SUCKER ROD LIFTING – MYTHS, UNTRUTHS AND MISNOMERS

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ABSTRACT

While the sucker rod lift method is still the one used the most in producing wells around the world, the terminology and slang that has been developed may not contribute to fully understand what is happening downhole. Additionally, some of the oil field terms or idioms that have been developed may not translate very well in other languages. Without the most appropriate understanding, incorrect diagnoses, troubleshooting, and recommendations to correctly fix problems may not occur.

This paper may be the first in a series that will discuss common terms that are commonly used but normally are not appropriately used. The first terms covered may be the most commonly misused and may generate a lot of discussion since what will be presented is contrary to the prior teaching that has been used in the industry.

BACKGROUND

Many people in the industry have used terms to try to express what they think may be happening downhole to the producing equipment; but, sometimes in an attempt to explain a complicated condition, inexact words are used. These words then may provide a totally different result or belief is happening downhole than truly exists. Additionally, if these terms are slang or idioms, they become difficult to translate into another language which then causes greater confusion when another language translates the word to a more familiar condition.
In an attempt to provide understanding to the reaction of the equipment downhole and more importantly extend the use of this lift method to deeper wells and higher produced lift rates, then the industry needs to know what are the true conditions and term usage.
There are many terms that could be discussed in this paper; but, only a few will be covered at this time. Depending on the results and discussions, more terms will be added and discussed in the future.

DISCUSSIONS

Rod Buckling

There are many definitions for buckling from using a metal clasp to fasten a shoe to the bending of a sheet, plate, or column supporting a compressive load. The latter condition is applicable to consider the loads and stresses applied to the column of sucker rods reciprocating up and down in a well that is attached to a free moving plunger in a downhole pump. However, in science or mechanics or strength of materials, buckling is an instability that leads to a failure mode. While the compressive load is being applied, bending of an originally straight column under the application of a centrally applied compressive axial load until the bearing capability is exceeded. At this point the rod column "buckles."
Leonhard Euler, a mathematician derived a formula in 1757 that provides the maximum axial load for a long, slender, "ideal" column that can be applied without buckling. An ideal column is one that is perfectly straight, homogeneous and free from initial stress. The maximum or critical load causes the column to be in a state of unstable equilibrium so that the slightest lateral force will cause the column to fail by buckling. If the value of the critical stress exceeds the proportional limit of the column material, then buckling occurs in the zone of plastic deformations. Figure 1 shows a typical configuration when buckling tendencies are being considered. The formula derived by Euler for columns with no consideration for lateral forces is given below. However, if lateral forces are taken into consideration the value of critical load remains approximately the same.

$$F = \frac{\pi^2 EI}{(KL)^2}$$

Where:

F = maximum or critical force or vertical load on the column,

E = modulus of elasticity,
I = area moment of inertia,
L = unsupported length of column,
K = column effective length factor; of which the value depends on the conditions of end support of the column, as follows.

- For both ends pinned (hinged, free to rotate), K = 1.0.
- For both ends fixed, K = 0.50.
- For one end fixed and the other end pinned, K = 0.699....
- For one end fixed and the other end free to move laterally, K = 2.0.

KL = the effective length of the column.

Examination of this formula reveals the following interesting facts with regard to the load-bearing ability of slender columns.

- Determination of the critical load depends on the elasticity and not the compressive strength of the material.
- Slender column critical load is very dependent on the boundary conditions and the distance from the inflection points of the deflected column.
- The restraint offered by the end connections of a column greatly affects the critical load.
- If the connections are perfectly rigid, the critical load will be four times that for a similar column where there is no resistance to rotation (in which case the column is idealized as having hinges at the ends).

It is interesting to consider the type of end supports required to have buckling. Figure 2 shows compressive loads applied to a laboratory test simulating buckling. The rods shown have been distorted and no longer straight in the axial loading condition. If the release of the load allows the rods to return to the straight condition, then the applied loads have not buckled the rods. Only if the rods have been deformed and not able to carry the compressive load should then they truly have buckled. But it should be noted that none of these conditions represent the rod string that is free to move since the plunger is not restrained under normal conditions.

There may be a condition when the plunger is stuck in the pump barrel and a end connection restraint may be considered rigid, then there may be a tendency to buckle if the rod string was not contained or restrained from lateral movement since is operates inside produced tubing.

In summary, buckling is characterized by a sudden failure of a structural member subjected to high compressive stress. If no compressive forces, or if the end conditions are not restrained, then buckling cannot occur. Even if compressive forces may be applied, the column or sucker rods may not buckle since they are restrained by the coupling, rod guides and the ID of the tubing. Mathematical analysis of buckling often only uses the axial applied load but in practice there may be eccentricities that can introduce a secondary bending moment, which is not a part of the primary applied forces considered being applied to the rod string. This then results in tri-axial loading that probably causes many of the downhole failures.

Rod Compression

Figure 3 provides a generalized surface dynamometer card that shows the key load and downhole conditions during one pump or stroke cycle[1]. During the upstroke and after the peak polished rod load is obtained, there is a condition called “compression of rods.” Then after the end of the upstroke occurs and the polished rod is going down on the down stroke, there is another condition called “compression” until the traveling valve pops open.
But are the rods ever in compression?

First consider there are many definitions for compression and the application of the term may depend on the type or condition of the material that is being acted on.

Typically for mechanics or strength of material, or for application of a steel or composite rod string, compression is normally the application of a balanced inward force or stress. This “pushing” type force or stress tries to reduce the size of the component that is being loaded. In uniaxial compression, the forces are directed along one direction only, so that they act towards decreasing the object's length along that direction. The compressive forces may also be applied in multiple directions; for example inwards along the edges of a plate or all over the side surface of a cylinder, so as to reduce its area (**biaxial compression**), or inwards over the entire surface of a body, so as to reduce its volume.

When put under compression (or any other type of stress), every material will suffer some deformation, even if imperceptible, that causes the average relative positions of its atoms and molecules to change. The deformation may be permanent, or may be reversed when the compression forces disappear. In the latter case, the deformation gives rise to reaction forces that oppose the compression forces, and may eventually balance them.

For compression to occur, the applied load or stress is negative. Having a stress less than the maximum does not mean the material is in compression; it just means that it is not in as high axial tension loading.

So observing the loads or stresses being applied in Fig 3, all are positive and well above the “0” load line. Since there are no compressive loads on the surface card, the conditions associated with “compression” cannot be occurring. There may be a decrease in load after the maximum peak polished rod load is reached. There may be a load or stress decrease due to relaxation of the applied axial tension load before the end of the upstroke and beginning of the downstroke, but, these conditions do not mean the applied load/stress has become less than zero and a compressive load is being applied.

As the loads are decreased from the surface to the rod string become less, there may be a tendency at a specific string depth where the stresses may be thought or assumed to be less than zero. However, for every rod in the rod string and down to the pump, there is always going to be a weight of the remaining on the rods from all the rods below it. Thus, there is always going to be an axial load that being applied which has to be reduced all the way down to the last sucker rod which is attached to the plunger. So even this rod will always have a the weight of the plunger on it and a compressive load may not ever be applied.

SUMMARY AND CONCLUSIONS

1. It is important to provide proper training and understanding of the actual conditions and factors affecting sucker rod lifting producing wells.
2. Slang terms and idioms become difficult to translate into other languages which then make it more difficult to convey proper operating conditions to others in other parts of the world.
3. Buckling may never occur in a rod string since it requires a compressive load or force and the end connections have to be fixed or rigid. While there may be bending occurring depending on the well bore deviation and applied load, buckling still may never occur since the rods are constrained from lateral movement by a combination of the couplings, rod guides, and most importantly, the ID of the produced tubing.
4. Compression is one of the most overused or inappropriate used term since it is not a normal condition that occurs and affects sucker rod loads.
5. Rods may never see a true compressive load if properly designed and operated.
6. Any tendency for the applied load to compress the rods have to always overcome the axial loads due to the weight of the rods and plunger all the way down to the bottom of the string.
7.

REFERENCES

1. Gipson, F. W. and Swaim, H.S, Beam Pumping Fundamentals, SWPSC, Lubbock, April 17-18, 1969

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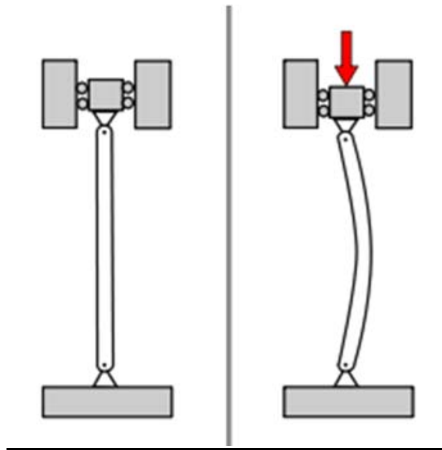

Figure 1 - Sketch of conditions normally required to conduct buckling tests. Note the ends supports are restrained and a compressive load is applied causing the rod to deflect. However, in a classical sense, this is not buckled unless it can no longer support the compressive load.

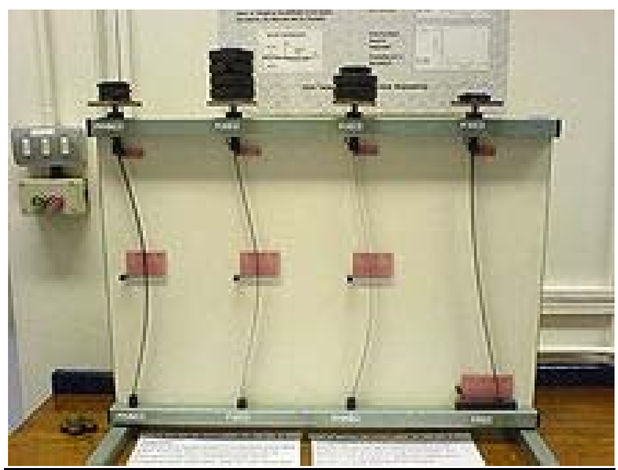

Figure 2 - A demonstration model illustrating the different "Euler" buckling modes. The model shows how the boundary conditions affect the critical load of a slender column. Notice that each of the columns is identical, except for the difference in end connection type or restraint.

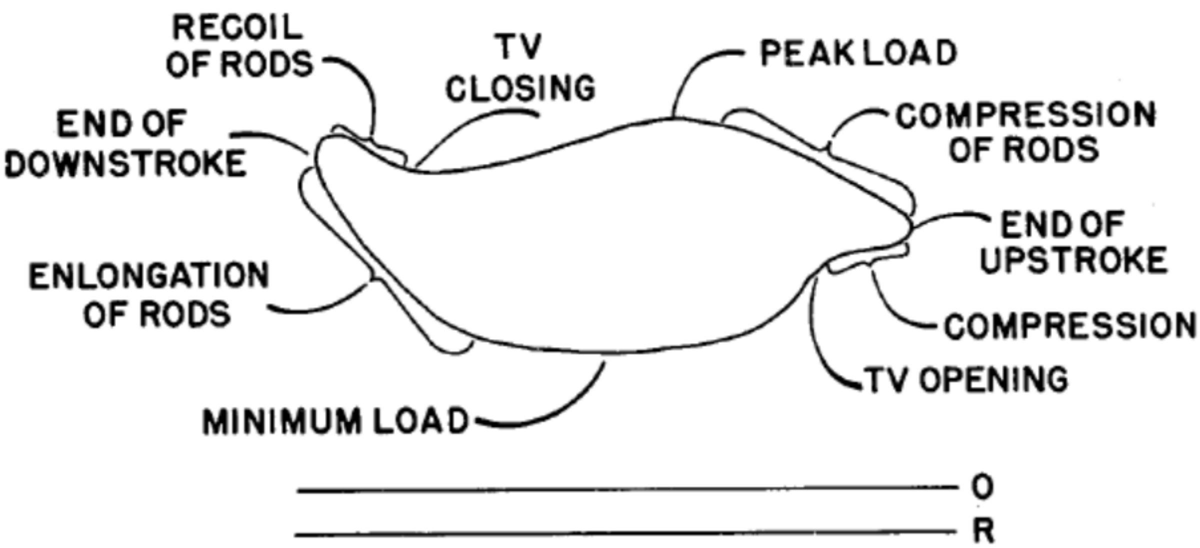

Figure 3 - Generalized surface dynamometer card representing “typical” conditions and factors affecting operations (Ref 1; Fig. 28)