Chapter 3: Belt Drives

The vee belt drive data given here has been taken from the most recent Fenner Catalogue available in 1997. Their catalogue gives data for several types of belts namely:

- *Vee belts* - the older type of design of vee belts. Now have been virtually superseded by wedge belts. However the generic term "vee belt" is still used to refer to both vee belts and wedge belts.
- *Wedge belts* - similar to vee belts but with a deeper profile. They are a little more expensive than vee belts but have a higher power rating so they are now more commonly specified for new designs. Pulleys for vee belts and wedge belts are interchangeable.
- *Banded belts* - these are essentially a number of belts joined together at the top so as to make a composite belt. This eliminates belt twist, belt whip and belt turnover.
- *Multi-pull belts* - these are similar to banded belts but have a different profile.
- *Link belts* - these are somewhat of a hybrid between vee belts and chain drives. They are built up from linked sections made of a reinforced urethane elastomer. This gives them a high heat, oil and chemical resistance and enables belts of any size to be made up to suit any centre distance. The same pulleys may be used as for wedge belts and vee belts.
- *CRE (cogged raw edge belts)* - these are similar to vee belts but there is a cogged edge on the side opposite the vee. They can be used with smaller pulleys and are often used in motor vehicles and other high-speed drives. The pulleys are the same as used for vee or wedge belts.
- *Synchronous belts* - these are essentially a flat belt with a tooth profile that mates with low profile gear teeth on the pulleys. This prevents belt slip and maintains pulley synchronisation. However, they have a lower load carrying capacity than vee or wedge belts.

Because wedge belts are now more common than vee belts, for this design manual, data is given for wedge belts and not vee belts. In fact, the Fenner catalogue does not give data for vee belts other than to give the belt designations and sizes.

The pulleys listed in the Fenner catalogue are all of the taper lock design. When specifying the pulley it is necessary to give the catalogue number of both the pulley and the bush.

The Fenner catalogue give a table of values for each belt designation that gives the belt length as well as the combined arc of contact and belt length correction factor. This table has colour coding and was not suitable for black and white reproduction. Hence a simplified table has been produced that is given on page 57. In some cases there is a slight difference in the values for the combined correction factor but this should be of little practical significance.

There is no Australian Standard for vee or wedge belts but Fenner wedge belts comply with both BS and ISO Standards.

Wedge belt selection and drive design

1. From Table 3 (page 56) determine the service factor. For a speed increasing drive it is necessary to multiply the service factor by an additional factor as listed on the top of the table.

2. Obtain the design power by multiplying the normal running power by the service factor. *Note* : normal running power is the maximum power at the driver end and excludes shock loading or hard start loading factors.

3. Use Table 2 (page 57) to select the most suitable belt section. Often two or even three belt sections may be suitable. For example, a design power 40 kW @ 1000 rev/min is at the top of the range of the SPA, mid range of the SPB and bottom of the range of the SPC. In practice, the correct procedure is to check out all possibilities for pulley size, number of belts and cost before making a decision. As a general rule, when two belt sections are suitable, choose the *largest* section because this will give the *least* number of belts (with appropriate pulleys).

4. Determine the speed ratio, namely the rev/min of the faster shaft divided by the rev/min of the slower shaft. If a speed tolerance applies, calculate the minimum and maximum driven shaft speeds.
   Note : a speed ratio of about 6:1 is the maximum obtainable with a single set of pulleys.

5. Select the minimum pulley diameter using Table 1 (page 56). For intermediate values choose the next closest larger size.
   Note : if the speed of the faster shaft is greater than 2880 rev/min, the minimum pulley diameter is that given for a speed of 2880 rev/min.

6. Select suitable smaller pulley pitch diameters for the belt section chosen using the appropriate table (pages 65 to 72). Start with the minimum pulley diameter (as chosen in step 5) and then select a number (say about five) of the next larger pitch diameters available. Multiply each of the smaller pulley pitch diameters by the speed ratio (from step 4) to determine the theoretical large pulley diameter. Then choose the closest pitch diameter available for the large pulley. For each combination of pulleys, calculate the driven pulley speed by multiplying the driver speed by the ratio of the pulley pitch diameters. Discard any combinations that give a driven pulley speed outside the tolerance range of speeds required. This will usually leave a number of combinations that will give the speed ratio to within the required range.

7. Select the combination of pulley pitch diameters that appears most suitable. The advantage of small pulleys is that the drive is compact and the belt speed low. The advantage of large pulleys is that they have a higher power rating and therefore will reduce the number of belts required. Without time to trial all possibilities, exercise some judgement to choose a suitable combination of pitch diameters bearing in mind the above.
   Note : in some cases maximum pulley sizes may be dictated by space requirements.

8. Calculate the belt speed using the formula $\upsilon = r\omega$ (from either the driver or driven pulley) and ensure that the belt speed does not exceed 40 m/s. If it does, select smaller pulleys.

9. If the centre distance is not specified, a good design rule is to choose a centre distance approximately equal to the sum of the pulley pitch diameters.

10. Calculate the required belt pitch length using the following formula:

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

Where
L = required pitch length of the belt in mm
C = approx. centre distance in mm
D = pitch dia. of the larger pulley in mm
d = pitch dia. of the smaller pulley in mm

11. Choose a standard belt length closest to that required using the table on page 58 for the belt section chosen .
Note : It is generally good practice to choose the next larger rather than the next smaller size.

12. Calculate the exact centre distance using the following formula:

$$C = A + \sqrt{A^2 - B}$$

where:

$$A = \frac{L}{4} - \frac{\pi}{8}(D+d)$$

$$B = \frac{(D-d)^2}{8}$$

L = standard belt length chosen

13. Obtain the basic power rating per belt from the tables on pages 59 to 64 by adding together the rated power and the additional power. For speeds intermediate to those listed in the tables use linear interpolation.

14. Obtain the combined arc of contact correction factor and belt length correction factor from the tables on page 58. Multiply the combined correction factor by the basic power rating per belt to obtain the corrected power rating per belt.

15. Calculate the number of belts by dividing the design power by the corrected power per belt. Since it is impossible to have fractions of a belt, select the nearest whole number. Some judgement may be needed. For example, if the number of belts turns out to be 2.8, then obviously 3 belts would be chosen. However, if the number turns out to be 2.3, should 2 belts be used or 3 belts? This depends on the accuracy of the design data, the safety factor and the required life. In the absence of more detailed knowledge, a good design rule is use the lower number for parts of a belt less than 0.3 and the higher number for parts above 0.3.

16. Obtain the catalogue number of the pulleys specified using the tables on pages 65 to 72 Check that pulleys are available with the number of grooves required. If not, it is usually preferable to redesign the drive rather than to make custom pulleys. Obtain the bush number. and check that the maximum bore does not exceed the shaft sizes being used. Obtain the catalogue number of the taper lock bushes specified using the table on page 73 for the required shaft sizes used in the drive.

Note : if a shaft size is greater than the maximum available for the bush, a larger bush is needed, and this in turn will mean larger pulleys. The drive calculation will then have to be repeated from step 7 onwards.

Example

Design a wedge belt drive from a 6 cylinder diesel engine governed to run at 1050 rev/min. The engine will drive a reciprocating gas compressor that is to run at 650 rev/min ± 3%. Maximum power is 50 kW and the drive will operate for more than 16 hours per day. The engine shaft is 70 mm diameter and the compressor shaft is 80 mm diameter.

Solution

Following the steps given in the design procedure:

1. From Table 3 (page 56) the service factor = 1.4

2. Design power = 50 x 1.4 = 70 kW

3. Using Table 2 (page 57), either the SPB or SPC section would be suitable. We will select the larger SPC section.

4. Speed ratio = 1050/650 = 1.615 (reduction).
   Driven pulley speed range = 650 ± 3% = 650 ± 19.5 rev/min = 630.5 - 669.5 rpm

5. From Table 1 (page 56), the minimum pulley diameter is 250 mm (next closest size).

6. For the SPC section belt, (pages 71 to 72) six pulley diameters as listed below are available for the driver pulley (from 250 mm upward). The required driven pulley diameter was calculated by multiplying the driver pulley diameter by the speed ratio. The closest pulley diameter was then selected and driven speed calculated by multiplying the driver speed (1050 rev/min) by the ratio of the pulley pitch diameters.

Driver pulley dia. mm	Reqd. driven pulley dia. mm	Closest driven pulley dia.	Driven pulley speed rev/min
250	404	400	656.2
265	428	425	654.7
280	452	450	653.3
300	485	475	663.2
315	509	500	661.5
335	541	530	663.7

7. All of these combinations give a driven pulley speed within the range required. Because larger pulleys have higher power ratings, we will choose 315:500 giving a driven pulley speed of 661.5 rev/min.

8. Calculating the belt speed from the driver pulley :

$$v = r\omega = \frac{0.315}{2} \times \frac{\pi \times 1050}{30} = 17.3\ m/s\ (OK<40)$$

9. Since the centre distance is not specified, make it $C = d + D = 315 + 500 = 815$ mm

10. Calculate the required belt pitch length using the formula:

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

$$= 2 \times 815 + \frac{(500 - 315)^2}{4 \times 815} + \frac{\pi}{2}(500 + 315)$$

$$= 2921\ mm$$

11. The closest standard belt lengths are 2800 and 3150 mm (SPC table on page 58). We will choose the larger namely 3150 mm.

12. Calculate the exact centre distance using the formula:

$$C = A + \sqrt{A^2 - B}$$

Now:

$$A = \frac{L}{4} - \frac{\pi}{8}(D + d) \text{ and } B = \frac{(D - d)^2}{8}$$

$L = 3150\ mm$, substituting:

$$A = \frac{3150}{4} - \frac{\pi}{8}(815) \qquad B = \frac{(815)^2}{8} = 4278$$

$$= 467.45$$

$$C = 467.45 + \sqrt{467.45^2 - 4278} = 930.3$$

13. Interpolating from the table on page 64:
Rated power per belt = (25.8 + 27.65)/2 = 26.725 kW
Additional power = (2.29 + 2.52) /2 = 2.405 kW
∴ Basic power/belt = 26.725 + 2.405 = 29.13 kW

14. From table on page 58 the combined correction factor is 0.9.
∴ Corrected power/belt = 29.13 x 0.9 = 26.217 kW.

15. Number of belts = 70/26.217 = 2.67 so use 3 belts.

16. From the table on pages 71 to 72, and the table on page 73, the pulley and bush catalogue numbers for the SPC belt are obtained and detailed as below:

Pulley	*Shaft dia mm*	*Pulley PCD mm*	*No. grooves*	*Pulley Cat. No.*	*Bush No.*	*Max bore mm*	*Bush Cat. No.*
Driver	70	315	3	031C0333	3525	100 (OK)	029J0070
Driven	80	500	3	031C0373	3525	100 (OK)	029J0080