THE EFFECTIVE OF PROPERLY SHOT PEENING SUCKER RODS AND EFFECT ON FATIGUE LIFE

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ABSTRACT
Shot peening has long been used in many applications to provide increased fatigue performance. This paper will provide a short summary of surface treating processes including details related to shot peening. Additionally, presented is information related to special process controls developed by a sucker rod manufacturer and trade marked “NOR-PEENING.”® Four point bending fatigue tests conducted by Tulsa University on unpeened and properly peened pony rod samples of a special, high strength rod grade will be provided. Furthermore, the implication and application of these test data to the expected sucker rod performance and Modified Goodman Allowable Stress Diagram will be discussed.

INTRODUCTION

There are a variety of special processes that can be applied to steel sucker rods during manufacturing. Some of these may increase strength; some may increase hardness and/or wear resistance, while some may be for corrosion resistance. Typically, no matter which process is applied, the sucker rods need to be properly cleaned and scale free for the processes to be effective.

Abrasive blasting has been used for many surface application methods to clean the surface of the material. Standards have been developed to determine how effectively the blasting has been done to clean a material. The process typically involves compressed air and a special gun that is used to shoot various types of abrasive media at the object being cleaned or blasted.

Depending on the system pressure, the media type along with the size and distribution of the blasting particles, the method is effective for removing scale, rust, paint, and minor surface flaws. Also the process can provide a clean, uncontaminated, rough surface finish for better adherence of surface coatings. The media that is typically used for abrasive blasting includes: aluminum oxide (as grit or shot), silicon dioxide (sand), iron or steel grit (as shot or grit), glass beads, and pumice. The media particles are typically hard, sharp and friable. Additionally, the media normally is reused or recycled without filtering. Normally, the specific type of blasting is dependent on the grit type, for example, shot blasting, sand blasting, Figure 1 shows a typical sand blasting process with necessary personal protective equipment worn by the operator.

SHOT PEENING

Shot peening is a manufacturing process that cold works the surface of a metal to improve its properties. Originally peening by mechanical means such as a hammer blows (peening hammer).While this method worked to improve the material properties it was slow. Currently, similar or better properties are improved by blasting a material with shot.

This process is similar to media blasting in that compressed air and a gun are used to focus the steel shot. However, the shot is normally has a distribution of shot size and the shot media is filtered to remove very fine particles and any surface scale. When properly applied, peening:

- Induces local compressive stresses,
- Relieves tensile (residual) stresses already present,
- Increases hardness and strength,
- Increases fatigue life, and
- May increase corrosion resistance.

Peening and cold working have been used effectively for centuries. Peening changes the surface microstructure or grains by deforming the local area. The deformation is very shallow, typically <0.005" to 0.020" deep. Normally, the deeper the deformations, the better the resulting material performance.

There are other surface treatments that could be applied to a material (typically steel). These surface techniques include:

- Induction hardening,
- Carburizing,
- Nitriding,
- Cyaniding, and
- Carbonitriding.

Shot peening is different than media blasting since it requires control over a consistent size and shape of shot media. The media must be conveyed by the compressed air with a consistent velocity and volume of shot striking the surface area. There must be a consistent length of time for exposure and area of coverage in order for the shot peening process to impart the benefits. While surface cleaning also may occur during peening, the angle of impact to the base material is more normal to the surface. As such, surface scale should be reduced as much as possible from the other processing during forging and heat treating sucker rods. When all of these factors are properly controlled the consistent, reperatable material properties will result.

SHOT PEENING PROCESS

The basis for the cold working and deformation from shot peening is shown in Figure 2. This shows an individual shot particle striking the surface of the base material. This results in a small, rounded depression . Plastic flow and radial stretching of the surface metal occur at the instant of contact. When this occurs, the edges of the depression ris slightly above the original surface.

The material beneath this compresses layer is not deformed, but the fiber try to restore the surface to the orignial shape. The induced tensile stress develop to achieve an equilibrium. The magnitude of the stresses varies. However, these compressive stresses normally are equal to one-half of the material yield strngth.

Subsequently, as other shot hits the surface, the edges of the depression are compressed and each shot particle that hist in the area further deforms and overlaps the depressions. This results in the surface area "completely" covered with uniform residual stresses that improve the base materials/sucker rod properties.

PROCESS CONTROLS

There are two main tests conducted to assure the shot peening is effective. These include the use of an Almen strip and visually checking the coverage area.

Almen strips are used to measue the intensity of the shot peening process. The test method and testing strips are controlled by ASTM procedures. Figure 3 shows a shematic of the steps involved in conducting the test. An Almen strip of appropriate thickness and hardness is selected and secured to the gauge block or Almen strip holder (as shown in Figure 4). This block is processed through the peening procedures. After peening, the strip is removed and the resulting defliction caused by the peening is measured. This deflection is compared to the required deflection to determine the intensity of the process.

The coverage area test is defined as the percent of the surface area obliterated by the indentations. Coverage can only be determined by visual inspection of the surface at 10 to 30X magnification. The amount of the deformed area is compared to visual indication standards. Figure 5 and 6 show two difference strips with not acceptable and acceptable coverage area, respectively. A special process that controls not only the shot peening procedures but also controls the other detrimental surface scaling processes during sucker rod manufacture was issued a registered trademark. This trademark for one sucker rod manufacture is called "NOR-PEENING®."

BENEFITS FOR PEENING ON SUCKER ROD FATIGUE PERFORMANCE

Shot peening has been proven to be beneficial to increase fatigue life for most materials. However, the effectiveness for sucker rod fatigue performance had to be established. The University of Tulsa performed a bending fatigue study on the life cycles of an AISI A 4330M – Nickel, Chromium, and Molybdenum special alloy rod. A variety of 1" diameter sucker rods that were non-peened or properly Nor-peened® were fatigued in their test machine. This machine was designed to test 2' (0.61m) pony rods in pure bending fatigue from four-point loading, to failure.

Table I and II show the results of the load or stress applied and the resulting fatigue life/cycles to failure. Additionally the numbers of pony rod samples tested at the given load/stress are shown in the tables. A resulting fatigue curve for the properly Nor-peened® and non-peened test results are shown in Figure 7. This fatigue life graph shows the tremendous performance improvement from applying the special trademarked process.

The tabular data for the properly shot peened rods showed a "run-out" test result when the sample was loaded to 63.56 KSI or approximately (63.56/140=) ~45% of the minimum tensile strength for this special grade of sucker rod. The sample lasted for over ~21.7 million cycles without fatigue failure. The normal convention for fatigue testing is to apply one log cycle or multiply the run-out cycle rate by 10 to obtain the

CONCLUSIONS and RECOMMENDATIONS

1. Shot peening is a special surface treating process that has been used effectively to increase fatigue life.
2. However, to be effective, it has to be properly applied.
3. One sucker rod manufacturer has developed special control features (Nor-peening®) has shown dramatic fatigue life increase.
4. However, subsequent damage to this surface will eradicate the benefits from conducting the special shot peening process.

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Table I
Bend Fatigue Results For Non-Peened Rods

NON-SHOT PEENED TEST RESULTS			
Force	*Stress Amplitude*	*Number of Test*	*Average Life Cycles*
90 lbs	89.64 ksi	2	27,515
80 lbs	83.12 ksi	2	50,782
70 lbs	76.60 ksi	3	114,787
60 lbs	70.08 ksi	5	170,005
50 lbs	63.56 ksi	6	139,482

Table II
Bend Fatigue Results For Nor-Peened® Rods

NOR-PEENED TEST RESULTS				Percent Increase
Force	*Stress Amplitude*	*Number of Test*	*Average Life Cycles*	
90 lbs	89.64 ksi	2	62,946	129%
80 lbs	83.12 ksi	2	164,748	224%
70 lbs	76.60 ksi	3	498,713	334%
60 lbs	70.08 ksi	3	7,702,305	4,431%
50 lbs	63.56 ksi	1	21,696,977 (NO FAILURE)	INFINITE

Figure 1- Sand Blasting Used for Cleaning

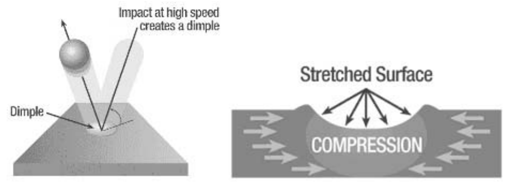

Figure 2 - Shot Peening Basics

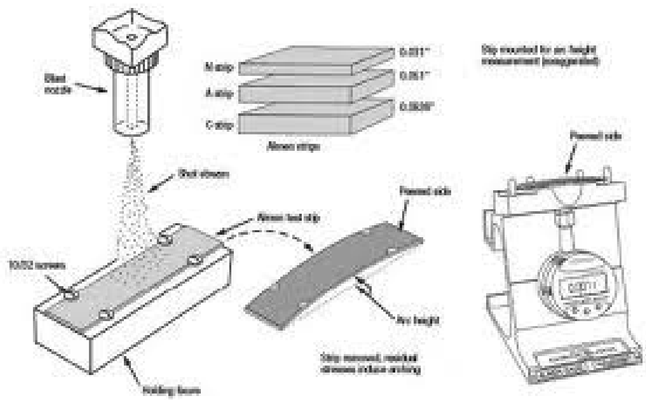

Figure 3 - Almen Strip Testing Basics

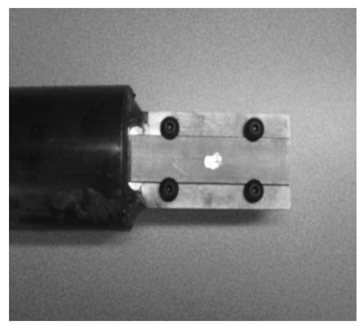

Figure 4 - Almen Strip Holder

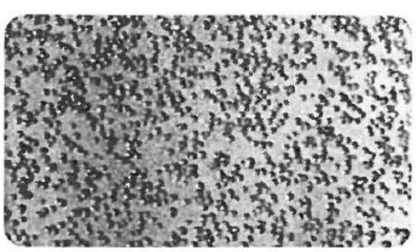

Figure 5 - Partial Peening Coverage

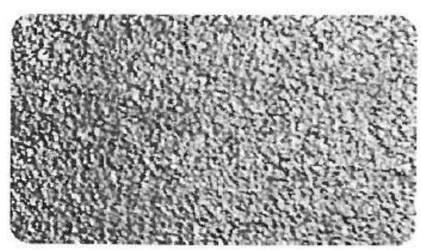

Figure 6 - Acceptable Peening Coverage

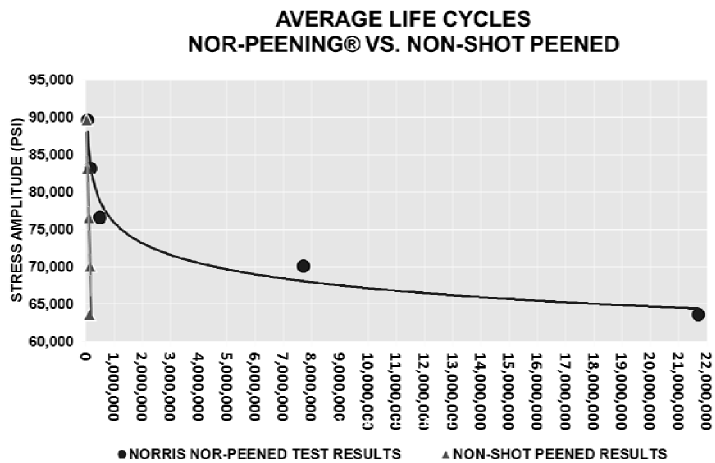

Figure 7 - Stress Fatigue Cycle Graph Two Different Conditioned Rods