Paris Session 2022

Carbon Fiber Composite Core Life-time Prediction using Arrhenius Plot

SC B2 (Overhead Line)

PS2, Q2.9 Based on the thermal ageing data what is the expected life (in years) of an ACCC conductor at 160 C operating temperature? What is the expected end of life (in years) of ACCC at 180 C ?

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The Arrhenius Equation

• A method to calculate the expected life-time for carbon fiber composite core's for overhead conductors using tensile test results after thermal ageing

•The linkage of the speed rate constant k and the absolute temperature (Kelvin), based on Arrhenius equation, is

$$k = A \times e^{-\frac{\Delta E}{RT}}$$

• This speed rate constant k affects the element's molecule breaking (pyrolysis) speed in the composite core that links to the degradation of the tensile strength

• A and ΔE are constant related to the material, R is gas constrant and T is the temperature

• The polymer matrix used in a composite core, which function is to contain and hold the carbon fibers, is a unique custom design and will have a speed rate constant specifically representing this composition

• Thus, the thermal ageing tests and the associated life-time prediction, using the Arrhenius equation, should be performed on each composite core design type

Using thermal ageing results to solve the Arrhenius Equation

- Samples of the composite core are aged at different temperatures & durations, and subject to tensile testing to prepare for the plots
- Plot the thermal ageing results on the semi-log graph: the tensile strength as a function of the ageing time (Fig. 1)
- Plot the test time and test temperature on the semi-log graph and solve the Arrhenius Equation (Fig. 2)
- Calculate the expected time at a certain temperature, or the maximum operating temperature at given specified life-time

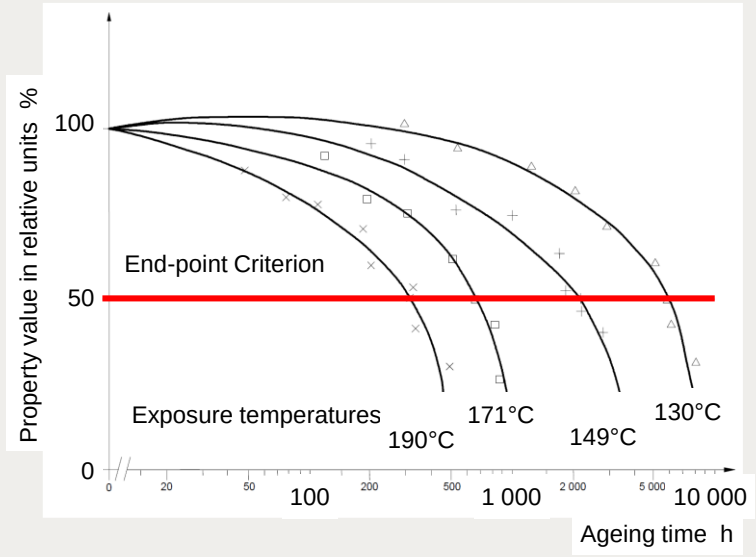

Fig.1 Sample case of Ageing Test results

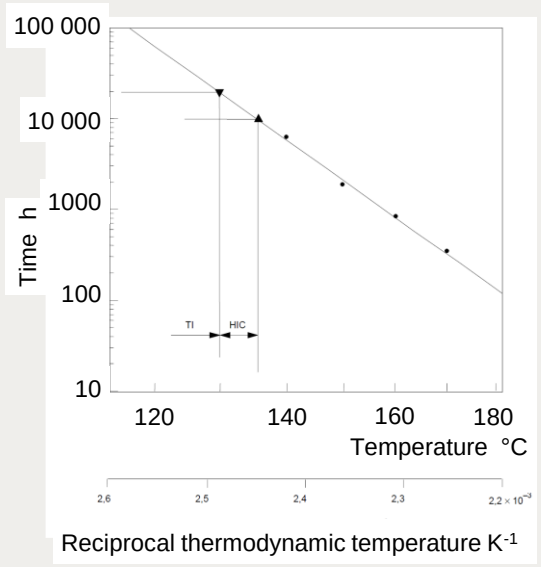

Fig.2 Sample case of Arrhenius plot

- Both graphs are taken from IEC 60216-1, one of the insulating material standards. In this standard, the end-point criterion is recommended at **50%, 25% or 75% of initial strength** (IEC 60216-2)
- At this time there is no IEC standard yet in relation to Overhead Conductor. Therefore most refers to ASTM B987, with an end-point criteria of **95% of rated tensile strength**
- Note that in case of thermal aluminum, a limit of **90% of initial strength** is the end-point criteria

- The expected life time and the maximum operating temperature depends on the end-point criterion of the thermal ageing test

Answering the question with our composite core as an example

- The end-point criterion is set as 90% of rated tensile strength. This criteria was agreed between the end-user and us in 2015
- In this case, core's expected life time at 180 °C is over 600 years and much longer at 160 °C
- An emergency operation temperature, as well as a potentially higher core temperature, as compared to conductor surface, should be considered as well
- If the end-point criterion changes, the expected life time and maximum operating temperature are also change
- An IEC working group is discussing which value is suitable to set as the end-point criteria