Sucker Rod String Service Factors

Norman W. Hein, Jr., P.E., President & Managing Director, Oil & Gas Optimization Specialists, Ltd. (OGOS)

and

Russell Stevens, Manager – Technical Services, Norris
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• Background on Goodman Fatigue Diagram
• Development of API Modified Goodman Diagram
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Original Goodman Diagram (1926)
Hein & Hermanson, SPE 26558, 1993

• Provided brief history of industry efforts to modify Goodman diagram for sucker rod use

• API Task Group met in the Mayo Hotel, Tulsa, OK, in early 1960’s

• Y-intercept have safety factor of 2 reducing max to the tensile strength (T) divided by 4

• Much discussions on the apex reduction
  – Ranges of T/ 1.5 to 2
  – Resolved arithmetical average of T/1.75

• Assumed 10 million cycles fatigue life in non-corrosive environment
Resulting API RP 11BR – Modified Goodman Diagram (MGD)

![Diagram showing the Goodman diagram with equations and annotations.]

\[ S_a = \left( T + M S_{\text{min}} \right) SF \]
\[ S_a = \left( 0.25T + 0.5625 S_{\text{min}} \right) SF \]
\[ \Delta S_a = S_a - S_{\text{min}} \]

where
- \( S_a \) = maximum available stress, psi (N/mm²)
- \( \Delta S_a \) = maximum allowable range of stress, psi (N/mm²)
- \( M \) = slope of \( S_a \) curve = 0.6625
- \( S_{\text{min}} \) = minimum stress, psi (N/mm²) (calculated or measured)
- SF = service factor
- \( T \) = minimum tensile strength, psi (N/mm²)
Pk Load = 17900 lbs. Stress = 29768 psi

Min Load = 9100 lbs. Stress = 15141 psi
Modified Goodman Diagram for Grade “D” Rods, T = 115,000 psi

Rod Loading = \( \frac{29768 - 15141}{37267 - 15141} \)

= 66%

\[ S_a = \left( \frac{T}{4} + 0.5625(S_{min}) \right)(SF) \]

= 37267 psi

\[ S_{min} = 15141 \text{ psi} \]

Pk Stress = 29768 psi
Service Factor (SF)

- API RP 11BR MGD Allowable stress formula:
  \[ Sa = \left( \frac{T}{4} \right) + 0.5625 \times S_{\text{min}} \times SF \]

- Paragraph 4.1 states:
  - “Since all well fluids are corrosive to some degree, if not 100% inhibited, and since the corrosivity of well fluids vary greatly, it is of extreme importance that the stress values determined from this diagram be adjusted by an appropriate service factor, based on the severity of the corrosion.”
  - “This service factor should be selected by each user as his experience indicates.”
  - “It could be greater than one, although normally it will be less than one, varying with severity of corrosion.”

![Fatigue Curves Diagram with Stress vs. Number of Cycles to Failure](image-url)
Usage Example with SF Applied:
Grade “D” Rods, $T = 115,000$ psi & $SF = 0.8$

Rod Loading = \( \frac{29768 - 15141}{29814 - 15141} \)

= 99.7%

\[ S_{min} = 15141 \text{ psi} \]

\[ S_{a} = \left( \frac{T}{4} + 0.5625(S_{min}) \right)(0.8) \]

= 29814 psi

\[ Pk \text{ Stress} = 29768 \text{ psi} \]
So, is there a problem?

• By applying the SF, the allowable rod string stress may be exceeded.

• This overload would be treated by:
  – Using more expensive, higher grade rods, OR
  – Using a larger Rod String taper

• In either case, this will cost more money not only the first time, but all future expenditures for replacement rods

• Also, the larger rod string taper will probably require a larger, more expensive pumping unit too
Texas Tech University – Fatigue Testing for Amerada Hess
# Recommendations from Permian Basin Operator

<table>
<thead>
<tr>
<th>SERVICE</th>
<th>API-C (default)</th>
<th>API-D (default)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NON-CORROSIVE</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>SALT WATER</td>
<td>.65</td>
<td>.9</td>
</tr>
<tr>
<td>HYDROGEN SULPHIDE</td>
<td>.50</td>
<td>.70</td>
</tr>
</tbody>
</table>

Permian*:
- Using C grade rods to SF of 1.35 before using D rods
- Using D rods to SF of 1.35 before going to high strength rods
- Inhibit
- Do not use case hardened rods

*from failure control in rod pump wells, SWPSC
Other Factors to Consider

- Reduction in allowable stress is slim hole couplings are used
- Reduction in allowable stress if used, inspected sucker rods are re-used
Fatigue strength, $S$

Gerber's parabola

Modified Goodman line

Tensile strength, $S_\text{u}$

Soderberg line

Static yield strength, $S_\text{y}$

Mean stress, $S_\text{m}$

Alternating stress, $S_\text{a}$
Conclusions & Recommendations

• The API Modified Goodman Diagram (MGD) is very conservative, originally based on compromise and WAG
• Many factors affect the fatigue life of sucker rods
• Corrosion inhibition is required for long life not only of the sucker rod string; but, surface flow lines and processing equipment, the tubing, pump and, most importantly, the downhole casing
• Since an adequate and effective corrosion inhibition program is required, applying the API RP 11BR M G D Service Factor with a value less than 1.0 adds more unnecessary conservatism
Conclusions & Recommendations (con’t)

• While some operators may apply a SF greater than 1.0 for the rod string design, this practice usually cannot be supported by sucker rod manufacturers due to implied warranty (do it at your own risk)

• Other factors such as use of slim hole couplings and rerunning used sucker rods should require the application of a SF but, most SRL well designers do not use them probably because most design computer programs do not include this information
• A joint industry program should be considered to conduct fatigue tests on coupled rods, applying current day understanding of fatigue and the factors that effect fatigue life, in order to ultimately change the MGD for rod string design
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Sucker Rod String Service Factors

Norman W. Hein, Jr., P.E.,
nwhein@prodigy.net; 432.694.3678
and
Russell Stevens,
rstevens@norrisrods.com; 432.561.8101