Paper No 24

Oxidation Kinetics in Beltcoat Compound

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Abstract

Because tires spend most of their lives at ambient temperature, knowledge of oxidation kinetics in this temperature regime is very important. Oxidation has been shown to be a key degradation mechanism in beltcoat compound governing belt edge durability in passenger tires. The ultra-sensitive oxygen consumption technique developed by K Gillen[1] was used to measure oxidation kinetics of a passenger tire belt coat compound over a wide temperature range, including ambient temperature. The ultra-sensitive oxygen consumption technique allows accurate measurements in this lower temperature regime, from which accurate time-temperature lifetime oxidation master curves can be obtained. In this way, it is not necessary to extrapolate to ambient temperatures to predict lifetime at service temperatures.

Strategy for Determining Aged Property Retention at Ambient Temperatures

Although the measurement of property decay at elevated temperatures and subsequent extrapolation using an Arrhenius fit has been used to predict property retention at ambient temperatures, it is generally not satisfactory[2]. The purpose of this work was to find another avenue to determine aged property retention of beltcoat compound at ambient temperatures. The oxidation kinetics was studied using the ultra-sensitive oxygen consumption technique developed by K Gillen[1]. This technique has been shown to be able to accurately measure oxidation kinetic at ambient temperatures [2-4]. These kinetic results were subsequently used in combination with physical property data to predict aged property retention at ambient temperatures. The aged property retention was studied using tensile properties on aged thin sheets in an oven under accelerated aging conditions. Thin samples were used in each case to ensure that diffusion limited conditions did not exist during the experiment. Experiments were conducted on passenger beltcoat/wedge compound extracted from the belts at the belt edge region. The tire was a passenger tire after 1.5 years of service with size P215/75R15.

Oxidation Kinetics

Oxidation kinetics was measured over a range of temperatures from 20°C to 80°C. The isothermal results are shown in Figure 1. A typical way to determine activation energy is an Arrhenius type plot shown in Figure 2. The results show that the activation energy for oxidation of beltcoat compound above 50°C was 100 kilojoules per mole. Below 50°C there was a deviation from the linear data expected by Arrhenius type analysis. In the same measurements carbon dioxide and carbon monoxide generation were measured. The carbon dioxide and carbon monoxide generation rates are shown in Figures 3 and 4, respectively. The carbon dioxide and carbon monoxide generation rate data appear to be linear in an Arrhenius type analysis. Their activation energies were 88 kilojoules per mole and 96 kilojoules per mole, respectively. By repeated ultra-sensitive oxygen consumption measurements on the same sample, the integrated oxygen consumption for each temperature was obtained (Figure 5). Time temperature superposition was used to generate a master curve through empirical shift factors (Figure 6). Subsequently, the shift factors were plotted as a function of temperature in an Arrhenius type plot (Figure 7). The shift factors were linear above 50°C with activation energy of 100 kilojoules per

Figure 2: Oxygen Consumption Rate for Beltcoat Compound as a Function of Temperature

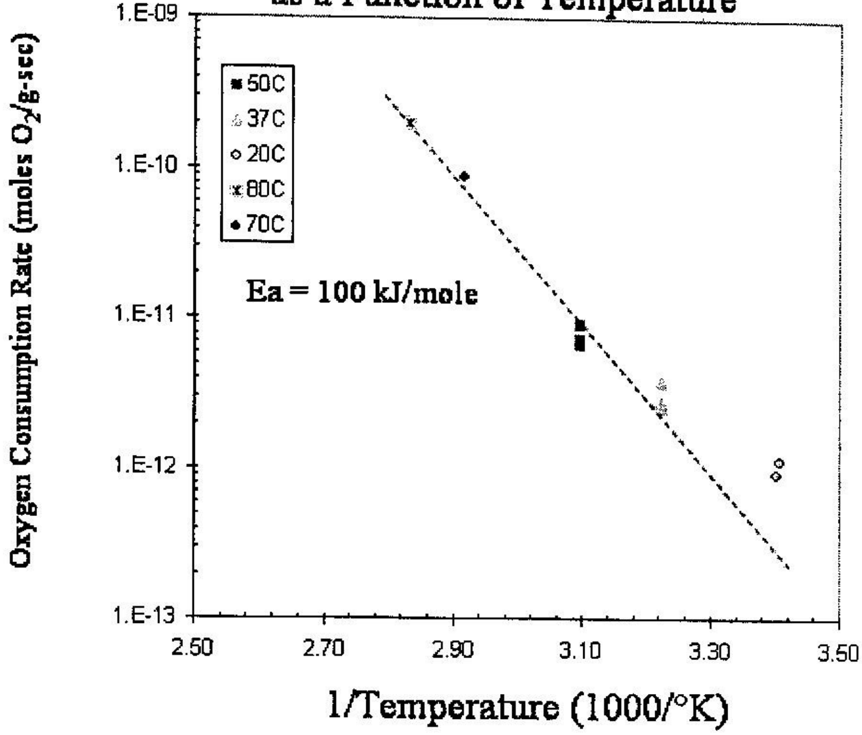


Figure3: Carbon Dioxide Generation Rate for Beltcoat Compound as a Function of Temperature

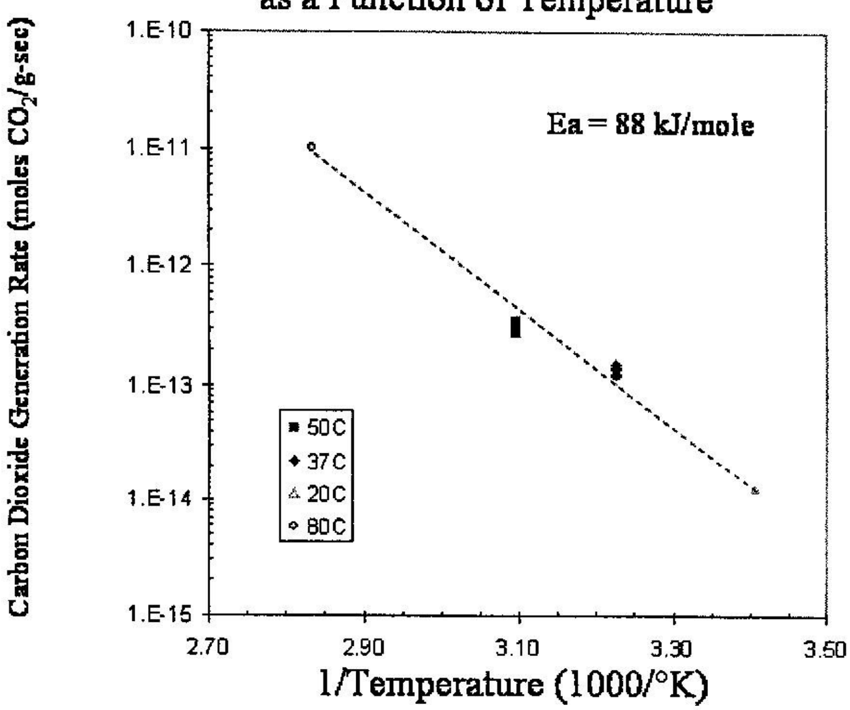


Figure 6: Time-Temperature Superposition of Integrated Oxygen Consumption

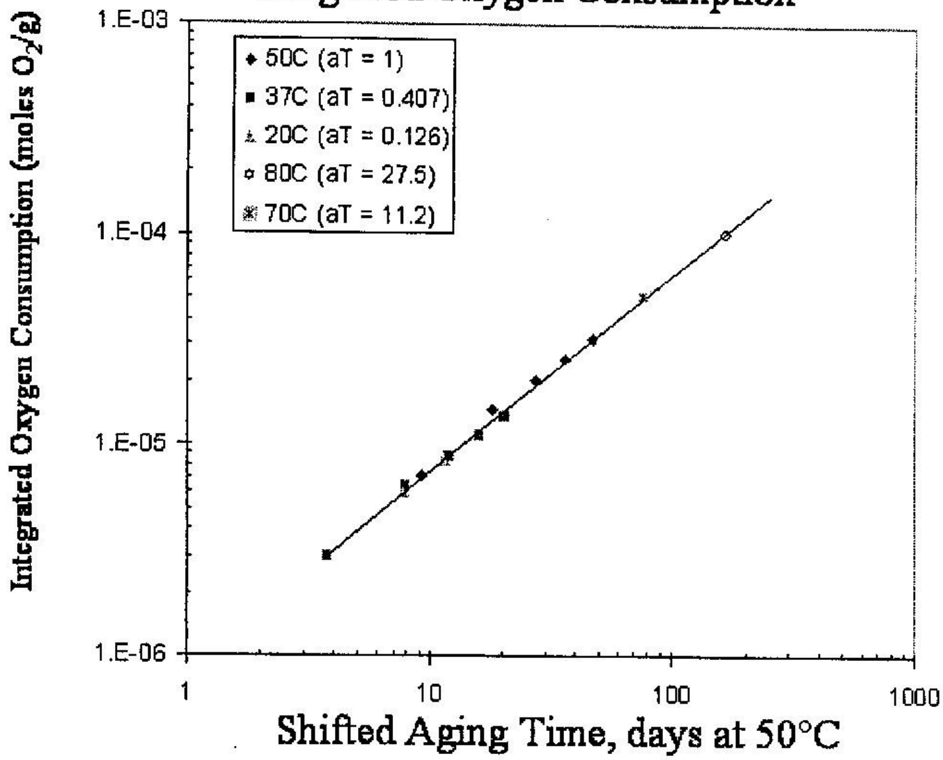


Figure 7: O_2 Consumption Shift Factors as a Function of Temperature

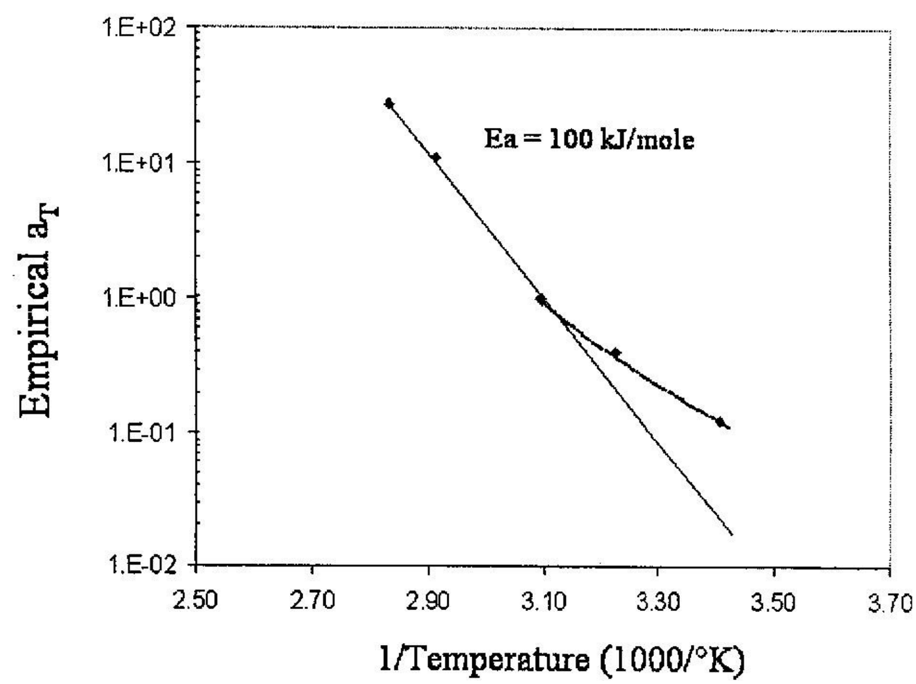


Figure 9: Time-Temperature Superposition of Elongation to Break

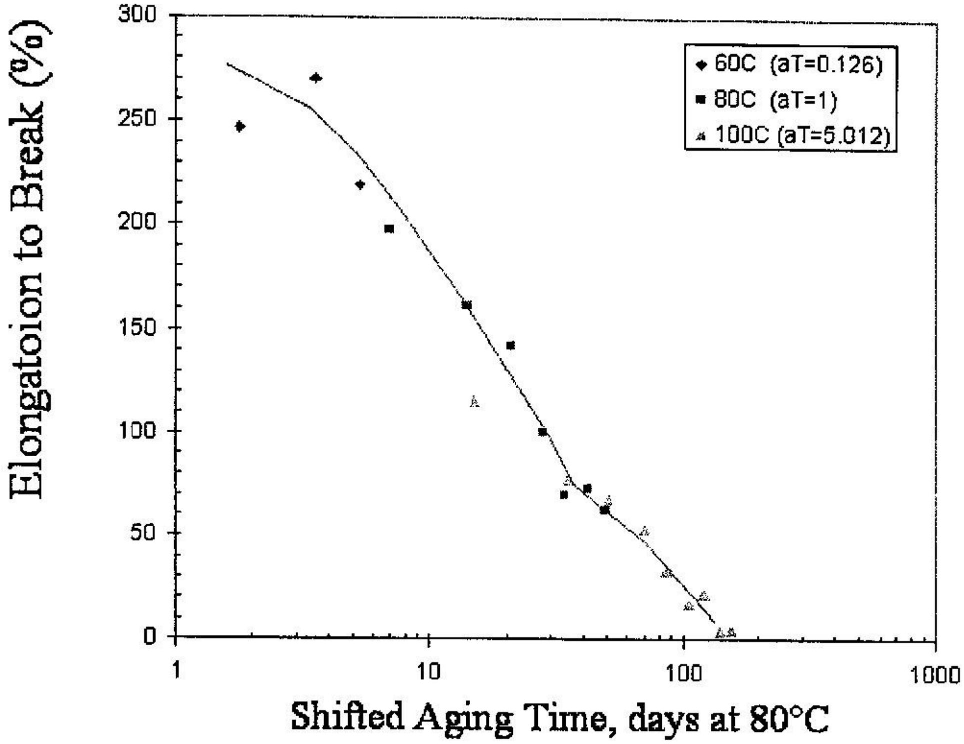


Figure 10: Elongation Shift Factors as a Function of Temperature

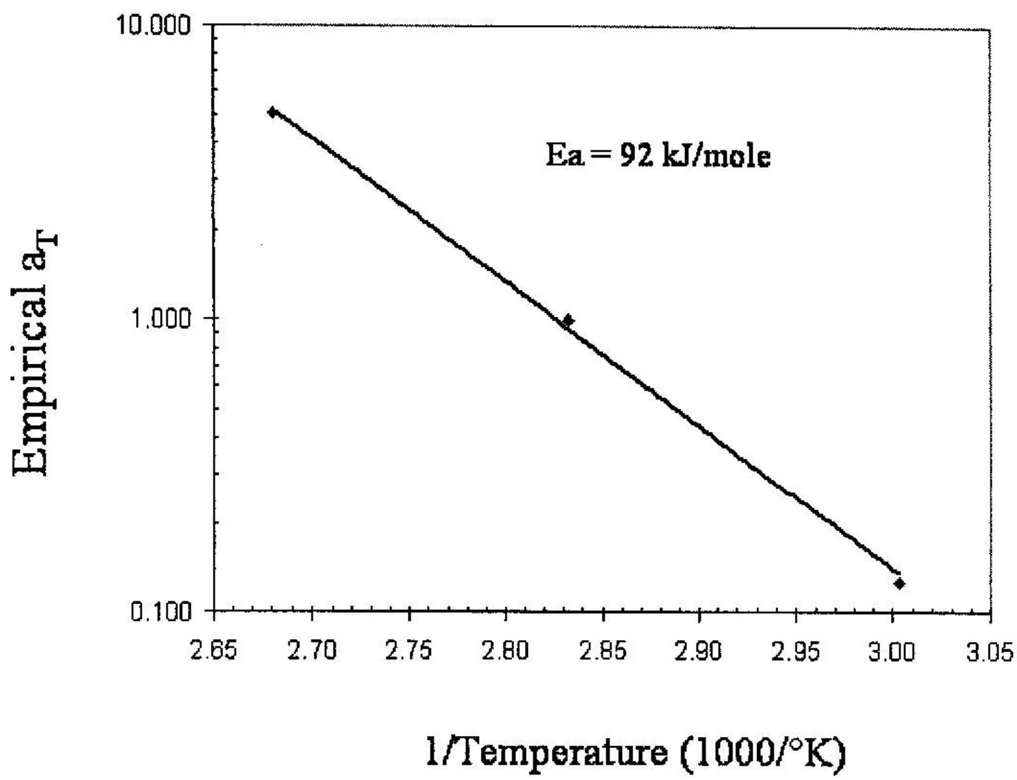
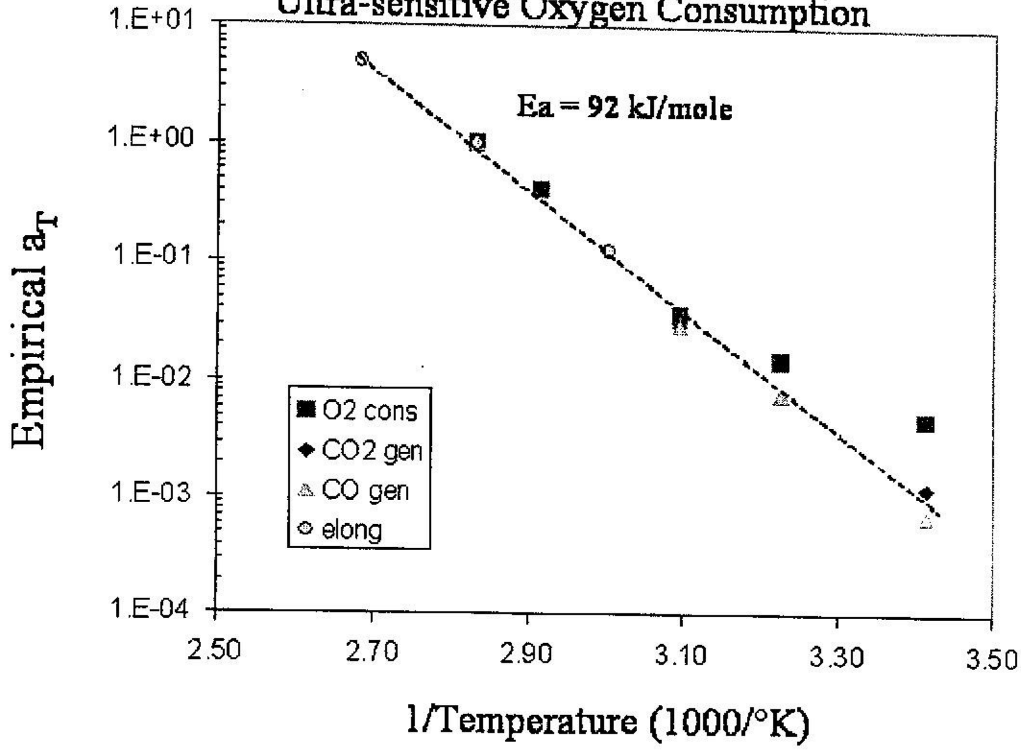


Figure: 12 Comparison of shift factors from Elongation and Ultra-sensitive Oxygen Consumption



Summary and Conclusions:

1. Extrapolations from high temperatures to lower temperatures can lead to invalid estimates of oxidation rates. To rank oxidation resistance in field tires it is preferable to measure oxidation kinetics at service temperatures.

2. The ultra-sensitive oxygen consumption technique allows accurate measurement of oxidation kinetics at temperatures below 50°C in a reasonable amount of experimental testing time (months instead of years).

3. At temperatures below 50°C there was a change in the mechanism of oxidation in beltcoat compound. Degradation was ten (10) times faster than extrapolated values from elongation to break data.

4. Elongation to break for various temperatures generated a property decay master curve. It was subsequently shift onto ambient (service) temperatures of interest. The ultra-sensitive oxidation method with time temperature superposition has generated the necessary shift factors in the ambient temperature region to predict physical property decay at ambient temperatures.