A DYNAMIC NEW CONCEPT IN BEAM PUMPING - ADJUSTABLE SPEED PUMPING

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Abstract

Many of the new concepts and equipment used in the petroleum industry today were developed and have been used for many years in industrial applications. This discussion will cover a prime mover used for over 50 years in industrial applications that has just recently been introduced to the oil industry. The Adjustable Speed Drive (ASD) system allows control over output speed and torque.

There are many advantages to adjustable speed pumping: 1) Soft start, 2) Speed control, 3) Torque control, 4) Intra-stroke speed change, 5) Pump-off interface. The ASD system has allowed a new concept in beam pumping to evolve. With the ASD system being relatively new to the oil industry, the broad spectrum of applications that can benefit for varying pumping speed has yet to be realized.

Introduction

Most prime movers powering beam pumping units today are one of three types; Gas Engines, Nema "D" motors, or Ultra-High Slip motors. With the new technology available in the oil field, new alternatives are emerging. This new prime mover that gives control over output speed and torque makes available an entirely new concept in the way wells are produced.

> Change strokes per minute with the turn of a dial - Run the downstroke significantly slower than the upstroke - Ease the entire pumping system into production at start-up.

These are just a few of the ways the Adjustable Speed Drive (ASD) system has allowed this new concept of variable speed beam pumping to begin to develop.

Adjustable Speed Drive System

The ASD system (Figure 1) is an integral combination of a Nema B motor, magnetic torque transmitter and solid state closed loop control system. The eddy current principle along with the closed loop control system is used to transmit and control power from the Nema B motor to the load. The drive input members have no physical contact between each other with the exception of the center support bearing. The drive couples the motor to the load through a magnetic field. Since the motor is not stopped or started each time the load is stopped or started, the motor and starter life is prolonged. This also permits the motor to be started under a no-load condition.[1]

The ASD incorporates several design features which makes it well suited for use in the oil field. Heavy duty bearings are used to handle the overhung loads that are seen in beam pumping. In addition, the torque transmitter has been sized to handle no less than 85% of the breakdown torque of the Nema B motor used.

The closed loop system (Figure 2) is comprised of two parts; the controlling and the controlled systems. The controlling system is a solid state oil pump control and the controlled system is the Adjustable Speed Drive. In the closed loop system, the output is measured, fed back and compared to the command input. Whenever the feedback signal differs from the command, an error is generated. This resulting error is used to increase or decrease the output until it is equal to the input command.

The speed input signal is adjustable and set by turning the run speed dial for desired output speed. The feedback signal is obtained from the tachometer generator driven from the output shaft of the drive. The torque limit pot provides an "override" feedback signal which indirectly limits the amount of motor torque transmitted to a preset maximum valve. The input is a motor current feedback signal from a current transformer positioned on one of the motor lead wires. Also included is a stall detection circuit that monitors the speed feedback signal and stops the drive if the operating speed drops below a preset stall speed for a given period of time.[2]

Soft Start

When power is applied to the ASD system the Nema B motor starts, however, the torque transmitter is not engaged until it receives the start signal for the ASD control. This means the motor starts in an unloaded condition which results in less inrush current (starting amps) for a reduction in starting KVA requirements.

Also, starting the motor under no-load allows the use of the Nema B motor in lieu of a Nema D, which has a high starting torque. Figure 3 shows typical speed torque curves for a Nema B and D motor. The Nema B design has a lower starting (locked rotor) torque. However, the ASD control first starts the motor at no load and brings it up to synchronous speed. Only then does the control engage the drive to the motor. The motor now can supply torque up to the higher Nema B breakdown torque for starting. Therefore, the ASD uses only the torque required up to the breakdown torque of the motor at start-up. Other motors will start the pumping equipment at locked rotor torque. This can create unnecessary stress on the pumping system.

Another feature of the soft start is a linear acceleration circuit. The circuit is adjustable from a nominal 3 to 90 seconds. When the drive is engaged, it will accelerate from zero to full speed following a linear ramp. This allows the entire pumping system to ease into operation and elevates any undue stress a conventional motor causes during start-up. For units that are on POC's or time clock, this means increased life of all the pumping system.

As an example, a conventional 150 H.P. motor using 10 D section belts for start-up operation was replaced with a 125 H.P. ASD system which required only 5 D section belts for start-up and operation of a Mark 1280 pumping unit.

Speed Control

The ASD system can be used to change the strokes per minute of the pumping equipment by simply turning the speed dial. This eliminates the need to change sheaves and allows the required strokes per minute to be achieved. In the ASD closed loop control system, the velocity feedback signal from the tachometer generator causes the controller to regulate and maintain the precise speed desired.[3] The ASD control also has pot adjustments which regulate both maximum and minimum speeds should the application call for either during the stroke.

In Case Study 1, there are two interesting factors shown regarding speed control. First, notice how close the SPM for each test was run. The speed was held within 0.6% for the first 3 ASD tests without changing sheaves. Second, the final ASD test was run in straight speed control. Note the increase in the efficiency of the surface equipment, up to 78.8%, which is a 19% increase over the test with the Ultra High Slip motor and an increase in overall efficiency of 8.5%.

Torque Control

In many applications it is beneficial to limit the torque applied to the pumping system. In straight torque control, the ASD system slows down during the peak loading periods of the upstroke and downstroke, which means a reduction in peak polished rod load and increased minimum polished rod load. This translates into lower gearbox torque and rod loads. In essence, it operates similar to an Ultra High Slip (UHS) motor except that in the ASD system the motor has approximately 2% slip and the speed variation comes from the slip in the drive.[4] Unlike an UHS motor, the slip in the ASD system is adjustable.

As indicated in Case Study 1, the ASD operates almost identically to the UHS motor. Note in Case Study 2 the reductions in loads over the conventional Nema D. It shows a 9% reduction in peak polished rod load with nearly a 22% increase in minimum polished rod load and a 21.4% decrease in peak gearbox torque while producing slightly more fluid.

The ability to limit the torque output of the drive allows the ASD to be adjusted to ensure the gearbox rating of the pumping unit is not exceeded. Another way torque limit can be used is reduce peak amps and smooth out the peaks and valleys of amps incurred with the cyclic load of beam pumping (Figure 4). This translates to lower KVA requirements which means reduced lifting cost.

Intra-Stroke Speed Change

The ASD dual speed system allows the upstroke and downstroke speeds to be set up independently. The dual speed control has two speed dials, one for each half of the stroke and are actuated by two position indicators. These position indicators are connected to a flip-flop circuit so that a signal from either indicator selects the corresponding speed dial and remains selected until the opposite signal is received. By controlling the speed of the upstroke and downstroke separately allows the beam pumping system to be operated in ways that were not available in the past.

1) Rod Fall - Slow downstroke (lets the rods fall without floating) with a fast upstroke to produce more fluid.

2) Gas Interference - Smoother fluid passage through the traveling valve with a slow downstroke.

3) Fluid Pound - Less shock load on equipment by easing the plunger through incomplete pump fillage with a slow downstroke.

4) Increase Plunger Travel - More production per stroke with a fast downstroke.

In Case Study 1, tests 2 and 3 were run using independent speed control. Test number 2 was run with a slow downstroke yet maintaining the same overall SPM and the overall efficiency of the system increased 9.2% over the base case. Test number 3 was run with a fast downstroke still maintaining the same overall SPM, which resulted in the downhole plunger travel increasing by 14.1% over the base case and overall efficiency increasing by 7.6%.

Pump-off Control Interface

Interfacing the ASD with a a pump-off controller should allow a well to be produced at its maximum capacity. This is almost an impossibility with a conventional prime mover, especially when producing in a secondary recovery field where reservoir pressures are in a constant state of change.

Allowing the pumping speed to be adjusted to match the well's productivity and keep the well pumping continuously should result in an increase in production. This increase in production would come from producing the oil that would be lost by time clocking or pump-off controlling. The amount of lost oil produced by pumping continuously will vary depending upon existing well conditions.[5]

CONCLUSION

The ability of an ASD to control speed and torque output makes it a viable alternative to conventional prime movers. Beam pumping applications requiring precise SPM or changing SPM during the stroke can benefit by using an ASD. Application where torque and equipment loads are critical, adjustable speed pumping can also be beneficial. Since the ASD has just been introduced to the oil industry, the broad spectrum of applications that can benefit from varying pumping speed has yet to be realized. Variable speed pumping deserves consideration when selecting the appropriate prime mover for an application.

References

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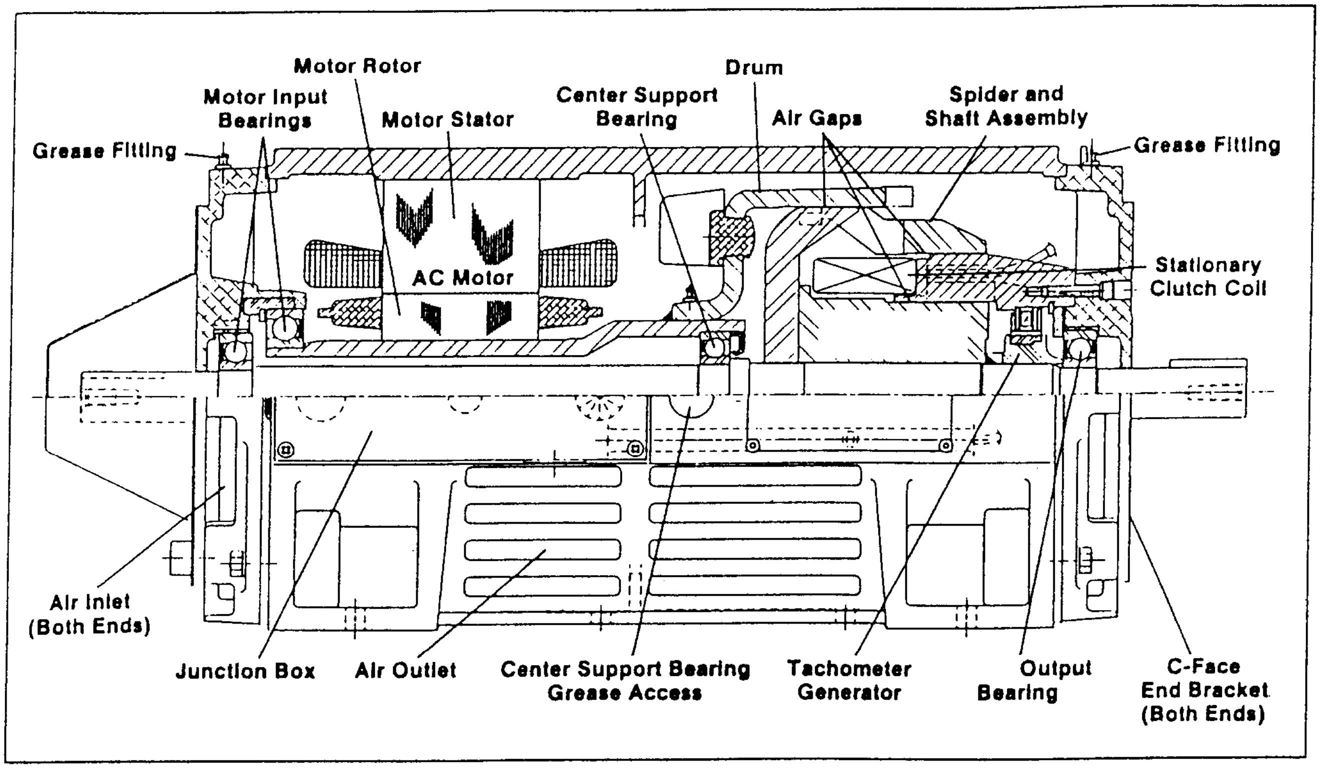

Figure 1

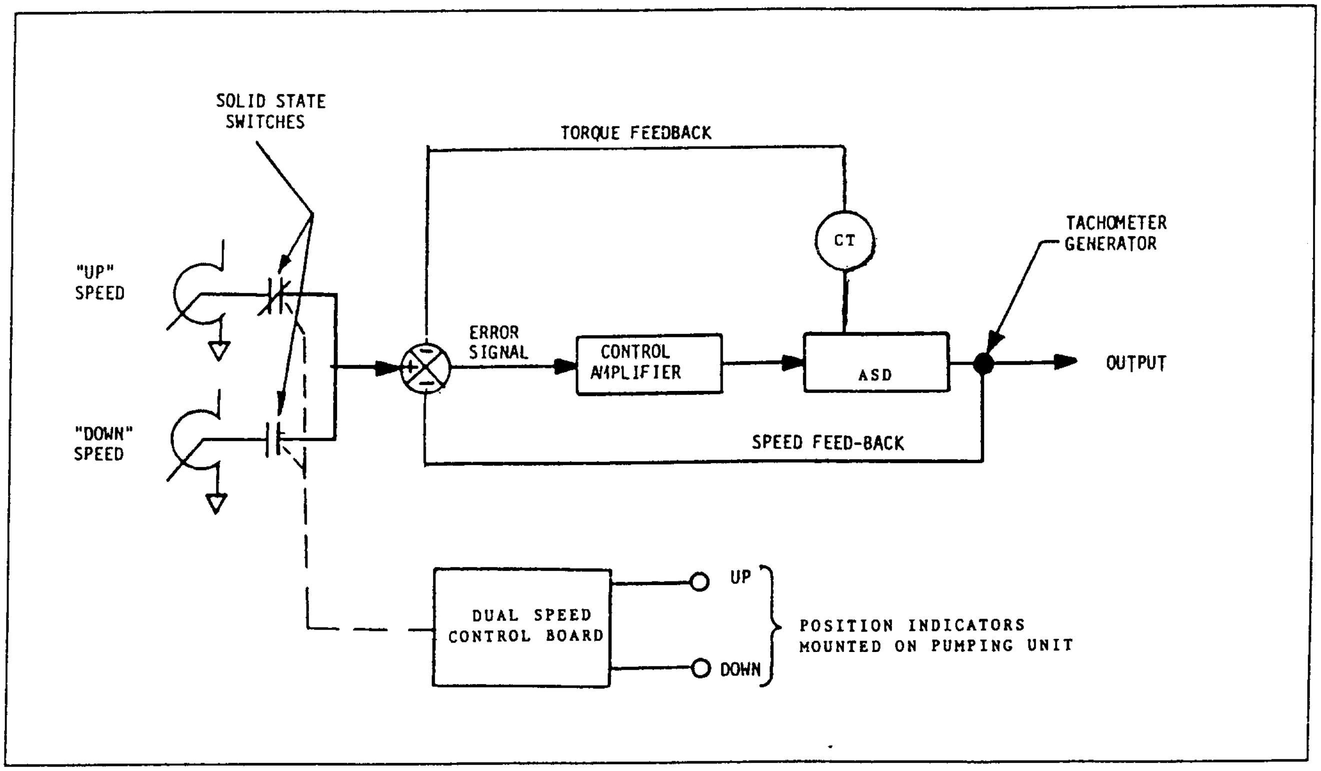

Figure 2

TYPICAL SPEED/TORQUE CURVES

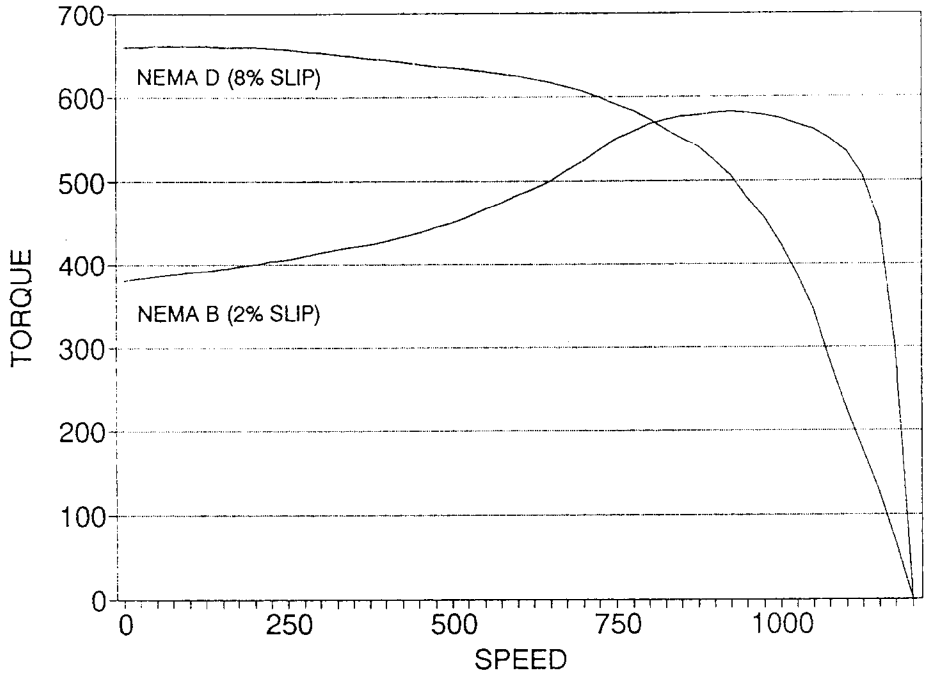

Figure 3

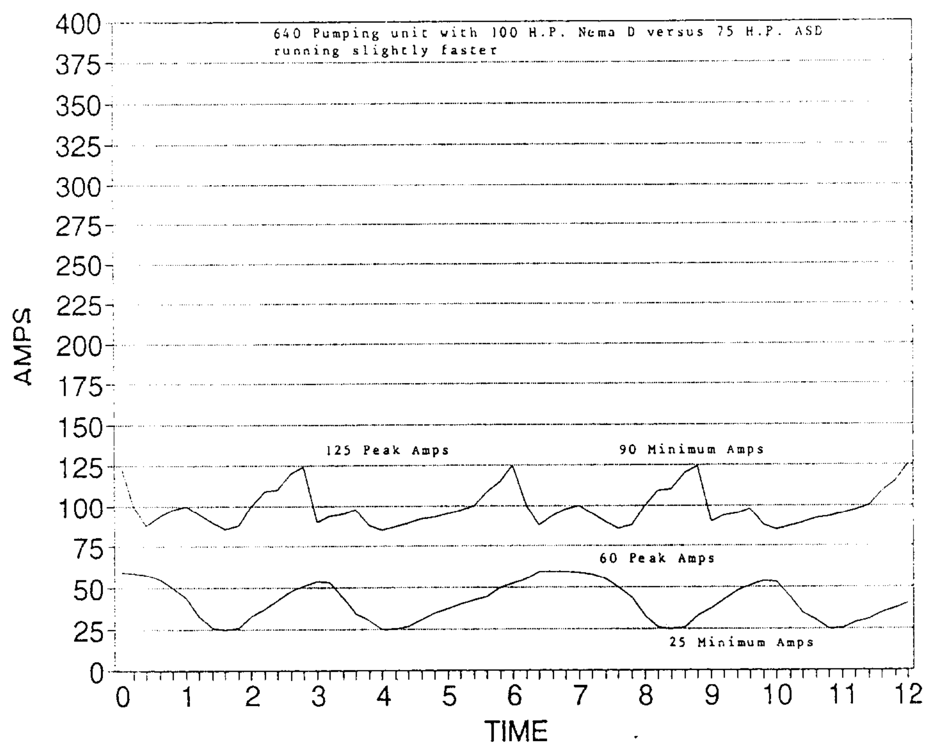

Figure 4

CASE STUDY NO. 1

Pumping Unit: C640-365-144
Pump Size: 2"
Depth: 6400'

Fluid Level: 6000'
Stroke Length: 123
Rods: Fiberglass w/Sinker Bars

Prime Movers:
Ultra High Slip Size C Medium Mode
Replaced with 50 H.P. Adjustable Speed Drive (ASD)

	BASE CASE UHS	TEST 1 ASD	TEST 2 ASD FU & SD	TEST 3 ASD SU & FD	TEST 4 ASD
SPM	8.35	8.30	8.34	8.38	9.66
PPRL #'s	26812	26791	26871	27242	27918
MPRL #'s	8459	9045	8488	8674	7215
Torque 1000 "/#'s	350.7	351	404	410	472
Net Pump Stroke/"	95.6	100.3	106.8	111.3	111.3
Gross BFPD	372	388	415	434.6	501
FG Rod Load Range @ Surface	18153	17546	18182	18368	20503
Mo. Power Cost @ .04/kw	946	814	835	922	1039
$/BFL	.085	.070	.067	.070	.069
Min SPM	6.99	6.60	6.26	6.76	9.38
Max SPM	10.21	9.62	9.76	10.08	10.21
% Speed Variation	32.5	31.4	35.8	33.0	7.0
Surf.Eqmt. Eff %	59.8	68.6	69.8	66.4	78.8
Overall Eff %	34.8	42.1	44.0	42.4	43.3

Note:

F = Fast
S = Slow
D = Downstroke
U = Upstroke

CASE STUDY NO. 2

Pumping Unit:	Mark 640-305-168	Fluid Level:	6999'
Pump Size:	1.5"	Stroke Length:	168
Depth:	6999'	Rods:	86 String

Well is on time clock running 73% of the time. Pump is set in the horizontal.

Prime Mover:
60 H.P. 1200 RPM Nema D
Replaced with 40 H.P. 1800 RPM Adjustable Speed Drive (ASD)

	NEMA D	ASD	% CHANGE
SPM	6.4	6.4	Same
PPRL #'s	17480	15905	9% Decrease
MPRL #'s	8757	11193	21.7% Increase
Peak G.T. "/#'s	60400	475000	21.4% Decrease
Loading Top Rod:			
Max Stress	22129	20124	9% Decrease
Min Stress	11277	14379	21.6% Increase
Stress Loading	61%	47%	14% Decrease
Gross Pump Displacement	192 BFD	195 BFD	1.5% Increase
KWHDay	281	210	25.3% Decrease