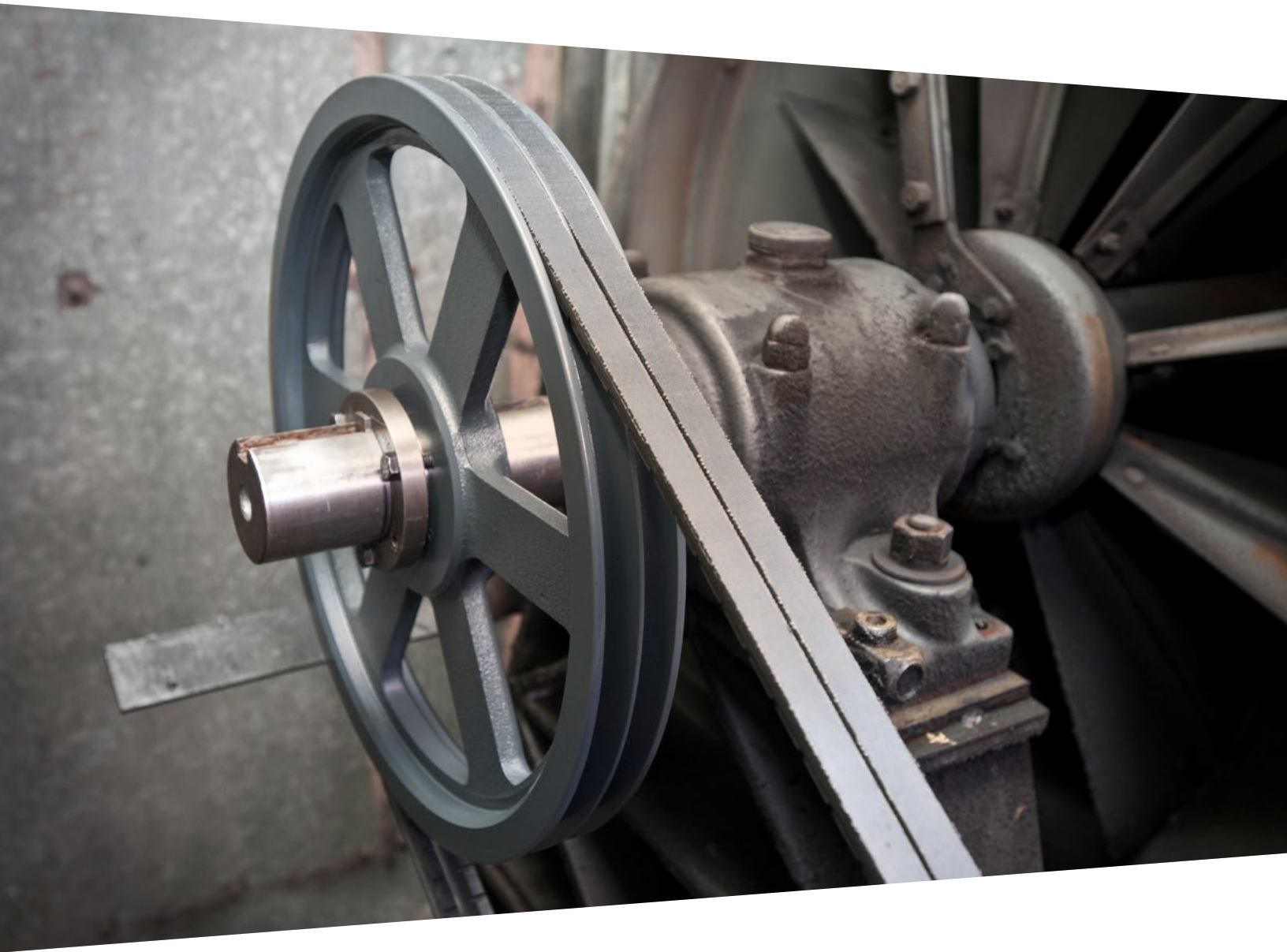




Recapturing The Lost Efficiency Of A V-Belt Drive



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Recapturing lost efficiency throughout the lifecycle of a V-belt drive



Old Drive (left) Replaced with “Optimized” Drive (right)

V-belt drives, which consist of a driver sheave (pulley), a driven sheave, one or several V-belts, and typically bushings to adapt the sheaves to varying shaft sizes, are often thought to be accessory items to a primary piece of equipment. These drives are required to transmit rotational motion and when this occurs, the installation is thought to be satisfactory. Indeed, a properly designed, installed and maintained V-belt drive can be very efficient with values approaching 98% under ideal conditions. **However, when those conditions are not present, the actual efficiency can be reduced by 20% or more as a result of less efficient product selection, worn components, and operational degradation.**

Fortunately, these efficiency losses can be recaptured. Energy conscious engineers and technicians can now take advantage of product improvements and new technology while employing best practices resulting in having the most efficient V-belt drives possible. Presented in this paper are factors that can be easily applied throughout the lifecycle of a V-belt drive that result in improved efficiency and better operational performance while significantly reducing energy costs.

I. Product Selection

Optimized Drive Selection:

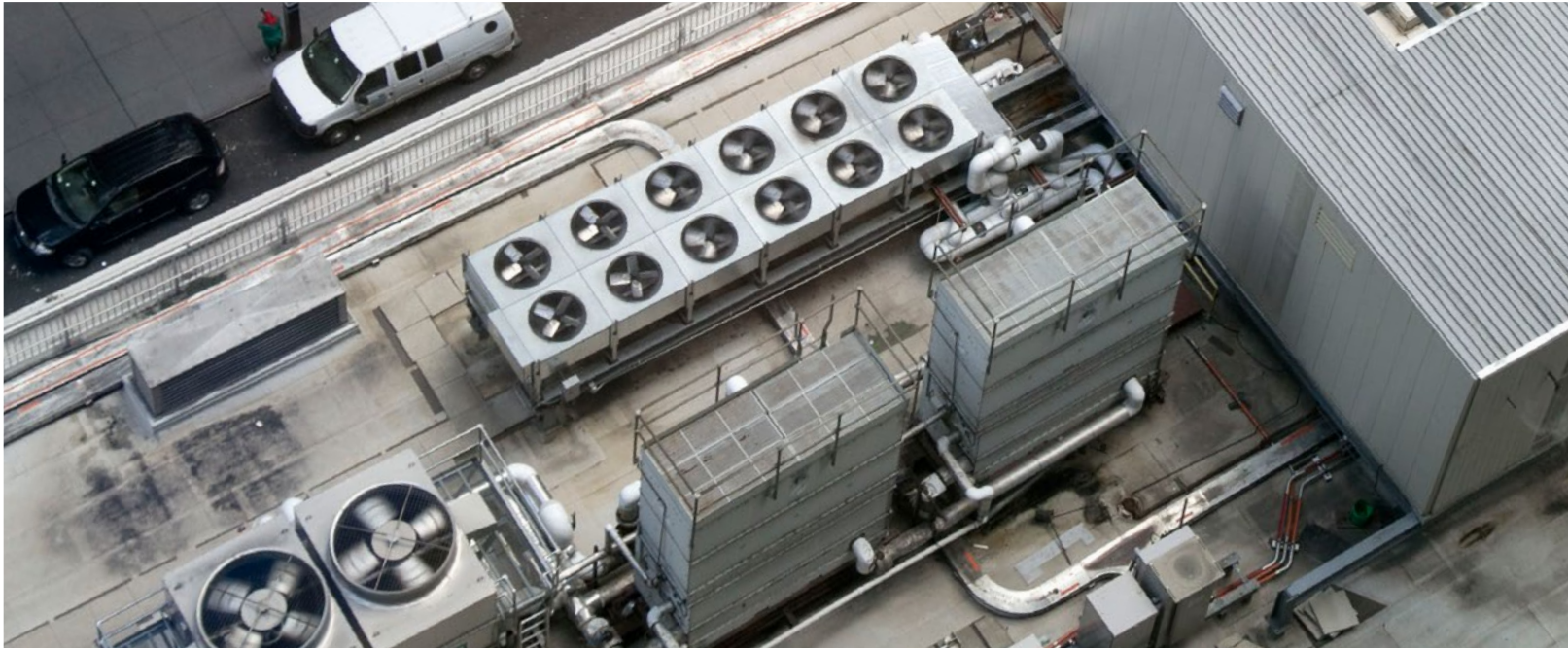
The starting point and basis for any efficient V-belt drive is the selection of the most efficient products. Often worn, damaged or failed components are replaced with new, identical parts.

This practice often leads to the installation of unnecessarily bulky components, or ‘over-belted’ drives, and fails to take advantage of product improvements that have taken place over the past 20 years. For example, a maintenance technician may be given the task of replacing a two-groove V-belt drive on an exhaust fan. Even though selecting and installing like components is an option, a more efficient and torque dense drive most likely exists. A properly chosen or “optimized” V-belt drive may require the use of only one V-belt. Selecting an optimized drive reduces the initial expense by reducing the component costs (single-groove sheaves and only one V-belt). But the savings do not end there.

The selection of a more efficient V-belt drive yields energy savings each month of the product’s lifecycle in the form of electricity usage. **Using the wrong components can decrease drive efficiency by as much as 10%!**

There are two generally accepted methods to help ensure the correct products are selected. The traditional method is to use the selection tables available in manufacturers’ catalogs. This approach, as a minimum,





provides for components that are mechanically suited to handle the loads required of the application, fit within the allotted space envelope, and satisfy the National Electrical Manufacturers Association (NEMA) guidelines. Some shortcomings that may exist, however, using this method are:

1. The most efficient components may not be selected.
2. The tension requirements for the specific selected components will not be known.
3. The drive's hub load will not be readily available.

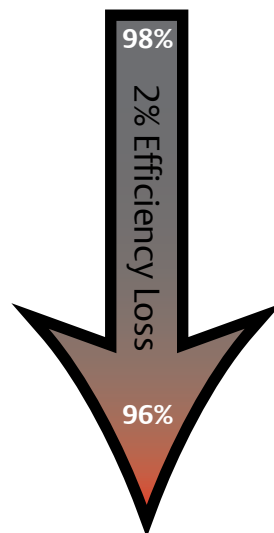
A more technologically advanced method of selecting V-belt drive components takes advantage of computer software developments. Most major suppliers of V-belt drives make available customer-friendly software programs that, with the proper input parameters, deliver the most efficient V-belt drive components available from that particular manufacturer. This includes a drive system that will most closely operate at its full rated capacity since this has been shown to yield the most efficient drive system when all other factors are equal (Shepherd 20). Many of these software solutions also provide precise tension guidelines and expected hub load values.

V-Belt Design:

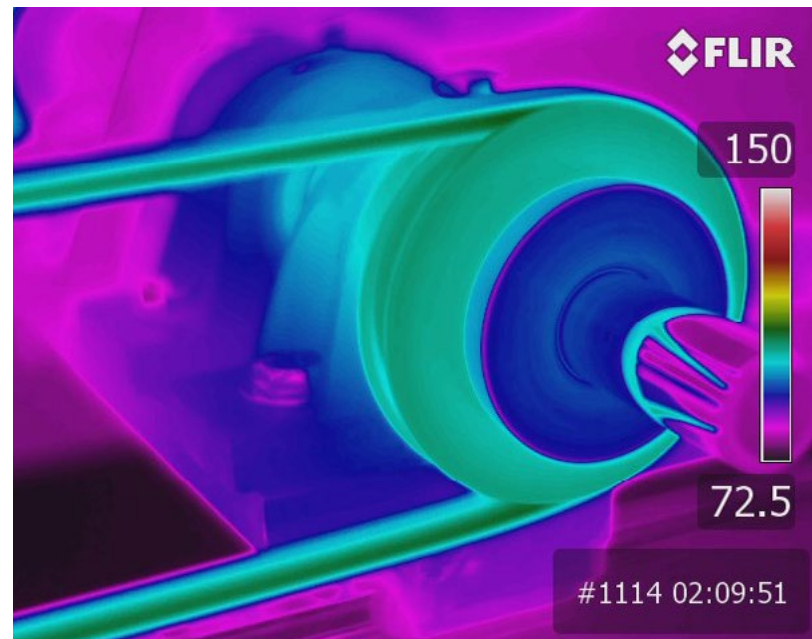
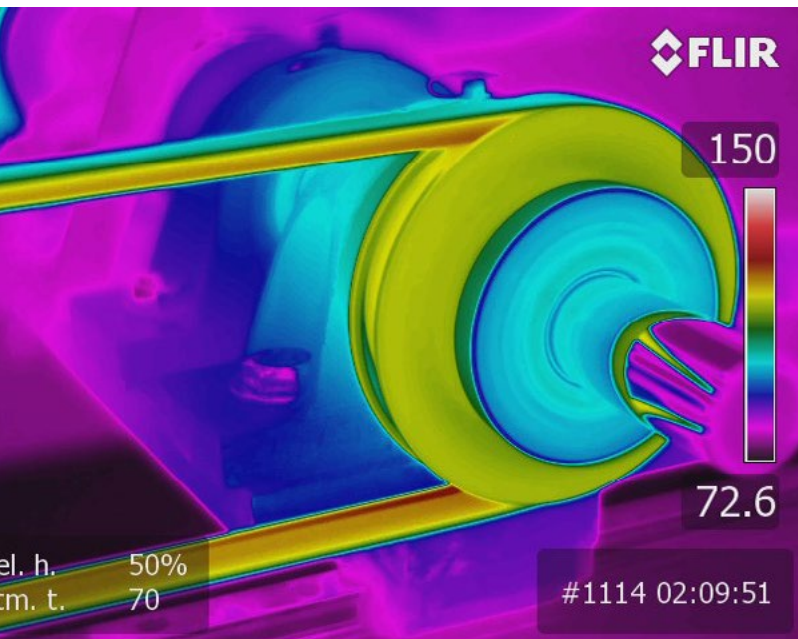
Industrial V-belts are available in a wide variety of types and sizes – both from a cross-sectional and a length standpoint. Even the geometry is often different among the different types of V-belts. The Rubber Manufacturers' Association

(RMA) is generally accepted as the governing body for maintaining consistency and interchangeability of products within the industry. The typical V-belts are those with a notched underside and “raw” edge, and those that are wrapped and do not have notches on their underside.

While both types of V-belts will operate with the same type of sheave, the US Department of Energy reports that the notched style V-belts run cooler, last longer and are about 2% more efficient than the un-notched V-belts (U.S. Department of Energy).



The reason that the notched-style belts are more efficient is easily understood. The absence of rubber (cogging) on the underside of notched-style belts reduces the compressive stresses during bending allowing for a much more flexible V-belt. Less resistance to flexing results in reduced wasted energy dedicated to bending around the sheaves and better engagement between the V-belt and sheaves. The “raw” edge of the notched-style V-belt allows the V-belts to maintain firmer contact with the sheave sidewalls while discouraging



Thermal Photograph of Un-notched (left) vs. Notched (right) V-belts

energy consuming slippage. Note the differences in operating temperature of notched-style V-belts compared to un-notched V-belts for a particular application in the illustration above. **A direct replacement of the same size wrapped V-belt with the equivalent notched V-belt typically provides 30-40% greater horsepower transmitting capabilities resulting in greater overall V-belt life when properly installed and maintained.**

Sheave Diameter:

The diameters of the driver and driven sheaves are very important factors in V-belt drives and directly impact the drive efficiency. Since most V-belt applications are speed reduction drives with the driven equipment operating slower than the motor, the sheave for the motor is typically the smaller of the two and should be selected first. NEMA Standard MG1-14.42 provides guidelines for selecting the minimum sheave diameter for a given motor based on frame size, horsepower, speed, and V-belt type. This guideline serves to protect the motor bearings by limiting the hub loading that a motor may experience if too small diameter sheaves are used. Then, based on the speed reduction ratio, the diameter of the driven sheave is determined. Studies show that V-belt drive efficiency improves steadily as the diameters of the sheaves increase. **Under certain conditions, the drive efficiency could be increased by as much as 10% when larger diameter sheaves are utilized.** Factors such as torque and tension play a major role.

Essentially, the largest sheaves possible considering space limitations and the overall economics, provide for the most efficient V-belt drives while reducing the stress on the other drive components. The benefits to using larger diameter sheaves include:

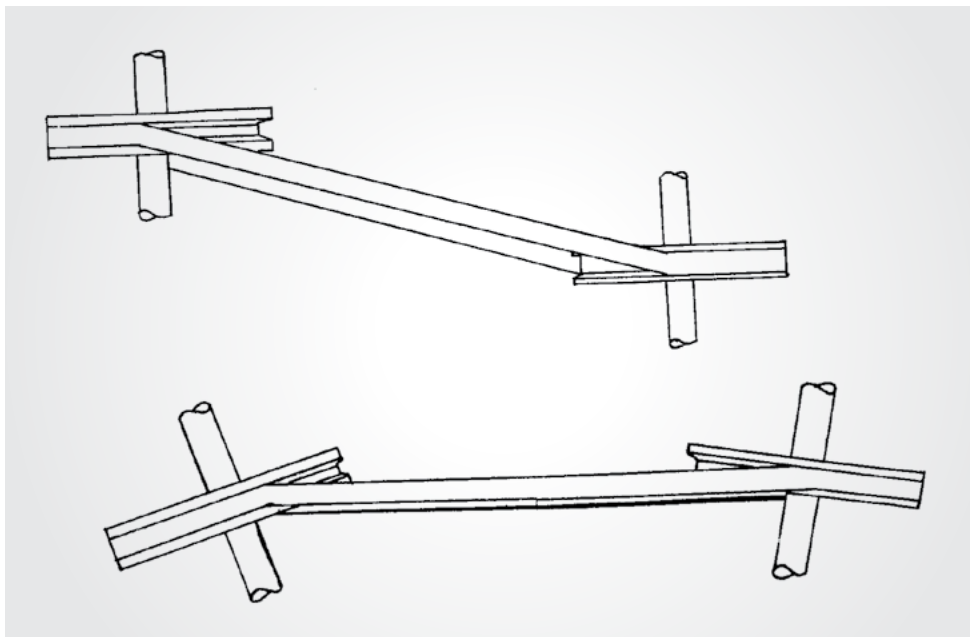
- > Less tension is required since more of the V-belt contacts the sheaves
 - Reduced tension translates to reduced loading on the bearings supporting the driver and driven shafts
- > The V-belts bend less and therefore generate less internal temperature
 - Less heat, more efficiency
- > Improved V-belt 'wedging' action in the sheave groove
 - Increased torque transmission, more efficiency
- > Less bending stresses in V-belt
 - Prolongs longevity with regard to fatigue

In his article, "Optimizing Belt Drive Efficiency", published by Power Transmission and Design in 1985, James Shepherd, Mgr. Product Application Dept., Gates Rubber Co., states that both NEMA and RMA recommend using larger sheaves to improve drive efficiency (Shepherd 21). Also, an





Notched V-Belt (top and center) and
 Wrapped V-Belt (bottom)



Exaggerated View of Parallel Misalignment (top) and
 Angular Misalignment (bottom)

article published by Goodyear Tire and Rubber Company, in 1998 reiterates this message by stating, “If space permits, you can increase belt speed and efficiency by using larger diameter pulleys” (Francis 34).

II. Installation

Alignment:

Proper alignment of V-belt drives refers to the positioning of the driver sheave with relation to the driven sheave. The two types of sheave misalignment typically associated with V-belt drives are parallel and angular and either type, whether alone or in combination, will rob efficiency when excessive. Although difficult to quantify, it is reasonable to expect that losses of up to 2% could occur under conditions of misalignment due to belt slip and excessive loads on other parts of the drive.

Parallel (or offset) misalignment between the driver and driven sheave results in the V-belt entry into the sheaves being skewed and favoring one side of the sheave groove. This condition causes V-belt slip resulting in increased heat build-up and loss of efficiency. Often, the sheave grooves wear unevenly when parallel misalignment exists which requires replacement of the sheaves on a more-frequent time interval.

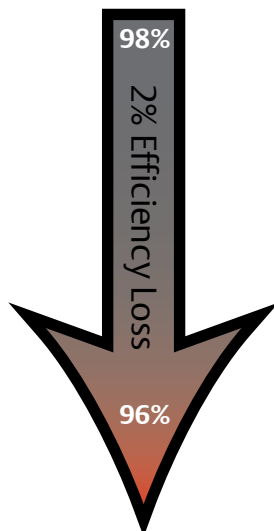
Angular misalignment, as the name suggests, occurs when the driver and driven shafts are

not parallel to one another leaving the sheaves out of the proper angular orientation. When this occurs, not only is the V-belt entry angle to the sheaves impaired but the tension on one V-belt will be significantly more than the other V-belts when multiple groove sheaves are in use. The V-belt(s) with less tension will typically slip and transmit less horsepower than could otherwise be transmitted under ideal alignment conditions.

Tension:

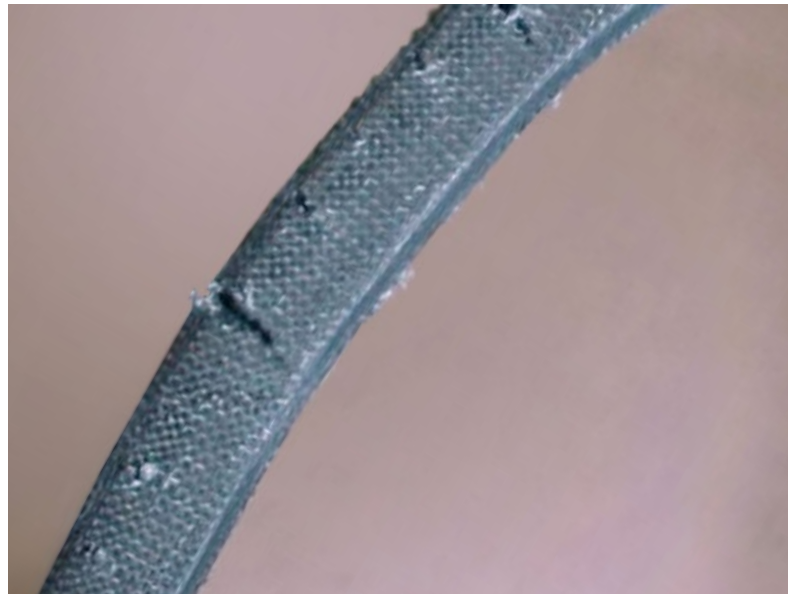
Improper tensioning of V-belts is probably the biggest thief of energy when it comes to V-belt drives. While both conditions of over-tensioning and under-tensioning adversely affect efficiency, the most frequently encountered problem is under-tensioning. **Estimates of the energy losses due to under-tensioned drives can be as much as 20% based on a Fenner Drives publication in 2013** (Bigler, Heston 2). Several of the leading factors affecting the degree of inefficiency are the amount of under-tensioning, torque, duty cycle and the amount of time the belt is operated in the under-tensioned condition.

V-belts that are under-tensioned normally make a squealing noise at start-up and will always present a shiny ‘glaze-like’ appearance on the sidewalls. This is evidence of the independent movement of the V-belt and the sheave and the V-belt sliding when in the sheave groove. The wearing away of the rubber material presents itself in the form of black dust (belt mass loss) that collects underneath the V-belt drive – either on the floor or within the safety shrouding. Under-tensioning accelerates V-belt slippage which also accelerates belt mass loss ultimately shortening the V-belt life as well as causing a decline in efficiency. **By definition, heat is energy and when it cannot be used to transfer mechanical motion like in the case of V-belt drives, it is lost energy which leads to**





Shiny Side Wall of Un-notched V-Belt



"Heat-aging" as a Result of Slippage

an inefficient drive.

When V-belts experience prolonged slippage conditions, they harden or 'heat age' becoming resistant to bending and flexing and more energy is then required for the V-belts to bend around sheaves. The stresses associated with bending and flexing of the V-belt during operation results in cracks on the underside of the V-belt. Proper tensioning not only reduces slippage but extends the life of V-belts.

III. Maintenance

Retensioning:

It is widely understood that the ideal tension for a V-belt drive is just enough to prevent excessive slippage and the 'squealing' noise when the drive first starts up. This amount of tension places less loading on the drive bearings and shafts and less burden on the V-belt drive components. This is a good rule-of-thumb but this tension can be difficult to achieve and maintain. **Even if the tension of the V-belt drive is properly established during installation and the sheaves are ideally aligned, it is not abnormal for the tension to drop off by 1 to 2 pounds after only 15-30 minutes of operation.** This drop in tension occurs not necessarily because the V-belt elongates or stretches as often thought but because the fabric of the belt warms up and becomes better form-fitted to the sheaves and any 'flashing' residue from the manufacturing process gets worn away. So in a relatively short period of time after installation, the efficiency of a V-belt drive will diminish if the loose tension condition is not corrected.



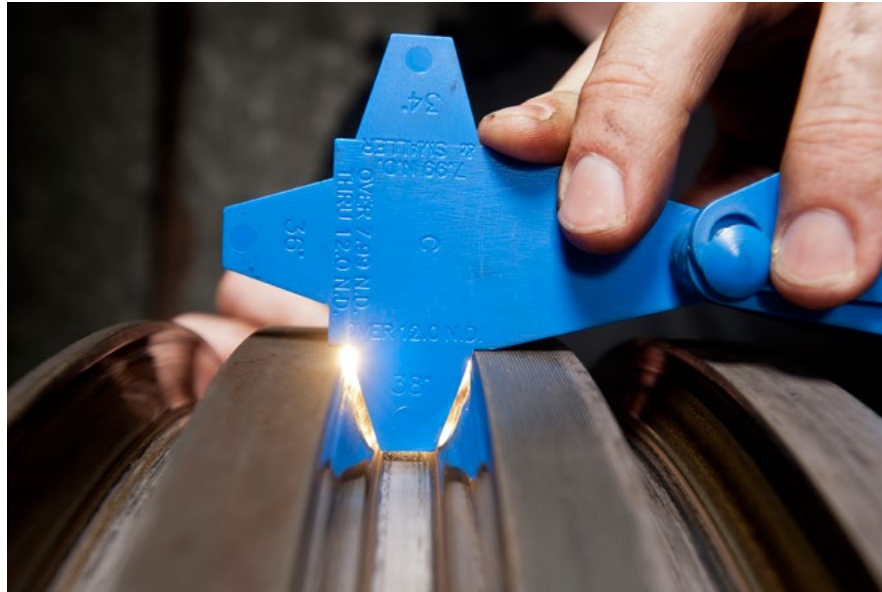
However, ensuring proper tension on numerous V-belt drives within a facility throughout the weeks and months of operation can be labor intensive. Re-tensioning requires locking-out the electric motor, removing the safety guarding, adjusting the motor base or idler, qualifying the tension, and then reinstalling the safety guarding and unlocking the electrical system. These tasks are indeed time-consuming but are imperative for a drive to perform at optimal efficiency. Fortunately, there are now proven automatic spring-loaded motor bases on the market that maintain the original tension of the V-belt drive. Properly applied, these tensioning devices help sustain the original efficiency gains. Unlike traditional idlers or some other types of spring loaded devices, auto-tensioning bases are durable and long-lasting because they do not provide tensioning via contact with the moving V-belt. Unless subjected to physical damage or corrosion failure, an auto-tensioning motor base like the one shown can be expected to last as long as the equipment to which it is attached.

Sheave Condition:

Most sheaves in V-belt drive applications are made from cast iron or steel and consequently provide several years of service. Sheaves that are properly selected and installed and operating in a non-abrasive environment with properly selected and tensioned V-belts can expect to reach 60,000-75,000 hours of operating life. The actual wear on a sheave typically occurs as a 'dished-out' appearance on the inside walls where the V-belt rides.



Auto-tensioning Motor Base

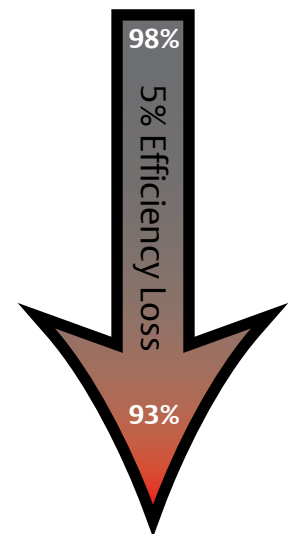


Worn Sheave as Indicated Using V-Belt Groove Measurement Device

When a significant amount of sheave wear is present, V-belts do not properly engage the sheave grooves leading to V-belt slip and elevated V-belt temperatures. This results in mechanical energy from the motor being converted to heat rather than to rotational motion of the driven equipment. If undetected or if not corrected, worn sheaves will sometimes lead maintenance personnel to over-tension a drive in order to stop the drive from squeaking. Over-tensioning leads to excessive loads on all drive components increasing the amount of work the motor has to do in powering the drive. This additional loading results in inefficiencies to the overall drive. Under normal conditions, the smaller diameter sheave of a given drive will wear faster because it makes much more contact with the V-belt. Efficiency losses of 5% or more can be expected when a wear gap of 1/32" is present. The typical method of checking for sheave wear is to use a gauge that is available from various manufacturers of V-belt drive components. Gauges are different depending on the intended V-belt for the particular groove and the diameter of the sheave and it is important to use the correct gauge during inspection. Merely place the gauge in the groove as squarely as possible and look for the presence of 'light' on the sides of the sheave grooves. If light is present, it may be time to replace the sheave.

Summary

Several factors which negatively affect the energy efficiency of V-belt drives as well as specific strategies for recapturing this energy have been presented in this paper. The overall effect of these factors can be quite large considering the high and rising cost of electricity. Many studies have been conducted and much has been written over the last 20 years regarding this topic. **A review of this literature reveals that experts in the industry and engineers from V-belt manufacturers expect an estimated efficiency improvement of between 2% and 20% when the contributing factors are optimized and maintained.**



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