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PARACHUTE AGING STUDIES

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Introduction

Over the last several years, our group has been heavily involved in degradation studies of polyamides, specifically Nylon and to a somewhat lesser extent Kevlar due to their use in weapon parachutes.[1-6] Previous work revealed that humidity aging resulted in a much faster rate of degradation than thermal-oxidative aging.[2] The bulk of the work examined either Nylon or Kevlar. In the real world though, one polymer is frequently in contact or near another polymer. Therefore a limited number of experiments were performed where Nylon and Kevlar were aged in the same vessel. It was initially assumed that there would be no detrimental effect when the two were aged together, thus a comprehensive and extensive set of experiments were not performed. The focus of this paper is to examine Nylon aged with Kevlar and as a secondary note, the result of Nylon aged in lower than 100% RH condition.

Experimental

Humidity experiments with 100% RH have been described in detail in a previous publication.[2] Briefly, they involved ~ 600 ml stainless steel cans with excess water placed in the bottom of the can to guarantee 100% RH at the aging temperature. An internal stainless steel sample basket supported by metal legs was used in order to keep the polymer in the 100% RH atmosphere above the water. Samples were cut and weighed and placed loosely in the baskets. The baskets were placed inside the cans after de-ionized water was added to the cans. The cans were sealed by bolting on valve assemblies and then were placed in a freezer overnight. After freezing, the cans were quickly placed on a vacuum manifold, evacuated, and backfilled with the specified pressure of either argon or oxygen. The assemblies were left to thaw overnight and then placed in elevated temperature aging ovens.

The 70% RH experiments were performed in a commercial humidity chamber (Model LH-1.5 Laboratory Humidity Chamber from Associated Environmental Systems, Ayer, MA) with ambient air flowing through the apparatus.

Results and Discussion

Due to the difficulty in obtaining data at different relative humidities, only two relative humidities, 70% and 100%, at 80 °C were studied (Figure 1). Data was also obtained where Nylon was aged in the presence of Kevlar at the same temperature (Figure 1).

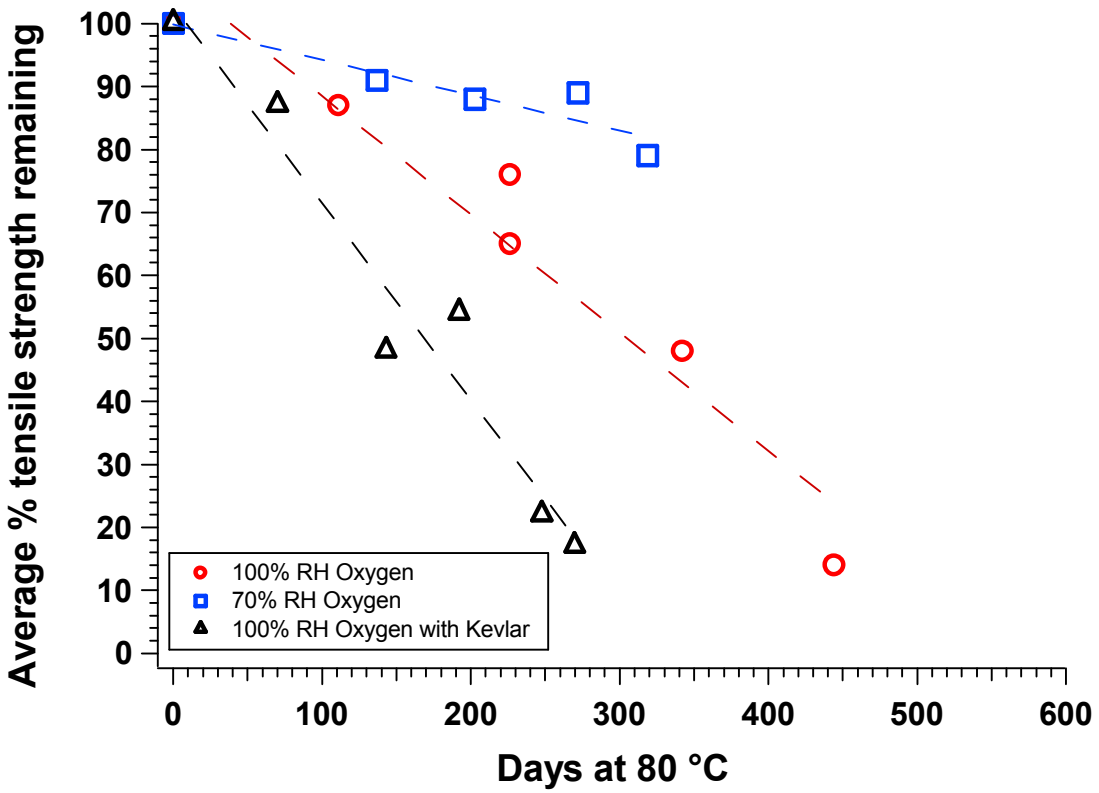

Figure 1. Nylon tensile strength loss under different aging environments, all at 80 °C and with a headspace gas of oxygen.

Although there is a fair amount of scatter and limited data, a linear fit to the three sets of data results in a reasonable degree of confidence in the slope values. When these slope values are normalized and compared, there appears to be a distinct difference between the conditions and degradation slope (Table 1). Reducing the relative humidity by 30% changed the slope value by ~70%. Although, materials in field environments are not expected to see 100% RH at all times, there are a number of scenarios that would involve aging of Nylon with Kevlar present. Addition of the Kevlar to Nylon aging samples increases the degradation slope value by 1.7.

Table 1: Nylon degradation slope comparison for sample exposed to 80 °C under different conditions.

Condition	Normalized slope
70% RH Oxygen	0.3
100% RH Oxygen	1
100% RH Oxygen with Kevlar	1.7

The aged Kevlar humidity cans have a noticeable odor to them when opened, and it is postulated that perhaps the Kevlar releases a degradation product that catalyzes and/or degrades the Nylon. A clue on this mechanism could be provided by to examining how the degradation rates would change under non-stagnant (flowing) conditions. It should be noted that the Nylon from the 70% RH study was in the presence of Kevlar under flowing air conditions, and a much larger volume than in the aging cans for the 100% RH study. This means that the value obtained from the 70% RH slope could be lower if the Kevlar was not present. Further experiments are necessary to understand flowing air systems with Kevlar present.

It appears that the presence or absence of Nylon has no effect on the Kevlar rate of degradation (data not shown). One possible explanation for this observation could be the result of an additive in the Kevlar absent in the Nylon. Once again, further experiments are warranted before any conclusions can be determined.

Although there was a very limited data set (3 different temperatures, 5 samples total, and only in the short time region), it appears that there was no difference between the samples of Nylon aged with or without Kevlar under 100% RH and an argon atmosphere (Figures 2-4). This conclusion is speculative based on the limited data, and lack of significant loss in tensile strength.

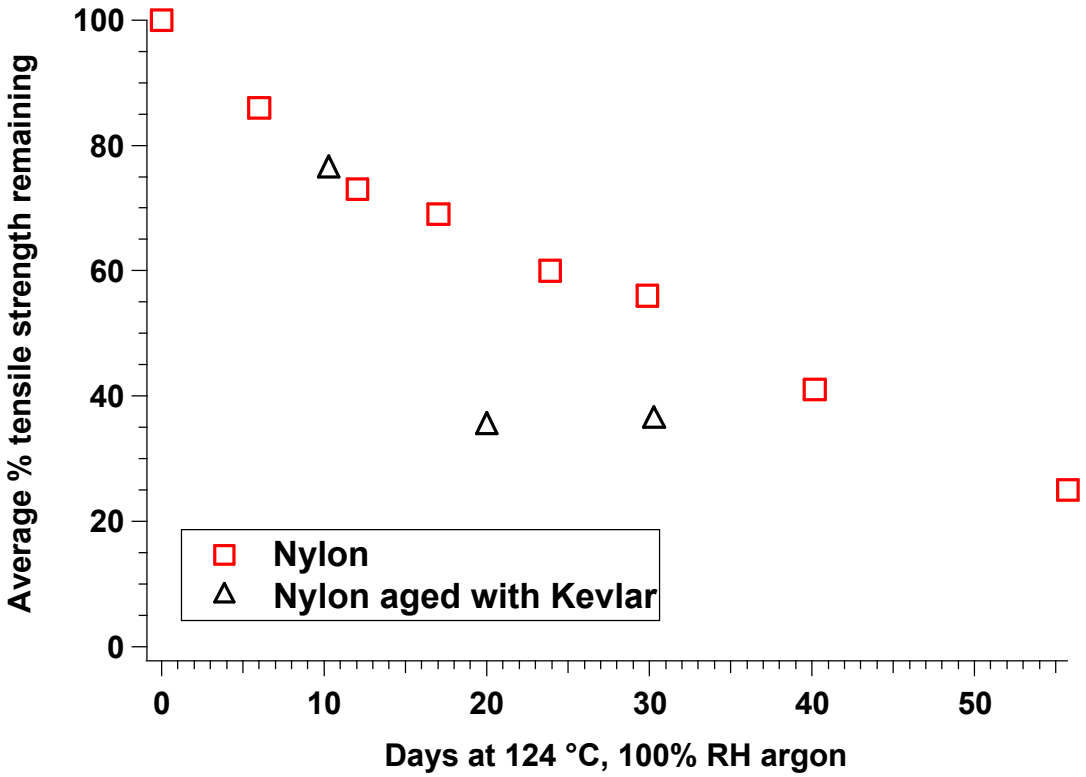

Figure 2. Comparison of Nylon aged alone and with Kevlar under an argon atmosphere at 124 °C.

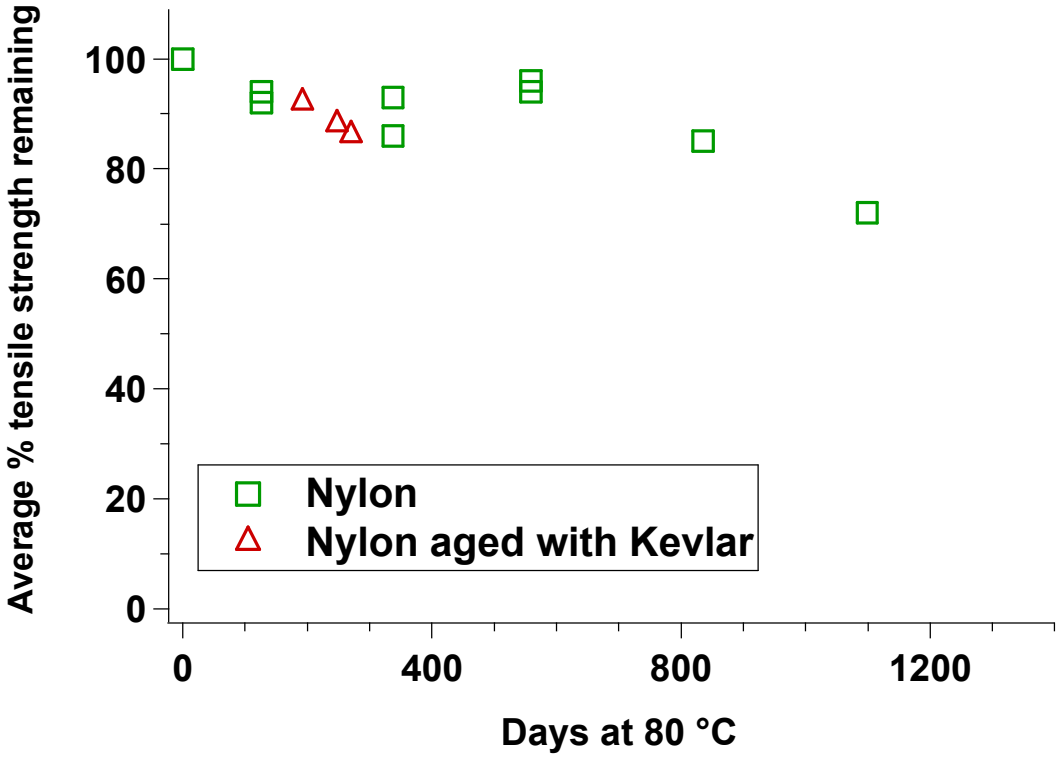

Figure 3. Comparison of Nylon aged alone and with Kevlar under an argon atmosphere at 80 °C.

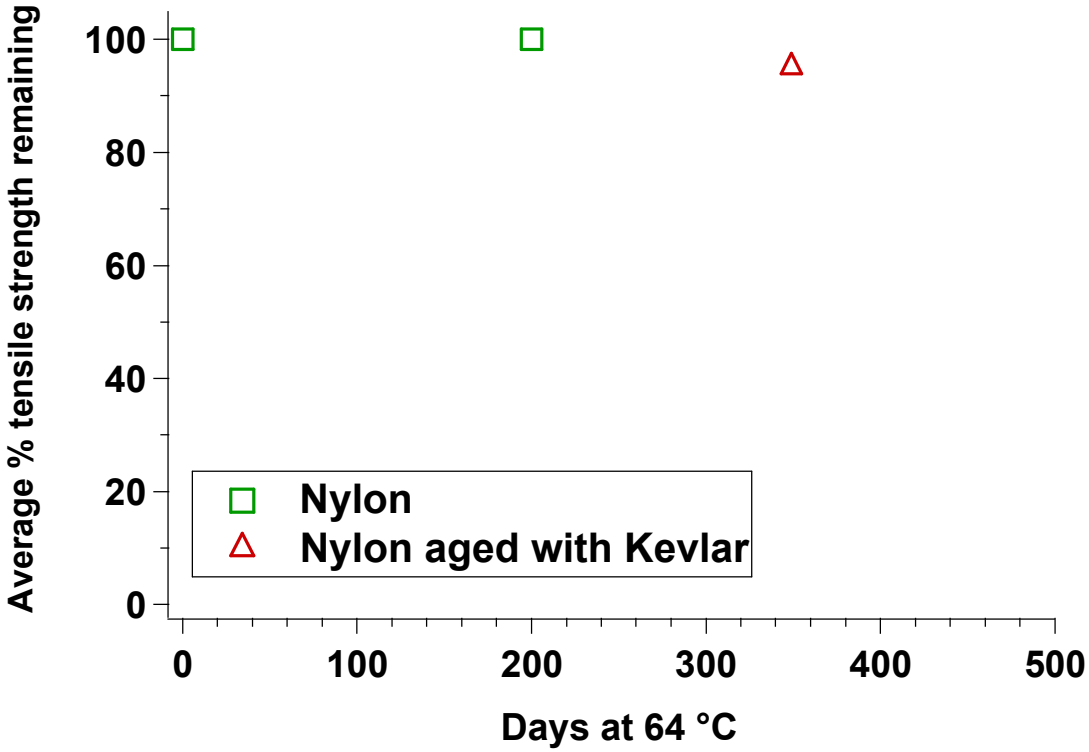

Figure 4. Comparison of Nylon aged alone and with Kevlar under an argon atmosphere at 64 °C.

Conclusions

Nylon aged with Kevlar at 100% RH clearly demonstrates an enhanced rate of degradation compared to that of Nylon aged alone. Careful studies of the degradation products of Kevlar could shed light on the rate enhancement; however it would be difficult to understand if the source of the rate enhancement is only present in catalytic quantities. With the limited data set for the argon, as a headspace gas, an increased rate was not yet apparent. Further work would be necessary to confirm this conclusion.

Acknowledgement.

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