DEVELOPMENT, TESTING AND FIELD RESULTS OF NEW SUCKER ROD GRADE

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INTRODUCTION

There are a variety of sucker rod grades available today for different pumping environments. In order to optimize the run time of an oil well, it is very critical to choose the correct sucker rod grade for a particular application. There are a lot of physical attributes (engineering attributes) which need to be considered for design aspects of a rod string. Some of the engineering concepts are yield, tensile, load carrying capability, stress-strain curves, elongation, reduction of area and toughness. The first segment of this paper addresses these sucker rod concepts using stress-strain curves.

One of the most well known practical problems faced in the field is the selection of sucker rod grade in a high load and corrosive environment. The obvious choice becomes a KD grade sucker rod because HS (High Strength) rods due to their mechanical properties should not be used in corrosive environments. As a result of this, the end users had no choice except to overload KD rods in corrosive environments. UPCO, Inc. has developed and tested a new grade of sucker rod which can be used in higher load wells where high strength rods are not an option due to corrosive nature of the well. The second segment of this paper addresses the development of the new grade of sucker rod (SD). SD grade of sucker rods fills the application gap between KD and HS rods. SD rods have better load carrying capability than a KD rod and a better toughness than a HS rod.

BASIC THEORY

The basic theory behind sucker rods can be explained with the help of a stress-strain curve. Refer to figure 1 for an illustration of stress-strain curve. The vertical axis represents stress which is the 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 a stress strain curve. They are as follows:

a. Elastic region of the curve
b. Plastic region of the curve

In the elastic region of the curve, the amount of stress or load is directly proportional to the amount of strain or elongation. 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. All design ratings, displacement values and load calculations need to be within the elastic region of the curve. This portion of the curve can be termed as the safe operating region for sucker rods.

In the plastic region of the curve, a sucker rod will undergo a permanent physical deformation. As a result of this, the load carrying capability of the sucker rod will be comprised. The horizontal distance in the plastic region of the curve represents the stretching of a sucker rod before failure. This is one of the critical parameters to consider before choosing a particular grade of sucker rod. If the sucker rod has the ability to elongate, it means that it is less sensitive (low notch sensitivity) to physically harsh (corrosive) environments. On the other hand, if the sucker rod does not have the ability to elongate, it will be highly sensitive to physically harsh environments. The vertical height illustrated in the elastic region of the curve represents the load carrying capability of a sucker rod. The load carrying capability and stretching ability of a rod should be considered in tandem before choosing a particular grade of sucker rod.

The area under stress strain curve is called the modulus of toughness. Modulus of toughness is a combination of load carrying capability and elongation of a sucker rod and is a very key parameter in choosing a rod grade.

TOUGHNESS CURVES

An example of toughness curves for different rod grades is represented in figure 2. The horizontal width of the individual bars represents the stretching ability of a particular rod grade. The vertical height of the individual bars represents the load carrying capability. Based upon the toughness curves, sucker rod grades can be divided into 3 major categories. They are as follows:

Category 1 –API Grade C and K
This category of sucker rods has a relatively lower load carrying ability and a good stretching ability.

Category 2 – API Grade CD, AD & KD
This category of sucker rods has medium load carrying ability and medium toughness properties.

Category 3 – HS (High Strength) rods
This category of rods is represented by a long skinny bar in the toughness curve (Figure 2). This means that HS grade of rods have good load carrying capability but are not compatible with physically harsh environments.

One of the more common problems experienced in the field and reflected in the toughness curve is the application gap between a KD and HS rod. In simple words, there was no rod which had better load carrying capability than a KD rod and a better stretching ability than a HS rod. This would alleviate the problem of overloading KD rods in physically harsh environments.

DEVELOPMENT OF NEW GRADE (SD) OF SUCKER ROD

The goal of this phase of the project was to develop a rod which would give a balance between the KD and HS rods. In order to achieve this, appropriate heat treatment methods and chemical balance of the alloying elements were required. Heat treatment of sucker rods is one of the key steps to achieve the desired mechanical and toughness properties. Mechanical properties of sucker rods include yield and tensile. Toughness properties include reduction of area and elongation. The mechanical and toughness properties are inversely proportional to each other. In simple words, if the mechanical properties of a rod are higher, the toughness properties will be lower and vice versa. A right balance between the two properties had to be established in order to fulfill the functional requirements of the SD rod. The right balance was achieved through heat treatment parameters and chemistry development.

Validation

The SD rod was validated through a series of tests conducted on yield, tensile and toughness. The toughness of the rod was determined by Charpy Impact tests. The yield and tensile properties of the rod was validated through tensile testing. Table 1 illustrates the test results conducted to validate the rod. The functional requirement or goal of this grade of sucker rod is to have better load carrying capabilities than KD rods and better elongation properties than HS rods. Figure 3 illustrates this fact.

Field Tests and Results

A total of 12 test wells were configured with SD rods to study the rod performance. This paper addresses three test wells. The first well is located in Permian Basin with a pump depth of 11172 feet and slightly sour environment. The well was configured with 1.5” fiberglass rod and MTBF (Mean Time between Failures) for rod failures was 237 days. The fiberglass rods were replaced with SD sucker rods and HS (High Strength) pony rods. Table 2 illustrates the steel rods configuration. After 373 days, a 2’ HS pony rod failed due to H_2S corrosion fatigue. The HS pony rods were replaced with SD and the well has not had another rod failure since (600 days as of 1/17/2011).

Test well #2 was a similar environment (slightly sour) with a depth of 8282’. The KD sucker rods could not handle the load and high strength were not an option due to corrosion. As a result, SD rods were a good option due to its mechanical and toughness properties. Table 3 represents the rod configuration of this well. There has been no SD rod failure in two and a half years (As of 1/17/2011).

Test well #3 is a relatively new well with no prior history. The well depth is 8600’ with 8% H_2S and 7% CO_2. Table 4 represents the rod configuration of this well. SD rods were chosen in this well due to higher load and corrosive environment. The well has been operational since 1/12/2009 and there have been no rod failures (As of 1/17/2011).

CONCLUSION

Field trials and testing were conducted to verify the functional performance of SD rods. A total of thirteen test wells were configured and run with SD sucker and pony rods. SD rods were selected in these wells because of higher load and lightly corrosive environments. The overall performance of the test wells improved significantly with the application of SD rods. SD rods are 33% stronger than KD rods and 12% tougher than HS rods and as a result fill the application gap between KD and HS rods.

Table 1

Rod	Actual Tensile	Actual Yield	Charpy (FT-LBS)
KD	115 KSI	91 KSI	98.6 AVERAGE
SD	138 KSI	107 KSI	60.3 AVERAGE
HS	145 KSI	122 KSI	15.6 AVERAGE

Table 2

Rod	Quantity
1 ½” X 22, polished rod	1
1 ¾” X 14’ linear	
8’,4’,4’,2’ – 1” HS pony rods	18
1” SD rods w/ full hole couplings	115
7/8” SD rods w/ full hole couplings	122
3/4” SD rods w/ full hole couplings	168
1” SD rods w/ full hole couplings	40

Table 3

Depth	Rod
2625’	7/8 X 25 SD
2000	7/8 X 25 AD
3500	3/4 X 25 AD
100’	1 ½” X 25 Grade 1 Sinker bars

Table 4

Rod	Quantity
1 ½” X 26 polished rod	1
7/8” SD rods	136
3/4” SD rods	207
1 1/2" sinker bars	8

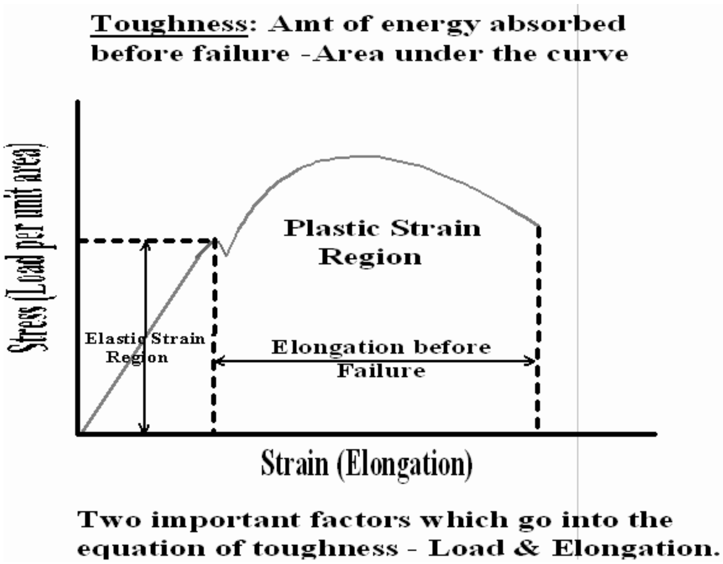

Figure 1

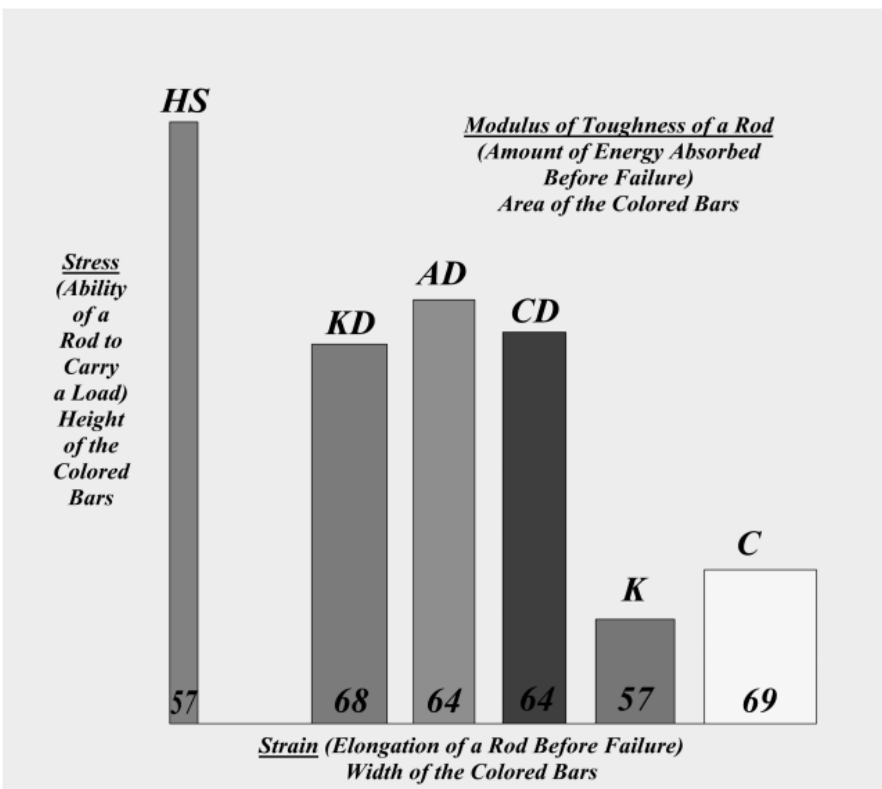

Figure 2

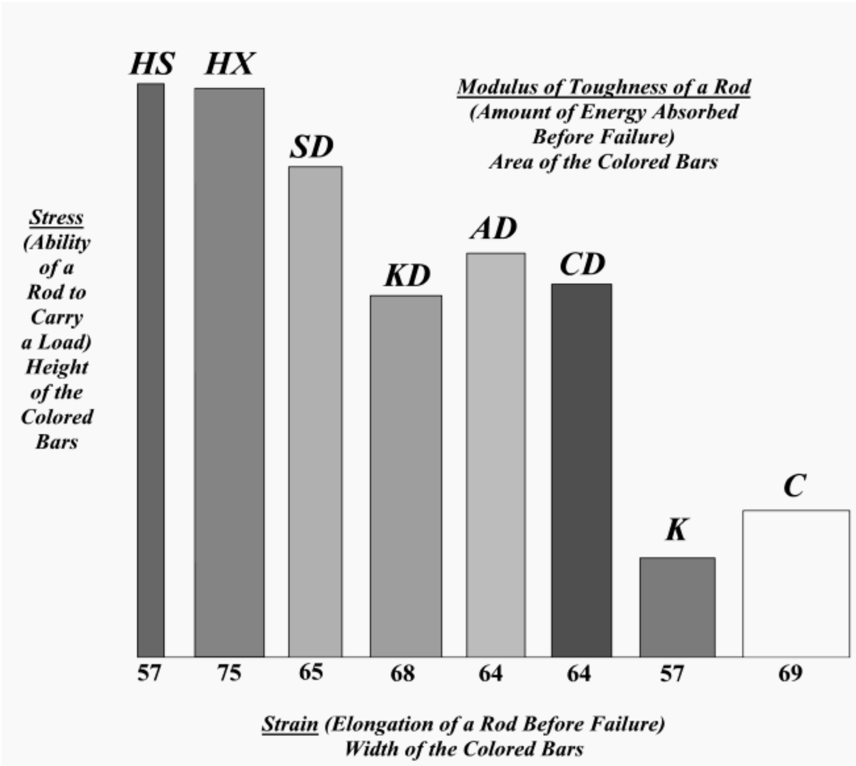
HS
HX
SD
KD
AD
CD
K
C
Modulus of Toughness of a Rod
(Amount of Energy Absorbed
Before Failure)
Area of the Colored Bars
Stress
(Ability
of a
Rod to
Carry
a Load)
Height
of the
Colored
Bars
57
75
65
68
64
64
57
69
Strain (Elongation of a Rod Before Failure)
Width of the Colored Bars

Figure 3