Principles Of Sucker Rod Pumping

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It might be said that the fundamentals of sucker rod pumping are very simple. The plunger pump has been known for many centuries, and the mechanical and hydraulic functionings of the modern deep well sucker rod pump are precisely the same as originally conceived. The materials and precision workmanship only have been improved. The principle of the pump is so well known that we shall only point out that the pump consists of a movable plunger into a tube. The plunger has a central passageway controlled by a check valve called the traveling valve. The tube also has a check valve below the plunger known as the standing valve. Each of these valves permits the flow of fluid only in an upward direction. On the upstroke fluid is drawn through the standing valve into the space vacated by the plunger. On the downstroke that fluid is transferred to the upper side of the plunger through the traveling valve. Thus, we see that the plunger does useful work toward lifting or pumping fluid only on the upstroke. The plunger falls through the fluid on the downstroke and does no useful work thereby. We assume that this is so well understood that we need not discuss it further at this moment.

The sucker rods serve only to transmit power on the upstroke to the plunger for lifting fluid. Gravity returns the plunger and the rods on the downstrokes. Depending on the distance from the rod hanger to the plunger these sucker rods may have a length of a few hundred feet to as much as two miles. The weight of these rods is much more than the force required to overcome friction on the downstroke, hence this weight returns a large quanity of work to the system on the downstroke which has been expended on the upstroke in lifting these same rods. It is quite plain that the work done at the polish rod is quite large on the upstroke since both the rods and the fluid are lifted simultaneously. And, as just pointed out, much of this work is returned to the system on the downstroke by the weight of the rods. The net work done in one complete cycle is therefore the work required to lift the fluid plus the work required to overcome friction. In order to equalize the work done by the source of power on the up and down strokes, we provide the system with a counterweight or counter balance whereby the falling rods on the downstroke raise the counterbalance thus storing energy which is used to lift the rods and fluid on the next upstroke as the counterbalance is lowered. By a careful adjustment of this counterbalance, we may equalize the total work done by the source of power on the up-and-down-strokes. When this is done we obtain the smoothest operation possible with any given set-up.

Of course, this does not mean that we have a constant or uniform flow of power in the system. The system is operated by a crank mechanism and when the cranks cross their dead centers, no power other than friction is required whereas when the cranks are near their 3 o'clock and 9 o'clock or most extended position, the power required is much more than the average power of the whole cycle. So there are always two high power peaks and two low power points in each cycle. Careful counterbalancing can reduce these peaks to a minimum, but of course cannot totally eliminate them.

Fundamentally, there is not much to know about the sucker rods. All I know is that they are made of steel and have all the properties of steel and no other. If they were made of some other material such as aluminum they would have all the properties of that material and no other. If, therefore, we know the properties of steel we know all there is to know about steel sucker rods.

Steel is an elastic material as opposed to a plastic material. That is to say, steel changes its dimensions quite in proportion to the forces acting upon it. A spring weighing scale operates on this property of steel. In fact the Johnson Fagg type of dynamometer uses this principle. It makes a magnified record of the minute changes in shape of two steel rings, due to the load imposed upon them by the rod load. In a rod only a foot long these changes in length due to load are quite small, and ordinarily may be disregarded. But, in oil wells the rod strings become quite long and the change in length of these rods due to load change cannot be disregarded.

I have here a toy known as "Slinky" which like sucker rod is made of steel, and behaves like all steel, but being formed of flat wire into a coil the stretch or change of shape is greatly magnified and may be readily observed. With it, I shall now demonstrate how steel behaves under changing loads.

Demonstration

(1) Show elongation of rod due to their own weight for various rod

lengths from 1,000 ft. to 8,000 ft.

(2) Show natural frequency of a straight string of rods from 1,000 to 8,000 ft.

(3) Show time lag in transmitting force through steel.

We now see that because rods must be stretched before they can carry an additional load (like lifting the fluid) and because rods can vibrate and because it takes time to transmit force from one end of the rod string to the other, the plunger in the pump cannot possibly have the same smooth motion as the polish rod.

Fortunately, the dynamometer can record the load at every instant in the pumping cycle. Knowing the numerical values for the properties of steel, we may calculate the change in length of the sucker rod string due to load for any point in the well cycle from the recorded load on the dynagraph. Of course, we must take into consideration all of the three properties of steel which we have just demonstrated. Since the dynagraph also records the position of the polish rod we may plot the relative position of the plunger for all positions of the polish rod. That in itself doesn't mean much. But if we could view the plunger and the polish rod at the same instant, the resultant motion of the plunger might be very illuminating and surely very interesting.

I have here a device which I choose to call a Dynagraph Animater by which we may view the polish motion relative to the plunger motion at the same time; of course, on a reduced scale. This by the way is the first public showing of the Dynagraph Animater. I hope you will at least enjoy it and perhaps receive some benefit therefrom.

This is not a mere theory. Each demonstration was prepared from actual dynagraphs. The motion of the polish rod and the plunger were carefully plotted from the dynagraph record and the only errors are personal errors or mechanical errors.

The following demonstration was made on the Dynagraph Animator.

(1) Excellent pumping
Tubing Anchor

(2) Cabletooling rods—well flowing.

(3) Too much fluid load for rods. Very small plunger motion.

(4) Pounding fluid or gas.

(5) Tubing motion and its effect on rod loads.