Variable Speed Drive Applications

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From early industrial development variable speeds have proved extremely useful to the metal working, web process, mixing and blending, textile and plastics industries. In approximately a year and one half of contact with the production branch of the oil industry and with the avowed purpose of selling the electric motor for your many applications of prime movers, I have enjoyed considering with my prospects utilization of standard industrial devices to provide variable speed from electric motors.

These calls have disclosed many pulleys, sheaves and belts in your warehouses, your riggers' field houses and your water flood central station housings. Evidently pumping speed changes both in oil production and flooding fluid handling systems are often required. May we look to the approaches that other industries have taken to meet changing speed requirements?

Today's process industries are as taken with the word "automation" as the machine tool industries and automotive industries have been since very early. Variable speed drives were originally developed to allow operator selection of speed without a belt movement or other shift or disengagement from a line shaft. This line shaft delivered power at a fixed ratio from a water wheel, steam engine, or other single prime mover source of power for the entire plant. Today on high production cutting and grinding equipment, feed rates are continuously changed to insure best tool life as well as improved quality and appearance of the machining operation. Packaged variable speed drives allow this production advantage.

In the automotive trades the conveyor assembly line, initiated by Henry Ford, has been improved until their present day equivalents require sophisticated main and feeder conveyor drives. These special synchronized and variable drives insure fine red wheels on a red car rather than paint and brush at the completion area to insure continuous production of items that end up unique from their adjacent production units.

These devices, originated by necessity in other fields, have been refined by years of redesign and improvement. They are available to the petroleum equipment designer whose project economics can be improved by electric motors with companion adjustable speed drives.

Where might these devices be employed to advantage? Initially let us discuss the pumping unit. The manufacturers provide variation of stroke length both by fulcrum movement and adjustment of radius of the crank arm. A gear reducer normally provides a reduction of 30:1 from the input shaft which may be either chain or gear. The high slip 1200 RPM three-phase electric motor is at present most often used on the electrified lease. To provide say 20 SPM, the motor would mount a 7-1/2 in. P D pulley on the motor and a 14 in. P D sheave on the pumping unit input shaft providing 600 RPM on the input shaft.

Most wells today are initially completed on either a single gas engine or a single electric motor. It is suggested that many of those completed with the electric motor might prove to be benefited by a variable speed element easily adjusted by the single operator or "pumper".

By having the speed adjustment convenient, more modifications could be made to obtain optimum pumping rates. If the down hole rate of fluid entry is found to vary on a pumping unit, it would be easy to determine if increased production could be obtained by increased pumping rates. A slower rate may provide a rate of pump off better suited to rate of entry; and slower rates may provide increased life of down hole equipment, yet not sacrifice allowable production since both length of pumping by the time clock and the number of strokes would be readily adjustable.

How would the wells that may benefit from the variable speed addition be spotted? It is suggested that for an individual field a specific number of sheave changes could be equated to the cost of the variable speed equipment capitalization. Any well requiring a sheave change to one less than that found to be the cost equalization point would have the variable system installed. Further adjustments on this "difficult" well could then be performed by the pumper himself.

Once the variable speed equipment was installed -- at time of monthly well test -- the pump could be tested easily at multiple pumping rates. To illustrate, the supervising engineer may now require this "difficult" well to be tested at ten per cent slower than the rate pumped during the previous period, at the same rate as the previous period, and at a rate ten per cent faster than the previous period. These changes could be made by a hand wheel setting. Then this information could easily be transmitted to the responsible engineer for review. He then could make the decision of best rate for the new pumping period based on better data.

It is believed that this test could be made at ten per cent slower and faster rates without counter balance compensation or load correction for this test purpose. If the data suggests a permanent change to the different speed, then counter balance and power factor correction devices may require adjustment when speed is set to the rate determined to be best.

In addition to the well whose history indicates it to have been troublesome, the newly completed well may benefit from variable speed equipment. The variable speed device might be employed three or four months to positively determine the best rate of fluid production before being replaced by the correct motor, belts and pulleys. The initial equipment would then be moved to the next completion to allow actual pumping rate and the load of the new well to be measured.

The final specific application where variable speed units on pumping may be useful would be the production unit on a five-spot water flood test. It is likely that this unit, under constant attention of the reservoir engineer, might provide him with additional useful information by having an easy modification of pumping rate whenever special tests are desired.

Just what are these devices that have been discussed? There are many on the market. The least expensive would be a variable pitch pulley adjustable while the unit is stopped, and with motor base adjusted to correct belt tightness and perhaps a belt change if there is insufficient take up in the adjustable base on which the motor is mounted. Some of these pulleys are single grooved and some multi-grooved. Speed variation is limited to a ratio of about 1.5 to 1.

The adjustable motor pulley available from several manufacturers is the basic component of a unit considered very suitable for the applications discussed.

The mounted variable speed pulley consists of two smooth-faced cone shaped discs, one mounted in fixed position on the motor shaft (some manufacturers allow both to move), the other designed to slide laterally on the hub of the fixed disc and a belt tension spring. For correct belt tension at all output speeds the belt tension spring automatically maintains pressure on the sliding disc. In addition to the pulley an adjustable motor base, allowing speed adjustment by a control shifting screw with handwheel, is required. A flat face pulley is mounted on the input shaft to the pumping unit to allow movement of the belt as it changes its axial position because of the angle of the disc. The final component of the drive is the belt, a "C" type belt of trapezoidal cross section.

With these four units, adjustable speed ranges of two to one and sometimes greater ratios may be obtained through 15 hp. A rating which is, however, an 8 hr rating. Similar to the gear reducer portion of the pumping unit and to the belts normally employed, service factors should be employed with the pulley and belt of the variable speed package. A service factor of 1.3 for time clock duty units and 1.5 for continuous pumping applications using the oil field pumping high slip motor is suggested.

Suppose a producing unit which has proven difficult to adjust to an optimum pumping rate shows a ten per cent over current being drawn on its existing 1200 RPM 5 hp oil well pumping motor which is now pumping at 16 SPM. Its pumping unit has a 30:1 reducer.

To provide a sufficient adjustment range, it is suggested allowing for pumping rates up to 20 SPM down to 10 SPM infinitely adjustable between these ranges. Considering the pumping load as constant torque, the hp required is calculated at 20 SPM. The unit will be pumped approximately ten days or 1/3 of a month.

$$\frac{5.5}{16} = \frac{x}{20}$$

$$x = 1.25 \times 5.5 = 6.875 \text{ hp}$$

Service factoring for motor pulley and belt provides:

$$6.875 \times 1.3 = 8.9375 \text{ hp}$$

The recommendation using Reeves nomenclature, would be:

One 7-1/2 hp, 1200 RPM, oil field pumping motor
Motor cost approximately $189.00

One adjustable base

One 10 hp motor pulley Package cost approximately $200.00

One 22 in. Flat faced pulley

One Belt 102 P D

This will provide 19.5 SPM down to 9.75 SPM with 5.5 hp available at 16 strokes and 7-1/2 - 8 available at 19.5 SPM. Center to center distance from reducer shaft to motor shaft will vary from 23.6 to 27.5 in.

Above 10 to 15 hp a more rigid support of the variable pulley system is normally required. For applications above 10 hp at 1200 RPM or 15 hp at 1800 at the input speed the packaged variable speed unit is known as Moto drive, Vari-speed, etc. manufactured by U. S. Motors, Reeves, Allis-Chalmers, Sterling, General Electric, to mention a few. This device is manufactured through 75 hp. Two variable pitch diameter pulleys made up of four discs with provision by a spring for constant belt tension are rigidly supported by a case that also mounts the drive motor. Provision by most of the manufacturers is made to allow integral gear reduction units if desired for optional low output speeds. While the drive is running a hand wheel adjusts the pitch diameter to desired range. Wide speed ranges are available, however, for the application of oil well pumping a two - one range is considered adequate.

A 30 hp unit equipped with a high slip 1200 RPM oil field duty input motor providing a 1120 to 560 RPM output would cost approximately $2,585 net, including motor.

Another new device -- now available in the 40, 50, 60, 75 hp area -- features three sheaves in contact with a varying radii of a central disc. There are multiple stages of these sheaves and discs, and all contacting surfaces are oil lubricated. This all metal drive takes its design from a German patent, and costs is not entirely known at this time. However, it is expected to be competative with other mechanical variable speed units of its torque ratings.

The Electrodynamic, Dynamatic and Adjusta-Speed electric variable flux clutches are applicable to drives in these horsepower ranges and above. Adjustment is gained by varying the flux linkage between the output and input (constant speed member). Air expanded friction clutches adjusted by regulated air or gas pressure may find application here and are mentioned as available to the system designer today with very improved friction face materials.

Numerous other variable speed devices are manufactured and an extensive amount of space could be devoted to their interesting operating features and unique principles. However, of importance is another area of possible application of the electric-driven variable-speed drive.

In surface water flood installations appear several potential applications that may provide economic justification for variable speed. The advantage sought is to allow adjustment of flow rates without by-passing fluid through adjustment of pumping speed. Potential savings would be realized by reduced power costs when maximum pumping speed is not required. Providing for convenient variation of speed and thus flow rate, no operator inconvenience is involved to adjust flows to the optimum required as often as justified.

Let us consider a five-spot flood test as our first potential application. It is suggested that total overall test cost might be reduced by using four skid mounted piston type injection pumps, each located in close proximity to its injection well. If the field has been previously electrified, the existing wire and poles may be able to be utilized during the test's life, and the investment in permanent injection plant is likewise deferred until test results are known. By increasing the horsepower rating by 1/3 on the pumps so mounted and by equipping with variable speed electric drives, additional tests of the individual wells injection rate can be easily checked both above and below design point. On the test, only source water lines at suction pressure would be required. If one of the wells is determined to be unable to take the water at the design rate, it is easily adjusted by speed modification and achieves immediate power savings. The skidded units offer a very flexible package for the purpose of the test and can easily be employed beyond their initial test application on similar test installations.

An individual skidded variable speed injection unit could also be used on a single injection well of a field serviced by a central plant. This one injection well might prove difficult to operate at or near the pressure requirements of the remainder of the injection wells. A variable speed unit applied to this "difficult" well would allow its individual rate and adjustment independent in all respects from the balance of the field. This may provide an advantageous method to use to add on an additional injection well when plant capacity is in danger of being exceeded when the decision to flood this well was made. It leaves this additional injection well free for additional adjustment during initial and subsequent operation.

In an injection plant originally designed with three pumps it may be advantageous to have one of the pumps with a variable speed drive. This one unit, if all are deliverying into a manifold system, could be used to adjust minor changes of say 10 to 15 per cent total fluid without by-passing, attempting to pay out through power saving. Handwheel adjustment to maintain read flow meter readings constant is anticipated. However, a continuous feed back loop using compressed air or gas as the operator can be designed to close the loop and insure constant flow rate through continuous speed changes initiated by a controller. Many automated systems of this nature are employed in chemical plants and refineries, and the application know how is available to the injection system designer.

Variable speed drives connected to pumps can, with proper instrumentation, provide liquid level control to close tolerance through use of bubbler tubes into the fluid tank or container. But if air or gas bubbling into the fluid would prove undesirable, a wide range of capacitor reading electrostatic devices can be used to sense liquid level, to provide a feed back signal and to be utilized to change pumping speeds to hold liquid level within limits. This may prove useful to production personnel on disposal or chemical additive injection systems.

Employment of a variable speed device on one pump of a multiple injection system may be desirable where commingling is found to be unadvisable. Initial flooding would perhaps start with two 50 hp AC induction motors driving two pumps on source water. A 30 hp pump driven by a variable-speed drive would be provided to pump produced water as soon as insufficient rate of return to supply one injection well is reached and would gradually be increased in speed and delivery until top speed was reached. At this time one of the existing 50 hp units would be transferred to this duty, while the variable-speed equipped unit would assist the other 50 hp unit on source water production. Then when the unit now on produced water comes up to capacity, the 30 hp variable-speed unit would be transferred back to assist it. Again when produced water is absorbing 80 hp worth of pumping equipment, the second 50 hp unit would be placed on produced water service and the variable unit would now be utilized to provide source water at system pressure only as required by changing availability of produced water. Perhaps one or two wells with provision for switching additional wells would be maintained on source water. Savings of power by varying speed rather than by passing fluids brought to system pressure must be evaluated to determine payout of the increased equipment.

There has been some discussion with system designers concerning the desired change in speed while backwashing filters. The total differential in speed desired and degree of automation desired must be evaluated to determine if the variable speed package will be more economical than would be a separate pump and motor specifically rated for the higher flow rate. This potential application will require additional investigation as do all the others. Application or engineering of the system must allow the system to function at the lowest operating and installed cost for its utilization period. It is felt the flood fluid handling systems may be served by variable speed, but the designer must determine the individual units economics.

In review, when one picks up the "T" square and triangles of the equipment engineer to design his surface pumping drives, he should consider the variable speed electric-drive as an additional tool capable of being employed. Initial decisions concerning gas, diesel or electric prime movers; continuous run or time clock; accessibility to servicing; and nature of nearby production come first and are uppermost. It is hoped, however, that this discussion of variable speed drives will provide the basis for potential producing cost savings through better knowledge of their employment.