TECHNICAL BULLETIN

ENDLESS ROD | LS-TB-027

LIFTING SOLUTIONS

BULLETIN	TOPIC	ISSUE DATE	ISSUED BY
LS-TB-027 V1	ENDLESS ROD PROPERTIES	OCTOBER 18, 2021	ENGINEERING

BACKGROUND:

To design an Endless rod string for PCP applications providing a reliable pumping operation for an extended period and considering that most rod breaks comprise of a fatigue mechanism with contributions from corrosion, the design of the rod string must consider the cyclic nature of the rod loading and the appropriate fatigue life or endurance limit of the material. Available endless rod design models calculate rod stress based on the well-known Goodman methodology.

The criteria for determining the mechanical and chemical characteristics required for an Endless rod application should consider properties related to fatigue life or fatigue endurance limit (ultimate tensile strength and toughness) and properties related to corrosion resistance (chemical composition and hardness).

This technical bulletin attempts to present the primary chemical and mechanical properties of Endless rod grades and outline considerations about the optimization of fatigue life and corrosion resistance.

ER CHEMICAL PROPERTIES

The chemical properties associated with alloying elements of steel for the different grades offered by Lifting Solutions are presented in Table 1.

AISI SERIES	STRENGTH	GRADE	CHEMICAL PROPERTIES (MIN - MAX) (%)									
			C	Mn	Si	Ni	Cr	Mo	Al	Ti	Cu	V
1537M	REGULAR	D	0.32 - 0.36	1.20 - 1.50	0.15 - 0.35	0.20 Max	0.10 - 0.20	0.040 Max	0.02 - 0.05	-	0.25 Max	-
1537M	HIGH	DS	0.32 - 0.36	1.20 - 1.50	0.15 - 0.35	0.20 Max	0.10 - 0.20	0.040 Max	0.02 - 0.05	-	0.25 Max	-
4119M	REGULAR	CD	0.18 - 0.21	0.30 - 0.50	0.15 - 0.35	0.20 Max	1.70 - 1.90	0.15 - 0.25	0.02 - 0.05	0.005 - 0.020	0.20 - 0.30	-
4119M	HIGH	CS	0.18 - 0.21	0.30 - 0.50	0.15 - 0.35	0.20 Max	1.70 - 1.90	0.15 - 0.25	0.02 - 0.05	0.005 - 0.020	0.20 - 0.30	-
4318M	REGULAR	ND	0.17 - 0.20	0.55 - 0.75	0.15 - 0.35	1.00 - 1.20	0.80 - 1.00	0.25 - 0.30	0.02 - 0.05	0.005 - 0.020	0.20 - 0.30	-
4318M	HIGH	NS	0.17 - 0.20	0.55 - 0.75	0.15 - 0.35	1.00 - 1.20	0.80 - 1.00	0.25 - 0.30	0.02 - 0.05	0.005 - 0.020	0.20 - 0.30	-

Table 1: Alloying Elements of Lifting Solutions Endless Rod Grades. *All grades P (max 0.015%). S (max 0.010%)

Each alloying element has a specific effect on the properties of the finished steel. Carbon (C) is the most important alloying element in steel. It increases strength and hardness. Manganese (Mn) and Molybdenum (Mo) are supplemental alloying elements that increase strength and hardness and intensify the effect of other alloying elements. Chromium (Cr) and Nickel (Ni) increase the strength, hardness, toughness and play a primary role in increasing the corrosion resistance. Titanium (Ti) and Phosphorus (P) in minimal amounts can increase strength but decrease toughness ductility; if present in large amounts, inclusions can be formed. Silicon (Si)

and Aluminum (Al) in minimal amounts serve as deoxidizers and grain refining. In general terms, the trade-off of the alloying elements increasing strength and hardness is related to lowering the ductility and toughness.

ER MECHANICAL PROPERTIES

In general, all Endless rod products are quenched and tempered. This continuous process typically delivers a tempered martensite microstructure in steel. Adjustable process parameters depending on mechanical strength requirements can produce high strength grades (max 36HRC) and low/regular strength grades (max 30HRC). Theoretical considerations related to hardness values and corrosion resistance have been established, showing that under ideal conditions steels with higher hardness have a greater susceptibility to being affected by corrosion phenomena.

AISI SERIES	STRENGTH	GRADE	MECHANICAL PROPERTIES		
			Tensile Strength (ksi)	Minimum Yield Strength (ksi)	Hardness (HRC)
1537M	REGULAR	D	115 Min	85	28 Max
1537M	HIGH	DS	140 Min	115	36 Max
4119M	REGULAR	CD	115 Min	90	28 Max
4119M	HIGH	CS	140 Min	115	36 Max
4318M	REGULAR	ND	115 Min	90	30 Max
4318M	HIGH	NS	140 Min	115	36 Max

Table 2: Mechanical properties of Lifting solutions Endless rod

Tempered martensite steel can achieve a high hardness with good toughness compared to most sucker rod steel that is normalized and tempered, as illustrated in the following Figure 1.

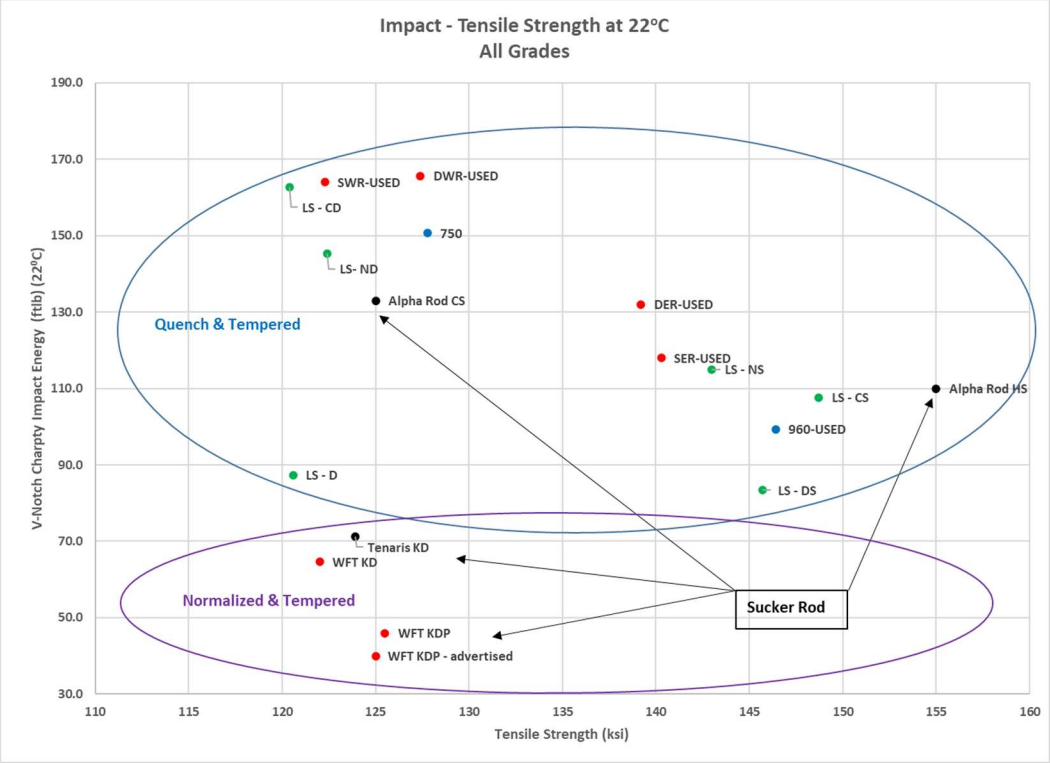

Figure 1: Impact Strength (as a function toughness) of "Quench & Temper" and "Normalize & Temper" rod steels.

CER Vs BER

In addition to the loads associated with the PCP application (axial, bending, torsion), the phenomenon of wear and corrosion in the rods is well known and is and common problem in certain deviated well or corrosive fluids. Damages related to corrosion and wear are not necessarily well known in terms of their impact on fatigue resistance. However, it is possible to concatenate surface damage with its negative impact on fatigue life or endurance limit. A wearable coating (Coated Endless Rod) is a practical and effective solution to reduce the damage associated with corrosion and wear, thus increasing the fatigue life.

CONCLUSION:

Classical theories (Goodman or Gerber) are the basis for software and designers to estimate the fatigue life in PCP rods. One key property is the ultimate tensile strength of the material, which rises with the hardness. However, other design considerations must be considered as part of the PCP application. Toughness and notch sensitivity directly impact the tolerance of the material under cyclic conditions with the preexistence of defects; thus, a favorable steel microstructure with high toughness or notch sensitivity should be considered. Likewise, the effect of corrosion and its relationship with chemical properties and hardness is also a relevant factor that needs to be considered in the endless rod selection. Similarly, wear is a phenomenon that impacts the rod surface integrity, and Coated Endless Rods is a suitable solution for high-wear applications. Last but not least, the historical failure mechanism analysis serves as an appropriate supply to guide the rod grade selection and the continued improvement of the application.