technical bulletin 020

Cable Rotation

By design, wireline cables develop torque when subjected toload, see Technical Bulletin “Minimizing Cable Torque During Cable design”. The load on the wireline cable is a result of theweight of the tool, the weight of the cable and any dynamic friction due to running conditions. If the tool end of the cable isfree to rotate, the cable will try to rotate to reduce this torque.

All cables used in oil field service operations are built with thetorque of the outer armor dominant over the opposing torqueof the inner armor. To balance the torque the cable will unwindin a direction to loosen the outer armor, which will tighten theinner armor. If the cable is free to rotate, this unwinding orrotation will continue until the torque in the inner armor equalsthe torque of the outer armor. The number of revolutions, Nf(per 1000 ft per 1000 lb), that the end of the cable will make toequalize the torque can be calculated as follows:

$$
\begin{aligned}
Nf = \Big(& 48 \times 10^{6} \,(cd - doa)\,(-cd + dia + 2\,doa) \\
& \Big(dia^{2}\,(cd - 2\,(dia + doa))\,nia\,pr\,\sin^{2}(\alpha\,ia) + dia^{2}\,(-cd + dia + 2\,doa)\,nia\,\cos^{2}(\alpha\,ia)\,\sin(\alpha\,ia) + \\
& \quad doa^{2}\,noa\,\sin(\alpha\,oa)\Big((cd - doa)\cos^{2}(\alpha\,oa) + (2\,(dia + doa) - cd)\,pr\,\sin^{2}(\alpha\,oa)\Big)\Big)\Big) \Big/ \\
\Big(& dia^{2}\,doa^{2})\,nia\,noa\,\pi^{2}\,ym\,((doa - cd)\cos(\alpha\,ia)\sin(\alpha\,oa) - (cd - dia - 2\,doa)\cos(\alpha\,oa)\sin(\alpha\,ia)) \\
& \Big(\tfrac{1}{2}(cd - dia - 2\,doa)\,(cd - doa)^{2}\sin(2\,\alpha\,oa)\cos^{2}(\alpha\,ia) + \\
& \quad \sin(\alpha\,ia)\,((cd - doa)\,(-cd + dia + 2\,doa)^{2}\cos^{2}(\alpha\,oa) + \\
& \quad \Big(-cd^{3} + (4\,dia + 6\,doa)\,cd^{2} - 5\,dia^{2}\,cd + 8\,doa^{3})\,pr\,\sin^{2}(\alpha\,oa)\Big)\cos(\alpha\,ia) + \\
& \quad pr\Big(-cd\,(cd^{2} - 4\,doa\,cd + doa\,(4\,dia + 5\,doa)\Big)\cos(\alpha\,oa)\sin(\alpha\,oa)\sin^{2}(\alpha\,ia) + \\
& \quad \Big(dia\,cd^{2} + doa^{2}\,(dia + doa)\Big)\sin(2\,\alpha\,oa)\sin^{2}(\alpha\,ia) + \\
& \quad \Big(dia^{3} + 5\,doa\,dia^{2} + 8\,doa\,(doa - cd)\,dia - 6\,cd\,doa^{2}\Big)\sin(2\,\alpha\,ia)\sin^{2}(\alpha\,oa)\Big)\Big)
\end{aligned}
$$

Example of Cable Rotation with Tool End Free to Rotate

Using Camesa Cable # 1N32 as an example:
Cd=0.322, doa=0.0445, dia=0.0445, noa=18,
nia=12, αoa =19.22, αia=21.54, pr*=0.47**

*pr = Poisson Ratio
**Testing has shown that 0.47 is the best value for EM cables

Nf = 17.2 revolutions / 1000 ft / 1000 pounds tension.

With 10,000 feet of new 1N32PP cable lowered into astraight dry hole, with a 500 lb tool, the total revolutions, N, the cable would make to equalize torque would be:

Cable weight lb / kft = 188 ;
Average tension due to cable = 188 X 10 / 2 = 940 lbEffective tension is 940 + 500=1440=1.44 klb; Nf x 1.44 x 10 = 17.2 x 1.44 x 10 = 247 revolutions

There are very few straight, dry holes but this calculation indicates the amount of rotation a new cable will try to make to equalize the torque. With fluid in the hole the tension would increase with cable speed coming out of the hole resulting inadditional unwinding revolutions.

Standard Camesa Cable Rotation

Nf– Number of Revolutions per 1000 feet per 1000 poundtension cable end free to rotate

TYPE	K22	N22	N29	N32	N38	N42
Nf	83	48	22	17	10	7

The above calculations represent the possible rotation of atypical new cable. As a cable becomes “seasoned “ it will rotateless with tension changes. A “seasoned” cable is one in which the outer armor wires have dug into the Zinc of the inner armor wires and mud plus corrosion by products have collected between the armor layers add to the friction between layersreducing the amount of cable rotation.

Cables armored with alloy wires like MP-35 or S-77 are an extreme case in cable rotation. The reason is that the alloy armor does not have a soft Zinc coating and it does not corrode creating friction between armor layers that reduces the rotation in cables armored with galvanized wire. For these reasons alloycables will continue to rotate in use and must be given extra care in field operations and periodically the outer armor needs to be “tightened”.

In operations, keep in mind that when ever the tension on the cable changes it will try to rotate. When cable tension is increased above the static tension by frictional drag on the cable,the increase in cable torque will try to unwind the outer armorwires. Frictional drag comes from bore hole friction and tight pressure control equipment. This frictional drag increases with the speed of the cable spooling. Coming out of the hole too fast can result in excessive frictional tension on the cable forcing thecable to rotate excessively , further loosening the outer armor. Going into the hole the tension in the cable is reduced by the frictional drag and the cable will try to rotate to tighten the outer armor. Going into the hole too fast will not give the cable time to rotate to tighten the armor. Experience has shown that for standard GIPS armored cables if the tension going into thehole is not less than 80% of static tension at that depth and the tension coming out of the hole is never more than 120% of static tension, the cable armor will remain tight. This rule does not apply to alloy cables, which require special care.

Cable rotation can cause the stress in the outer armor wires tobe reduced, which not only leads to loose outer armor wires butalso significantly reduces the cable breaking strength. Thereduction in cable breaking strength with the cable free torotate will be covered in a later Technical Bulletin. For additional effects of cable rotation and cable torque see Technical Bulletin “Wireline Torque”.

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