Armor Coverage

Armor coverage is a very important property of electromechanical wireline cables. Proper design and armor coverage permits cables to operate under tough operating conditions of high temperatures and high tensile loads. The term "armor coverage" refers to how close the armor wires are together. If a layer of armor wires were to have 100% coverage, it would mean that all of the armor wires in that layer were touching their adjacent wires.

There are a number of very important reasons why the armor coverage of both the inner and outer armor layers must be carefully controlled. If the coverage on either layer were 100%, the cable would be so stiff it would not be able to bend around a sheave wheel without forcing one of the wires out of the layer, creating a high wire. If the armor coverage is too low a premature electrical short could result under high temperature and high load conditions.

The range and requirements for the coverage of the inner and outer armor layers is quite different. To calculate coverage there are at least 4 good formulas. In the case of oil field electro mechanical cables (wirelines), there is little difference in the calculated coverage values using any of these formulas. The formula that has been accepted by the major oil field service companies and Camesa is:

$$\% \, Ci = \frac{di}{(Dc - 2\,do - di)\,\mathrm{Sin}[\frac{\pi}{Ni}]\,\mathrm{Cos}\,[\alpha i]} \; x100$$

$$\% \, Co = \frac{do}{(Dc - do)\,\mathrm{Sin}[\frac{\pi}{Ni}]\,\mathrm{Cos}\,[\alpha o]} \; x100$$

Ci = Percent coverage of the inner armor layers
Co = Percent coverage of the outer armor layers
di = Diameter of the individual inner armor wires
do = Diameter of the individual outer armor wires
Ni = The number of wires in the inner armor layers
No = The number of wires in the outer armor layers
αi = the lay angle of the inner armor wires
αo = the lay angle of the outer armor wires
Dc = Finished cable outside diameter

Inner Armor Coverage acceptable range: 97.5% to 99.5%, ideal is 98.5%.

The importance of keeping the inner armor coverage as high as possible is to contain the plastic insulation covering the conductor. During cable manufacturing the equal spacing between the inner armor wires is carefully controlled and the inner armor wires are partially embedded in the plastic insulation to preserve this equal spacing. This equal spacing is important to spread the coverage equally between each wire thus minimizing the gap at any one location.

A cable under load generates a pressure on the core and if the inner armor wires are not close enough (low coverage %), the plastic insulation can be squeezed out between the armor wires. With an inner armor coverage over 98% cables can operate under rated operating conditions of temperature and tension without the plastic insulation being squeezed out in the gap between the inner armor wires. When a cable is subjected to high downhole temperatures and excessive tension some plastic insulation may be forced out between the inner armor wires, even when the armor coverage is in an acceptable range. Excessive operating conditions, stuck tools, and pulling out of the weak point can often create this phenomena. In these cases it is good operational practice to cut back on the cable end to be assured of full electrical insulation.

Outer Armor Coverage acceptable range: 96.5% to 98.5%, ideal is 97.5%.

The importance of allowing a lower coverage on the outer armor is to give the cable sufficient flexibility to wrap around standard sheave wheels. On cables used in high pressure operations it is important to keep the outer armor coverage on the high side to better control pressure in the flow tubes.

The outer armor being applied over the inner armor can not be embedded to control spacing. For this reason, new cables when they are first spooled may cause the outer armor wires to shift around resulting in what appears to be an excessively wide gap. This is perfectly normal. When a new cable has a dark protective grease applied, this grease will collect in this wider gap giving an appearance that the cable is "gappy". After a few runs in the hole the outer armor will equalize the gap between the adjacent armor wires and the appearance of a "gappy" cable will disappear.

Sample inner armor coverage calculation:
Camesa 1N29PTZ

$$Ci = \frac{di}{(Dc - 2\,do - di)\,\mathrm{Sin}[\frac{\pi}{Ni}]\,\mathrm{Cos}\,[\alpha i]} \; (100);$$

di = 0.0405;
do = 0.040;
Dc = 0.288;
Ni = 12;

$$\alpha i = \frac{\pi}{180}\,19.5$$

Ci = 99.1%

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