LUBRICANT SELECTION USING CIRCUMFERENTIAL DISPLACEMENT OF SUCKER RODS

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INTRODUCTION

Beam pumping systems are operated in challenging and hostile environments due to the ever increasing demand to produce oil in a fast and efficient manner. The goal of this project is to maximize the efficiency of these beam pumping systems by choosing the correct choice of lubricant for the sucker rod-coupling make up process.

Customer feedback indicated failures due to over, under, and loss of displacement. There have been a significant number of issues regarding the displacement values, the choice of lubricant used and other critical factors affecting the displacement values. This paper describes the testing of various thread lubricants for sucker rod-coupling make up. The project uses the core engineering concepts of stress, strain, torque, and circumferential displacement. A comprehensive engineering analysis was conducted in a laboratory using an exclusive displacement testing machine which led to the selection of the best lubricant for field application. A total of 13 tests (12 lubricants + 1 no lube) were conducted under laboratory conditions.

The current displacement values used in this industry were established back in the 1970s. Some of the critical factors which affect these displacement values are as follows:

a. Material.
b. Smoothness of surface finishes.
c. Lubricity of the lubricants.
d. Mechanical characteristics of the power tong.

Modern technology (CNC machining, quality of raw material) has improved to such a remarkable extent that the current displacement values have to be reverified. The first phase of this project is to establish a thread lubricant which produces maximum efficiency (maximum clamping force) for the sucker rod-coupling make up with the recommended API displacement values. The second phase (in process) of this project is to reverify the API recommended displacement values with the best lubricant established in the first phase.

BASIC THEORY

A. Normal and Shear Forces

To understand the sucker rod-coupling joint, refer to figure 1 (attached). There are two major forces acting on the joint:

a. Normal forces
b. Shear forces

Normal forces act in a direction parallel to the axis of the rod body. The amount of clamping force (force which keeps the sucker rod-coupling together) is directly proportional to the amount of normal forces generated in the system. As a result, this is a very desirable attribute in the make up process.

Shear forces act in a direction perpendicular to the axis of the rod body. As a result, shear forces tend to aid in the bending moment of the rod which may result in premature failure. As a result of this, the normal forces need to be maximized and shear forces need to be minimized when choosing a lubricant. The normal and shear forces (Strain) can be measured by strain gauges.

B. Stress-Strain Relationship

The most important scientific concept applied in this experiment is the stress-strain curve which can be stated as; stress is directly proportional to strain (in the elastic region of the curve).

Stress / Strain = Modulus of Elasticity.

Modulus of elasticity (Elastic modulus) can be calculated using an in-house tensile test. Strain can be measured using the strain gauges. There are two types of strain gauges used for this experiment to measure the normal and shear strain, respectively. Using these known values, the unknown factor of stress and load in the stress relief of the pin can be calculated.

DISPLACEMENT TESTING MACHINE

The test was performed using a displacement testing machine (Strain gauge testing apparatus) designed and built in-house. The machine has the torque capability to shear a 1 1/8" sucker rod pin. The normal and shear forces were measured by using strain gauges, and the torque applied on the system was captured by a load cell. The strain gauges were pasted on the stress relief of the sucker rod pin and were connected to the data acquisition system. The data acquisition system has a capability of capturing 10000 data points per second. Figures 2, 3 and 4 illustrate the strain gauges and displacement testing machine.

DISPLACEMENT TEST

The samples for testing were made as consistent as possible by choosing the same heat numbers for all sucker rod and coupling samples. The manufacturing consistency was also maintained by running all samples in the same batch and machine. The tread lubricants were applied only on the threads of the sucker rod samples, and each lubricant was tested under the following scenarios.

Subtest 1: New rod and new coupling with new run displacement values.
Subtest 2: Old rod and new coupling with re-run displacement values.
Subtest 3: Old rod and old coupling with re-run displacement values.
Subtest 4: Old rod and old coupling with re-run displacement values.

Subtest 3 and 4 are similar except in the latter subtest, the joint was made up until failure. All the computed values were averaged across the four subtests.

The sucker rod-coupling sample was made up to the recommended API displacement values and a typical output captured by the data acquisition system is given in graph 1. An output from the system will contain dynamic values/curves of torque applied, normal strain and shear strain. The graph can be typically divided into five sections for better understanding. In zone A, the torque is applied until the joint is made up to the minimum displacement value. During this period, it can be observed that the normal strain, shear strain and torque applied on the system increases from zero (hand tight level).

In zone B, the torque is relieved to zero. There is a phenomenon which can be observed where a portion of the shear forces (strain) gets converted to normal forces (strain) which is a very desirable attribute in choosing a lubricant. After this stage the joint is made up to maximum displacement position which can be seen in zone C. The maximum torque and shear strain values can be seen in this zone.

The torque is relieved to zero when the joint is at the maximum displacement value. The phenomenon where a portion of the shear forces gets converted to normal forces can be observed in this zone as well (Zone D). The joint is then relaxed to hand tight level which can be seen by the negative torque and shear strain values in zone E. The same procedure was followed for all the subtests mentioned above.

DATA ANALYSIS

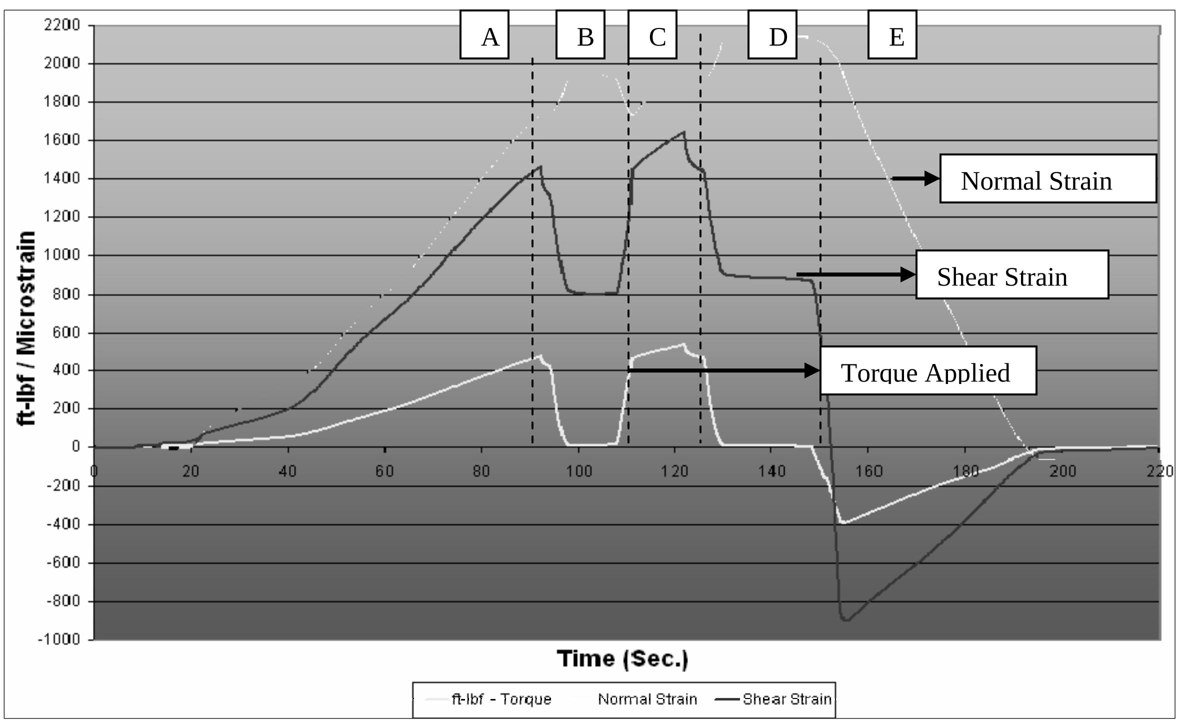
A typical output from the displacement test will have dynamic values of torque applied, shear strain and normal strain. The three outputs were used to compute eight parameters, or performance indicators, which were used to judge the performance of the individual thread lubricant. The thread lubricants were ranked in accordance with these performance indicators and a list of good, medium and low performing lubricants was developed. Table 1 gives the comprehensive ranking list for all the thread lubricants with their generic classification.

CONCLUSION

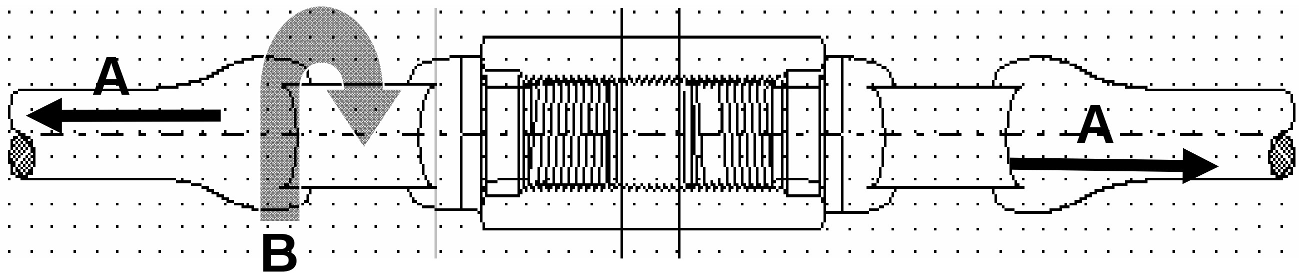
The studies indicated that high pressure lubricants performed better than low pressure lubricants for the field application of sucker rod-coupling make up. The correct choice of thread lubricant can enhance the load carrying capabilities of the rod string up to 40 %. Refer to table 1 for the final performance rankings for all the thread lubricants tested. It can be observed that “No lubricant” (Ranked 13) performed the worst which in itself is a validation for this project.

Table 1
Ranking of all thread lubricants

Name of Lubricant	Overall Ranking Index	Classification
Lube 1	31	High Pressure – Molybdenum/Aluminum
Lube 2	33	High Pressure – Lithium, Al, Zn, Moly & Titanium
Lube 3	47	Proprietary
Lube 4	48	High Pressure – Lead, Zinc, Copper
Lube 5	48	Low Pressure
Lube 6	50	Low Pressure
Lube 7	51	High Pressure - Molybdenum/Aluminum
Lube 8	57	Low Pressure
Lube 9	59	Low Pressure
Lube 10	68	Low Pressure – Lithium Based
Lube 11	69	Low Pressure/High Temp – Lithium
Lube 12	70	Low Pressure – Lithium Based
No Lubricant	93	None



Graph 1 - Typical Output from a Displacement Test



A – Normal Forces
B – Shear Forces

Figure 1

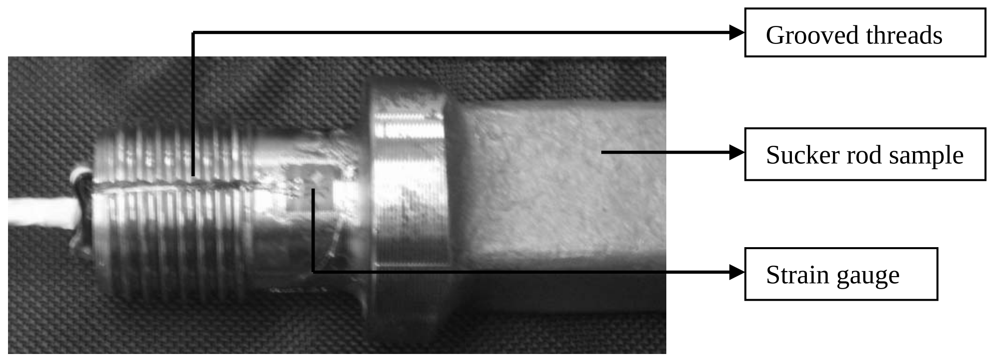


Figure 2 - Strain Gauge Pasted on the Stress Relief of the Sucker Rod Pin

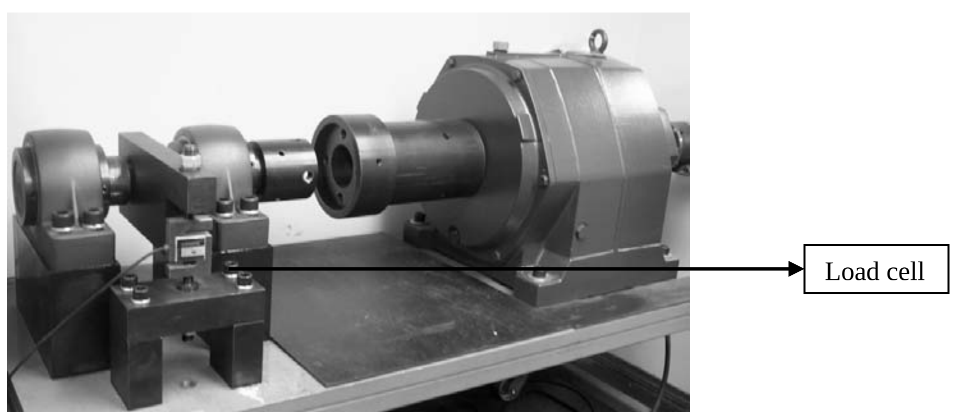


Figure 3 - Displacement Testing Machine with the Load Cell

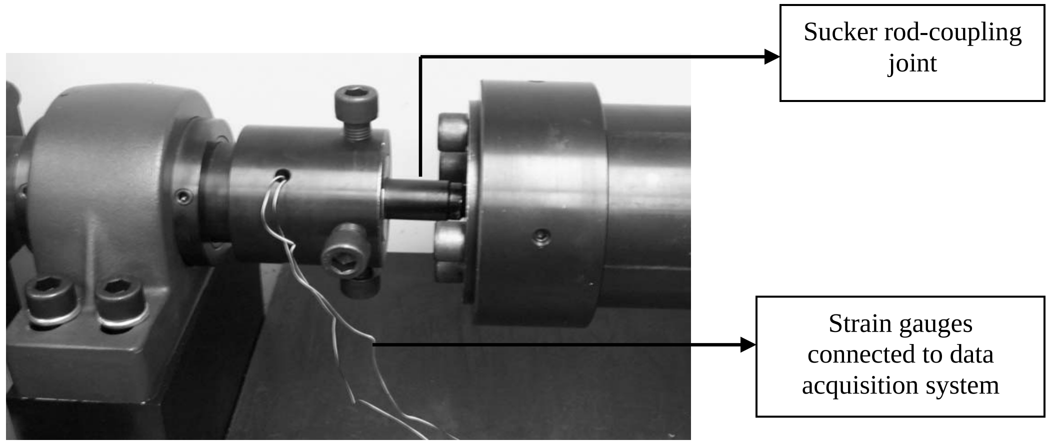


Figure 4 - Sample With Strain Gauges Connected to the Data Acquisition System