Efficient belt drives

This infosheet contains information about:

- the types of belt drives available;
- the benefits of belt drives; and
- how to correctly maintain them.

BHP Billiton Steel's Western Port plant redesigned their V-belt drives. This resulted in annual savings of $100 000, 1473 tonnes of CO_2 and 1 000 000 kWh. The payback period was two months.

INTRODUCTION

Gears, chains and belts are the main methods of transmitting power in today's machinery. When the speed of the driven shaft is different from that of the driver shaft, or when some distance separates these shafts, belts are usually the preferred method of transmitting power. Belt drives are designed for a specific range of applications and, if well maintained, are efficient transmitters of power.

Table 1: Transmission efficiency for drive transmission options

Drive transmission option	Transmission efficiency (%)
Belt drives	95–98
Chain drives	95–99
Worm and spur gears	92–96

The correct design, installation and maintenance of belt drive systems are critical in minimising energy costs and, therefore, in minimising the production of greenhouse gas emissions.

TYPES OF BELTS

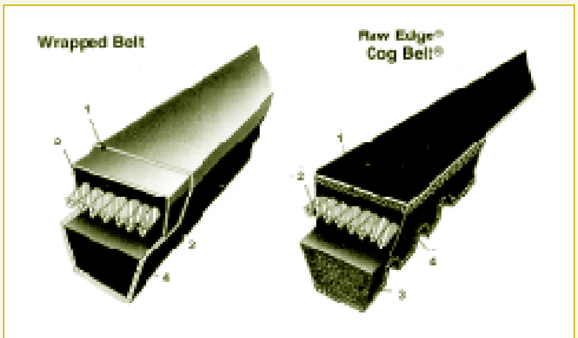


Figure 1: Cogged and conventional V-belts

The material and design differences in belt drives (summarised below) can affect running costs and energy outlays.

Apart from efficiency, belt drives present a number of advantages over other forms of power transmission, including:

- low initial cost;
- low noise;
- no lubrication required;
- ease of installation; and
- low maintenance requirements.

Conventional wrapped V-belt

These belts (as shown in Figure 1) have the following properties:

1. cotton–polyester fabric cover, impregnated with synthetic rubber;
2. tension section of rubber compounds that stretch as the belt bends;
3. fibre cords that carry the horsepower loads; and
4. rubber compression section that supports the cords compressing as it bends around sheaves.

Cog belt

These belts have the following properties:

1. stress relieved fabric that stretches up to 176% more than ordinary bias-cut fabric, which improves tension section stretch as the belt bends;
2. up to 20% more belt cord, made of HiModulus™ synthetic fibre, which carries high loads with minimal stretch;
3. compression section of exclusive Stiflex® rubber compounds with precision-moulded cogs that increase flexibility while maintaining even cord support; and
4. raw edge® belt sidewalls that grip better, minimising belt slip.

TYPES OF BELT SYSTEMS

There are two main types of belt configuration: V-belt and flat-belt. This infosheet concentrates upon industrial belt types only.

Industrial V-belt drives

The classic industrial belt or the narrow industrial-type belt can be used for most industrial multiple V-belt drives. The narrow belt is usually considered for new types of drives.

Classical wrapped belts

Classic industrial belts provide moderate performance, reasonable efficiency and long life at minimum cost. They are composed of a rubber-impregnated fabric covering that acts as the contact surface with the pulley face and holds the construction together. Beneath this is a rubber tension section, followed by fibre cords that transmit the load and rubber compression section.

Narrow belts

Narrow and cogged V-belts have a number of advantages over wrapped classic V-belts. They generally have a higher power transmission capacity for a given belt width for two reasons: they have more load-bearing members (up to 20%); and they can operate at higher speed ratios between the motor and driven machine by using smaller diameter pulleys. This leads to a reduction in bending losses (because the cogs allow the belt to bend easily around the pulley) and a reduction in belt slippage (due to increased sidewall grip).

Narrow belts have higher power ratings than their classic counterparts due to their greater section depth. The higher rating of the narrow belts reduces the number of belts required on a drive, improving energy efficiency.

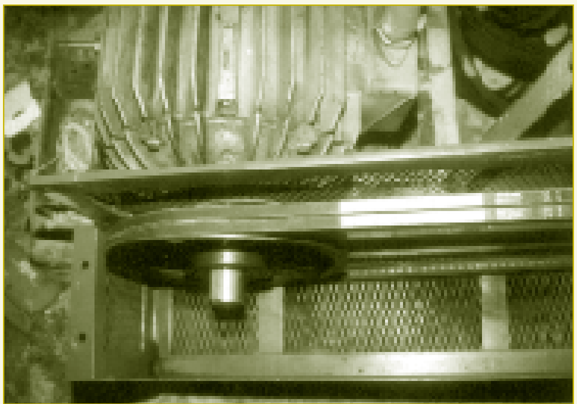


Figure 2: Industrial cogged V-belt drive

FLAT BELT DRIVES

In general, flat belts can operate more efficiently on a smaller diameter pulley than a V-belt. This makes flat belts desirable on drives where very high speed ratios require the use of small pulleys.

In flat belt drives, the controlling factor is the coefficient of friction. This frictional grip along the arc of the belt's contact with the driven pulley is important in transmitting power.

The ability of the belt to cope with the power transmitted is affected by:

- the width, thickness and grade of product;
- the number of plies; and
- the type of tensile member and tension ratio.

Flat belt drives don't have speed ratios exceeding 6:1, and at higher ratios long centre distances are needed to ensure sufficient arc of contact.

The two common types are the cordless and corded variety. Cordless belts are made of leather, woven fabric or all-elastomer. Other types of belts use the elastic characteristics of the belt, rather than a special tensile member, to resist the required tension. On the other hand, corded belts use a load-carrying tensile cord as a working element. Sometimes a sheet of plastic is used in place of cords.

Leather belt construction

Being the oldest type of industrial belting, leather is the standard against which modern belt materials and constructions are compared. Leather has a high coefficient of friction and, if the belt is maintained properly, this coefficient will increase with age.

Rubber belt construction

Rubber belts are more widely used due to the variety of construction and power transmission properties. These belts have a range of suitable coefficients of friction and are generally operated at higher tensions than leather belts.

They also have less initial stretch, better tracking properties, greater lateral stiffness and tolerate extreme environments.

Table 2: Comparing the two common types of flat belt drives

Flat belt	Power transmission (kW)	Speed (rpm)	Operating temperature range (°C)
Cordless	~ 750	100–7000	–20 to 100
Corded	~ 225	100–10 000	–30 to 100

Standard rubber belt construction

Reinforced rubber flat belts of cordless construction can be made of multiple layers of rubber-impregnated canvas or cotton duck fabric. The fabric provides working strength, while the rubber gives a good coefficient of friction. It also protects the fabric and bonds the layers together. This construction is economical and is easily spliced on the drive, but will stretch more than corded belts. Rubber flat belts can be raw-edged or covered. Corded construction rubber flat belts have better stretch resistance than the plied construction and can operate on smaller-diameter pulleys. These belts must be endless as they cannot be spliced due to their construction and the compounds that are used.

Plastic belt construction

Plastic belts are manufactured for high speed and general service applications. They usually employ a tensile member of sheet plastic that is often pre-stretched in the direction of pull to prevent excessive stretch. The tensile member is covered on both sides with other materials to provide a satisfactory wear and friction surface.

Fabric belt construction

These belts are made entirely from woven fabric with no rubber or bonding material, and in various numbers of plies. Flat fabric belts are used on special applications in the textile industry and for high speed drives.

SYNCHRONOUS BELT DRIVES

Synchronous belt drives operate on the 'tooth grip' principle.

The belt resembles a flat belt with evenly spaced teeth on the inside surface. The moulded teeth of the belt are designed to make positive engagement with suitably shaped mating grooves on the pulley or sprocket. Synchronous belts don't solely rely on friction to transmit power. Because of the positive tooth engagement, there is little relative motion between the belt and pulley. This 'no-slip' characteristic provides exact synchronisation between the prime power source and driven unit. Thus these belt drives are extremely useful where indexing, positioning or a constant speed ratio is required.

These belt drives are up to 98% efficient due to the positive, non-slip characteristic and reduction in binding tension of the belts. The belt operates at lower temperatures due to low slippage, and centrifugal tension is reduced due to the low profile and mass. The common types of synchronous belt drives are described below.

Timing belts

The need for timing belts arose out of the need for a power transmission system to fill the void between roller-chain and conventional rubber V-belts. The first synchronous belt product line included one trapezoidal tooth profile and pitch. These belts can operate at speeds ranging from 100–20 000 rpm and can transmit up to 150 kW.

High torque drive (HTD)

The curvilinear profile was originally developed and patented by Uniroyal Inc. These belts have full-rounded, deeper, more closely spaced teeth than a conventional trapezoidal timing belt. The more even distribution of tooth loading to the belt tensile members allows overall higher loading. These belts can transmit up to 450 kW at speeds ranging from 10–4000 rpm and operate at temperatures ranging from –30–85°C.

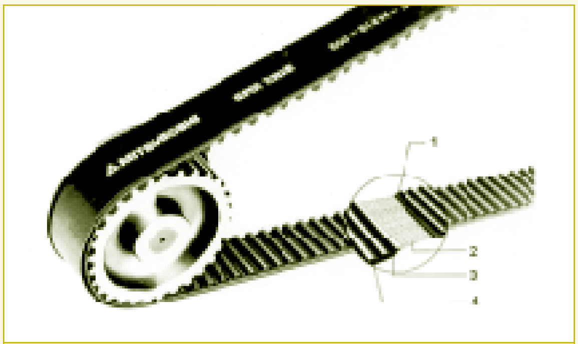


Figure 3: Standard HTD belt construction

High torque-drive belts (as shown if Figure 3) have a number of beneficial properties including the following.

1. Nylon facing: wear-resistant nylon fabric with low friction coefficient assures the smooth engagement of the belt in mating pulley grooves.
2. Glass fibre cord: tough, heat-resistant, spirally-wound glass fibre cords are located within the belt pitch line, generating correct and positive belt engagement with the pulley, and negligible belt stretch in operation. In addition, special cords twisted in S and Z designs prevent belt thrust force, resulting in longer service life.
3. Chloroprene teeth: correctly placed chloroprene teeth engage with the pulley grooves and are inherently resistant to oil, heat and ageing.
4. Chloroprene backing: flexible chloroprene backing protects the glass fibre cords from oil and moisture, and also from frictional wear when power is transmitted from the back of the belt.

CONSTRUCTION OF SYNCHRONOUS BELTS

Body and tooth

Most synchronous belts are made of a premium oil and heat-resistant elastomer compound. Special compounds are available which provide high oil resistance, static electricity build-up, static conductance and non-marking characteristics.

A more recent development made in synchronous belt performance by Gates Rubber Company is called Poly Chain Belt. It consists of a combination of polyurethane, Dupont Kevlar tensile members and nylon fabric tooth facing. The material improvements made permit a much higher overall belt loading than any other synchronous belts.

The teeth are precisely spaced so that their root lies substantially at the pitch line and their spacing is not changed by the shear forces imposed by the sprocket. The shear strength of the teeth is greater than the strength of the tensile member when at least six belt teeth are in mesh with the pulley or sprocket grooves. Since the latest curvilinear design improves stress distribution, the overall loading on many drives can be higher compared to the conventional trapezoidal profile.

Backing/overcord

Overcord is bonded to the tensile member and provides protection against grime, oil and moisture. It also protects from frictional wear if a backside idler is used, or if power is transmitted from the backside of the idler. Backings can be specially compounded for applications where non-marking is critical, such as on printing or food processing belt drives.

In some instances, when a special belt thickness tolerance is required, the belt overcord is ground. Presently, there is no industry standard establishing thickness tolerance for various classes of ground back belts. However special classes of grinds are widely used.

Tensile member

Fibreglass is the standard and most commonly used tensile cord in synchronous belts. Its high modulus, low-stretch characteristics make it excellent for a wide range of general applications. Care must be taken when handling, storing and installing it so the tensile member, which has little or no compression strength, is not damaged. Alternative cord materials are Dupont Kevlar, steel and polyester. Kevlar and steel generally have slightly higher ultimate strengths than fibreglass. However, this doesn't directly translate into increased belt capacity. A belt's overall performance is optimised by a balance of factors, such as:

- fatigue life;
- environmental stability;
- strength; and
- tolerance of shock loading and ambient temperatures.

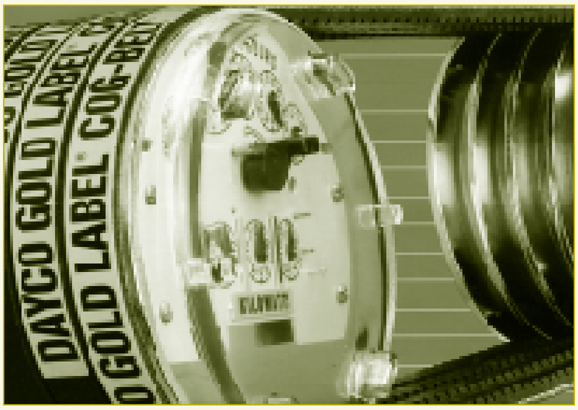
Kevlar has excellent shock resistance compared to steel, fibreglass and polyester. It has been used instead of steel—particularly where low weight, high fatigue life, corrosion resistance and flexibility are important factors.

Belt 'ratcheting', due to under-tensioning, should also be avoided as the damage to the belt may not be visible. It is likely that belt life will be dramatically reduced. Extreme belt-tooth wear, as well as tooth cracking, will occur due to increased tooth loading. Ratcheting will be transmitted directly to shafts, bearings and other drive components, resulting in damage or failure.

MAINTENANCE

There are a number of factors that can affect the efficient operation of belt drives. You should be aware of the following points.

- Proper maintenance can be very effective in increasing V-belt drive efficiency. Improper belt tensioning can result in efficiency reductions of up to 10%.
- Flat belts are generally 5–15% more efficient at power transmission than a V-belt in a similar installation. This is due to a reduction in wedging and bending stress.
- Audible noise can also provide clues to existing or potential problems. Improperly placed guards, loose belts or excessive vibration can result in the belts rubbing against the guard. V-belt squeal can be caused by:
    - inadequately tensioned belts; and
    - debris, grease, oil or paint in the pulley grooves.



- Low frequency vibration is more significant for V-belts due to a greater cross-section transmitting the same power. Slapping may indicate the belt is striking a guard or some other obstruction. A squeal or chirping indicates the belts are too loose. Re-tensioning may be required after the drive is stopped.
- Re-tensioning and alignment are normally not required for flat belts, whereas V-belts have to be matched if two or more are transmitting power.
- To maintain efficiency, V-belts also periodically need to:
  - be re-tensioned;
  - have their pulleys aligned; and
  - have their alignment checked.

For troubleshooting and general maintenance suggestions see Table 3.

CONCLUSION

There is a large range of belt drives to choose from. Ensuring that you have the correct one for an application can lead to reduced equipment maintenance and replacement, substantial reductions in energy consumption and significant cost savings.

Table 3: Troubleshooting and general maintenance of belt drives

Symptom	Problem	Solution
Hot spots	Build-up of foreign material inside the guard	Remove foreign material build-up
Belt deterioration and slippage	Excessive build-up of oil	Provide proper protection, and repair source of oil
Unequal belt stretch	Misaligned drive; therefore unequal work being done by each belt	Realign and re-tension belts
Belt slipping	Heat build-up	Re-tension belts
Rapid belt failure	Tensile members damaged through improper installation	Replace with matched set
Worn sheave grooves	Service ageing or poor sheave material	Check with groove gauge and replace sheave if required
Belt side-walls soft and sticky	Oil or grease on belts or sheaves	Remove source of oil or grease and clean belts with solvent
Belt side-walls dry and hard	High temperatures	Remove source of heating and improve ventilation
Extreme cover clearance	Belts are rubbing against belt guard or other clearance obstruction	Remove obstruction or align drive to increase wear
Bottom of belt cracked	Sheaves too small	Redesign for larger sheaves using engineering manuals
Belt noise	Belt slipping or hitting obstruction	Re-tension belts using appropriate instruments
Bearings overheating	Drive over-tensioned. Worn grooves, belts bottoming and will not transmit power until over-tensioned	Replace sheaves, re-tension belts
Poor bearing	Under-designed bearings or poor maintenance condition	Follow recommended bearing selection and maintenance
Sheaves out too far on shaft	Improper installation	Place sheaves as close as possible to bearings