NOR-PEENING®

Value-Added Technology from Apergy

NOR-PEENING® is value-added technology provided by Apergy on every newly manufactured Sucker Rod, Pony Rod and Drive Rod® from the Norris plant in Tulsa and the Alberta Oil Tool plant in Edmonton. NOR-PEENING® is a carefully controlled and monitored process that relies on the precise selection and control of the shot peening media, intensity, coverage and equipment for a surface enhancement treatment that minimizes sensitivity to fatigue and stress corrosion failures. This results in improved product performance and increased service life in all your downhole operating environments.

Benefits obtained from NOR-PEENING include improvements in:

- Fatigue life (axial, bending, and torsional)
- Fatigue strength (partially offsets the effects of decarburization)
- Corrosion tolerance (hydrogen assisted cracking, intergranular, stress corrosion cracking)
- Notch sensitivity (pitting)

NOR-PEENING® is a method of bombarding the surface of the rod with thousands of small, uniform, steel spheres called shot. The intensity and coverage of the peening media must be effective enough to uniformly cover the entire surface of the rod. Each piece of shot striking the rod acts as a tiny "peening" hammer and has the effect of work-hardening the outer surface of the rod with a very thin, uniform surface layer that is in permanent compression. The residual compressive stress induced by NOR-PEENING® is a percent of the ultimate tensile strength of the steel, and this percentage increases as the strength/hardness of the rod increases. (The magnitude of residual compressive stress produced by NOR-PEENING® is thought to be possibly as great as half the ultimate tensile strength of the steel.)

The compressive stress generated from NOR-PEENING® offsets or lowers the applied tensile stress and it is the depth of the compressive layer that resists and retards crack growth. Since nearly all fatigue and stress corrosion failures originate at or near the surface of the rod due to tensile stress, and since the primary failure mode for nearly all rod body failures involves some form of fatigue (i.e., stress fatigue, stress corrosion fatigue, unidirectional bending fatigue, torsional fatigue, etc.), the compressive stresses induced on the outer surface layers by NOR-PEENING® should provide a significant increase in service life. Shot-peening (NOR-PEENING®) is not a new concept and is a widely accepted engineering principle that has been successfully applied to a vast array of products designed for fatigue applications in both the aerospace and automotive industries.

Decarburization is the reduction in surface carbon content of a ferrous alloy during thermal processing in a medium that reacts with carbon. Unless special precautions are taken, the risk of losing carbon from the surface of steel is always present in any thermal processing system utilizing temperatures above 1,290 °F (700 °C) in an oxidizing atmosphere. (Decarburization is typically most severe when steel is heated to temperatures above 1,670 °F (910 °C).) The effect of decarburization is much greater on high-tensile strength steels than on steels with a low tensile strength. It has been shown that decarburization can reduce the fatigue strength of high strength steels, in the same category as the special sucker rod grades of Type 96 and Type 97, by as much as 45 – 55%. Shot peening (NOR-PEENING®) has proven to be effective in restoring most, if not all, fatigue strength lost due to decarburization.
The University of Tulsa performed a study on life cycle rates of AISI A-4330-M Nickel-Chromium-Molybdenum Alloy Steel both with and without NOR-PEENING®. The Mechanical Engineering Department tested newly manufactured 3/4” (19.05 mm) Norris Type 97 Pony Rods on a rotating-bending fatigue test machine. The machine was designed to test 2’ (0.61 m) pony rods in pure bending, from four-point loading, to failure. (A four-point rotating-bending fatigue machine gives a constant bending moment over the entire test-section of the specimen; thus allowing the test specimen to have a test-section of constant diameter.) Table 1 shows that the NOR-PEENING® process resulted in 129% increase in test sample life at a stress amplitude of 89.64 ksi (618 MPa), and a 4,431% increase in test sample life at 70.08 ksi (483 MPa). Moreover, when a lower stress of 63.56 KSI (438 MPa) was applied, the sample did not fail after over 21 million cycles, reflecting a potentially infinite life.

NASA performed a study on crack growth rates of 2024-T3 aluminum with and without shot peening. Engineers tested samples with an initial crack of 0.050” (1.27 mm) and then cycle tested the samples to failure. (An initial crack of 0.050” (1.27 mm) was chosen because that is the USAF damage tolerance for a rogue flaw.) NASA confirmed that crack growth rates were significantly delayed when the samples were properly shot peened. As evidenced by the results in Table 2, at a 15 ksi (104 MPa) net stress condition the remaining life of the test samples increased by 237% and at a 20 ksi (138 MPa) net stress condition the remaining life of the test samples increased by 81% when properly shot peened. The NASA study concerning crack growth rates for aluminum reflect test conditions that are harsher than those expected for new Sucker Rods, Pony rods and/or Drive Rods®, since newly manufactured products wouldn’t be expected to have flaws and since API Specification 11B limits transverse critical flaw size to 0.004”.

For more information please contact your Norris Representative.

<table>
<thead>
<tr>
<th>Force</th>
<th>Stress Amplitude</th>
<th>Number of Tests</th>
<th>Average Life Cycles</th>
<th>Force</th>
<th>Stress Amplitude</th>
<th>Number of Tests</th>
<th>Average Life Cycles</th>
<th>Percent Increase</th>
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<tbody>
<tr>
<td>90 lbs</td>
<td>89.64 ksi</td>
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<td>27,515</td>
<td>90 lbs</td>
<td>89.64 ksi</td>
<td>2</td>
<td>62,946</td>
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<td>80 lbs</td>
<td>83.12 ksi</td>
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<td>83.12 ksi</td>
<td>2</td>
<td>164,748</td>
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<tr>
<td>70 lbs</td>
<td>76.60 ksi</td>
<td>3</td>
<td>114,787</td>
<td>70 lbs</td>
<td>76.60 ksi</td>
<td>3</td>
<td>498,173</td>
<td>334%</td>
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<td>60 lbs</td>
<td>70.08 ksi</td>
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<td>170,005</td>
<td>60 lbs</td>
<td>70.08 ksi</td>
<td>3</td>
<td>7,702,305</td>
<td>4,431%</td>
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<tr>
<td>50 lbs</td>
<td>63.56 ksi</td>
<td>6</td>
<td>139,482</td>
<td>50 lbs</td>
<td>63.56 ksi</td>
<td>1</td>
<td>21,696,977 (no failure)</td>
<td>Infinite</td>
</tr>
</tbody>
</table>

Note: Notches were placed in the surface via the EDM process. These samples were loaded in fatigue until the crack grew to 0.050” (1.27 mm) and, if the test sample was shot peened, it was peened after the initial crack of 0.050” (1.27 mm) was generated.1

NOR-PEENING®

A Look At Fatigue Life Benefits

NOR-PEENING® is value-added technology provided by Apergy on every sucker rod, pony rod and Drive Rod manufactured at the Norris plant in Tulsa, Oklahoma and the Alberta Oil Tool plant in Edmonton, Alberta. NOR-PEENING® is a carefully controlled and monitored process that relies on the precise selection and control of the shot peening media, intensity, coverage and equipment for a surface enhancement treatment that minimizes sensitivity to fatigue and stress corrosion failures. This results in improved product performance and increased service life in all your downhole operating environments.

Extensive testing was undertaken to verify that NOR-PEENING® of sucker rods increases rod fatigue life. The tests were conducted on three pieces of equipment, placing the rods under both rotary and reciprocating conditions to collect the data for two studies. The fatigue life of Norris Grade 96 rods taken from the same manufacturing batch, half of which went through the NOR-PEENING® process and the other half of which did not, was compared. As can be seen in the graph, the rods which underwent NOR-PEENING® had a fatigue life that was up to 8 times higher, dependent on load, than the untreated rods.

Norris rods and those of thirteen competing grades were then tested at various load levels. The results of the tests were used to create graphs of the rods’ lifecycle performance at given loads, called S-N curves. The results of the tests conducted at 40% of a given rods’ tensile strength can be seen in the graph to the right, and the fatigue life benefit of NOR-PEENING® is readily apparent, with the Norris rods far outlasting even the closest competitor.
This fatigue life benefit is not unique to a single load level. By running a large number of tests on each grade of rod at multiple load levels and plotting the results on log-log coordinates, a rod’s fatigue life at any given loading becomes apparent. As shown in the S-N curves, NOR-PEENING® improves performance across the full range of loads.

The NOR-PEENING® process generates compressive stress in the surface of the rod which offsets or lowers the applied tensile stress and resists and retards crack growth. Since nearly all fatigue and stress corrosion failures originate at or near the surface of the rod due to tensile stress, and since the primary failure mode for nearly all rod body failures involves some form of fatigue (i.e., stress fatigue, stress corrosion fatigue, unidirectional bending fatigue, torsional fatigue, etc.), the compressive stresses induced on the outer surface layers by NOR-PEENING® should provide a significant increase in service life.

Norris’ NOR-PEENING® process give you the confidence of knowing that your sucker rods will enjoy improved performance and increased service life in your downhole environments.

*For more information on the testing performed as well as the complete test results, please contact your Norris sales representative and ask for the Effects of Shot Peening on Sucker Rod Fatigue Life.*
Because the majority of failures of sucker rods are caused by fatigue, all grades of Norris Sucker, Drive Rods® and Pony Rods now include the Nor-Peening® value-added technology. Nor-Peening® is a surface treatment that work hardens the outside layer of the metal to produce a rod that has a higher fatigue life, fatigue strength, corrosion tolerance and reduced notch sensitivity than before Nor-Peening®. Nor-Peening® is based on the practice of shot peening, which is a process that has been used for many years in the automotive and aerospace industry but has only recently adapted to sucker rods.

The benefits of shot peening and similar processes in the automotive and aerospace industries have been well documented, but the effect that this process has on sucker rods has only recently been studied. In 1997, the University of Tulsa’s Mechanical Engineering Department performed a series of tests on Peened and un-peened Norris Grade 97 pony rods. For these tests, an industry standard four-point bending rotary fatigue test was adapted to run pony rods until fatigue failure. This testing revealed that when the peened and un-peened rods were subjected to the same loading, the peened rods experienced a significant increase in fatigue life for various stress levels. These tests were then replicated by Norris using Grade 96 Pony Rods which yielded similar results for peened and un-peened rods, which confirmed that Nor-Peening® has a drastic increase fatigue life.

Further testing by Norris has shown that the Nor-Peening® process is effective for increasing the fatigue life for the Grade 97, 96, and 78 Norris rods. These three grades of rods where tested against competitor rods where the rods where subjected to a bending stress that is equivalent to approximately 40% of the rod’s Ultimate Tensile Strength (UTS). When comparing the high strength rods, the Grade 96 rods saw a 66% increase and the Grade 97 saw a 75% increase in fatigue life over the next closest competitor rod. The results for the high strength rods are summarized in the following figure.

![High Strength Rod Performance at 40% UTS](image-url)
When comparing the API Grade D rods, the Norris Grade 78 rod saw a 250% increase in its fatigue life when compared to the next closest competitor. The results for the API Grade D rods are summarized in the following figure.

Norris continues to test all grades of Sucker Rods, Drive Rods® and Pony Rods with the goal of maximizing the life of the rods. This continues Norris’ commitment to providing the highest quality product on the market.

*For more information please contact your Norris sales representative.*
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