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Linear Elastic Cable Model With Creep Proportional to Tension

This document illustrates differences in the way creep is handled in the "Linear elastic with permanent stretch due to creep proportional to creep weather case tension" cable model compared to cable models available in earlier versions. You may download a PLS-CADD/Lite project for the example used in this discussion from http://www.powline.com/technotes/creep_proportional_to_tension.bak should you want to experiment with this yourself. Our thanks to Mr. Greg Chapman of Ergon Energy for his contributions to the development of this cable model and this tech note.

There are three types of cable models that are available for modeling conductors in PLS-CADD. The first and most accurate is the **non-linear cable model** which uses separate polynomials for initial and creep behavior for inner and outer materials. The second is the **improved linear cable model** which models permanent stretch due to creep proportional to the creep weather case tension. The third is the **linear cable model** with permanent stretch due to creep specified as a user input temperature increase.

As shown below in Figure 1, the improved linear cable model more accurately reflects the sag of the non-linear cable model in the creep condition at various tensions. You can see how at 22 kN all three cables are very similar in their creep display since this is the tension selected when stringing the conductor. However when the cables are strung at 44 kN instead of 22 kN, you can see how the new improved linear cable model more accurately reflects the creep sag of the non-linear cable model.

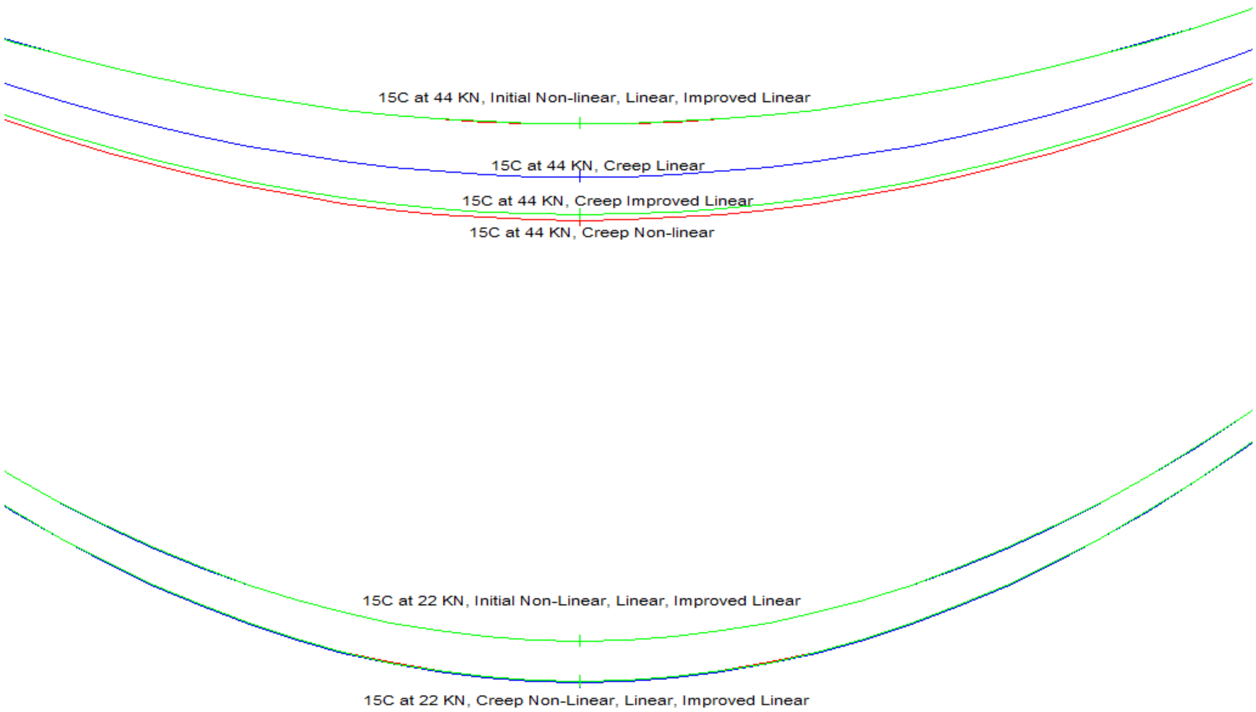


Figure 1

Linear Cable Models vs. Non-Linear Cable Model

Figure 2 below illustrates the method of modeling long term creep by a temperature shift such that the plastic creep is modeled as thermal strain which is the model that was used originally in PLS-CADD for a linear cable.

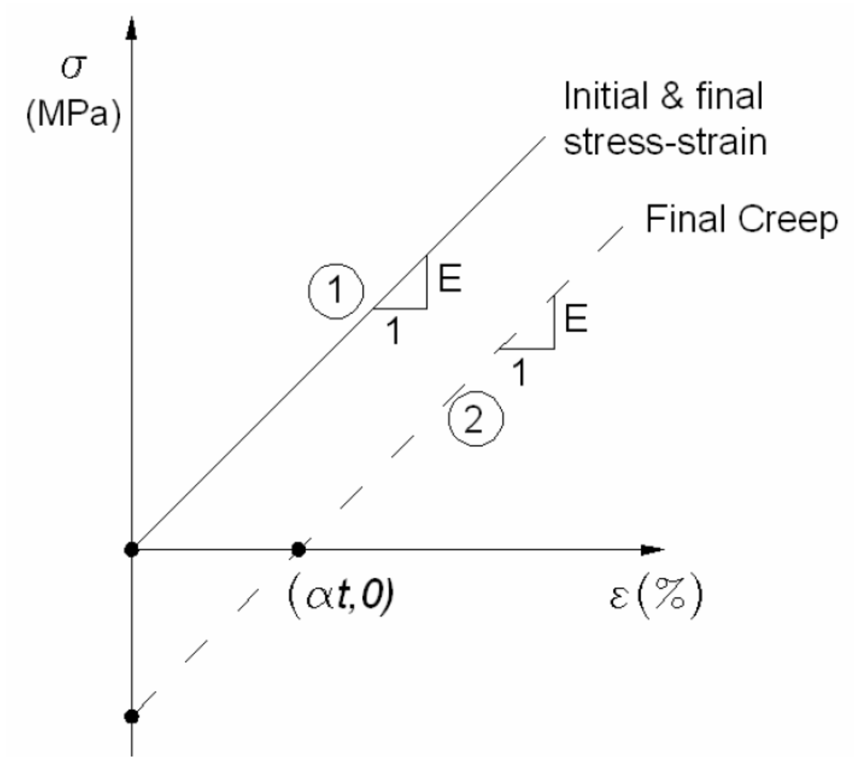


Figure 2

Linear Cable Model
Long Term Creep Modeled as Thermal Strain

The variables used in the figure are

α = coefficient of linear thermal expansion per 100°C

E = final modulus of elasticity/100 (MPa/100)

t = temperature compensation for long term creep (°C)

The equation for the elastic stress-strain curve (number 1) is

$\sigma = a_0 + a_1\varepsilon$

where $a_0 = 0$ and $a_1 = E$

while the equation for the creep curve number (2) is

$\sigma_c = b_0 + b_1\varepsilon$

where $b_0 = -E\alpha t$ and $b_1 = E$

The primary disadvantage to this model is that a constant allowance is made for creep that is not related to the value of the stringing tension.

The other more accurate approach is to pro-rata the creep as shown in Figure 3 below.

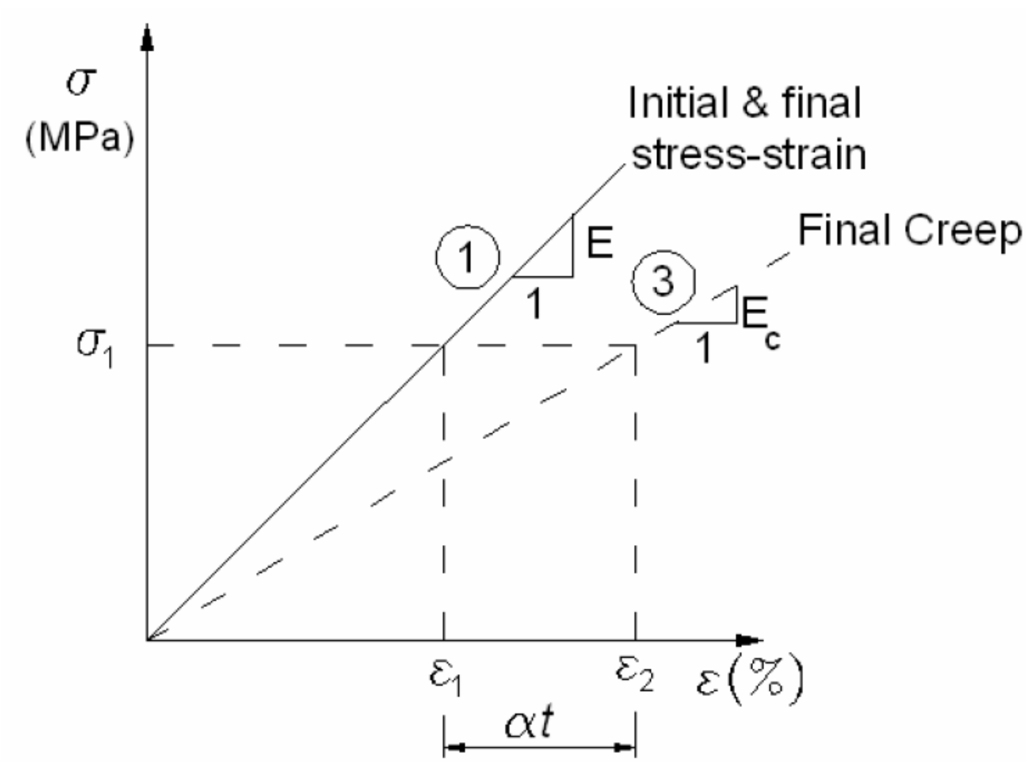


Figure 3

Improved Linear Cable Model
Long Term Creep Modeled as Proportional to Tension

From initial curve number (1)

$E = \sigma_1/\varepsilon_1$

$E_c = \sigma_1/\varepsilon_2$

$\varepsilon_2 = \varepsilon_1 + \alpha t$

Solving for E_c gives

$E_c = 1/(\frac{1}{E} + \frac{\alpha t}{\sigma 1})$

Therefore the equation for the final creep curve number (3) is

$\sigma_c = c_0 + c_1 \varepsilon$

where

$c_0 = 0$

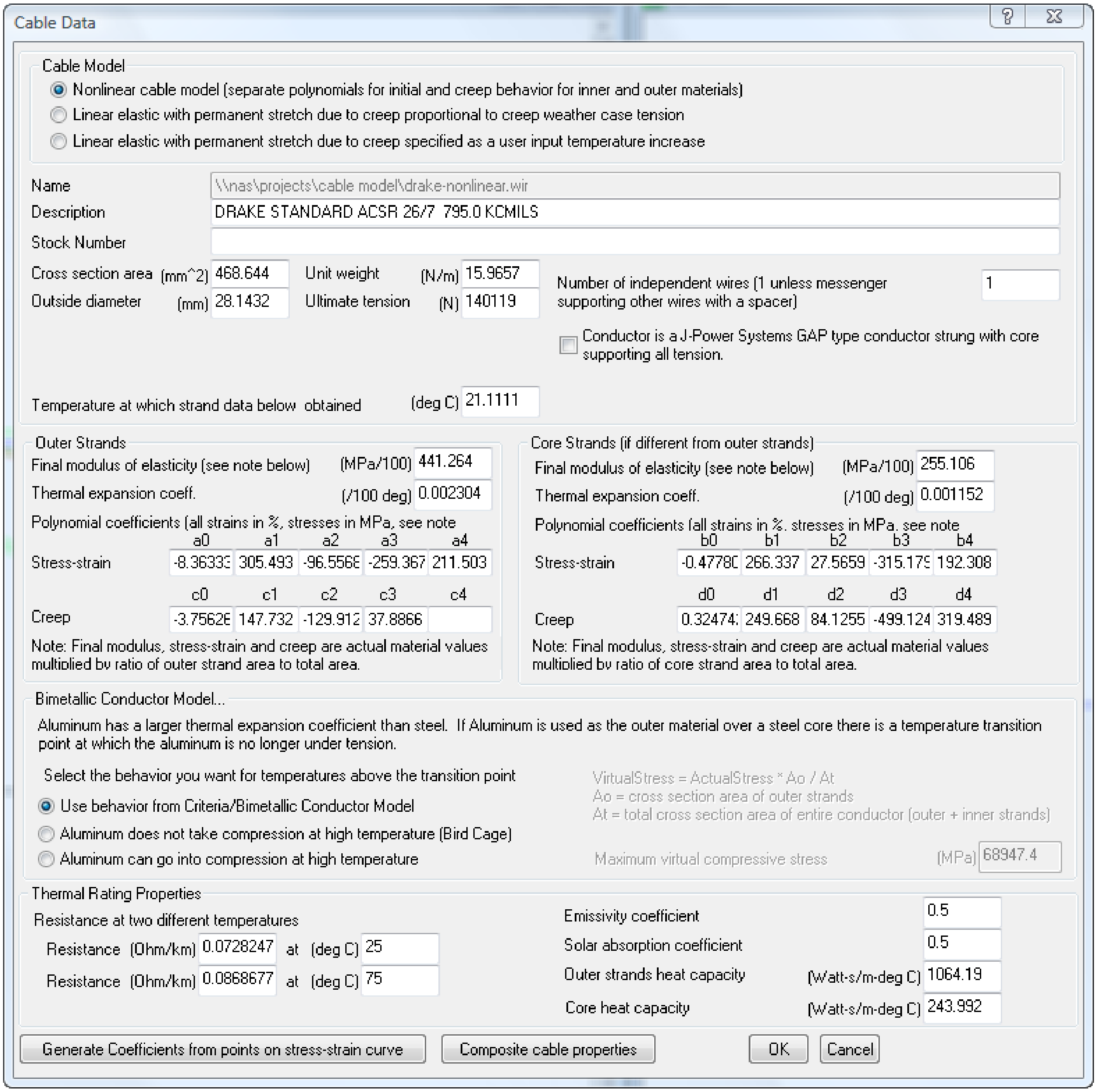
$c_1 = E_c$

"σ_1" is the constant value of stress that produces a creep strain equivalent to t°C. It would normally be the "full" tension value of stress where experimental values of creep strain have been evaluated.

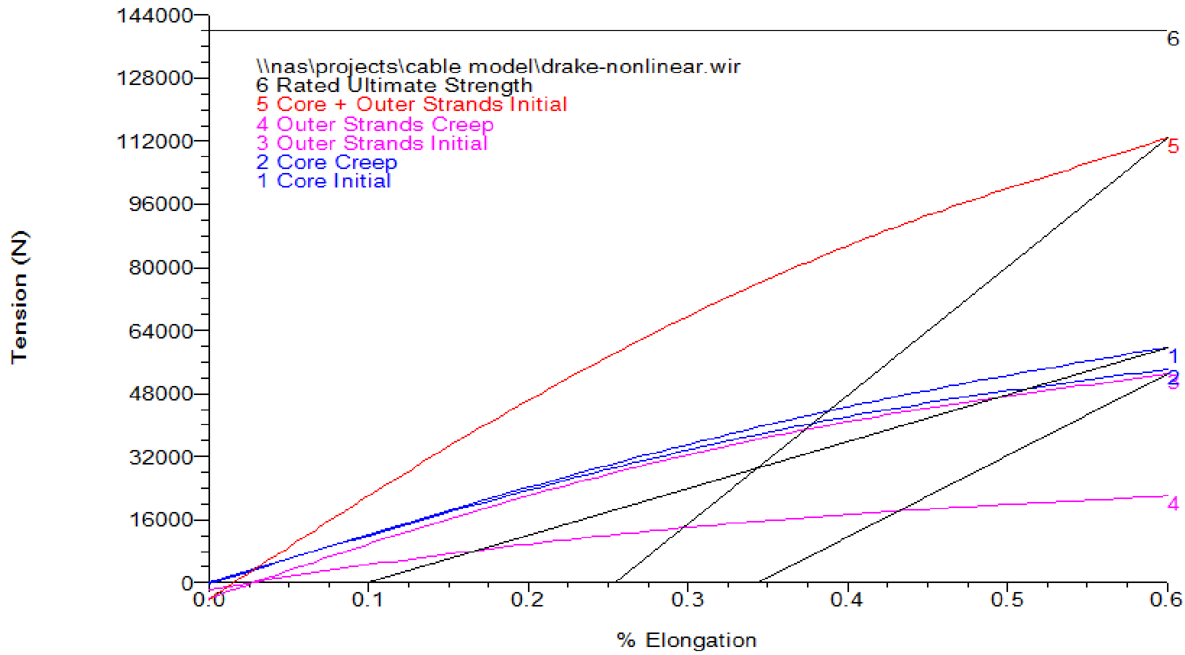
It is important that "t" represents only the metallurgical value of creep strain; the elastic strain, thermal strain, and strand settling strain components having been accounted for in the test results.

The best method of cable modeling is to include the polynomial coefficients for the non-linear stress-strain curve and for the non-linear creep curve.

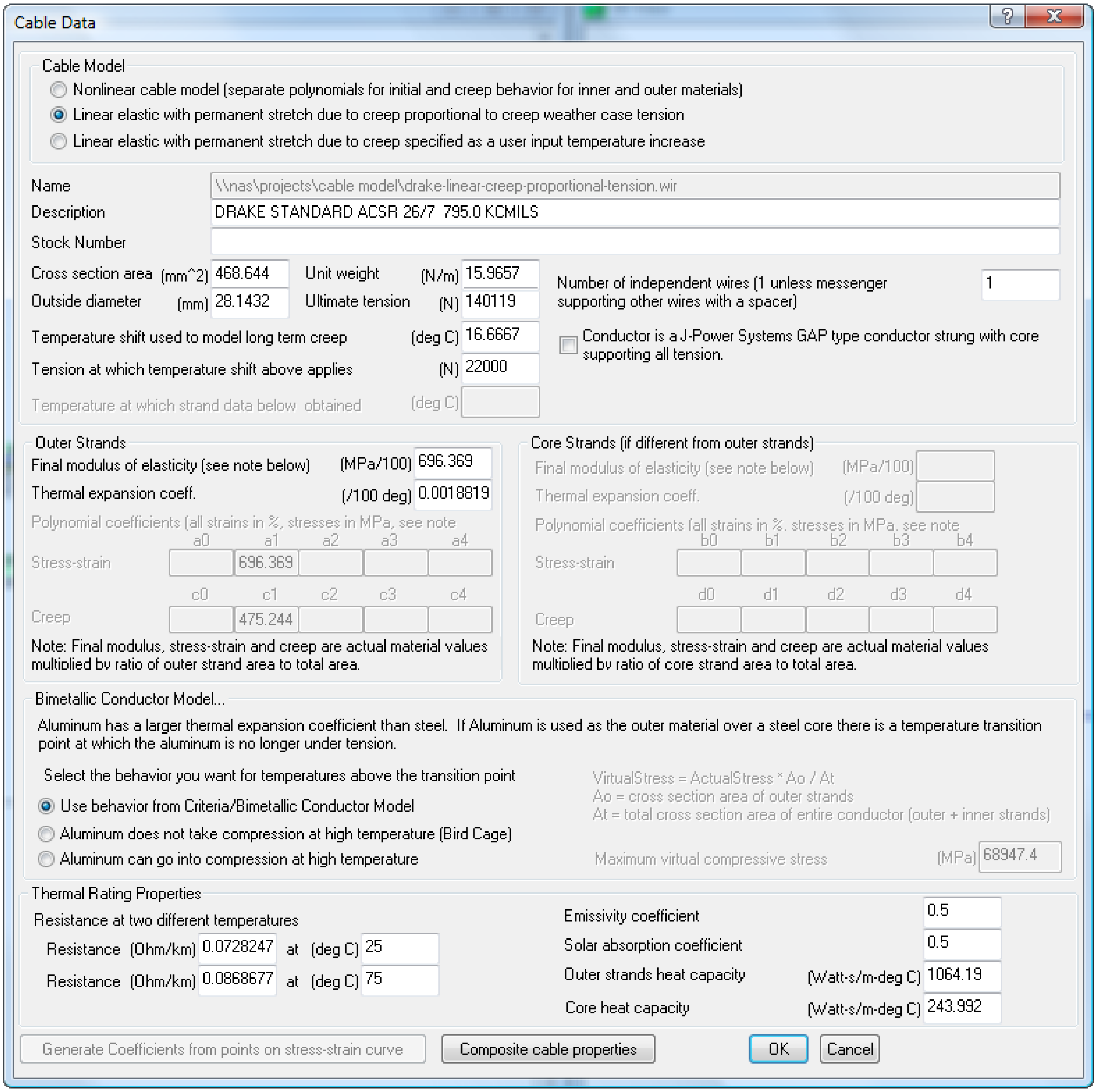
Below are the cable data input dialog from PLS-CADD including a graph of the % Elongation vs. Tension for the three different cable types as used in the example file that can be downloaded above.



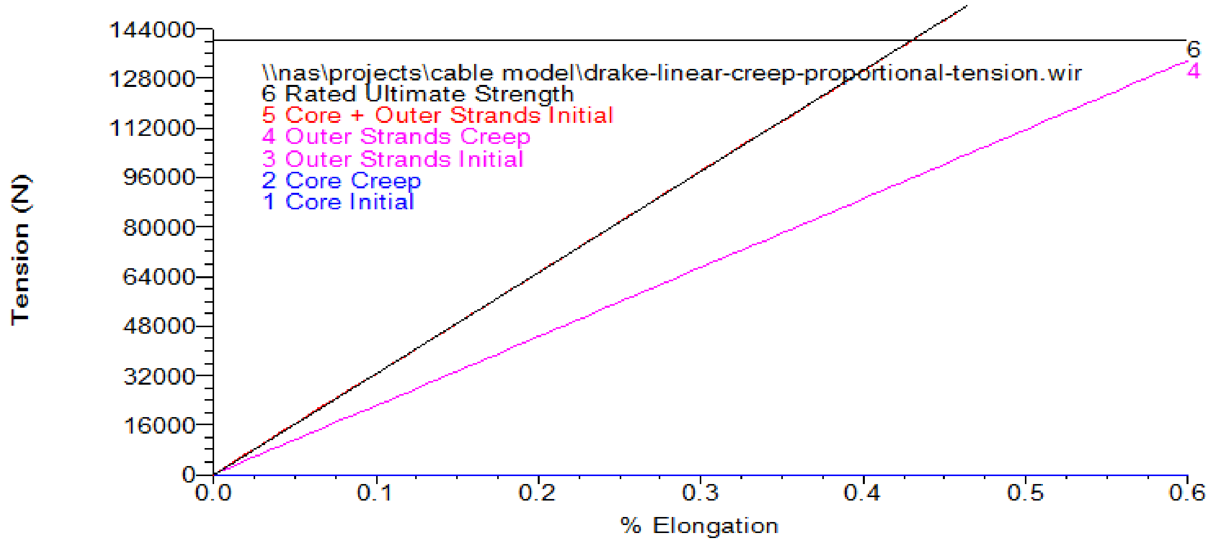
Nonlinear Cable Model
Long Term Creep Modeled with Polynomial



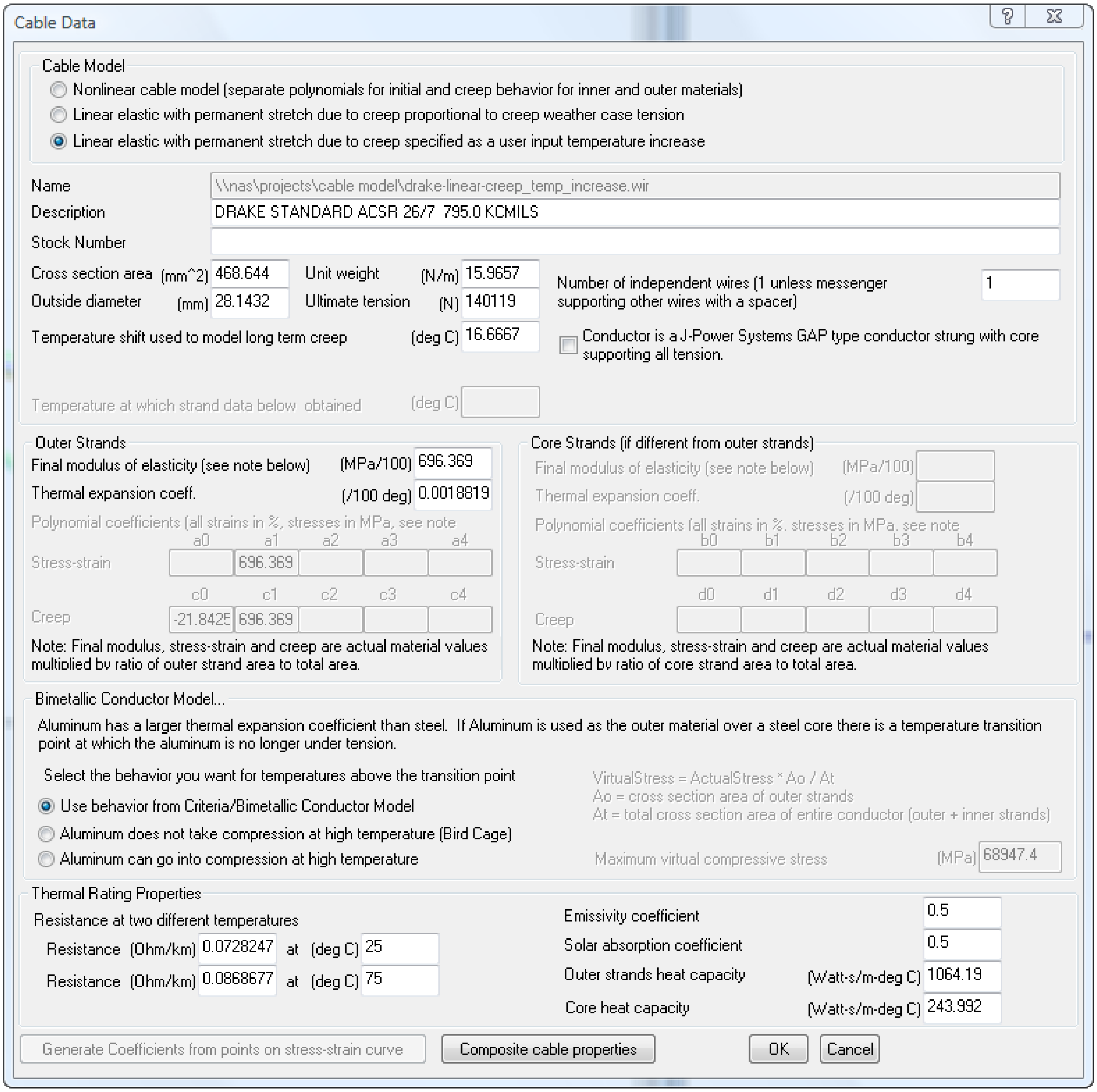
Nonlinear Cable Model
Long Term Creep Modeled with Polynomial



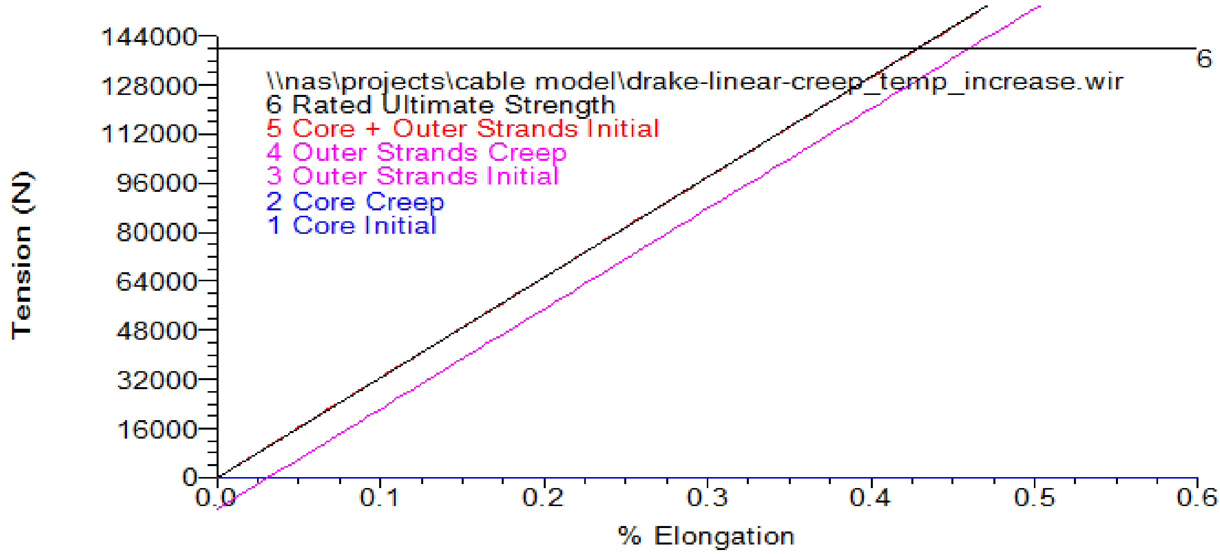
Improved Linear Cable Model
Long Term Creep Modeled as Proportional to Tension



Improved Linear Cable Model
Long Term Creep Modeled as Proportional to Tension



Linear Cable Model
Long Term Creep Modeled as Temperature Shift



Linear Cable Model
Long Term Creep Modeled as Temperature Shift

