OPTIMIZED PUMPING WITH ULTRA-HIGH-SLIP MOTORS

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Introduction

Since the electrification of oil fields, electric motors have been used to rotate the beam pumping system to produce oil. Not until the Ultra-High-Slip motor was there any electric motor designed specifically for the cyclic load of the beam pumping system. By merely viewing the operation of the beam pumping system, it initially appears to be a relatively simple system to operate. However, upon analyzing the system, complex and critical loads are developed within the rod string and gear box of the beam pumping system. By optimizing operating ideas using the Ultra-High-Slip motor, these loads can be minimized to provide a more efficient pumping system.

Newton's 3rd law of motion states that for every action there is an equal but opposite reaction. Within the beam pumping system it is extremely difficult to pinpoint the equal but opposite reaction, but it does occur. The magnitude may be substantial but camouflaged within vibration, friction and motion of the system.

One should not discuss, analyze or change any one portion of a beam pumping system without considering the effects on the remaining system. When an engineering evaluation is performed on a beam pumping system using an electric prime mover, the motor is often evaluated upon its single point efficiency and not on the system efficiency or system performance. Many reports and evaluations are performed on electric motors assuming a constant load or a steady state condition. Under these parameters, the electric motors will perform differently and therefore difficult to correlate to a cyclic loading condition.

The benefits that can be realized from the use of the Ultra-High-Slip motor are:

Mechanical Benefits

Lower Gear Box Torque
Lower Rod Load Range
Increased Net Pump Stroke
Increased System Efficiency

Electric Benefits

Minimize Kilowatt Consumption
Lower KVA
Higher Power Factor

There are five misconceptions about the Ultra-High-Slip motor when applied to a beam pumping system which will be addressed and are as follows:

1) The motor must be loaded (90-100%) to minimize Kilowatt consumption.
2) High slip means lower efficiency.
3) Less speed variation will minimize Kilowatt consumption.
4) Mechanical and electrical benefits do not apply to Mark II pumping units.
5) Only purchase the Ultra-High-Slip motor for mechanical benefits -- not electrical.

Many of the benefits of the Ultra-High-Slip motor can be realized by its installation under the exact same conditions as that of the Nema D motor. However, to maximize the system efficiency and minimize operating cost, some changes may be required to optimize the Ultra-High-Slip system. The amount of effort required to optimize your installation will depend upon the particular well. In this paper, we will be discussing three well tests. All of them were conducted in 1985, Andrews County, Texas, for two different operators and on three different wells.

<u>Effects of Sheave Changes</u>

Andrews County Well #6 was being operated with a Nema D motor on a conventional 456 pumping unit. Three tests were performed to determine the performance of the system when sheave changes were made to optimize the system. A 24 hour running time was required after any changes to the system. Test #1 was run using the existing system and Test #2 was run with the Ultra-High-Slip motor (see Figure 1). The motor sheave was the only variable changed between Test #1 and Test #2, and was done to maintain the same pumping S.P.M. The mechanical loading differences realized from the Ultra-High-Slip motor were a 3% reduction in gear box torque, 28% increase in production and a 2% increase in rod load range. The electrical consumption was reduced 1%.

In Test #3, the motor and pumping unit sheaves were changed from the original 44" pumping unit and 9" motor sheave to a 36" pumping unit and 8.5" motor sheave. After a 24 hour stabilization time, test data showed an additional gear box torque reduction of 20% was achieved, with production remaining the same and an 11% reduction in the rod load range. The electrical consumption was also reduced from .484 KW/BBL/1000' lift to .408 KW/BBL/1000' net lift -- a 16% reduction in kilowatt consumption. When the Ultra-High-Slip motor was installed on the conventional API unit under original operating conditions, both mechanical and electrical loadings were reduced; however, when efforts were made to optimize the system, additional benefits were realized.

<u>MARK II Pumping Units</u>

Two wells equipped with Mark II pumping units were selected and tested to determine the results when used with the Ultra-High-Slip motor. Andrews County Well #31 was equipped with a Mark II 640 pumping unit and a 60 H.P. Nema D motor. When the Ultra-High-Slip motor was installed, the gear box torque was reduced from 610,000 in-lbs torque to 501,000 in-lbs of torque for an 18% reduction in gear box torque. The rod load range was reduced 10%, production increased 21% and the kilowatt consumption was reduced 5%.

Andrews County Well #39 was also equipped with a Mark II 640 pumping unit and a 60 H.P. Nema D motor. The pumping speed was increased 13% because of the sheave and speed variation combination. The result was an 8% increase in gear box torque, an increase of 7% in rod load range and an increase in production by 11%. The kilowatt consumption was reduced from .390 KW/BBL/1000' net lift to .330 KW/BBL/1000' net lift -- a 15% decrease in kilowatt consumption. Figure 2 shows these results and all pertinent well data.

Motor Loading and Speed Variation

Motor loading is defined as:

$$\frac{\text{Actual Thermal Amps}}{\text{Rated Thermal Amps}} \times 100 = \%\ \text{Loading}$$

Speed variation is defined as:

$$\frac{\text{Maximum Motor RPM} - \text{Minimum Motor RPM}}{\text{Maximum Motor RPM}} \times 100 = \text{Speed Variation}$$

All three Andrews County wells are shown in Figure 3. Andrews County #31 shows that the Ultra-High-Slip had a lower KW/BBL/1000' net lift than the Nema D. The Nema D motor was 87% loaded, whereas the Ultra-High-Slip motor was only 80% loaded and had a 24% speed variation.

The Andrews County Well #39 equipped with the Ultra-High-Slip motor was loaded 75% as compared to the Nema D motors 65% loading. The Ultra-High-Slip motor had a 10% lower KW/BBL/1000' net lift.

Andrews County #6 shows that even with the Ultra-High-Slip motor only being 72% loaded with 29% speed variation, its KW/BBL/1000' net lift was 16% lower than that of the Nema D motor which was 79% loaded. The speed variation, which can approach 35-40% in some cases, not only improves the mechanical loading on the pumping system, but does not necessarily result in an automatic increase in kilowatt consumption. The kilowatt reduction is a result of improved system efficiency.

Mechanical and Electrical Benefits

For a good many years, the mechanical benefits of Ultra-High-Slip motors have been stressed because of the high cost of steel and the shortage of equipment. Now with increased electrical costs, emphasis has shifted and some in the industry feel that the mechanical benefits are outweighed by electrical costs.

To minimize the overall operating cost, both mechanical and electrical benefits must be constantly monitored. The electric cost is an ongoing monthly well cost, whereas the pulling and equipment cost is only seen every 12, 18, 24 or 36 months depending upon the well; but the old adage still applies: "You can pay me now or pay me later." -- Meaning that if you neglect mechanical benefits, sooner or later you pay for them.

The following example shows the importance of both mechanical and electrical benefits. In the case of Andrews County #6, the electrical savings over a three year period would have been $1,441.44 at a cost of .06$/K.W. If the reduced rod load range on the sucker rods would extend the life of the sucker rods just 3.5 months, then the mechanical benefits would equal the electrical benefits (see Figure 4).

The best operating practice would be to maximize the mechanical and electrical benefits, thereby optimizing the system efficiency of the beam pumping system.

Well Data

	NEMA D 50 H.P.	ECONO-PAC EPII-4-LT	ECONO-PAC EPII-4-LT
Pumping Unit	456 Conventional	456 Conventional	456 Conventional
Unit Sheave, in.	44	44	36
Motor Sheave, in.	9	10.5	8.5
API Rod Design	86	86	86
Pump Diameter, in.	1.5	1.5	1.5
Well Depth, ft.	9275	9275	9275
Stroke Length, in.	105	105	105
SPM	8.6	8.6	8.7
Depth to Fluid Level, ft.	9275	9275	9275
Production, BFPD	23.6	30.2	30.4
Motor Run Time, %	45	45	45

Analysis

Gearbox Torque, 1000 in-lb	335	326	261
Rod Load Range, % Loading	85	87	77
KW/BBL/1000' Lift	0.487	0.484	0.408
Thermal Amps	27	22	27.5
Max. Motor RPM	1258	1200	1227
Min. Motor RPM	1172	851	830
Speed Variation, %	7.1	28.5	33
KVA Used	21.53	17.53	17.19

Figure 1 - Andrews County #6

Well Data

	NEMA D 50 H.P.	ECONO-PAC EPII-5-MT
Pumping Unit	Mark II 640	Mark II
Unit Sheave, in.	50	50
Motor Sheave, in.	10	10
API Rod Design	86	86
Pump Diameter, in.	2	2
Well Depth, ft.	6550	6550
Stroke Length, in.	168	168
SPM	8.2	8.9
Depth to Fluid Level, ft.	4789	5063
Production, BFPD	339	411
Motor Run Time, %	80	80

Analysis

Gearbox Torque, 1000 in-lb	610	501
Rod Load Range, % Loading	103	93
KW/BBL/1000' Lift	0.381	0.363
Thermal Amps	65	58
Speed Variation, %	11.8	24.5
KVA Used	51.79	46.21

Figure 2a - Andrews County #31

Well Data

	NEMA D 60 H.P.	ECONO-PAC EPII-5-MT
Pumping Unit	Mark 640	Mark 640
Unit Sheave, in.	50	50
Motor Sheave, in.	10	10
API Rod Design	86	86
Pump Diameter, in.	2	2
Well Depth, ft.	6600	6600
Stroke Length, in.	168	168
SPM	8.4	9.5
Depth to Fluid Level, ft.	2562	3050
Production, BFPD	573	638
Motor Run Time, %	100	100

Analysis

Gearbox Torque, 1000 in-lb	461	498
Rod Load Range, % Loading	81	87
KW/BBL/1000' Lift	0.390	0.330
Thermal Amps	49	49
Speed Variation	10.4	18
KVA Used	39	31.07

Figure 2b - Andrews County #39

	ECONO-PAC	NEMA D
% Loaded	80	87
% Speed Variation	24	10.9
KW/BBL/1000' Lift	0.363	0.368

ANDREWS COUNTY #39

	ECONO-PAC	NEMA D
% Loaded	75	65
% Speed Variation	18	10.1
KW/BBL/1000' Lift	0.350	0.390

ANDREWS COUNTY #6

	ECONO-PAC	NEMA D
% Loaded	72	79
% Speed Variation	33	7.1
KW/BBL/1000' Lift	0.408	0.487

Figure 3 - Andrews County #31

Mechanical Repair Cost

API 96 Rod String 9275'	$14,573.00
Pumping Unit Cost	500.00
	$15,273.00

Note: Average life of a string of sucker rods is based upon 10,000,000 cycles at 100% rod load range or 3 years at 6.55 SPM.

Mechanical Savings

($15,273.00/36 Months) (3.5 Months) = $1,484.88

Note: Extended life of rod string of 3.5 months.

Electrical Savings

[(.487) - (.408) KW/BBL/1000' Lift](30.36 BBL) (30 Days/Month) (9.275)

= 667 KW/Month X .06 $/KW

= 40.04 $/Month X 36 Months

= $1,441.44 $/3 Years

Total Savings

= Mechanical Savings + Electrical Savings

= $1,484.88 + $1,441.44

= $2,926.32

Figure 4 - Andrews County #6