USE AND APPLICATION OF DYNAMOMETERS FOR SURFACE AND DOWNHOLE ANALYSIS

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INTRODUCTION

Dynamometer analysis and well analysis are becoming far more common terms in the oil producing industry than in recent years. These terms are becoming well known because oil producers encounter substantial costs and lost production if their beam pumped wells do not operate efficiently. Dynamometer analysis is one important technique used to expose inefficiencies and provide information for the analyst to make recommendations for improvement.

PURPOSE

The purpose of this paper is to present an objective non-technical discussion, describing and comparing surface and downhole analysis. Previous discussions of surface and downhole analysis have been offered with only casual reference to each other. Both surface and downhole analysis can play an important role in practical well analysis programs.

DEFINITIONS

SURFACE CARD - This term will be used as another name for the load vs. displacement graph (dynagraph) as it is observed at the surface. Surface dynamometer card is another term used having the same meaning.

DOWNHOLE PUMP CARD - This term will be used to describe the load vs.displacement graph (downhole dynagraph) as it would appear at the pump (as if it were measured at the pump instead of the surface).

PURPOSE OF WELL ANALYSIS

Simply stated the purpose of well analysis is most often to provide information that can guide the operator to the most efficient operation of the well that is practical. Likewise, the most efficient and practical analytical methods and techniques are most desirable. Well analysis can provide many different facts about a producing well. Various conclusions and recommendations can be formed based on data gathered. No attempt will be made in this paper to cover every possible application of dynamometers. Only the more common applications will be discussed in the interest of space and time.

Following is a list of important items a qualified well analyst can observe using either surface or downhole analysis techniques:

* Traveling valve check
* Standing valve check
* Fluid pound
* Gas compression
* Polished rod loads
* Counterbalance effect

These items can be observed visually by studying the surface dynagraph. Additional important information about the operation of the well can be determined by simple mathematical techniques using data taken from the surface card and well data files. Examples include:

* Pump efficiency
* Pump intake pressure
* Fluid level
* Downhole rod stress
* Pump fillage
* Pump stroke length
* Gearbox torque
* Prime mover load
* Tubing movement

Of the many items that could be included, these are the most often used.

To determine how efficiently a pump system is operating, the analyst must have a reference point for comparison. The most widely used references for beam pump systems are the API standards and bulletins related to beam pumping.[1] These standards offer the analyst a means of determining approximate loads and capacities of a pump system if the system is operating normally. The API techniques are based on certain assumptions which are rarely all satisfied in actual practice. However, the technique is sufficiently accurate and simple to use. By comparing data measured in the field (loads, capacities, dynagraph shape) with a reference (API predicted loads, capacities, dynagraph shape) the analyst can often determine whether or not the well is performing normally.[2] Opportunities for improved performance can also be discovered by this comparison of actual and predicted data.

METHODS OF ANALYSIS

Two fundamental approaches to dynamometer analysis are currently being used widely to determine well performance. One is thorough analysis of the surface card. The other is thorough analysis of the downhole pump card. Of the two approaches the more widely used is surface card analysis. Downhole pump card analysis is actually an extension of surface card analysis. The downhole card is generated as a result of mathematical manipulation of surface card data. Downhole pump card analysis is becoming more popular as a result of industry awareness and recent developments in availability of computer software to allow the oil producer to do his own well analysis.

SURFACE CARD ANALYSIS

The analysis of surface cards has been a profitable effort for oil producers for years. Some companies have set up departments for the specific purpose of surface card acquisition and analysis. Many of

these companies are using the earlier referenced API comparison technique.

Once a surface dynamometer card has been obtained the analyst can study loads on the pumping unit gearbox, prime mover, rod string and pump. (See Figs. 1-5) Downhole stress at each taper of a tapered rod string can be determined. Rod parts and pump problems such as leaking valves, split pump barrel, gas interference and fluid pound can often be identified.

A typical thorough analysis of the surface card involves some calculations prior to taking field data. These calculations provide the analyst with predicted polished rod peak, minimum, traveling valve, and standing valve loads. API dimensionless constants can be calculated to allow the analyst to use the API bulletin containing surface dynagraph shapes. From that bulletin the predicted surface card for the specific well to be analyzed can be selected. With these predicted loads and knowing the approximate dynagraph shape to expect the analyst can make some initial judgements in the field when the surface card is run at the well. For example, if the actual measured loads are all within 5 percent of their calculated values and the shape of the surface card compares favorably with the shape obtained from the API bulletin, the analyst can conclude that the well is performing approximately as predicted. This does not mean that there are no problems nor does it mean there is no room for improvement. Further calculations of stress analysis, torque analysis, pump efficiency, etc. must be performed before final conclusions and recommendations can be made.

On the other hand if the measured loads and actual surface card shape does not compare favorably with predicted loads and shape, the analyst can conclude that something is wrong. It is important that this comparison be done at the well such that any further investigation or tests can be performed immediately if advisable.

The advantages of surface card analysis are that it is a widely known technique; it is more economical than downhole pump card analysis; it can be done without the use of a computer. With a hand-held programmable calculator and dynamometer the average field technician can perform a fairly complete well analysis.

Disadvantages of surface card analysis are that each set of well conditions produces a slightly different surface card shape. If the surface card shape does not appear in the API bulletin, the analyst can have difficulty in determining how the pump is performing.

DOWNHOLE PUMP CARD ANALYSIS

Many years ago it was suspected that loads measured at the pump could be meaningful to the well analyst. Early efforts to determine loads at the pump involved installing load measuring equipment downhole in a well at the pump. The downhole pump card that resulted did have value but was far to difficult to obtain to receive wide acceptance. Recognizing the potential value of the downhole pump card Shell Oil developed a computer program using the wave equation to mathematically determine the downhole pump card using the surface card as input.[3]

The polished rod load and displacement as a function of time is required to satisfy part of the input requirements of the wave equation. Shell's computer technique for developing the downhole pump card requires this data to be digitized (Surface dynamometer cards are analog representations of load and displacement).

While downhole pump card analysis has not been widely used as long as surface card analysis, the former is a valuable technique.

A surface card must be obtained first. The surface card data must be digitized. The digitized surface card and appropriate well data must be entered into a computer for a solution to the wave equation and a downhole pump card to be developed. Once the downhole pump card is available to the analyst, accompanying calculations must be performed (manually or by computer). These calculations include pump stroke length, pump capacity, expected through put of the pump, downhole rod stress, gearbox torque, etc. (See Figs. 5-8) If the analyst is only performing a downhole pump card analysis, no predicted surface loads are calculated for comparison purposes and the predicted shape of the surface card is not determined.

When all calculations and the downhole pump card are available to the analyst, conclusions about the well's performance can be drawn and appropriate recommendations can be made.

The advantages of downhole pump card analysis is the similarity of shape of downhole pump cards. When a well is operating without mechanical problems and the pump if filling properly, the downhole pump card shape should be approximately rectangular. Based on variations from the rectangular shape the analyst can form conclusions and make recommendations.

In some cases, surface cards have unusual shapes that do not allow the analyst to be confident in his evaluation of well performance. In these cases, capability of downhole pump card analysis is advantageous.

Disadvantages of downhole pump card analysis are cost, a computer is required, and there are fewer qualified analysts than in the case of surface card analysis.

COMPARISON

Surface or downhole analysis techniques can be applied to most rod pumped wells. The rare exception would be where the analysis equipment could not be installed. Many wells can be satisfactorily analyzed using surface card analysis techniques. When surface card analysis yields logical conclusions there is generally no need to use downhole card analysis techniques.

These are cases that surface card analysis will not yield completely satisfactory results. These cases are ideal candidates for downhole card analysis. The additional expense of performing downhole analysis is justified if the technique provides the analyst with enough additional information to form logical conclusions and recommendations. There are cases that cannot be satisfactorily analyzed using either technique.

It is recommended that the analyst first apply surface card analysis techniques to evaluate well performance. If downhole card analysis is necessary or desirable in a particular case, it should follow. Downhole card analysis begins with obtaining a surface card. It is desirable to obtain all surface cards in a manner that allows use of downhole card techniques.

EQUIPMENT AND SERVICE

Well analysis equipment is available to the industry from independent suppliers. Well analysis is also offered on a service basis by various companies in the industry.

Equipment including dynamometer, surface data recorder and data input units can be used to gather and input the data into computer software available on the timeshare network. This makes it possible to perform any degree of analysis (surface or downhole) right in the field office if desired. If only surface analysis is desired, this can be performed at the well site with dynamometer and calculator.

SOFTWARE

Software is available and designed so the average technician can use it. Computer operators are not required to run many of the programs available. Some producing companies have their own software. Most have chosen to use software available on one of the timeshare networks because of broad geographic availability.

CONCLUSIONS

The availability of equipment, technology, and computer software has made it possible for large and small producing companies to take advantage of well analysis techniques. Surface analysis is generally less expensive than downhole analysis and can provide the analyst with satisfactory results. While downhole card analysis is more expensive and requires a computer, it is justified when surface analysis fails to provide the analyst with enough information to form logical conclusions and recommendations.

Software for downhole card analysis has been made available for use by oil producers recently. As more analysts become trained in the use of downhole card analysis software, the techniques are becoming more popular. Well problems that were left unsolved can now be resolved in many cases.

Both surface and downhole pump card equipment and techniques can be used in house or on a service basis from a contractor.

REFERENCES

1. American Petroleum Institute, "API RP11L", "API BUL 11L2", "API RP11BR", "API STD 11E".

2. Rodney Morgan and Fount E. McKee, "Well Analysis Made Easy", Petroleum Engineer International, Energy Publication, August 1977.

3. S. G. Gibbs, "Predicting the Behavior of Sucker-Rod Pumping Systems", Journal of Petroleum Technology, July 1963.

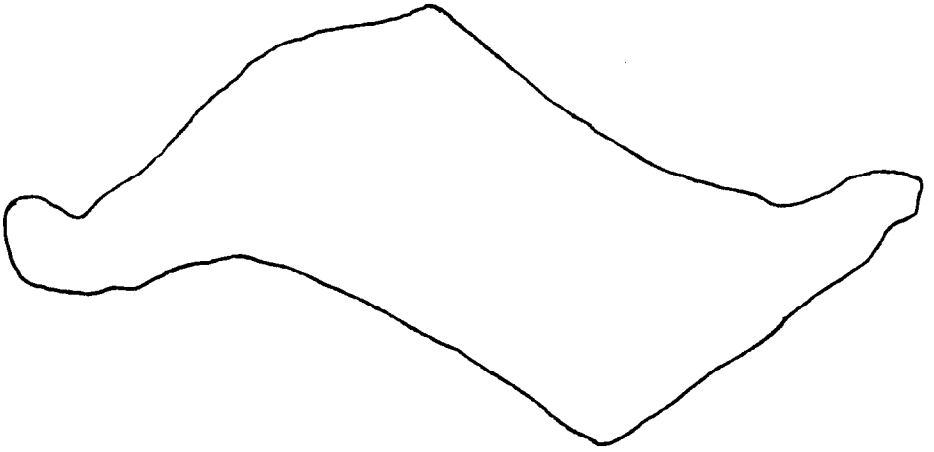

FIGURE 1—SURFACE DYNAMOMETER CARD

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WELL IDENIFICATION: HUM1

PREDICTED SYSTEM LOADS (PSL)

CALCULATIONS FOR CONVENTIONAL PUMPING UNIT

PLUNGER SIZE	STROKE LENGTH	PRODUCTION	PUMPING SPEED	PEAK POL ROD LOAD	MIN POL ROD LOAD	TRAVEL VALVE	STAND VALVE
2.25	75.5	543.	13.50	18010.	5079.	13497.	8766.

ROD SIZE	LENGTH	MAX STRESS	MIN STRESS	% MGDA
8	1100.	22934.	6468.	83.7
7	1950.	23735.	5179.	91.7
6	1400.	19980.	1846.	83.6

PEAK TORQUE	CBE	POLISHED ROD HP	MAXIMUM ACCELERATION	PUMPING ORDER
276273.	12237.	14.708	0.195	4.563

FO/SKR	N/NO	N/NOP	FC	WR	ER	ET
.191	.250	.2192	1.1422	2.2073	.6847E-06	.

* *

FIGURE 2—PREDICTED SYSTEM LOADS

* *

WELL IDENIFICATION: HUM1

DOWN-HOLE STRESS ANALYSIS (DSA)

CALCULATIONS FOR CONVENTIONAL PUMPING UNIT

PLUNGER SIZE	STROKE LENGTH	PRODUCTION	PUMPING SPEED	PEAK POL ROD LOAD	MIN POL ROD LOAD	TRAVEL VALVE	STAND VALVE
2.25	75.5	543.	13.50	18200.	3900.	13497.	8766.

ROD SIZE	LENGTH	MAX STRESS	MIN STRESS	% MGDA
8	1100.	23176.	4966.	89.6
7	1950.	23973.	3703.	97.1
6	1400.	20115.	1006.	86.6

PEAK TORQUE	CBE	POLISHED ROD HP	MAXIMUM ACCELERATION	PUMPING ORDER
305545.*	11713.	16.267	0.195	4.563

FO/SKR	N/NO	N/NOP	FC	WR	ER	ET
.191	.250	.2192	1.1422	2.2073	.6847E-06	.

FIGURE 3—DOWNHOLE STRESS ANALYSIS

WELL IDENTIFICATION: TEST

TORQUE CALCULATIONS FOR CONVENTIONAL UNIT
WITH COUNTERBALANCE EFFECT = 13240.

UPSTROKE

	CRANK ANGLE	TORQUE	PERMISSIBLE LOAD	ACTUAL LOAD
	15.0	8573.	29454.	13036.
	30.0	79332.	17998.	14134.
*	45.0	122731.	15623.	14371.
	60.0	96143.	15576.	13712.
	75.0	57184.	16754.	13768.
	90.0	38983.	18704.	14877.
	105.0	-871.	21076.	15199.
	120.0	-51851.	23566.	14211.
	135.0	-62310.	26022.	13584.
	150.0	-39330.	28755.	13500.
	165.0	-12309.	33867.	12387.
	180.0	28230.	65609.	11576.

DOWNSTROKE

CRANK ANGLE	TORQUE	PERMISSIBLE LOAD	ACTUAL LOAD
195.0	65849.	-12319.	11679.
* 210.0	79084.	5058.	12401.
225.0	76252.	7926.	12501.
240.0	60546.	8600.	12603.
255.0	38808.	8628.	12868.
270.0	34375.	8330.	12185.
285.0	40290.	7727.	11330.
300.0	26592.	6741.	10950.
315.0	11252.	5188.	10507.
330.0	-12570.	2541.	10410.
345.0	-32064.	-3581.	10651.
360.0	-35544.	-56509.	12553.

* INDICATES PEAK TORQUE.

PEAK TORQUE WHEN COUNTERBALANCED.....= 99492.

CBE REQUIRED TO COUNTERBALANCE UNIT..= 14249.

FIGURE 4—TORQUE ANALYSIS

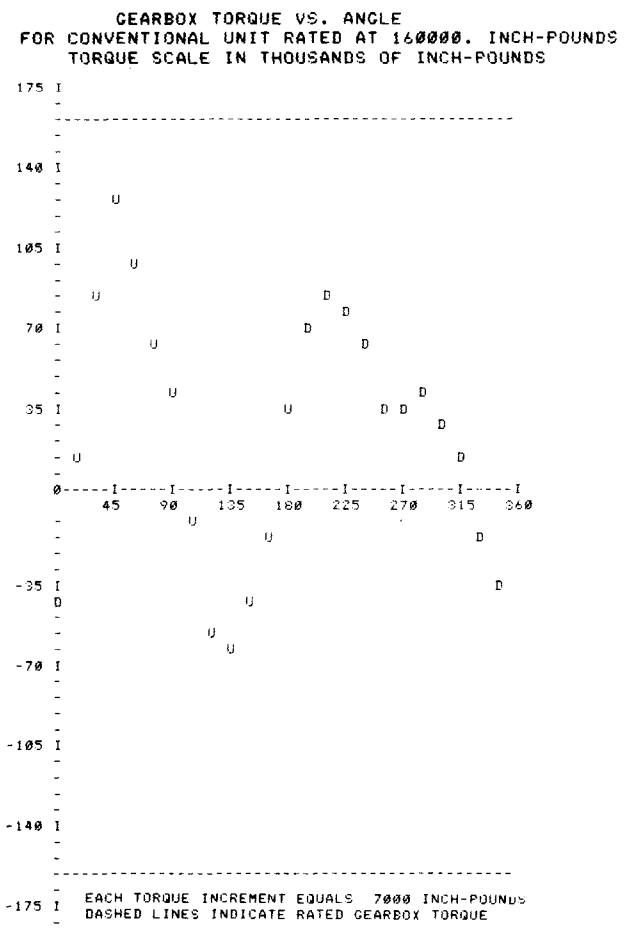

FIGURE 5—TORQUE PLOT (DATA FROM FIG. 4)

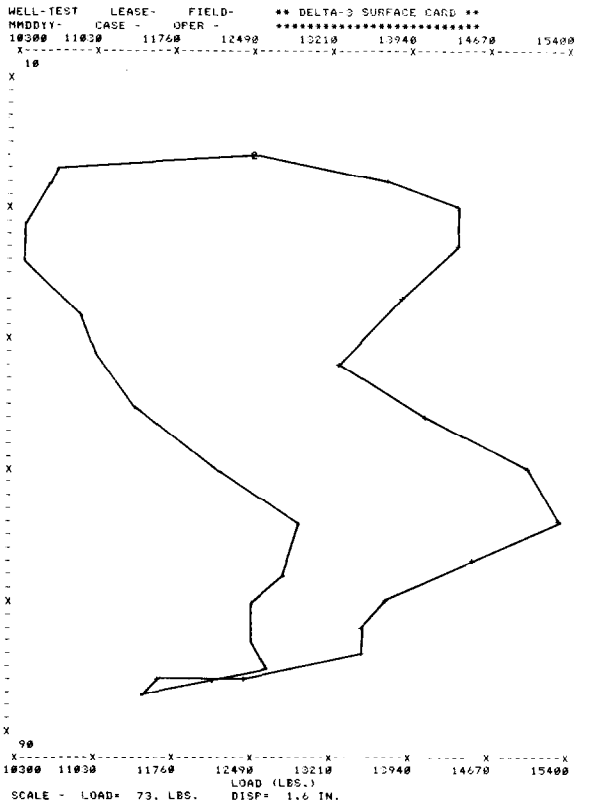

FIGURE 6—SURFACE CARD FROM DOWNHOLE PUMP CARD COMPUTER PROGRAM OUTPUT

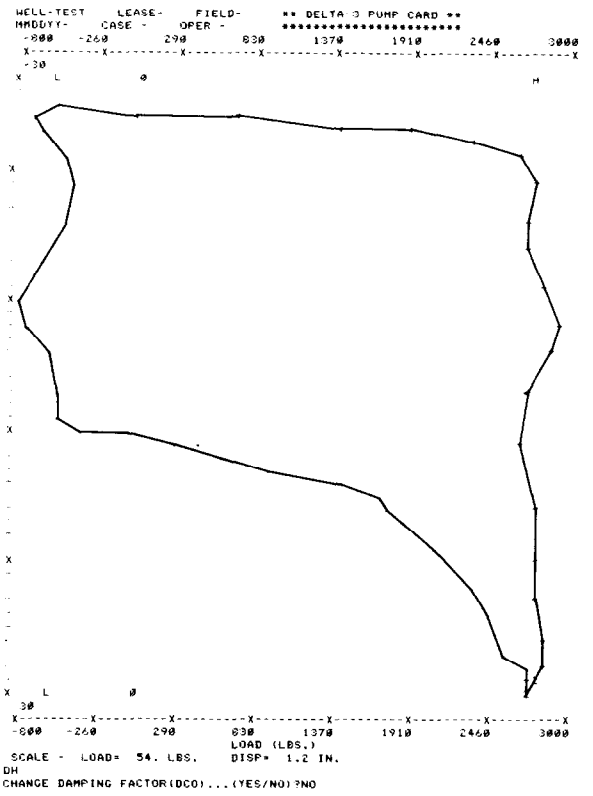

FIGURE 7—DOWNHOLE PUMP CARD BASED ON SURFACE CARD IN FIGURE 6.

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                        SURFACE DATA

 STROKE LTH    PPRL    MPRL   TORQUE  FLUID LOAD   FLUID GRD
     64.5     15300.  10400.   79013.     3291.       0.427

                         ROD DATA

 DIA      MAX STRESS      MIN STRESS      MOD LMT    %MOD
  6         34637.          23544.         35744.     91.
  5         30379.          14761.         30803.     97.

 TOTAL ROD LENGHT   8460.0      TOTAL ROD WEIGHT  11266.6

                         PUMP DATA

              GROSS STROKE     GROSS PROD     GROSS EFFN
                  53.0            120.6          81.3

              NET STROKE       NET PROD       NET EFFN
                  29.1            66.2           148.1

 PUMP FILLAGE   54.9%

              AV MAX LOAD    AV MIN LOAD     AV MAX DISP
                 2718.          -573.           29.1

              MAX LOAD       MIN LOAD        MAX DISP
                 2956.          -777.           53.0

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DO YOU WISH TO RUN AGAIN.....?NO

PROGRAM STOP AT 0
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FIGURE 8—CALCULATED SURFACE DATA AND PUMP DATA PUMPED ON SURFACE CARD IN FIGURE 6.