IZMIR INSTITUTE OF TECHNOLOGY

Department of Mechanical Engineering

ME311 Machine Elements 1

Belt Design Report

HW2

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INTRODUCTION

The objective of this assignment is to select an appropriate V-belt drive from the SKF product line capable of transmitting power to a reciprocating compressor. The selection procedure was carried out using the SKF Power Transmission Belt Catalogue, which provides detailed guidelines for determining the suitable belt cross-section, pulley dimensions, belt length, and the required number of belts.

The design parameters of the system were defined based on each student's identification number, as specified in the assignment. Using these given inputs, all calculations were performed in accordance with the step-by-step selection procedure recommended in the SKF catalogue. This approach ensures that the selected belt system satisfies the operating requirements of the reciprocating compressor while remaining fully compliant with SKF design limits and performance recommendations.

DESIGN

GIVEN DESIGN PARAMETERS

Design parameters for student number of 280203076 are shown below.

Driver Power: 34 kW

Driver Speed: 2076 rpm

Driven Speed: 1048 ± 5 rpm

Service: 9 h/day

Adjustable distance between centers: 1058 ± 75 mm

1- SERVICE FACTOR(C2)

According to the SKF Power Transmission Belt Catalogue, the first step in the belt selection procedure is the determination of the service factor, denoted as C_2. The service factor is a dimensionless coefficient used to account for the operating conditions of both the driver and the driven machine, including load characteristics and duty cycle.
In this study, the service factor was determined using Tables 2 and 3 of the SKF catalogue. These tables evaluate the influence of parameters such as the type of load, operating environment, daily service duration, and dynamic behavior of the driven equipment. By incorporating these effects through the service factor, the calculated design power more accurately represents real operating conditions, ensuring a reliable and conservative belt selection.

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Table 2

Types of prime mover

Soft starts Electric motors:	**Heavy starts** Electric motors:
AC – Star delta start	AC – Direct-on-line start
DC – Shunt wound	DC – Series and compound wound
Internal combustion engines with 4 or more cylinders	Internal combustion engines with less than 4 cylinders.
Prime movers fitted with centrifugal clutches, dry or fluid couplings or electronic soft start devices	Prime movers not fitted with soft start devices

Figure 1: Prime Mover Selection

The service factor was determined using Tables 2 and 3 of the SKF Power Transmission Belt Catalogue, taking into account the type of driven machinery and the starting characteristics of the prime mover.

Based on the given driver power of 34 kW, the prime mover was classified as operating under heavy start conditions according to Table 2 (Figure 1). Furthermore, since the driven equipment is a reciprocating compressor, it was categorized as heavy-duty machinery (Class 3) in accordance with Table 3 (Figure 2).

Using the "10 hours and under" operating condition for heavy-duty machinery combined with a heavy-start prime mover, the service factor was selected as $C_2 = 1.4$ from Table 3.

The driver and driven machine speeds were treated according to the values specified in the assignment, and the corresponding speed ratio was considered during pulley diameter selection. No additional correction factor from Table 1 was required beyond those already incorporated into the service factor and pulley selection procedure.

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Types of driven machinery		Soft starts Duty time h/day 10 and under	Over 10 to 16	Over 16	Heavy starts Duty time h/day 10 and under	Over 10 to 16	Over 16
Class 1 Light duty	Blowers, exhausters and fans (up to 7,5 kW), centrifugal compressors and pumps. Belt conveyors (uniformly loaded).	1,0	1,1	1,2	1,1	1,2	1,3
Class 2 Medium duty	Agitators (uniform density), blowers, exhausters and fans (over 7,5 kW). Rotary compressors and pumps (other than centrifugal). Belt conveyors (not uniformly loaded), generators and excitors, laundry machinery, lineshafts, machine tools, printing machinery, sawmill and woodworking machinery, screens (rotary).	1,1	1,2	1,3	1,2	1,3	1,4
Class 3 Heavy duty	Agitators and mixers (variable density), brick machinery, bucket elevators, compressors and pumps (reciprocating), conveyors (heavy duty). Hoists, mills (hammer), pulverisers, punches, presses, shears, quarry plant, rubber machinery, screens (vibrating), textile machinery.	1,2	1,3	1,4	1,4	1,5	1,6
Class 4 Extra heavy duty	Crushers (gyratory-jaw roll), mills (ball-rod-tube).	1,3	1,4	1,5	1,5	1,6	1,8

Table 3

Figure 2: Service Factor Selection

$$C_2 = 1.4$$

2- DESIGN POWER

The second step in the belt selection procedure is the determination of the design power, P_d, which represents the effective power to be transmitted by the belt drive under actual operating conditions. The design power accounts for the influence of service conditions and is used as the basis for selecting the appropriate belt cross-section and the required number of belts.

In accordance with Step 2 of the SKF Power Transmission Belt Catalogue, the design power was calculated by multiplying the rated driver power by the previously determined service factor. This approach ensures that the belt selection reflects the combined effects of load characteristics, operating conditions, and machine dynamics, resulting in a reliable and conservative design. The formula used for determining the design power is:

$$P_D = P * C_2$$

Where:

- P is the driver's power input (34 kW in this case).
- C_2 is the service factor determined in the previous step (1,4).

Substituting the known values into the formula:

$$P_D = 34 * 1.4 = 47.6kW$$

3- BELT CROSS SECTION

The third step of the belt selection procedure involved determining the appropriate belt cross-section based on the calculated design power and operating conditions. This selection was carried out using Diagrams 1, 2, and 3 provided on pages 17 and 18 of the SKF Power Transmission Belt Catalogue.

By correlating the design power with the rotational speed of the smaller pulley, the relevant operating point was identified on the catalogue diagrams. The belt cross-section corresponding to this operating region was then selected in accordance with SKF recommendations. This method ensures that the chosen belt cross-section is capable of transmitting the required design power while satisfying the system's durability and performance requirements.

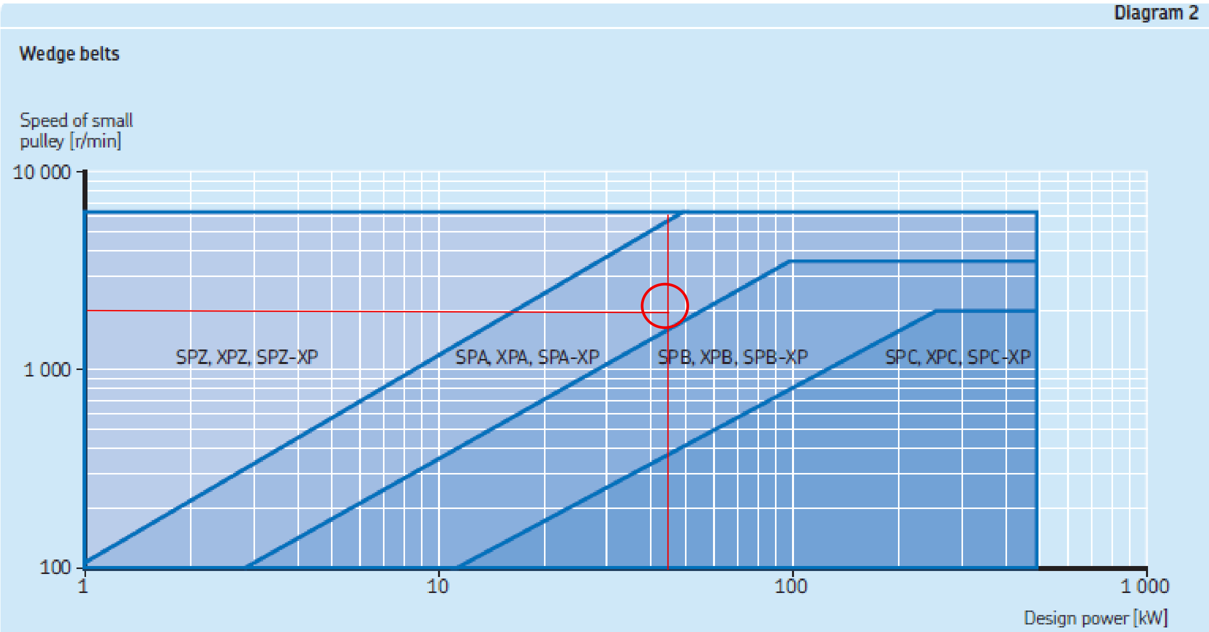

Figure 3: Belt Cross Section- Wedge Belts

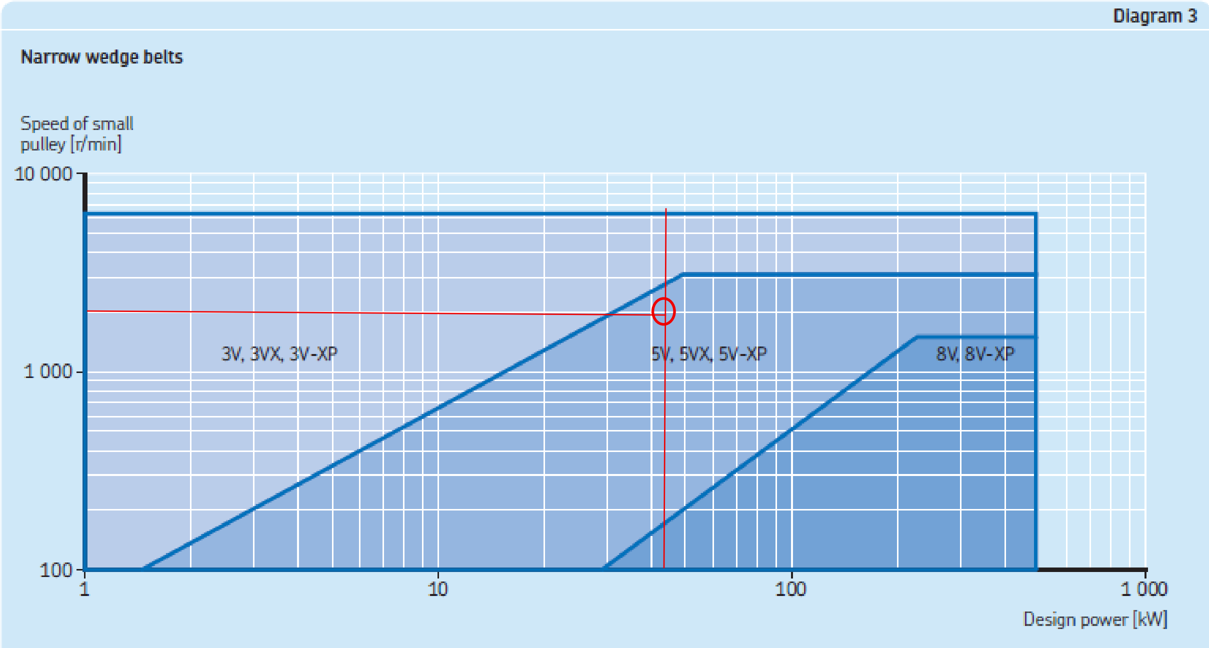

Figure 4:Belt Cross Section- Narrow Wedge Belts

Based on the operating region identified in the belt cross-section selection diagrams, several V-type narrow wedge belt options were found to be suitable for the design. As shown in Figure 3, the applicable belt sections include SPA, XPA, and SPA-XP. Similarly, Figure 4 indicates that 5V, 5VX, and 5V-XP belt types also fall within the acceptable operating range for the calculated design power and pulley speed.

At this stage, these belt types are considered as potential candidates that satisfy the preliminary power transmission requirements. A final selection among these alternatives is not made in this step. Instead, the specific belt type will be determined in Step 6, where additional criteria such as belt length availability, center distance constraints, correction factors, and the required number of belts are evaluated in accordance with the SKF selection procedure.

4- REQUIRED SPEED RATIO

The fourth step of the belt selection procedure involved determining the speed ratio, I_r, between the driving and driven shafts. The speed ratio defines the required relationship between the rotational speeds of the shafts and serves as the primary basis for selecting appropriate pulley diameters.

Using the specified driver and driven speeds, the speed ratio was calculated and subsequently used to ensure that the selected pulley diameters satisfy both the desired speed reduction and the geometric constraints of the belt drive system. This step is essential for maintaining consistency between the operating speeds and the selected pulley dimensions in accordance with SKF design guidelines

The required speed ratio (I_r) can be calculated using the formula:

$$I_r, max = \frac{Driver\ Speed}{Min\ Driven\ Speed}$$

$$I_r, min = \frac{Driver\ Speed}{Max\ Driven\ Speed}$$

Speed ratio calculation according to the values used in this report:

$$\mathrm{I}_r, \max = \frac{2076\ rpm}{1043\ rpm} = 1{,}99$$

$$\mathrm{I}_r, \min = \frac{2076\ rpm}{1053\ rpm} = 1{,}97$$

5- CHECKING THE CENTER DISTANCE TABLES WRT SPEED RATIO

Centre distances tables (4a to 4p) are not used for this homework so we will continue with the sixth step.

6- PULLEY DATUM DIAMETERS (d,D)

Using the calculated speed ratio, the diameters of the driving and driven pulleys were determined with reference to Tables 5a and 5b, shown in Figures 5 and 6 of the SKF Power Transmission Belt Catalogue. These tables relate the speed ratio to standard pulley diameter combinations that are compatible with specific belt cross-sections.

During this evaluation, the SPA belt type was identified as the most suitable option for achieving the required speed ratio while satisfying the design power and operating constraints. Consequently, the SPA cross-section was selected in Step 3 over the other candidate belt types.

After confirming the SPA belt selection, the allowable pulley diameter range for this belt type was reviewed. The corresponding values of the small and large pulley diameters, d and D, that satisfy the target speed ratio were then extracted from Figure 6 in accordance with SKF recommendations.

Although alternative belt types such as XPA, SPA-XP, and narrow wedge belts (5V, 5VX, and 5V-XP) were initially identified as feasible based on power transmission capability, they were not selected. Narrow wedge belts generally require larger minimum pulley diameters and are typically preferred for higher power or more compact drive arrangements. Similarly, cogged belt types offer increased flexibility, which was not necessary for the given operating conditions. Therefore, the SPA belt was selected as the most appropriate and efficient option for the required speed ratio and pulley geometry.

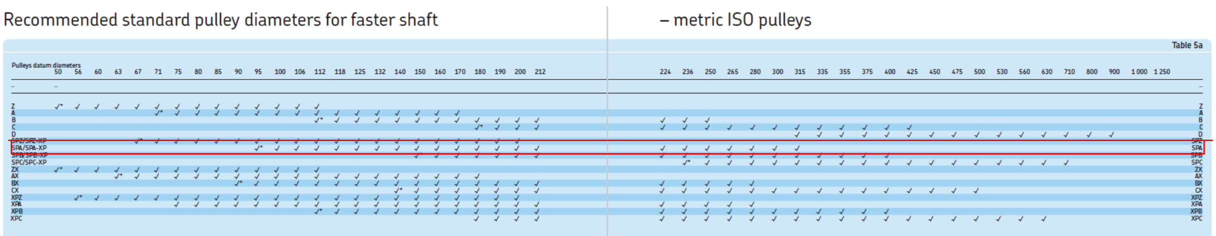

Figure 5: Standard Allowable pulley diameters for V belt Types

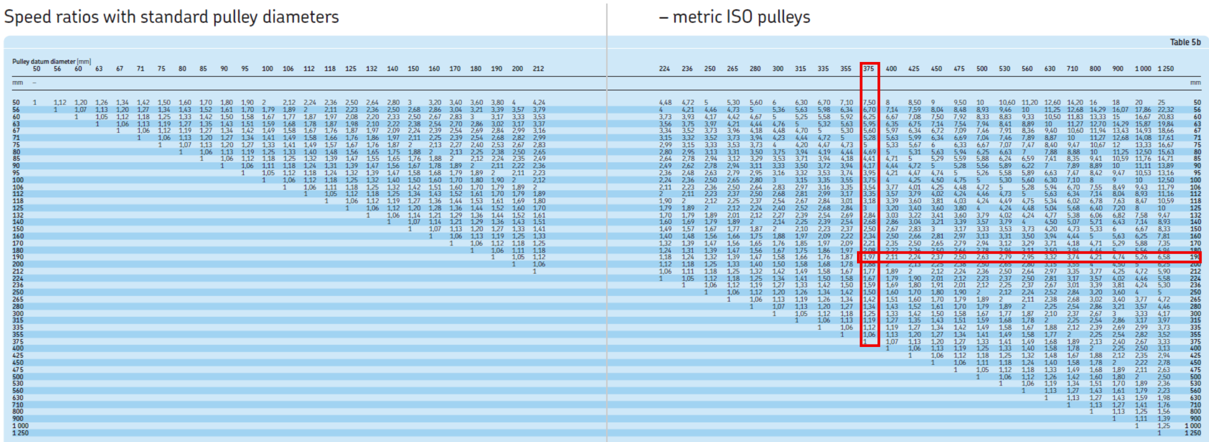

Figure 6: Standard Pulley Diameter for given Speed Ratios

$$d = 190$$

$$D = 375$$

7- CENTER DISTANCE PRELIMINARY (CC_P)

In step 7 of the belt selection procedure, the center distance between the driving and driven pulleys is evaluated to ensure geometric feasibility of the belt drive system. The minimum and maximum preliminary center distance limits are considered solely as a feasibility check to confirm reasonable pulley spacing.

These preliminary limits are not used directly to select the belt length. Instead, the final belt length selection is based on a nominal center distance within the allowable installation range, after which the actual center distance is recalculated and verified. The corresponding calculations are presented below.

$$\boldsymbol{CC}_{\boldsymbol{p_{min}}} = 0.7(D + d) = 0.7\,(375\,mm + 190\,mm) = 395{,}5mm$$

$$\boldsymbol{CC}_{\boldsymbol{p_{max}}} = 2(D + d) = 2(375\,mm + 190\,mm) = 1130mm$$

8- BELT DATUM LENGTH (L_d)

$$L_d = 2C + \frac{\pi(D + d)}{2} + \frac{(D - d)^2}{4C}$$

$$L_{d\,min} = 2 * 983\ + \frac{\pi(375 + 190)}{2} + \frac{(375 - 190)^2}{4 * 983} = 2862\,mm$$

$$L_{d\,max} = 2 * 1133 + \frac{\pi(375 + 190)}{2} + \frac{(375 - 190)^2}{4 * 1133} = 3161\,mm$$

The calculated values of $L_{d,\mathrm{min}}$ and $L_{d,\mathrm{max}}$ are used only as a verification step to ensure that the selected belt length lies within a feasible range for the pulley system. These values are not employed directly in the belt selection process.

2 932	12,7	10	PHG SPA2932
2 982	12,7	10	PHG SPA2982
3 000	12,7	10	PHG SPA3000
3 032	12,7	10	PHG SPA3032
3 082	12,7	10	PHG SPA3082

Figure 7:SKF Wrapped Wedge Belt Table

9- CENTER DISTANCE (CC)

Shigley's 9th edition textbook (Equation 17-16b) used for calculating center distance.

$$CC = 0{,}25 * \left[L_d - \frac{\pi}{2}(D+d)\right] + \sqrt{\left(L_d - \frac{\pi}{2}(D+d)\right)^2 - 2 * (D-d)^2}$$

$$CC = 0{,}25 * \left[3000 - \frac{\pi}{2}(375+190)\right] + \sqrt{\left(3000 - \frac{\pi}{2}(375+190)\right)^2 - 2 * (375-190)^2} = 1052.3\ mm$$

10- BELT BASIC POWER RATING (P_b)

Power ratings

Section SPA

Table 9g

Faster shaft speed	Rated power per belt for small pulley datum diameter [mm]													Additional power per belt for speed ratio			
	90	95	100	106	112	118	125	132	140	150	160	180	200	1,00 to 1,05	1,06 to 1,24	1,25 to 1,59	> 1,59
r/min	kW													kW			
100	0,25	0,28	0,31	0,35	0,38	0,42	0,46	0,50	0,55	0,61	0,67	0,79	0,90	–	0,02	0,03	0,03
200	0,45	0,51	0,57	0,64	0,71	0,78	0,86	0,94	1,03	1,14	1,25	1,48	1,70	0,01	0,04	0,05	0,06
300	0,64	0,72	0,81	0,91	1,01	1,11	1,23	1,34	1,48	1,64	1,81	2,14	2,46	0,01	0,05	0,08	0,09
400	0,81	0,92	1,03	1,16	1,30	1,43	1,58	1,73	1,91	2,13	2,34	2,77	3,19	0,02	0,07	0,11	0,12
500	0,97	1,11	1,24	1,41	1,57	1,73	1,92	2,11	2,33	2,59	2,86	3,38	3,91	0,02	0,09	0,14	0,15
600	1,13	1,29	1,45	1,65	1,84	2,03	2,25	2,48	2,73	3,05	3,36	3,98	4,60	0,03	0,11	0,16	0,18
700	1,28	1,46	1,65	1,87	2,10	2,32	2,58	2,83	3,13	3,49	3,85	4,57	5,27	0,03	0,13	0,19	0,21
720	1,31	1,50	1,69	1,92	2,15	2,38	2,64	2,90	3,20	3,58	3,95	4,68	5,41	0,03	0,13	0,20	0,22
800	1,42	1,63	1,84	2,10	2,35	2,60	2,89	3,18	3,51	3,92	4,33	5,14	5,93	0,03	0,14	0,22	0,24
900	1,56	1,80	2,03	2,31	2,59	2,87	3,20	3,52	3,89	4,34	4,80	5,69	6,58	0,04	0,16	0,24	0,27
960	1,64	1,89	2,14	2,44	2,74	3,03	3,38	3,72	4,11	4,59	5,07	6,02	6,96	0,04	0,17	0,26	0,29
1 000	1,69	1,95	2,21	2,52	2,83	3,14	3,50	3,85	4,26	4,76	5,25	6,24	7,21	0,04	0,18	0,27	0,30
1 100	1,82	2,11	2,39	2,73	3,07	3,40	3,79	4,18	4,62	5,16	5,70	6,77	7,82	0,05	0,20	0,30	0,33
1 200	1,95	2,26	2,57	2,93	3,30	3,66	4,08	4,49	4,97	5,56	6,14	7,29	8,42	0,05	0,21	0,33	0,36
1 300	2,07	2,40	2,73	3,13	3,52	3,91	4,36	4,81	5,31	5,94	6,57	7,80	9,00	0,06	0,23	0,35	0,39
1 400	2,19	2,55	2,90	3,32	3,74	4,15	4,63	5,11	5,65	6,32	6,98	8,29	9,57	0,06	0,25	0,38	0,42
1 440	2,24	2,60	2,96	3,39	3,82	4,25	4,74	5,23	5,78	6,47	7,15	8,48	9,79	0,06	0,26	0,39	0,43
1 500	2,31	2,68	3,06	3,51	3,95	4,39	4,90	5,41	5,98	6,69	7,39	8,77	10,12	0,06	0,27	0,41	0,45
1 600	2,42	2,82	3,21	3,69	4,16	4,62	5,16	5,70	6,30	7,05	7,79	9,24	10,65	0,07	0,29	0,44	0,48
1 700	2,53	2,95	3,37	3,86	4,36	4,85	5,42	5,98	6,62	7,40	8,18	9,70	11,17	0,07	0,30	0,46	0,51
1 800	2,63	3,08	3,51	4,04	4,56	5,07	5,67	6,26	6,92	7,74	8,55	10,14	11,67	0,08	0,32	0,49	0,54
1 900	2,74	3,20	3,66	4,21	4,75	5,29	5,91	6,53	7,22	8,08	8,92	10,56	12,15	0,08	0,34	0,52	0,57
2 000	2,83	3,32	3,80	4,37	4,94	5,50	6,15	6,79	7,51	8,40	9,28	10,98	12,61	0,09	0,36	0,54	0,60
2 100	2,93	3,43	3,93	4,53	5,12	5,70	6,38	7,04	7,79	8,72	9,62	11,38	13,05	0,09	0,38	0,57	0,63
2 200	3,02	3,55	4,07	4,68	5,30	5,90	6,60	7,29	8,07	9,02	9,95	11,76	13,48	0,09	0,39	0,60	0,66

Figure 8:Table 9g for Finding Power Rating

From the relevant SKF power rating table, the higher shaft speed was identified as 2076 rpm, and the selected small pulley diameter was 190 mm. Since the exact operating speed and pulley diameter were not listed in the table, linear interpolation was performed.

First, interpolation was carried out between the 2000 rpm and 2100 rpm speed values corresponding to pulley diameters of 180 mm and 200 mm, respectively. Based on this interpolation, the rated belt power was determined as 12.11 kW.

Using the actual operating speed of 2076 rpm and the calculated speed ratio of 1.97, a second interpolation was performed to account for the speed ratio effect. As a result, the additional belt power was calculated as 0.6228 kW.

$$Belt\ Basic\ Power\ Rating\ (P_b) = Rated\ Belt\ Power + Additional\ Belt\ Power$$

$$Belt\ Basic\ Power\ Rating\ (P_b) = 12{,}11\ kW + 0{,}6228kW = 12{,}7328\ kW$$

11- CORRECTION FACTORS (C_1, C_3)

Belt length is 3000 mm so C_1 value is interpolated between the given values. These values are from table 8.

$$C_1 = 1{,}03$$

Table 8

Belt length correction factor C_1

Belt length	Correction factor SPZ SPZ-XP XPZ 3V 3V-XP 3VX	SPA SPA-XP XPA	SPB SPB-XP XPB 5V 5V-XP 5VX	SPC SPC-XP XPC	8V 8V-XP	Z ZX	A AX	B BX	C CX	D
mm	–									
400	0,50					0,87	0,68			
475	0,65					0,90	0,74	0,64		
530	0,74					0,93	0,78	0,70		
630	0,82	0,77				0,96	0,81	0,76		
710	0,84	0,79				0,99	0,83	0,78		
900	0,88	0,83	0,76			1,05	0,87	0,82	0,73	
1 000	0,90	0,85	0,78			1,06	0,89	0,84	0,76	
1 120	0,93	0,87	0,80			1,08	0,91	0,86	0,78	
1 250	0,95	0,89	0,82			1,11	0,93	0,88	0,80	
1 400	0,96	0,91	0,84	0,70		1,14	0,96	0,90	0,82	
1 600	1,00	0,93	0,86	0,74		1,17	0,99	0,93	0,84	
1 800	1,01	0,95	0,88	0,77		1,22	1,01	0,95	0,86	
2 000	1,02	0,96	0,90	0,80	0,78	1,25	1,03	0,98	0,88	0,78
2 240	1,05	0,98	0,92	0,83	0,80	1,28	1,06	1,00	0,91	0,80
2 500	1,07	1,00	0,94	0,86	0,80	1,29	1,09	1,03	0,93	0,82
2 800	1,09	1,02	0,96	0,88	0,82	1,29	1,11	1,05	0,95	0,84
3 150	1,11	1,04	0,98	0,90	0,84		1,13	1,07	0,97	0,86
3 550	1,13	1,06	1,00	0,92	0,86		1,15	1,09	0,99	0,88

Figure 9:Belt Length Correction Factor From Table 8

From Table 7, we can find the C_3 value.

$$\frac{D-d}{CC} = C_3$$

$$\frac{375-190}{1052} = 0{,}176$$

So, $\frac{D-d}{CC}$ value is assumed as 0,20 and C_3 equals to 0,97.

Table 7

Arc of contact power correction factor C_3

$\frac{D-d}{CC}$ *	Arc of contact on small pulley	Arc of contact correction factor C_3
mm	deg.	–
0,00	180	1,00
0,05	177	0,99
0,10	174	0,99
0,15	171	0,98
0,20	169	0,97
0,25	166	0,97

Figure 10:Arc of Contact Power Correction Factor From Table 7

12- BELT POWER RATING (P_r)

The belt power rating was obtained by multiplying the rated belt power by the applicable correction factors calculated in the previous steps. These correction factors account for the effects of belt length and arc of contact, ensuring that the resulting belt power rating accurately reflects the actual operating conditions of the system.

$$P_r = P_b * C_1 * C_3$$

$$P_r = 12{,}7328 * 1{,}03 * 0{,}97 = 12{,}72\ kW$$

13- NUMBER OF BELTS (N)

The required number of belts was determined by comparing the design power, P_d, with the belt power rating, P_r. The number of belts is calculated using the following relation:

$$N = \frac{P_d}{P_r}$$

$$N = \frac{47{,}6}{12{,}72} = 3{,}74$$

Since the number of belts must be an integer, the result was rounded up to ensure that the belt drive can safely transmit the required design power. Therefore, four V-belts were selected for the final design.

14- INSTALLATION AND TAKE UP ALLOWANCES (MIA AND MTA)

For the selected standard belt datum length of 3000 mm, the installation allowance and take-up allowance were determined as 25 mm and 45 mm, respectively, based on SKF Table 10a. Using these values, the corresponding minimum and maximum center distances were calculated as 1027 mm and 1097 mm.

Since this center distance range lies entirely within the allowable adjustable center distance of the system, the selected belt length satisfies the installation and tensioning requirements. Therefore, the belt drive configuration is considered feasible.

Table 10a

Single V-belts

Datum length	Minimum take-up allowance for tensioning	Minimum installation allowance – for fitting Z ZX	A AX	B BX	C CX	D	XPZ 3VX SPZ SPZ-XP 3V 3V-XP	XPA SPA SPA-XP	XPB 5VX SPB SPB-XP 5V 5V-XP	XPC SPC SPC-XP	8V 8V-XP
–	mm	mm									
400–1 199	25	15	20	25	40	–	15	20	–	–	–
1 200–2 099	35	20	20	30	40	50	20	25	25	–	–
2 100–2 799	40	20	25	30	40	50	20	25	25	35	40
2 800–3 399	45	–	25	30	40	50	20	25	25	35	40
3 400–4 399	55	–	25	30	50	55	20	25	25	35	40
4 400–5 399	65	–	25	40	50	60	–	25	25	35	45

Figure 11:MIA and MTA values from Table 10a

$$C_{min} = 1052 - 25 = 1027$$

$$C_{max} = 1052 + 45 = 1097$$

15- BENT TENSION

Proper belt operation requires the belt tension to be maintained within an appropriate range. Accordingly, the belt tension calculations were performed following the guidelines provided on page 70 of the SKF Power Transmission Belt Catalogue.

Two belt tension values were evaluated in this analysis. The first is T_{used}, which represents the minimum belt tension during normal operation. The second is T_{new}, corresponding to the maximum belt tension required for a newly installed belt. These values are used to ensure adequate power transmission while preventing excessive belt loading.

$$V = \frac{d * n}{19100}$$

$$V = \frac{190 * 2076}{19100} = 20{,}65 \frac{m}{s}$$

Wrapped V, wedge and banded belts

Section	Smallest pulley diameter	Speed range	Belt tension per single belt* New belt	Used run-in belt	Mass Single belt	Belt in a band**
–	mm	r/min	N		kg/m	
Z	40–60	1 000–2 500	104	69	0,051	n/a
		2 501–4 000	121	81		
	61–over	1 000–2 500	174	116		
		2 501–4 000	174	116		
A	75–90	1 000–2 500	332	222	0,115	0,150
		2 501–4 000	254	169		
	91–120	1 000–2 500	391	261		
		2 501–4 000	332	222		
	121–175	1 000–2 500	469	313		
		2 501–4 000	411	274		
B	105–140	860–2 500	469	313	0,193	0,260
		2 501–4 000	391	261		
	141–220	860–2 500	567	378		
		2 501–4 000	528	352		
C	175–230	500–1 740	1 017	678	0,320	0,417
		1 741–3 000	841	561		
	231–400	500–1 740	1 251	834		
		1 741–3 000	1 115	743		
D	305–400	200–850	2 210	1 473	0,69	0,870
		851–1 500	1 877	1 251		
	401–510	200–850	2 698	1 799		
		851–1 500	2 268	1 512		
SPZ	56–79	1 000–2 500	338	226	0,076	n/a
		2 501–4 000	262	175		
	80–95	1 000–2 500	383	255		
		2 501–4 000	415	276		
	96–over	1 000–2 500	477	318		
		2 501–4 000	438	292		
SPA	71–105	1 000–2 500	575	383	0,134	0,155
		2 501–4 000	524	349		
	106–140	1 000–2 500	696	464		
		2 501–4 000	628	418		
	141–over	1 000–2 500	872	581		
		2 501–4 000	876	584		

Figure 12:Selection of M value from Table 13

$$T_{used} = \frac{510 * (2{,}2 - C_3) * P_d}{C_3 * N * V} + \frac{MV^2}{1{,}11}$$

$$T_{used} = \frac{510 * (2{,}2 - 0{,}97) * 47{,}6}{0{,}97 * 4 * 20{,}65} + \frac{0{,}134 * (20{,}65)^2}{1{,}11} = 423{,}9\ N$$

$$T_{new} = 1{,}5 * T_{used} = 635.85\ N$$

16- BELT DEFLECTION FOR PEN TESTER

Deflection force required for tension verification was determined using the pen tester method, following the procedure outlined in the SKF Power Transmission Belt Catalogue. This method relates belt tension to the force required to produce a specified belt deflection over a given span length.

The deflection force was calculated for both operating conditions. The deflection force corresponding to the minimum operating belt tension is given by $F_{d,\mathrm{used}}$, while the deflection force associated with the maximum tension of a newly installed belt is represented by $F_{d,\mathrm{new}}$. These forces were calculated using the following expressions:

$$\mathrm{F_{d,used}} = \frac{\frac{\mathrm{T_{used}} * \mathrm{N}}{16} + \frac{\mathrm{N} * \mathrm{K} * \mathrm{S_p}}{\mathrm{L}}}{9{,}81}$$

$$\mathrm{F_{d,new}} = \frac{\frac{\mathrm{T_{new}} * \mathrm{N}}{16} + \frac{\mathrm{N} * \mathrm{K} * \mathrm{S_p}}{\mathrm{L}}}{9{,}81}$$

Table 16

Belt modulus factor

Section	K
Z, ZX	2,67
A, AX	2,94
B, BX	3,87
C, CX	5,87
D	8,01
SPZ, XPZ, 3V, 3VX	2,89
SPA, XPA	3,12
SPB, XPB, 5V, 5VX	4,01
SPC, XPC	6,23
8V	7,57

Figure 13: Belt Modulus Factor (K) from Table 16

For a multiple V-belt arrangement, the ratio $S_p/L$was taken as 1, in accordance with the SKF pen tester method. The pen tester constant was selected as $K = 3.12$based on the catalogue recommendations.

Using these values, the deflection force corresponding to the minimum operating belt tension was calculated as:

$$\mathrm{F_{d,used}} = \frac{\dfrac{423{,}9 * 4}{16} + \dfrac{4 * 3{,}12 * 1}{1}}{9{,}81} = 12{,}07\ kg$$

$$\mathrm{F_{d,new}} = \frac{\dfrac{635.85 * 4}{16} + \dfrac{4 * 3{,}12 * 1}{1}}{9{,}81} = 17{,}47\ kg$$

These results provide the appropriate deflection force limits for belt tensioning using a pen tester. Applying these forces during installation and operation ensures proper belt tension, reliable power transmission, and compliance with the design requirements.

17- ELONGATION METHOD

Taking into account the belt tension applied during operation, the elongation method was used to determine the belt lengths for both the new and used conditions. This method considers the elastic elongation of the belt under different tension levels and provides a practical means of verifying proper belt installation and operation.

The required belt elongation values were obtained by linear interpolation using the data provided in Table 17 of the SKF Power Transmission Belt Catalogue. This approach ensures that the calculated belt lengths accurately reflect the tension conditions specified for the selected belt type.

Table 17

Length addition for 1 000 mm of belt strand

Single belt, banded belt	A	B	C	D	SPA SPA-XP	SPB SPB-XP 5V 5V-XP	SPC SPC-XP	8V 8V-XP
–	Elongation per 1 000 mm of belt strand (mm)							
(N)								
200	3,4	1,5	–	–	3,0	–	–	–
250	4,3	1,8	–	–	3,8	–	–	–
300	5,1	2,2	–	–	4,5	–	–	–
350	6,0	2,6	–	–	5,3	–	–	–
400	6,8	2,9	2,4	–	6,0	2,1	–	–
450	7,7	3,3	2,7	–	6,8	2,6	–	–
500	8,5	3,7	3,0	–	7,5	3,1	–	–
550	9,4	4,0	3,3	–	8,3	3,6	1,9	–
600	10,2	4,4	3,6	3,2	9,0	4,1	2,2	–
650	11,1	4,8	3,8	3,4	9,8	4,6	2,5	–

Figure 14:Elongation Values from Table 17

Elongation per 1000mm of belt standard for 423,9 N is 6,4 mm.

Elongation per 1000mm of belt standard for 635.85 N is 9,6 mm.

Table 18

Belt length multiplier

Single belt, banded belt	A	B	C	D	SPA SPA-XP	SPB SPB-XP 5V 5V-XP	SPC SPC-XP	8V 8V-XP
–	Belt length multipliers							
200	1,0034	1,0015	–	–	1,0030	–	–	–
250	1,0043	1,0018	–	–	1,0038	–	–	–
300	1,0051	1,0022	–	–	1,0045	–	–	–
350	1,0060	1,0026	–	–	1,0053	–	–	–
400	1,0068	1,0029	1,0024	–	1,0060	1,0021	–	–
450	1,0077	1,0033	1,0027	–	1,0068	1,0026	–	–
500	1,0085	1,0037	1,0030	–	1,0075	1,0031	–	–
550	1,0094	1,0040	1,0033	–	1,0083	1,0036	1,0019	–
600	1,0102	1,0044	1,0036	1,0032	1,0090	1,0041	1,0022	–
650	1,0111	1,0048	1,0038	1,0034	1,0098	1,0046	1,0025	–

Figure 15:Table 18 for Finding Belt Length Multiplier

Belt length multiplier for used belt is 1,0064.

Belt length multiplier for new belt is 1,0098.

These values are calculated with interpolation method.

CONCLUSION

In this study, a V-belt drive system suitable for operating a reciprocating compressor was designed by strictly following the step-by-step procedure outlined in the SKF Power Transmission Belt Catalogue. All design decisions were made in accordance with the priorities specified in Homework 2, with particular emphasis on achieving the required speed ratio using standard and recommended components.

Based on the operating conditions, a service factor of $C_2 = 1.4$ was selected, resulting in a design power of 47.6 kW. Using this value, the SPA belt cross-section was identified as the most appropriate option. The required speed ratio was satisfied by selecting standard pulley diameters of 190 mm for the driving pulley and 375 mm for the driven pulley. A standard belt datum length of 3000 mm was then chosen from the SKF catalogue.

For the selected belt length, the actual center distance was calculated as approximately 1052 mm. The corresponding installation and take-up allowance range (1027–1097 mm) lies entirely within the allowable adjustable center distance of the system, confirming that the belt can be properly installed and tensioned. Therefore, the selected belt length and center distance are compatible with the geometric constraints of the design. In addition to the geometric compatibility, available space was also considered during the belt selection process. Although limited space conditions may require the use of smaller pulleys or shorter belt lengths, such configurations are generally not recommended due to reduced belt life and unfavorable operating conditions.

After applying the relevant correction factors, the belt power rating was evaluated, and the required number of belts was calculated as 3.74. Since the number of belts must be an integer, four SPA V-belts were selected to safely transmit the required power. In this design, cost considerations were taken into account primarily through the number of belts used**.** While pulley cost was not considered, selecting an appropriate number of belts was essential to avoid unnecessary overdesign and increased system cost. Belt tension calculations were performed for both new and used conditions. Using the pen tester method, the required deflection forces were determined as 12.07 kg for normal operation and 17.47 kg for a newly installed belt. In addition, the elongation method was applied using SKF Table 17 to verify belt length changes under operating tension.

Overall, the final belt drive configuration satisfies all performance, geometric, and installation requirements. The selected system is feasible, reliable, and suitable for the intended reciprocating compressor application, provided that the recommended installation and tensioning procedures are followed during operation.