TECHNICAL INFORMATION

TITLE: MOTOR SELECTION FOR BELT-COUPLED CONVEYOR DRIVES

INTRODUCTION

Rated power is only one of the parameters to be considered when motors are selected for a conveyor. Unfortunately, the success of a conveyor installation also depends on a motor parameter that is frequently ignored. After the power requirement has been determined, the next most important parameter to be considered is rated speed. Rated speed affects load sharing between directly coupled motors and belt stretch interacts with motor slip to affect load sharing between belt-coupled drums—these are running problems. Fortunately, if rated speed is chosen to minimize the load-sharing problems, the accompanying torque-speed and current-speed characteristics provide good starting performance for belt conveyors. The purpose of this discussion is to present the requirements of both the starting and the running conveyor so that motors can be selected with knowledge of the consequences.

POWER REQUIREMENTS

The power-requirement for a belt conveyor is made up of the following components:

⇒ the power required to run the empty belt,
⇒ the power required to horizontally move the load,
⇒ the power required for any vertical lift,
⇒ the power required for friction from any additional equipment such as skirting or side-travel rollers, and
⇒ the power required for acceleration.

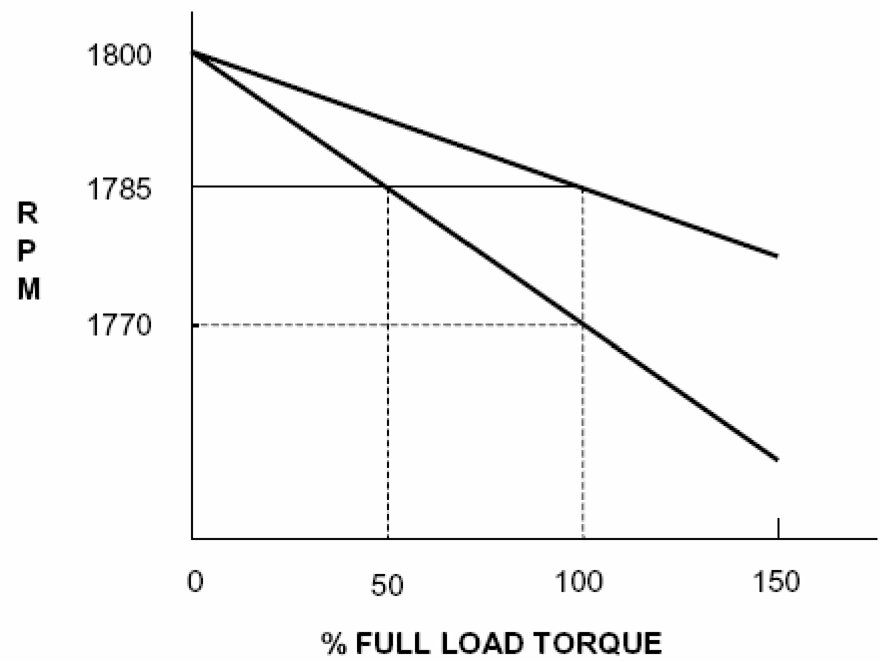
The sum of the first four components is the power required to run the conveyor. The acceleration component is only required during starting. For acceleration times longer than 15 seconds, the acceleration component is usually small with respect to the connected power and little advantage is obtained by increasing acceleration time above 20 or 25 seconds. The usual method used to determine the total power required is to multiply the sum of all five components by 1.1 and choose the next largest standard size. The result of the 1.1 factor, rounding up, and the acceleration component is that conveyors typically use approximately 75% of connected power when running at design capacity. This is rather fortunate because most induction motors reach peak efficiency at 75% load.

THE STARTING CONVEYOR

There are two common misconceptions with respect to the torque required to start a belt conveyor. One misconception is that a belt conveyor has a high breakaway torque. Static friction is higher than rolling friction; but, a conveyor does not break away all at once. Rather, it breaks away one element at a time due to belt stretch and the action of the belt-tensioning device—static friction does not have a significant influence on starting. The other misconception is that it takes significantly more torque to start a conveyor than to run a conveyor. The only component of the power requirement associated with starting is the acceleration component. The torque required for the other four components increases with speed and their sum is a maximum at rated speed. Consequently, a starting torque just slightly higher than the running torque will eventually start the conveyor. If the power requirement has been determined correctly, any starting technique that can deliver 75% rated torque, or more, throughout the start sequence should be able to start the conveyor. However, in order to control acceleration and to allow for occasional overloads, it is prudent to choose a starting technique capable of providing 100% rated torque throughout the start sequence.

THE RUNNING CONVEYOR

When directly coupled motors start a conveyor, slip is high and load sharing among all motors automatically occurs because small differences in motor speed result in small differences in motor torque. In fact, motors with different hp ratings and operating speeds will share a starting load according to their respective hp ratings. When the starting technique allows the motors to achieve running speed before torque transfer begins, the motors have the same load-sharing problem while starting the conveyor that directly coupled motors have with load sharing while running. The problem of load sharing while running can be illustrated by expanding the torque-speed curve of an induction motor in the operating range. Shown below is the expanded torque-speed characteristic of a 1770- and a 1785-rpm motor:



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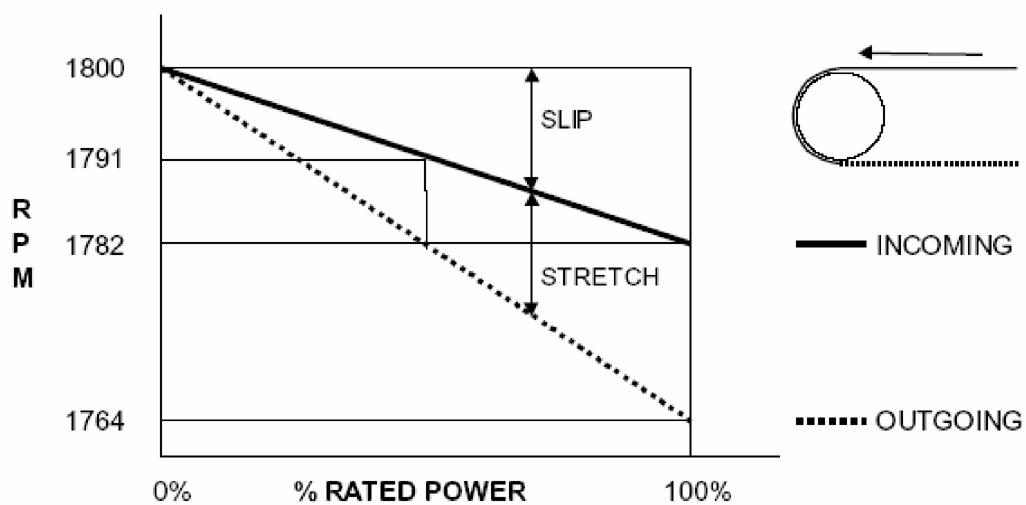
In the range shown, torque-speed characteristics are very nearly linear. If these two motors drive the same conveyor drum and are forced to run at the same speed, the 1770-rpm motor will be 50% loaded when the 1785-rpm motor is delivering rated power. Assuming equal hp ratings, any loading beyond 75% of the total rating would cause the 1785-rpm motor to be overloaded. An interesting corollary to this observation is that motors with different hp ratings can be directly coupled and they will load share according to their hp ratings if their rated speeds are the same. On the other hand, new motors with the same nameplate data might not equally share the load. Unless a premium is paid for dynamometer testing, motors are rated to the nearest 5 rpm. This means that two new motors rated at 1785 rpm could be mismatched by 23.5% when operating at the same speed. The mismatch can be even higher after a motor is repaired.

Belt stretch introduces an extra dimension to the problem of load sharing in conveyor drives. In order for a drive drum to transfer power to a belt, it must increase tension in the belt and stretch the belt so that a section of belt leaving the drive drum is shorter than the same section of belt as it enters the drive drum. In order to stretch a belt, speed of the drive drum must be equal to or greater than belt speed at all points of contact. Consequently, the speed of a belt entering a drive drum is equal to the tangential velocity of the drum and its exit velocity is lower by the amount of belt stretch. Consider a single drive drum with 1782-rpm motors (1% slip) and a belt that stretches by 1% at rated power—a stretch-to-slip ratio of 1.0 for the drum. For illustration, belt speed is referenced to the motor shaft:



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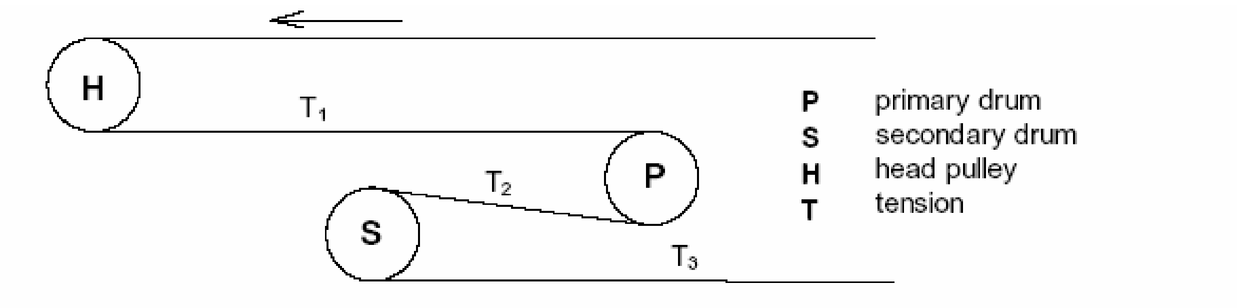
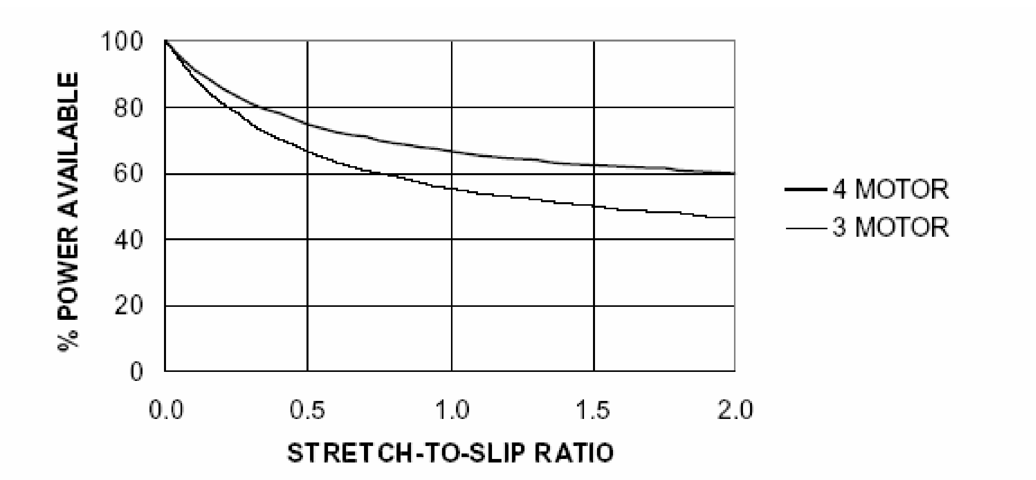
Provided tension in the outgoing belt and the coefficient of friction between the belt and the drum are sufficient to maintain incoming belt speed equal to drum speed, outgoing belt speed will be less than incoming belt speed by the product of slip and the stretch-to-slip ratio.

In a tandem conveyor drive, incoming belt for the secondary drum is the outgoing belt from the primary drum:



Since belt stretch is proportional to belt tension, speed of the primary drum is greater than the speed of the secondary drum when $T_1 > T_2 > T_3$ and both drums are driving. Maximum power available to the conveyor, without a motor overload, occurs when the motors driving the secondary drum are at rated power. If the primary and secondary drives are the same as the one in the 1%-slip, 1%-stretch example, the RPM Vs % RATED POWER graph indicates that, at rated secondary output, the speed of the primary drum is 1791 rpm. At 50% slip, the primary drum delivers 50% rated power and the tandem drive delivers 75% of connected power before an overload occurs. The previous example used specific values for illustration—the following graph is a general solution showing percent of connected power available as a function of stretch-to-slip ratio for 3- and 4-motor drives. Stretch is per motor and identical drums and motors are assumed:



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If a belt is inelastic, this graph shows that 100% of the connected power is available and all motors will share the load equally. Any increase in belt elasticity or rated speed of the motors causes a decrease in power available before the secondary motor(s) becomes overloaded.

In a study on a 3-motor, 750-hp drive at a local potash mine, manufacturers data on the belt indicated belt stretch to be 0.765% per motor. The motors were rated at 1776 rpm resulting in a stretch-to-slip ratio of 0.57 per motor. The graph shows that for a stretch-to-slip ratio of 0.57 for a 3-motor drive, only 64% (480 hp) of rated power is available before the motor driving the secondary drum goes into overload. When the secondary drum delivers rated power, the sum of stretch and slip for the primary drum is 100%. Since the stretch-to-slip ratio is 1.15 for the primary drum, slip on the primary motors is $100 \div 2.15 = 46.5\%$ and total power available is $(100 + 2 \times 46.5) \div 3 = 64\%$. To improve load sharing, a 1769-rpm motor was used on the secondary drum. The graph cannot be used directly for this example because it assumes all motors are the same; however, the increase in power available is easy to calculate since the sum of stretch and slip for the primary is increased to 129% ($31 \div 24$) when secondary drum delivers rated power. Slip on the primary motors is $129 \div 2.15 = 60\%$ and total power available is increased to $220 \div 3 = 73\%$. For comparison, 1785-rpm motors on the same conveyor would have a stretch-to-slip ratio of 0.92 and power available would be only 57%.

Tie gears between the primary and secondary drums eliminate the load-sharing problem associated with belt stretch between belt-coupled drums. Tie gears force the primary and secondary drums to run at the same speed so that all drive motors are forced to share the running load to the extent that their individual rated speeds allow. However, tie gears do not permit load sharing between the drums. Tie gears effectively transfer all motors to the secondary drum and the primary drum does not contribute to belt tension unless the belt slips on the secondary drum due to the increased torque available to it—this is most likely to happen during starting.

CONCLUSIONS

Unbalanced load sharing is not a problem unless it unnecessarily forces one or more motors into overload. Some unbalance is expected between motors on the same drum and between the primary and secondary drums. It is impractical and unnecessary to try to eliminate unbalance. The simple solution is to use high-slip (1770 rpm or lower) motors that reduce unbalance to a tolerable amount. Any solution that involves motor matching or individual adjustments for each motor is unnecessary and expensive. The logistics of maintaining an industrial plant with numerous similar installations are simplified if a single motor is selected that can be used in any location. Design-C motors are high-slip motors and they are recommended for conveyor applications. The additional benefit of design-C motors is a torque-speed characteristic that solves most conveyor starting problems.

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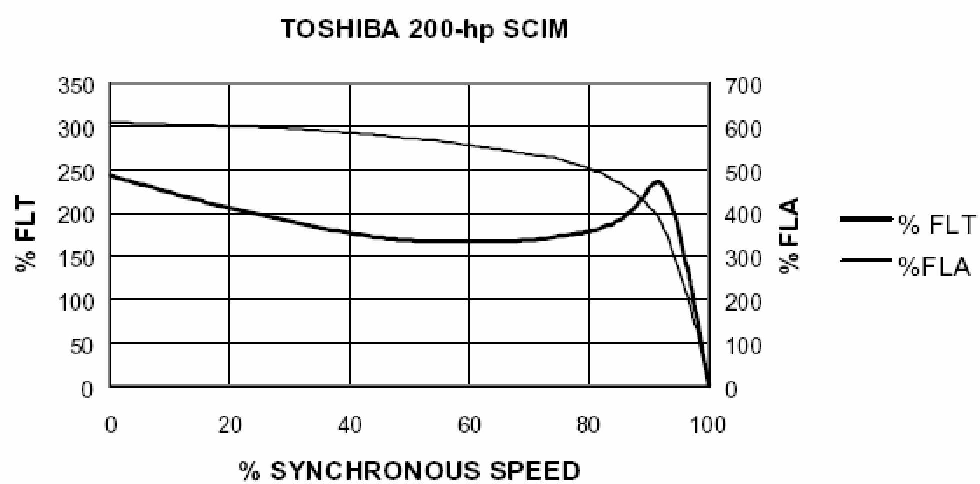
Utilities and regulatory agencies are encouraging the use of high efficiency motors. These motors are acceptable in single-motor applications; however, they have all the wrong characteristics for multiple-motor conveyor drives. High-efficiency motors have low-impedance rotors that operate at low slip, load share poorly, draw high locked-rotor currents, and have poor torque constants. The term “high efficiency” can be a misnomer because, in some applications, the power consumed by a high-efficiency motor exceeds that of a standard efficiency motor.

The torque-speed characteristics of two motors recommended for conveyor applications are shown below. The Toshiba motor has a 447TZ frame and a rated speed of 1770-rpm. It has a locked-rotor torque = 243% FLT at 607% FLA, a breakdown torque = 235% FLT, and a pull-up torque = 167% FLT. It can deliver 100% FLT with only 425% FLA at the saddle in its torquespeed curve. It is marked as a design B for marketing reasons, but it is actually a design C:



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The Westinghouse motor has a 449T frame and a rated speed of 1769 rpm. It has a locked-motor torque = 259% FLT at 653% FLA, a breakdown torque = 204% FLT, and a pull-up torque = 233% FLT. It can deliver 100% FLT with only 320% FLA at 60% speed. This is a design-C motor with ideal characteristics for a conveyor: