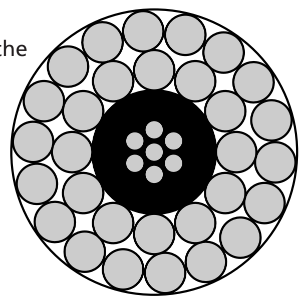
Minimizing Cable Torque During Cable Design

All electromechanical wireline cables that are used in oil well service operations are designed with two layers of armor wires around a core of insulated conductors. By design, wireline cables develop torque when subjected to load. The inner layer of armor wires is normally wrapped around the core in a right hand direction while the outer layer of armor wires are wrapped over the inner armor wires in a left hand direction. By wrapping the layers in opposite directions the torque from the inner armor opposes the torque from the outer armor. The result is that the net torque in the cable is the difference between the torque generated by each armor layer. In theory it is possible to design a cable in which the torque generated by each layer is exactly equal, resulting in a cable that has no torque under load and therefore would not rotate under load but there are a number of reasons that this is not a practical design for oilfield service operations. To better understand the impact of cable torque see Technical Bulletin "Wireline Torque".

The torque in the cable is the difference between the torque in the outer armor, Qo, and the inner armor, Qi, The factors that determine the torque in each layer are:



$$Qo \geq \frac{Do}{2} \text{ No } do^2 \text{ to Sin } [\alpha o]$$

$$Qi \geq \frac{Di}{2} \text{ Ni } di^2 \text{ ti Sin } [\alpha i]$$

Di = the pitch diameter of each inner layer
Do = Is the pitch diameter of each outer layer
Ni = Is the number of wires in each inner layer
No = Is the number of wires in each outer layer
di = Is the diameter of the wires in each inner layer
do = Is the diameter of the wires in each outer layer
αi = Is the lay angle of each inner layer
αo = Is the lay angle of each outer layer
ti = Is the wire tension in each inner layer
to = Is the wire tension in each outer layer

The net torque in the cable, Qc= Qo – Qi

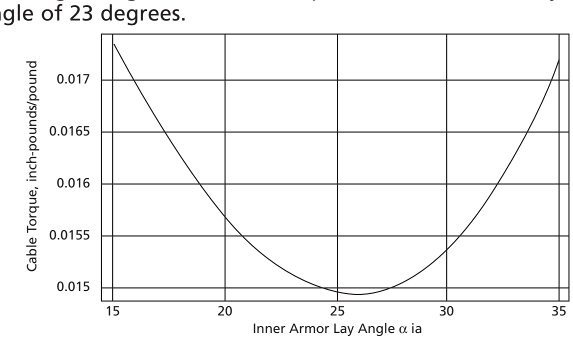
Looking at the picture of a standard cable type with 12 inner and 18 outer armor wires and the factors that determine the torque in each layer , the outer armor torque will be greater than the inner armor torque because:

- Do > Di the outer armor is always over the inner armor
- No > Ni in any cable with equal diameter armor wires
- do = di With the standard 12 / 18 armor package

These 3 factors give the dominate torque to the outer armor layer. When designing a cable the torque can be minimized by adjusting the lay angles of each layer. To decrease the torque generated by the outer armor wires the lay angle of the outer armor is reduced to as small of an angle that does not compromise the spooling characteristics of the cable . This angle in most cases is 19 degrees. Experience has shown that when the lay angle is less than 19 degrees the outer armor wires are easily crossed if the cable gets slack during operations.

To off set the dominant outer armor torque, the lay angle of the inner armor is increased. From cable design we know there is an angle of maximum torque for the inner armor. This is because the portion of cable tension carried by the inner armor decreases as the inner armor lay angle is increased. Therefore; even though the larger lay angle will result in increasing the component of tension that generates torque, if the tension is decreased excessively, the torque will also decrease. The result is an angle of maximum torque for the inner armor, which in turn is the angle that results in the minimum cable torque. (Q =Qo-Qi).

The minimum torque angle for a cable with a 12/18 armor package is about 25 to 26 degrees. Again in cable design there are compromises to be made. As the lay angle of the inner armor is increased to reduce cable net torque, it also reduces the breaking strength. The best compromise between breaking strength and cable torque is an inner armor lay angle of 23 degrees.



The actual computation of cable torque under load is a complicated problem as when the angles of inner and outer armor are changed, the tension carried by each layer and the torque are changing.

The full calculation of cable torque, qcc, for the Camesa cable 1N32 looks like this:

$$qcc = \left((cd - doa)\, doa^2\, noa \sin(\alpha\, oa) \left(\cos^2(\alpha\, oa) - \frac{(cd - 2\, dia - 2\, doa)\, pr \sin^2(\alpha\, oa)}{cd - doa} \right) - dia^2 (cd - dia - 2\, doa)\, nia \sin(\alpha\, ia) \left(\cos^2(\alpha\, ia) - \frac{(cd - 2\, dia - 2\, doa)\, pr \sin^2(\alpha\, ia)}{cd - dia - 2\, doa} \right) \right) \Bigg/ \left(2 \left(nia \cos(\alpha\, ia) \left(\cos^2(\alpha\, ia) - \frac{(cd - 2\, dia - 2\, doa)\, pr \sin^2(\alpha\, ia)}{cd - dia - 2\, doa} \right) dia^2 + doa^2\, noa \cos(\alpha\, oa) \left(\cos^2(\alpha\, oa) - \frac{(cd - 2\, dia - 2\, doa)\, pr \sin^2(\alpha\, oa)}{cd - doa} \right) \right) \right)$$

cd = 0.322	dia = 0.0445	doa = 0.0445	nia = 12
noa = 18	aia = 23	aoa = 19	pr = 0.47

qcc = 0.0151162 inch-pounds of torque / pound of tension

At a working tension of 5000 pounds, the cable torque, Qc would be:
Qc = 75.6 inch pounds of torque

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