FACTORS THAT AFFECT RELIABILITY OF COUPLINGS

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INTRODUCTION

Failures in the sucker rod industry can be costly and time consuming. As an end user in this industry, it is very critical to understand the mechanics behind couplings. This paper addresses some of the important aspects of couplings which play an important role in the overall reliability of the rod string. The following topics are addressed in this paper:

1. Strength of material analysis of coupling and sucker rods.
2. What happens to a sucker rod coupling joint during an improper make up process?
3. Types of manufacturing processes for couplings.
4. Recommended field practices.

STATIC AND DYNAMIC CONDITIONS

When a sucker rod is displaced with a coupling, there are two types of load conditions which act upon the joint:

a. Static condition of loading.
b. Dynamic condition of loading.

In the case of static condition of loading, the applied load remains a constant or does not change during the entire pumping cycle. The sucker rod pin which is displaced with a coupling is under static condition of loading. The design criteria for the static condition of loading is 85% of the deign yield of the material.

In the case of dynamic condition of loading, the applied load changes anywhere between zero to one hundred percent on the load scale depending on the location of the pumping cycle. The sucker rod body experiences dynamic condition of loading. The Modified Goodman Diagram recommends the use of T/4 equation for rod body design calculations where T is the tensile strength of the material.

Figure 1 represents the different load zones in a sucker rod coupling joint. Zone 1 represents the sucker rod stress relief or undercut section of the pin. When a sucker rod is displaced with a coupling, this section of the joint is in pure tension. The amount of stretch is typically measured using strain gages. In a properly made up condition, this section of the joint should always experience static condition of loading.

Zone 2 represents the thread engagement area between coupling and sucker rod threads. This zone or thread contact area experiences variable strain rate during a makeup process. The first thread next to the stress relief of the sucker rod pin experiences 100% static loading and the last thread at the end of the pin experiences 0% loading. Under properly made up conditions, zone 1 and 2 should experience static condition of loading. In the case of improper make up, the sucker rod pin starts to experience dynamic conditions of loading. The dynamic condition of loading makes the pin a weak link in the joint which in turn leads to pin failures.

Zone 3 represents the dynamic area in a coupling where there is no contact with sucker rod threads. This zone is in a dynamic condition of loading. The load carrying capability of this zone is given by the equation T/4 where T is the tensile strength of the material.

Figure 2 represents the load calculations of the different zones in a sucker rod coupling joint. The first calculation is the load carrying capability of sucker rod body. This is under dynamic condition of loading and is designed using the T/4 equation. Using the equation, the load carrying capability of the rod body (3/4” Class D) was 12698 lbs. The thread engagement area is under static condition of loading. The amount of preload stress in the pin is typically 85% of the design yield of the material. In the example provided in the figure, the load carrying capability of the thread engagement area was 31912 lbs. The third calculation shown in the picture represents the load carrying capability in the hollow section of the coupling. This section is in a dynamic condition of loading and is calculated using the T/4 equation. The load carrying capability of this section was 30039 lbs.

Graph 1 represents the relative strengths of sucker rods (D Rod) with the respective couplings. SH represents the load carrying capability of a slim hole coupling and FS represents the load carrying capability of full size couplings. Graph 2 represents the relative strength comparison between High Strength rods and slim hole and full size couplings. In all the scenarios listed, the coupling is the stronger link based upon design criteria and cross sectional areas.

COUPLING MANUFACTURING PROCESSES

Bar stock material is one of the methods used to manufacture couplings. The bar stock is cut to size and the center of the material is bored. After the boring process, the internal dimensions including the threads are machined. There are two common methods for threading sucker rods and couplings.

a. Roll Threads
b. Cut Threads

Steel is made up of grains and flow lines and the flow lines are in a direction parallel to the axis of the rod body. In the case of cut threads, the flow lines are getting cut and as a result the strength of the thread flanks are weaker. In the case of roll threads, the flow lines are transformed into the shape of the threads and as a result the strength of the thread flanks is stronger than cut threads.

The second type of manufacturing process is the extrusion process. This is a much more physically harsh process or in other words there are some residual stresses induced as part of the manufacturing process. The residual stresses are removed using heat treatment methods.

THEORY BEHIND OVER DISPLACEMENT AND LOSS OF DISPLACEMENT

Stress strain graph is a curve which explains the behavior of sucker rods when it is subjected to a load. The vertical axis represents stress which is load applied per unit cross sectional area. The horizontal axis represents strain which is the amount of stretch a sucker rod undergoes when it is subjected to a load. There are two distinct regions in the curve as shown in figure 3.

The elastic portion of the curve is a region where the stress is directly proportional to strain. In other words, when a sucker rod is subjected to a load in the elastic region of the curve, it does not undergo any permanent physical deformation or the load carrying capabilities are not compromised. Elastic region of the curve is a safe operating region for sucker rods.

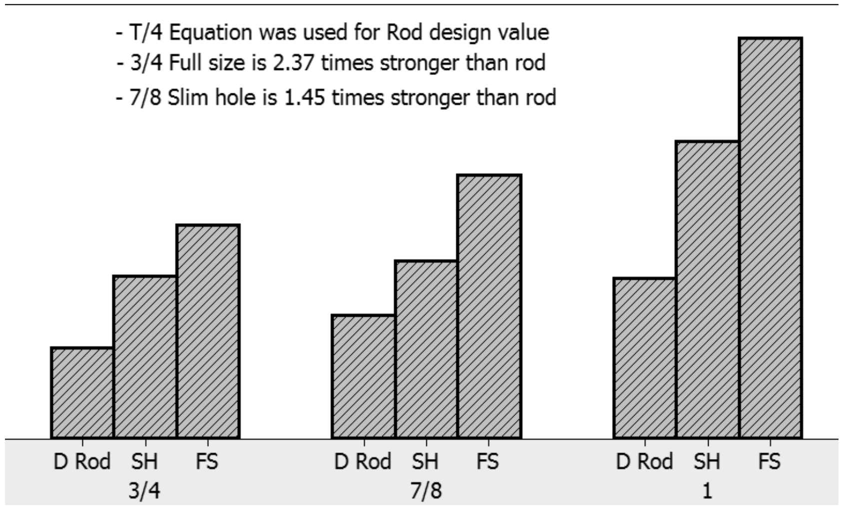
The plastic region of the curve is an area where the load applied on the sucker rod will have a detrimental effect on the rod string. All field applications and practices should be within the elastic region of the curve. In an over displaced condition, the sucker rod will be subjected to a load in the plastic region of the curve which would compromise the load carrying capabilities of a sucker rod.

Loss of displacement is a scenario where the amount of preload stress in the pin is not enough to hold the joint together. As a result, the joint breaks apart and leads to a string failure. In both these cases, it is very critical to use the manufacturer’s recommended circumferential displacement values.

CONCLUSION

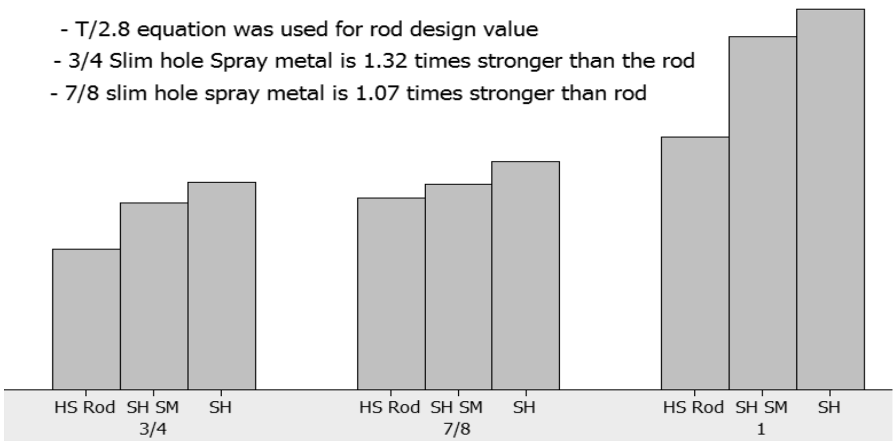
Sucker rod string reliability depends on a lot of factors. As an end user, it is very critical to understand the important reliability factors on a sucker rod string. Field failures are costly and time consuming. Awareness and education on the science behind sucker rods and couplings is the first step towards minimizing field failures.

Strength of Material Analysis for D Grade Rods.



Graph 1

Strength of Material Analysis for High Strength Grade Rods.



Graph 2

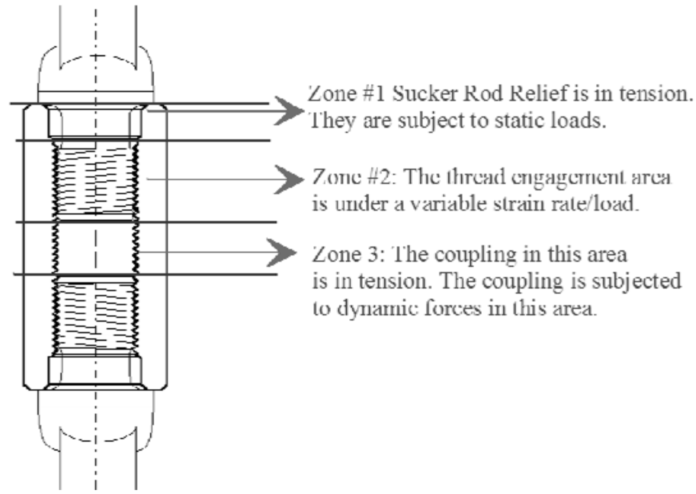


Figure 1 – Static and Dynamic conditions of loading

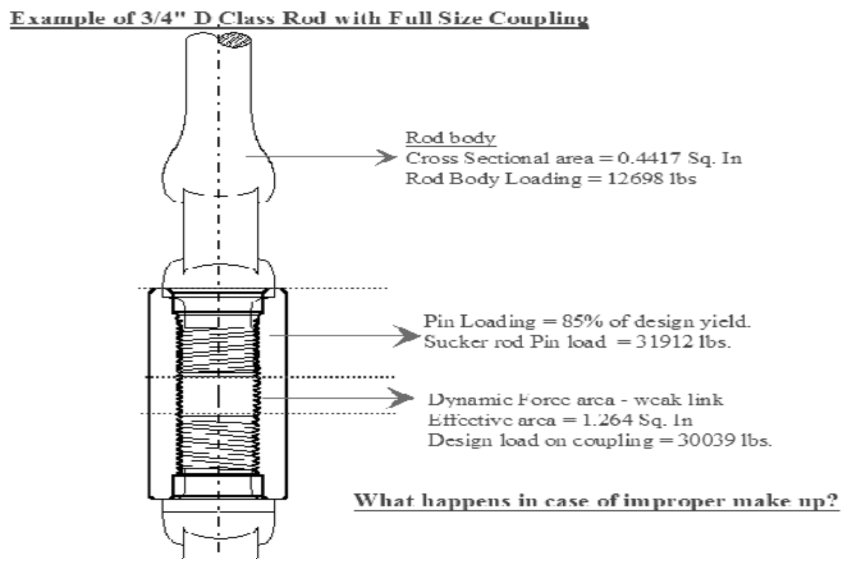


Figure 2 – Load calculations for different zones in a sucker rod Coupling Joint

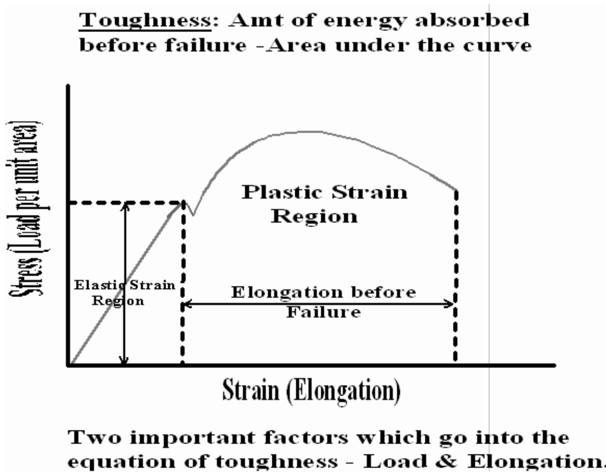


Figure 3 – Stress-Strain Curve