講演番号 283 文献番号 20225283

Proposal of a Method for Predicting the Temperature and Humidity Deterioration Life of PA66 in an Actual Environment Using an Enhanced Arrhenius Model

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KEY WORDS: **Common Infrastructure, Durability Test, Simulation/Modeling,** Improved Arrhenius Model [F2]

This research was an attempt to use the Eyring model of reaction rate theory to predict the deteriorated life of PA66 fabric due to thermal oxidation and hydrolysis resulting from temperature and humidity deterioration. However, verification of the results indicated a large divergence between the measured values and experimental modeled values. The results had low accuracy. Therefore a reaction rate theory model to replace this was developed based on the Arrhenius model.

Testing was conducted to determine the reduction in tensile strength retention rate in PA66 yarn after it had undergone deterioration by heat aging (relative humidity of 1%RH or lower) and humidity aging (relative humidity of 95%RH). The time taken to yield a strength retention rate of 90% was defined as the life of the material. By multiple regression analysis of the aging temperature and relative humidity that yield this life, the Eyring model constant can be identified.

Figure 1 shows the Eyring model represented by an Arrhenius plot with the calculated values (solid lines) and measured values (plotted points and dashed lines). When the calculated values and measured values were compared, a large deviation appeared between their slopes, especially at 95%RH. This suggested that the Eyring model had low life prediction accuracy.

The Arrhenius model can only deal with temperature factors. If the values at each humidity are grouped together, however, then only temperature factors remain, and this model can deal with them.

Figure 2 shows an Arrhenius model with the values divided into a 1%RH group and a 95%RH group. The straight lines are linear approximations of the respective plots. When the two Arrhenius plots of 1%RH and 95%RH are compared, it becomes apparent that the slope k_i and segment a_i vary with the humidity. The relationship between this slope k_i and the relative humidity S_i was therefore described using a first-order model.

$k_i = -8405.745 \cdot S_i + 16915.057 \quad \ldots (1)$

The relationship between segment a_i and the relative humidity S_i was also similarly described using a first-order model.

$a_i = 18.550 \cdot S_i - 35.649 \quad \ldots (2)$

Then Eqs. (1) and (2) can be plugged into the below Arrhenius model in Eq. (3), making it possible to create an Arrhenius model that can better predict the life L at a strength retention rate of 90% in terms of the absolute temperature T and the relative humidity S_i.

$Ln(L) = a_i + k_i(1/T) \quad \ldots (3)$

Using this enhanced Arrhenius model, it becomes possible to accurately predict the life of PA66 fabric that is exposed to an environment with arbitrarily defined temperature and arbitrarily defined relative humidity.

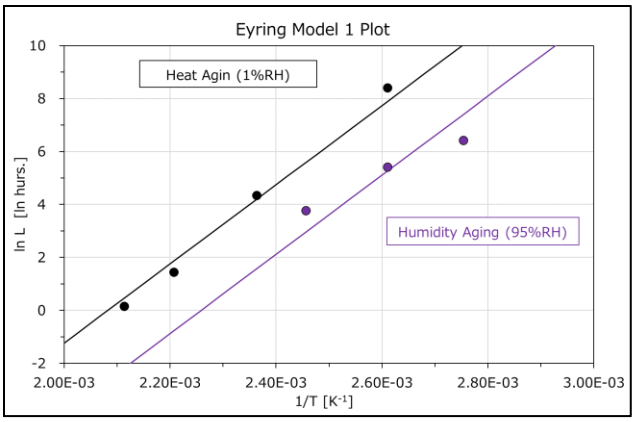

Fig.1 Arrhenius Plot of Eyring Model 1

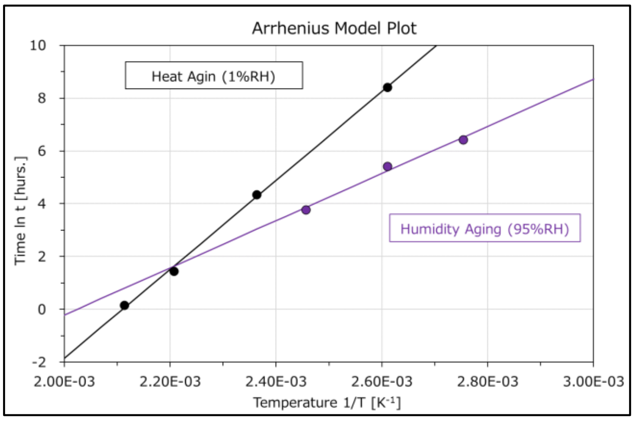

Fig.2 Arrhenius Plot of 1%RH & 95%RH