technical bulletin 008

2/2012

Cable Breaking Strength

New and properly maintained Camesa cables have been designed and manufactured to have a breaking strength that you can depended on. This bulletin will discuss these cables and how field operating conditions affect breaking strength. A later bulletin will discuss the mechanical failure or reduced breaking strength of cable due to effects such as fatigue, acid, H_2S, corrosion and wear.

The breaking strength of cable, listed in the Camesa catalog, is the guaranteed minimum strength at which the cable will break when the ends of the cable are prevented from rotating. When a cable is loaded, with no rotation allowed, the outer armor wires are stressed slightly more than the inner armor wires. For this reason when a cable breaks with ends fixed, the outer armor wires will always break first and the inner armor wires stretch out before they break.

Oilfield cables are constructed with two layers of contrahelically applied armor wires. Under load each layer of wires develop torque. The torque developed by the inner armor is in opposition to the torque of the outer armor. The torque developed by each layer of armor wires is determined primarily by the total area of steel in each layer and the distance of the wires from the cable center. The outer armor wires are always further from the cable center than the inner armor and for practical reasons the outer armor layer has a greater area of steel. The outer armor layer, therefore, develops much greater torque than the inner armor layer. This imbalance in torque can be partially but not completely offset by adjusting the lay angles of the inner and outer armor wires.

If a cable under load is free to rotate, such as a cable hanging in a vertical cased hole, the dominant torque of the outer armor wires will cause the cable to rotate in such a direction as to unwind the outer armor and reduce its stress. As the outer armor wires unwind, the inner armor wires are forced to wind tighter and this increases the stress in the inner armor. If allowed, this unwinding will continue until the torque between the layers is equal, and when this occurs the stress in the inner armor is much higher than in the outer armor. When a cable is free to rotate or is forced to unwind by improper operating conditions the breaking strength is significantly reduced and when it does break, the inner armor will break first, and then the outer armor wires will stretch out before they break.

In normal operations, with proper tensions going in and out of the well, the lower portion of the cable, if free to rotate, will unwind in proportion to the tension but due to friction in the borehole, there is less unwinding near the surface, so the cable breaking strength at the surface is close to “ends fixed” strength. The breaking strength will be reduced further by field operations that force the cable to unwind. This includes: trying to control pressure with a tight pack-off instead of using more flow tubes; wide cable tension variations that result from allowing the cable to “free fall” into the hole and coming out of the hole at speeds that cause excessive high tensions; improper sheave groove size or sheave alignment can also contribute to loosening the outer armor. When the outer armor has become loose it is important to have a cable shop “normalize” and post-form the cable to tighten the outer armor and restore its normal breaking strength.

Camesa cables are designed to exceed the catalog breaking strength. All incoming armor wire has certified tensile strength. In addition Camesa routinely tests the wire and finished cables to verify the strength.

Calculating Cable Breaking Strength

EXAMPLE - Camesa Cable type 1N32PP
(units-- inches, square inches, psi, pounds, degrees)
$D = 0.322$ - Cable diameter
$d_o=0.0445$ - Outer armor wire diameter
$D_o= D - d_o = 0.2775$ - Pitch diameter outer armor layer
$d_i = 0.0445$ - Inner armor wire diameter
$D_i = D_o - d_o - d_i = 0.1885$ - Pitch diameter inner armor layer
$D_c= D_i - d_i = 0.144$ - Effective core diameter after compression
$N_i = 12$ - Number of inner armor wires
$N_o= 18$ - Number of outer armor wires
$A_i = N_i(\pi/4)d_i^2 = 0.018663$ - Total cross sectional area of all inner armor wires
$A_o= N_0(\pi/4)d_o^2 = 0.027995$ - Total cross sectional area of all outer armor wires
$L_i = 1.50$ - Inner armor lay distance
$L_o= 2.50$ - Outer armor lay distance
$\sin\alpha_i = \pi D_i / [(\pi D_i)^2 + (L_i)^2]^{1/2} = 0.3672$
$\sin\alpha_o = \pi D_o / [(\pi D_o)^2 + (L_o)^2]^{1/2} = 0.3293$
$\cos\alpha_i = L_i / [(\pi D_i)^2 + (L_i)^2]^{1/2} = 0.9301$
$\cos\alpha_o = L_o / [(\pi D_o)^2 + (L_o)^2]^{1/2} = 0.9442$
$\alpha_i = 21.54$ - Inner armor lay angle
$\alpha_o = 19.22$ - Outer armor lay angle
$P = 0.33$ - Poisson’s ratio for plastic
$S = 270{,}000$ - Wire tensile strength

Breaking Strength - Ends Fixed

$\sigma_F = [\cos^2\alpha_i - P(D_c / D_i)\sin^2\alpha_i] / [\cos^2\alpha_o - P(D_c / D_o)\sin^2\alpha_o]$
$=0.9521$
- armor stress ratio, ends fixed
$BF = S[\sigma_F (A_i \cos\alpha_i) + (A_o \cos\alpha_o)]$
$BF = 11{,}370$ - Calculated minimum
$BF = 11{,}200$ - Catalog minimum

Breaking Strength - Free Rotation

$\sigma_R = [A_i D_i \sin\alpha_i] / [A_o D_o \sin\alpha_o] = 0.50496$ - armor stress ratio, ends free
$BR = S[(A_i \cos\alpha_i) + \sigma_R (A_o \cos\alpha_o)]$
$BR = 8{,}120$ - Calculated minimum
$BR = 7{,}900$ - Catalog minimum

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