Belt drives

5.1 Introduction

Belts are used to transmit motion between shafts that are located at a considerable distance from each other. They are not used for exact fixed speed ratio because slipping may occur during motion. They are very flexible when considering the distance or the angle between the two shafts.

5.3 Types of belts

The four principle types of belts are shown in table (6.1) with some of their characteristics. Crowned pulleys are used for flat pulleys, and grooved pulleys or sheaves for round and V- belts. Timing belts require toothed wheels or sprockets.

Table (5.1) types of Belts

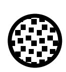
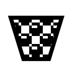
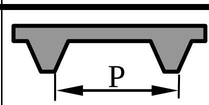
Belt type	Sketch	Joint	Size range	Centre distance
Flat		yes	t = { 0.03 to 0.20 in 0.75 to 5 mm	No upper limit
Round		Yes	D = $\frac{1}{8}$ to $\frac{3}{4}$ in	No upper limit
V		None	t = { 0.31 to 0.91 in 8 to 19 mm	Limited
Timing	 	None	P = 2 mm and up	Limited

Figure (5.1) illustrates the geometry of flat belt drives. Two types of reversing drives are shown. Notice that both sides of the belt contact the pulleys and so these drives can not be used with V-belts or timing belts

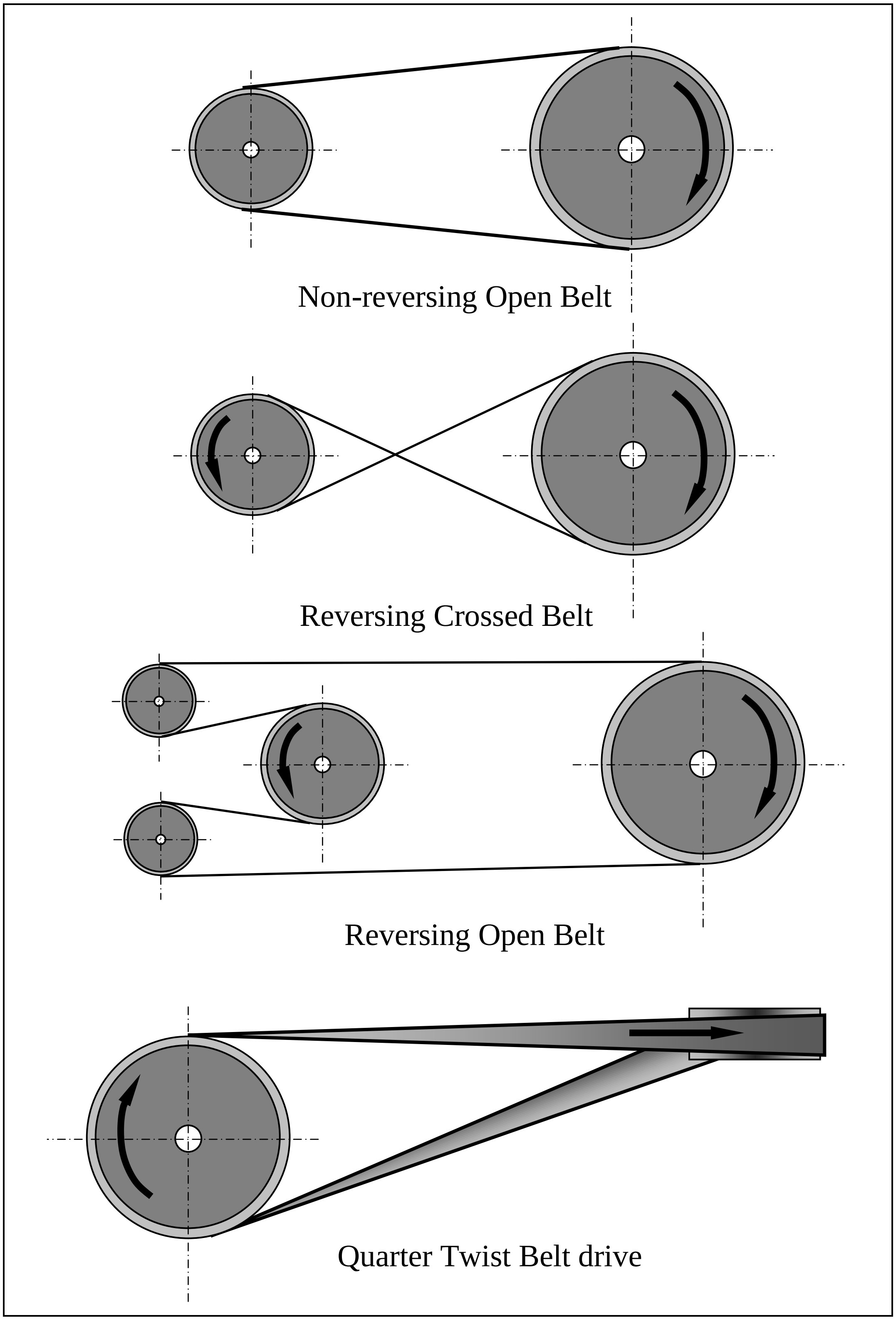


Fig. (5.1)Layout of Flat belt drive

V-Belts

V-belts are used widely in machine tools. They can be obtained with different lengths and sizes. There are five standard sizes of V-belts: A, B, C, D, E as shown in fig. (5.2).

5.2 Selection of V-belts:

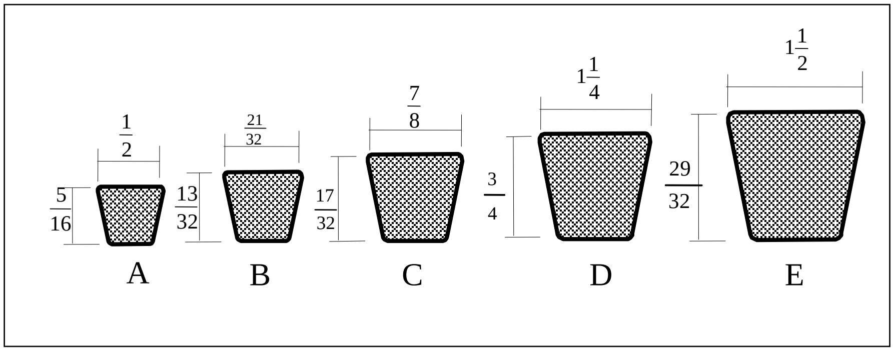


Fig. (5.2) Cross-sections of V-belts

The following information should be available for the selection of a suitable V-belt:

1. Power to be transmitted
2. Speed of the small or large pulley
3. Speed ratio
4. Field of application.
5. Approximate distance between the centres of the two pulleys

The following steps can used to select a suitable V-belt based on the information mentioned above:

1. Determine the service factor *depending on the field of application*, from table (5.2).Obtain the design power from the equation:
   Design power = transmitted power x service factor (5.1)
2. Select a suitable belt size from fig.(5.3) at the intersection of the speed of the small pulley and the design power.
3. Find the diameter of the small pulley (d) from table (5.3).
4. Find the diameter of the large pulley (D) from the equation:
   D= d x speed ratio (5.2)
5. Find the length of the belt using the equation:

$$L = 2C + 1.57(D + d) + \frac{(D - d)^2}{4C} \qquad (5.3)$$

Where:

L: length of belt
C: Centre distance between shafts

6. Obtain the standard length of the belt from table (5.4)

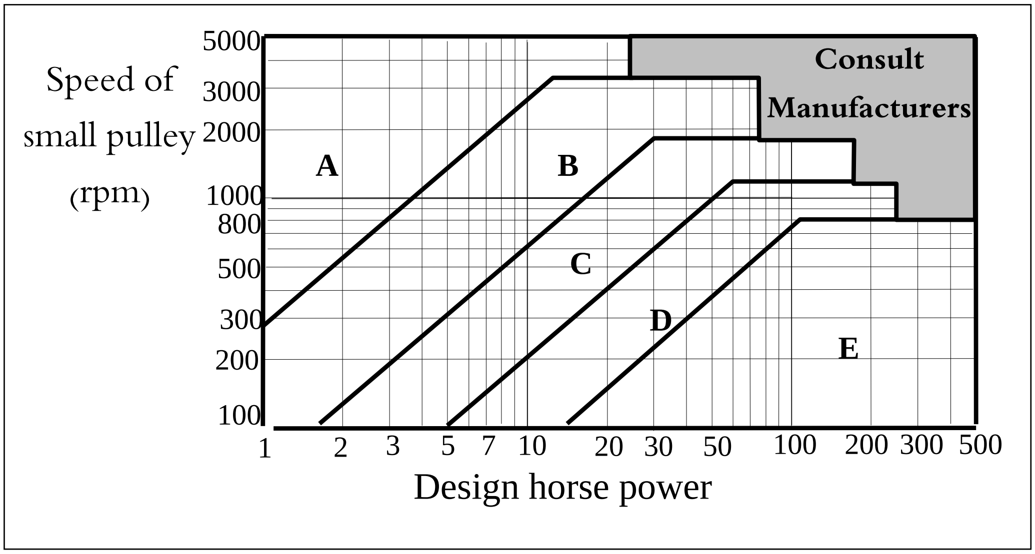


Fig. (5.3) Selection of V-belts

7. Calculate the exact centre distance from the equation:

$$C = \frac{b + \sqrt{b^2 - 32(D-d)^2}}{16} \quad (5.4)$$

Where,

$$b = 4L - 6.28(D + d) \quad (5.5)$$

8. Find the angle of lap (arc of contact), from the equation:

$$Angle\ of\ lap = 180 - \frac{(D-d)60}{C} \quad (5.6)$$

9. Find the capacity of one belt from the equation:

Capacity of one belt = $XS^{0.91} - \frac{YxS}{d_e} - ZS^3$ (5.7)

The values of X,Y and Z can obtained from table (5.5)

The equivalent small pulley diameter d_e can be obtained from the equation:

d_e = *diameter of small pulley x coefficient of small pulley* (5.8)

The coefficient of the small pulley is obtained from table (5.6)

The linear speed of the belt, S, in thousands of feet can be obtained from the equation:

S = (3.142xP.D x *RPM)/12000* (5.9)

Where P.D. is the pitch diameter of the small pulley

10. Find the power transmitted by one belt from the equation:

11. *Power of one belt =belt capacity x length coefficient x coefficient of arc of contact* (5.10)

The coefficient of arc of contact can be obtained from table (5.7) and the length coefficient can be obtained from table (5.8)

12. The required number of belts can be obtained from the equation:

No. of belts = Design power/ power of one belt (5.11)

TABLE (5.2) SERVICE FACTOR

Application	AC Motor: Normal torque, Squirrel Cage ,Synchronous, Split Phase ,DC Motor :Shunt wound, Engines :Multi-cylinder Internal, Combustion			AC Motor: High torque , High-slip Repulsion-Induction Single-phase ,Series Wound, Slipping, DC Motor : series wound Compound Wound Engine :Single- cylinder Internal Combustion, Line shafts :Clutches		
Hour in daily service	3--5	8-10	16-24	3-5	8-10	16-24
Agitators for liquids, Blowers and exhausts , Centrifugal pumps and compressor , Fan up to 10 hp and machine tool, Light-duty conveyors	1.0	1.1	1.2	1.1	1.2	1.3
Belt conveyors for sand, grain, etc. Dough mixers and Fan over 10 hp Generators and line-shafts, Laundry and printing machinery , Punches, presses ,shears , Positive displacement rotary pumps, Revolving and vibrating screens Brick and textile machinery	1.1	1.2	1.3	1.2	1.3	1.4
Bucket elevators and exiters ,Piston pumps and compressors ,Hammer-mills and paper-mill beaters , Conveyers and pulverizers, Positive displacement blowers, Sawmill and wood-working machinery	1.2	1.3	1.4	1.4	1.5	1.6
Crushers ,mills and hoists Rubber calendars , extruders and mills	1.3	1.4	1.5	1.5	1.6	1.8

Table (5.3) SHEAVE DIMENSION

Size of belt	**Pitch diameter**		**Standard Groove Dimensions**					
	Minimum recommended	Range	Groove angle	**W**	**D**	***X***	**S**	**E**
A	3	2.6 to 5.4 Over 5.4	34^0 38^0	0.494 0.504	0.490	0.125	5/8	3/8
B	5.4	4.6to 7.0 Over 7.0	34^0 38^0	0.637 0.650	0.580	0.175	¾	½
C	9.0	7.0 to 7.99 8.0 to 12.0 Over 12.0	34^0 36^0 38^0	0.879 0.887 0.895	0.780	0.200	1	1 11/16
D	13.0	12 --12.99 13.0 -- 17.0 *Over 17.0*	34^0 36^0 38^0	1.259 1.271 1.283	1.050	0.300	1 7/16	7/8
E	21.0	18.0 to 24.0 Over 24.0	36^0 38^0	1.527 1.542	1.300	0.400	1 3/4	1 1/8

Table (5.4) STANDARD PITCH LENGTHS

Standard Designation	A	B	C	Standard Designation	A	B	C	D	E
	Standard Pitch Lengths , Inches				Standard Pitch Lengths , Inches				
26	27.3	….	….	97	….	98.8	….	….	….
31	32.3	….	….	105	106.3	106.8	107.9	..…	….
33	34.3	….	….	112	113.3	113.8	114.9	….	..…
35	36.3	36.8	…..	120	121.3	121.8	122.9	123.3	….
38	39.3	39.8	…..	128	129.3	129.8	130.9	131.3	….
42	43.3	43.8	….	136	….	137.8	138.9	….	….
46	47.3	47.8	….	144	….	145.8	146.9	147.3	….
48	49.3	49.8	…	158	….	159.8	160.9	161.3	….
51	52.3	52.9	53.9	162	….	….	164.9	165.3	….
53	54.3	54.8	….	173	….	174.8	175.9	176.3	….
55	56.3	56.8	….	180	….	181.8	182.9	183.3	184.5
60	61.3	61.8	62.9	195	….	190.8	197.9	198.3	199.5
62	63.3	63.8	….	210	….	211.8	212.9	213.3	214.5
64	65.3	65.8	….	240	….	240.3	240.9	240.8	241.0
66	67.3	67.8	….	270	….	270.3	270.9	270.8	271.0
68	69.3	69.8	70.9	300	….	300.3	300.9	300.8	301.0
71	72.3	72.8	….	330	….	….	330.9	330.8	331.0
75	76.3	76.8	77.9	360	….	….	360.9	360.8	361.0
78	79.3	79.8	….	390	….	…	390.9	390.8	391.0
80	81.3	….	….	420	….	….	420.9	420.8	421.0
81	….	82.8	83.9	480	….	….	….	480.8	481.0
83	….	84.8	….	540	..…	..…	….	540.8	541.0
85	86.3	86.8	78.9	600	….	..…	….	600.8	601.0
90	91.3	91.8	92.9	660	…	….	….	660.8	661.0
96	97.3	..…	98.9	….	….	..…	….	….	….

Table (5.5a) FACTORS X , Y AND Z

Regular Quality Belts					
Belt Cross Section					
FACTORS	**A**	**B**	**C**	**D**	**E**
Values of X , Y and Z to be Used in H.P. Formula					
X	1.945	3.434	6.372	13.616	19.914
Y	3.801	9.830	26.899	93.899	177.74
Z	0.0136	0.0234	0.0416	0.0848	0.1222

Table (5.5b) FACTORS X , Y AND Z

Premium Quality Belts					
Belt Cross Section					
FACTORS	**A**	**B**	**C**	**D**	**E**
Values of X , Y and Z to be Used in H.P. Formula					
X	2.684	4.737	8.792	18.788	24.478
Y	5.326	13.962	38.819	137.70	263.04
Z	0.0136	0.0234	0.0416	0.0848	0.1222

Table (5.6) SMALL DIAMETER FACTORS

Speed Ratio Range	Small Diameter Factor	Speed Ratio Range	Small Diameter Factor	Speed Ratio Range	Small Diameter Factor
1.000 - 1.019	1.00	1.110 - 1.142	1.05	1.341 - 1.429	1.10
1.020 - 1.032	1.01	1.143 - 1.178	1.06	1.430 - 1.562	1.11
1.033 - 1.055	1.02	1.179 - 1.222	1.07	1.563 - 1.814	1.12
1.056 - 1.081	1.03	1.223 - 1.274	1.08	1.815 - 2.948	1.13
1.082 - 1.109	1.04	1.275 - 1.430	1.09	2.949 - and over	1.14

Table (5.7) ARC OF CONTACT CORRECTION FACTORS

Arc of Contact on Small sheaves	Type of drive		Arc of Contact on Small sheaves	Type of drive	
	V to V	V to Flat		V to V	V to Flat
	Correction Factor			Correction Factor	
180	1.00	0.75	130	0.86	0.86
170	0.98	0.77	120	0.82	0.82
160	0.95	0.8	110	0.78	0.78
150	0.92	0.82	100	0.74	0.74
140	0.89	0.84	90	0.69	0.96

Table (5.8) LENGTH CORRECTION FACTORS

Standard Length Designation	Belt Cross Section			Standard Length Designation	Belt Cross Section				
	A	B	C		A	B	C	D	E
	Correction Factor				Correction Factor				
26	0.81	….	….	97	….	1.02	….	….	….
31	0.84	….	….	105	1.10	1.04	0.94	..…	….
33	0.86	….	….	112	1.11	1.05	0.95	….	..…
35	0.87	0.81	….	120	1.13	1.07	0.97	0.86	….
38	0.88	0.83	….	128	1.14	1.08	0.98	0.87	….
42	0.90	0.85	….	136	….	1.09	0.99	….	….
46	0.92	0.87	….	144	….	1.11	1.09	0.90	….
48	0.93	0.88	….	158	….	1.13	1.02	0.92	….
51	0.94	0.89	0.80	162	….	….	1.03	0.92	….
53	0.93	0.90	….	173	….	1.15	1.04	0.93	….
55	0.96	0.90	….	180	….	1.16	1.05	0.94	0.91
60	0.98	0.92	0.82	195	….	1.18	1.07	0.96	0.92
62	0.99	0.93	….	210	….	1.19	1.08	0.96	0.94
64	0.99	0.93	….	240	….	1.22	1.11	1.00	0.96
66	1.00	0.94	….	270	….	1.25	1.14	1.03	0.99
68	1.00	0.95	0.85	300	….	1.27	1.16	1.05	1.01
71	1.01	0.95	….	330	….	….	1.19	1.07	1.03
75	1.02	0.97	0.87	360	….	….	1.21	1.09	1.05
78	1.03	0.98	….	390	….	…	1.23	1.11	1.07
80	1.04	….	….	420	….	….	1.24	1.12	1.09
81	….	0.98	0.89	480	….	….	….	1.16	1.12
83	….	0.99	….	540	..…	..…	….	1.18	1.14
85	1.05	0.99	0.90	600	….	..…	….	1.20	1.17
90	1.06	1.00	0.91	660	…	….	….	1.23	1.19
96	1.08	..…	0.92	….	….	..…	….	….	….

Example:

An engine lathe is driven by a squirrel cage electric motor through a V-belt. The electric motor runs at 1500 rpm with a maximum power of 3 hp. If the input speed to the engine lathe is 500 rpm and the centre distance between the motor pulley and the lathe pulley is 30 in. Select a suitable size, length and number of belts if the lathe is expected to be working for two shifts, 16 hours/day.

Solution:

Exercises:

1. A centrifugal pump is driven by 10 hp squirrel cage electric motor through V-belts. The electric motor runs at 150 rpm while the centrifugal pump runs at 800 rpm. The centre distance between the shaft of the pump and the electric motor is 45 inches. Select a suitable size, length and number of belts if the pump is expected to be working for 10 hours/day.

2. A stone-crusher is driven by a six cylinder diesel engine which can develop 100 hp. The engine speed is 1000 rpm while the crusher speed is 400 rpm. The centre distance between the engine and the crusher is 100 inches. If the crusher operates for 8 hours daily select suitable V-belts for driving the crusher.

3. An oil engine of 125 hp drives a centrifugal water pump running at 1200 rpm through V-belts. The engine runs at 350 rpm. The centre distance between the engine shaft and the pump shaft is approximately 75 inches. If the pump set operates 12 hours daily select proper size and number of belts.

4. Design a V-belt drive for a 160 hp gas engine running at 360 rpm. The engine drives a vertical deep-well centrifugal pump running at 1150 rpm. The centre distance between the engine shaft and the pump shaft is approximately 10 ft. make a layout for the drive and a double pulley idler. (***Note: The horse power rating of a V-belt used on a quarter-turn drive should be taken as 75% of that of a straight drive***.)

5. Design a V-belt drive for a 5 hp squirrel-cage electric motor running at 1180 rpm and driving an air compressor at 500 rpm. The centre distance between the pulleys should not exceed 40 in.

6. A bucket elevator is driven by 3 hp Normal torque electric motor through V-belts. The electric motor runs at 1500 rpm while the shaft of the elevator runs at 300 rpm. The centre distance between the shaft of the bucket elevator and the electric motor is approximately 40 inches. Select a premium quality suitable size, length and number of belts if the bucket elevator is expected to be working for 10 hours/day

7. A paper-mill beater is driven by 8 hp squirrel cage electric motor through V-belts. The electric motor runs at 1500 rpm while the paper-mill beater runs at 500 rpm. The centre distance between the shaft of the paper-mill

beater and the electric motor is approximately 45 inches. Select a premium quality suitable size, length and number of belts if the printing machinery is expected to be working for 8 hours/day

8. A printing machinery is driven by 5 hp Normal torque electric motor through V-belts. The electric motor runs at 1200 rpm while the printing machinery runs at 600 rpm. The centre distance between the shaft of the printing machinery and the electric motor is approximately 50 inches. Select a premium quality suitable size, length and number of belts if the printing machinery is expected to be working for 8 hours/day