,09	0,98	0,95	–
6300	–	–	1,23	1,12	1,01	0,97	0,92
7100	–	–	–	1,15	1,04	1,00	0,96
8000	–	–	–	1,18	1,06	1,02	0,98
9000	–	–	–	1,21	1,09	1,05	1,01
10000	–	–	–	1,23	1,11	1,07	1,03
12500	–	–	–	–	1,17	1,13	1,08
15000	–	–	–	–	1,20	1,17	1,11
18000	–	–	–	–	–	1,20	1,16

Table 5 – **Influence of the number of belts operating simultaneously**

z	2-3	4-6	≥6
C_z	0.95	0.9	0.85

where C_z – coefficient taking into account the influence of the number of belts operating simultaneously

Table 6 – **Linear weight (to find influence of centrifugal forces)**

Belt section	Z (0)	A	B (Б)	C (B)	D (Г)	E (Д)	EO (E)
q {θ}, kg/m	0.06	0.10	0.18	0.30	0.60	0.90	1.50

Note. For drives with automatic belt tension $\theta \cdot V^2 = 0$.

Table 7 – **Number of cycles N_c for V-belts with cord fabric (Class I)**

Belt section	Z (0), A	B (Б), C (B), D (Г)	E (Д), EO (E)
N_c	$5.6 \cdot 10^6$	$5.7 \cdot 10^6$	$2.5 \cdot 10^6$

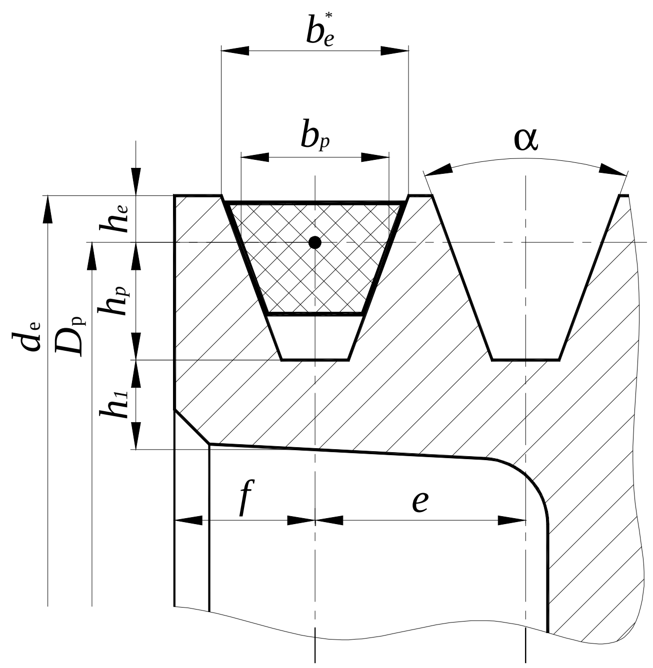
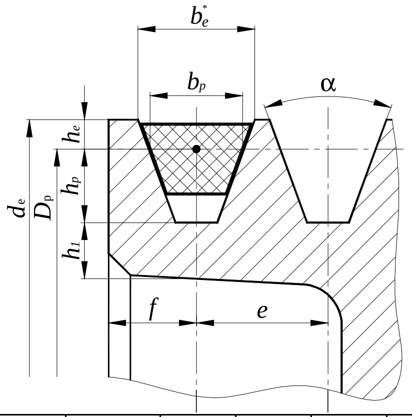


Fig. 3. Section of the Rim

Table 8 – **V-belt Rim parameters**



1) All linear dimensions are given in millimeters.

2) The maximum deviations b_e^* of the distance between the first and any other groove in a multi-groove pulley should not exceed the maximum deviations for size e

Section	b_p	h_p	h_e	h_1	r	e		f		D_p	b_e^*	α, deg
Z	8.5	7.0	2.5	6	0.5	12	±0.3	8.0	±1	63...71	10.0	34°
										80...100	10.1	36°
										112...160	10.2	38°
										180	10.3	40°
A	11	8.7	3.3	6	1.0	15	±0.3	10.0	+2 –1	90...112	13.1	34°
										125...160	13.3	36°
										140...400	13.4	38°
										450	13.5	40°
B	14	10.8	4.2	8	1.0	19	±0.4	12.5	+2 –1	125...160	17.0	34°
										180...224	17.2	36°
										250...500	17.4	38°
										560	17.6	40°
C	19	14.3	5.7	10	1.5	25.5	±0.5	17.0	+3 –1	200...315	22.9	36°
										355...630	23.1	38°
										710	23.3	40°
D	27	20.0	8.1	12	2.0	37.0	±0.6	24.0	+3 –1	315...450	32.5	36°
										500...900	32.8	38°
										1000	33.2	40°

Table 9 –**V-belts parameters (option)**

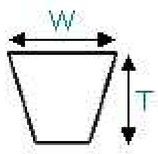
Section	Top width *W*, mm	Height *T*, mm	Sketch	Belt weight (kg/m)	Wedge angle, deg
Z	10	6		0.065	40°
A	13	8		0.112	
B	17	11		0.198	
C	22	14		0.330	
D	32	20		0.675	
E	38	25		1.030	

Table 9 –**Standard Sections (option)**

Section ISO	Section GOST
Z	О
A	А
B	Б
C	В
D	Г
E	Д
F	Е

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