Variable Frequency Drives for a Vacuum Pump System

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Editor's Note: Responding to requests from readers many of whom work with vacuum pumping systems Pumps and Systems is introducing this new column with the January issue. Look for it periodically.

In many process plant applications, using a Variable Frequency Drive (VFD) to control the capacity of a liquid ring vacuum pump (LRVP) is an innovation. Previous system designs consisted of sizing the LRVP to operate efficiently for a certain portion of the process cycle and then using a recycle control valve system to maintain the desired LRVP suction pressure. This usually meant a loss of system efficiency for most of the operation cycle.

A liquid ring pump can be used in vessel evacuation or batch processes where the load volume is high at startup and diminishes as the vessel is emptied and the subsequent vacuum level increases. At the end of the cycle the usual intent is to hold as high a vacuum level as possible for a given period of time. This high vacuum level is a function of the properties of the service liquid, which boils or vaporizes as specific conditions exist. The liquid ring pump handles the least amount of net capacity at this high vacuum. The majority of the capacity at this point is the vaporized service liquid. The LRVP operating at full load rpm is oversized for the vacuum end point. By slowing down the pump, the operator can maintain the desired vacuum, but pumping capacity is decreased, lowering the brake horsepower.

An additional feature is that the drive could be set up to operate at a speed that stays within the horsepower rating of the motor and automatically adjusts as the LRVP power demand decreases.

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A given frame size pump has a predetermined impeller tip speed range that would be programmed into operational parameters in the control room. The impeller tip speed is a function of the impeller diameter. (The tip speed or tangential velocity is the rate of the outer tip of the impeller.) The pump would then run in this tip speed range while staying below the maximum horsepower rating of the motor. At the holding point, the pump is slowed to the minimum speed low enough to hold the desired vacuum. This saves power and wear on the pump. Current system design usually includes a provision for over-capacity at the holding point. The device may be a vacuum relief valve or recycle valve system. This design approach can waste energy. An energy audit of a particular facility may be required to determine the feasibility of installing VFD's on the current LRVP system. The system design engineers should take a serious look at incorporating this approach in future design specifications.

Useful LRVP Calculations (approx. relationships):

$rpm_1/rpm_2 = (hp_1/hp_2)^2$

$Capacity_1 / Capacity_2 = rpm_1/rpm_2$

As an example, the capacity of a 25 horsepower LRVP can be adjusted while operating from about 1000 rpm up to 1750 rpm. This represents an impeller tip speed range of 40 to 70 ft/sec. At 1750 rpm and at atmospheric suction pressure, the capacity of this pump is approximately 300 Actual Cubic Feet per Minute (ACFM). Depending on user specific conditions, the brake horsepower (BHP) may exceed 25 briefly during an evacuation cycle.

The motor rpm can be reduced to keep the brake horsepower below 25 during this period. When the system is totally evacuated and the vacuum level is at its maximum, the pump is then slowed to a speed at which it operates adequately and does not cavitate. A word of caution - there is a minimum impeller tip speed which is a function of the pump's compression ratio or vacuum level. If the pump speed is reduced below this minimum impeller speed, the liquid ring will collapse, causing system instability or "upset."

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The minimum impeller speed can be determined to be the noncondensable load quantity (which sets the pump suction pressure) as a function of the compression ratio desired. More energy is required in the liquid ring to achieve a high vacuum than a low vacuum, so as the compression ratio increases, the pump must rotate faster than it does at lower compression ratios. On the other hand, at low vacuum levels it is beneficial to maintain as high an impeller speed as possible in order to maximize the pump's ACFM capacity.

Figure 1 illustrates a typical 50 horsepower LRVP operating at a