# Torque Loads And Plunger Displacement From The Dynagraph

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Last year at this short course the dynagraph animater was given its first public showing. Since that time it has had numerous showings in the mid-continent area. It is supposed that some of those present have witnessed such a showing either here or elsewhere.

In order to clarify the present discussion, it is thought wise to review briefly the discussion and demonstration of last year, to help you visualize the properties of sucker rods, and the significance of the dynagraph.

The dynagraph of an oil well is no more than a graphical record of force recorded against a distance from some starting point. We usually consider the lowest point in the polished rod travel, which is the beginning of the upstroke as the starting or reference point. The dynamometer is usually supplied with a vibrating device whereby the time element may be separately recorded with respect to the starting point.

The record force is that force which exist at the polished rod clamp only for each continuous position of that clamp or polished rod. The load and relative position at any other point in the sucker rod system does and must have an influence upon the magnitude of that force. However, we do know that if a load be imposed upon any solid material, that material is deformed. That is; its physical dimensions are changed by the load. In the case of a truly elastic material, such as steel, we may calculate the magnitude of the deformation from a known load, and, with a high degree of accuracy. We can best picture this by viewing the action of steel under load.

We shall now demonstrate that action by a toy known as "Slinky" which is made of steel of uniform cross section.

Thus the top coil of "Slinky" would serve as a dynamometer if we recorded its stretch or deflection supplemented by a proper calibration. From that information by deduction and reasoning we could learn what happened at all the other coils. Likewise, it is possible by the same process to determine what happens in the sucker rod system of a pumping well, from the forces recorded at the polished rod clamp. While it is rather difficult to separate the several forces existing simultaneously in the rod system which produce the recorded force at the dynamometer, it is not of necessity impossible, however tedious it may be. It is beyond the scope of this discussion to enter into the methods used to accomplish this end. Time and space bids us to be content with a viewing of the results of this method, rather than a study of the method itself.

We shall now demonstrate the plunger travel under 5 typical well conditions by means of the dynagraph Animater.

1. Smooth 2 1/2 order pumping.
2. Due to rod vibration above.
3. Excessive rod stretch.
4. Gas interference.
5. Pounding fluid.

The dynamometer is in the middle, so to speak, of a system, with the power source at one end and the pump plunger at the other end. We might say "between the Devil and the deep sea." Since action and reaction are equal and opposite, the forces recorded by the dynamometer finally reach the source of power with such modifi-cations by mechanisms as may exist along the way.

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We are at the moment interested in how these forces arrive at the speed reducer in the form of torque. The walking beam and the cranks are a system of levers connected together by the pitman. This sort of a system is technically known as a kinematic chain. This is a high sounding name which may frighten the non-technical mind but a lever is a lever no matter where you find it. We all understand that if we use a bar as a pry such that the long end of the pry is four times as long as the short end, then the long end would move 4 times as fast as the short end and could lift 4 times as much as the force applied. Thus we see that the velocity multiplied by the force at each end of the bar must be equal to each other. Anyone familiar with the method of kinematics can very easily determine by simple geometry the relative velocities of the wrist pin and the polished rod for a pumping unit for any and all crank positions and therefrom plot a relative velocity curve for that pumping unit. Notice I said "by simple geometry." Now that means that the relationship by geometry between the length and positions of the walking beam, pitman and crank all influence the relative velocities and forces at the wrist pin and the polished rod. That relationship of fixed dimensions of a pumping unit we choose to term "the geometry of the units of the same stroke length but of different geometly or proportions, the one which had the lesser maximum relative velocity between the wrist pin and the polished rod is said to have the better gemotry because for the same polished rod load, the better geometry would produce a smaller torque at the crankshaft.

From the geometry of the pumping unit and by simple geometry, we may determine the position of the polished rod for any and all positions of the crank. For instance, what is the polished rod position when the crank is at the 1 o'clock position? at 2 o'clock? 3 o'clock? and so on. Thus we may plot a curve showing the polished rod position for all possible crank positions.

From these two curves we can now predicate the polished rod load taken from any point on the dynagraph, upon the wrist pin and thereby determine the torque imposed at the crankshaft due to polished rod loads recorded on the dynagraph.

But that is not the whole story. The counter balance on the crank imposes an opposing torque to the load torque and thereby reduces the torque at the crankshaft. We usually designate the size of the counterbalance by its effective weight at 1/2 the stroke length. Thus, 10,000 lb. counterbalance at a 48" stroke would produce an opposing torque or negative torque of 24 inches times 10,000 lbs. or 240,000 in lb. maximum. This refers to the 2 horizontal positions of the crank only where the effective counterbalance torque is maximum. At the two vertical positions of the crank, the effective torque is zero. The effective counterbalance torque varies from zero to maximum and back according to a simple sine curve.

Figure I is a chart where-in the three curves just described are plotted in terms of percent of stroke length for a floor clearance unit of about average geometry. Some pumping units have better geometry and some have less desirability geometry. The chart is predicated upon the maximum stroke length of the unit and is applicable to any size unit having the same geometry for its maximum stroke length.

Let us take a specific example and see how this chart works. Suppose we had a unit of this geometry with a 48" stroke. Suppose we wished to know the torque on the unit due to a 13,000 lb. load at the dynamometer which load occurred 17" up on the upstroke. Simple division shows the 17" is 35 percent of 48" which is the total stroke. At 35 percent of the polished rod travel we find that the crank is at 60 degrees. At 60 degrees the torque factor is 109 percent. Therefore, the tangential load at the wrist pin is 13,000 lb. x 109 percent of 14,170 lbs. Hence the torque due to 13,000 lb. at the polished rod is 14,170 lb. times 24" or 340,000" lbs. Now suppose by actual measurement we found that the effective counterbalance was 8,000 lbs at 24" or 192,000" lbs maximum. But we see from the chart that at the 60 degree crank position the effective counterbalance is 92 percent. Hence the effective torque due to counterbalance is 92 percent of—192,000" lbs. or only—176,000" lbs. The net torque is then 340,000 in. lb.—176,600" lb. or 163,400" lb.

Some engineers figure the torque the easy way. Like this: 13,000 lb. PRL minus 8,000 lb. ECB equals 5,000 lb. net and 5,000 lb net at 24" equals 120,000" lb. net torque. In this instance they are only wrong by 36 percent. It could not be classified as a good guess. We learn from this that in arriving at the torque imposed upon a unit pumper from the dynagraph, it is necessary to reckon with the geometry of the pumping unit in question.

This discussion deals with rotary or crank counterbalance only. Other types such as beam or air balanced units give different results but the method of analysis remains the same.

In order to visualize the variation of torque on a pumping unit throughout a complete pumping cycle, charts have been prepared from the dynagraph and adapted to be shown on the animator which also contains the element of time and hence shows not only the magnitude of the torque variations but also the rate of change in torque which is indicative of shock. Shock is no more than a very rapid change in force or load.

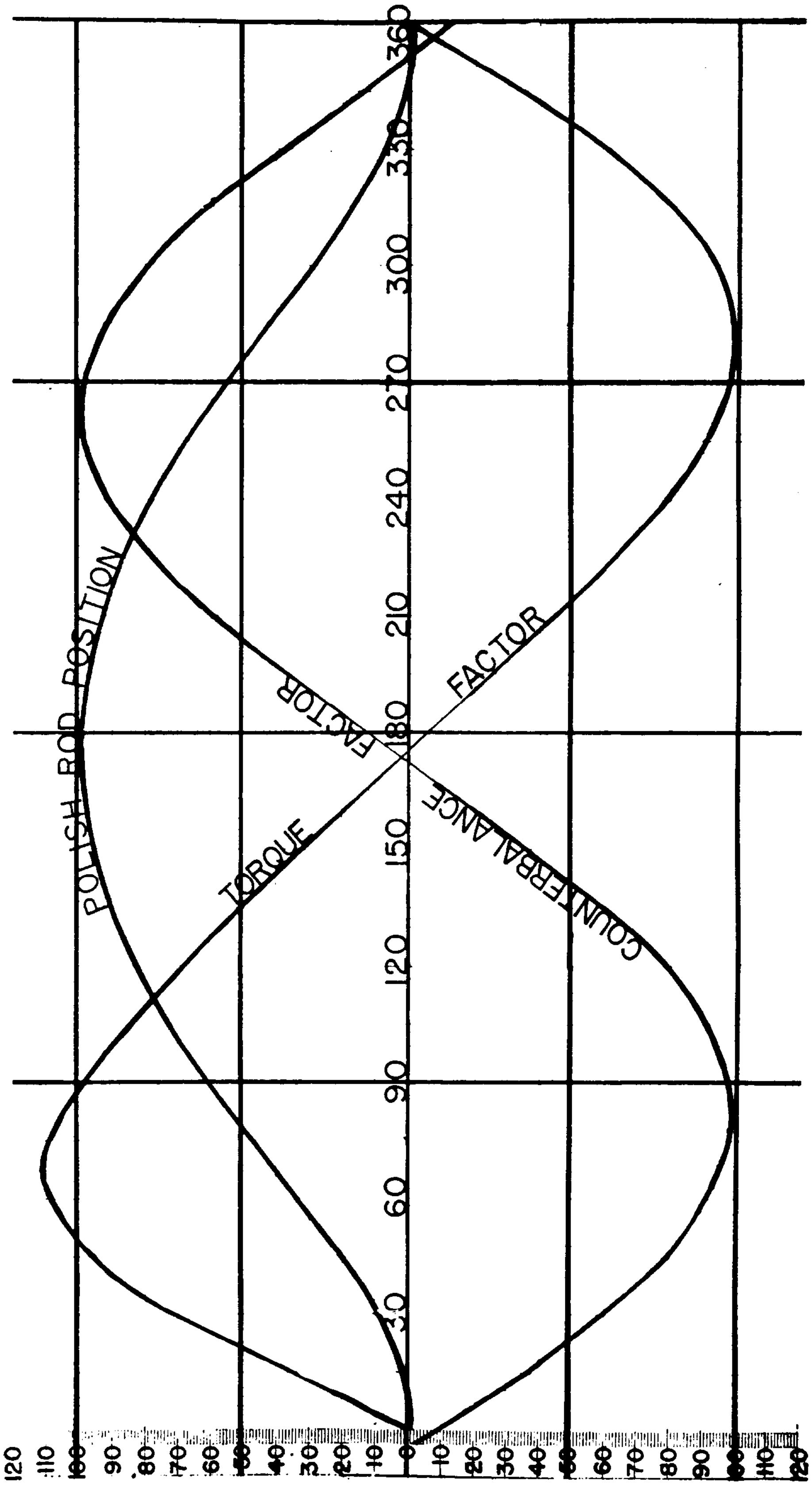

FIGURE 1