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EFFECT OF OXYGEN ON DYNAMIC MECHANICAL PROPERTIES

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Effect of Oxygen on Dynamic Mechanical Properties

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* Speaker

Abstract
The objective was to determine the effect of atmospheric environment (gas type) on dynamic mechanical properties of tire compounds, especially the effect of oxygen. The results have implications on the effect of inflation gas on rolling resistance. The effect of oxygen may induce cross-linking reactions sufficient to affect the dynamic mechanical properties. The results showed that the effect of oxygen concentration on dynamic mechanical properties was not significance over a short test period. A model tread compound and a model wirecoat compound were analyzed under different atmospheric composition. In one case, the sample was in an inert gas environment. In the second case, oxygen was present. Complete removal of the dissolved gases was performed, after which the gas was replaced with a pure gas, either oxygen or nitrogen. During the testing, the sample gas environment was maintained. The sample was tested in simple shear using a DMA at 70°C.

Background and Purpose:
A paper by Nader Jalili and Prakash Venkataraman suggested that nitrogen inflation would reduce (improve) tire rolling resistance.[1] They suggested that lower rolling resistance would be achieved through better retention of tire inflation pressure. Other authors have suggested that oxygen concentration in the inflation gas has an important role in tire durability[2] and treadwear[3]. The proposed chemical mechanism is oxidation of the rubber compounds, leading to crosslnks and loss of properties. The goal of this paper was to understand whether there could be an effect of oxygen concentration on the material contribution to rolling resistance; in other words, the effect of oxygen concentration on dynamic mechanical properties. The key question was whether oxygen could induce crosslinking reactions sufficient to affect the dynamic mechanical properties during a tire rolling resistance test.

Experimental – Sample Preparation and Test Methods

The brass-to-rubber (dual lap shear test specimen) sample to be tested was first sealed in a reactor. Next, a vacuum is pulled in the reactor to around 13.80psi. After applying vacuum, either oxygen or inert gas (helium) was added under slight pressure (approximately 4.70psi). O_2 was added for testing under air and He is added for testing under N_2. The reactor is then let sit for two to three days. After this period of time, an open/close test is done to make sure little to none of the pressure has dissipated. After this test, a vacuum (about 13.80psi) is again pulled in the reactor; this gets rid of all the gases dissolved in the sample before the start of this experiment. Next, the sample is put under higher pressure (about -13.80psi) of the same gas as before and let sit for at least a day. After sitting for this time, the manifold has a vacuum pulled in it followed by it being set with the same higher pressure as the reactor was set before the set amount of time. An open/close test is done to again check for leaks. Finally, after leaks are checked for, the reactor is brought down about 0.50psi then opened to retrieve the sample.

Now that the sample had been saturated with the gases desired, the dynamic mechanical properties are measured during a temperature sweep using a Metravib model DMA+150. The inter-conversion of the Metravib from air to nitrogen environment is shown in Figures A to D. While taking measurements with the Metravib, air or N_2 was flushed across the sample (see below for N_2 flow set up) to maintain the design gas envirnment. The test starts at room temperature (about 24.0°C). It then uses a ramp of 2°C per minute to reach a desired 70°C. The temperature is held steady there for an hour while data readings are taken every 15 seconds. Another ramp of -3°C per minute is used to cool the sample back down to 28°C. The dynamic strain was +/- 10% (20% peak to peak dynamic strain amplitude) with a frequency of 10 Hz. The static strain was zero.

Metravib Set-Up Change for Nitrogen Conversion

Figure A: Original Configuration

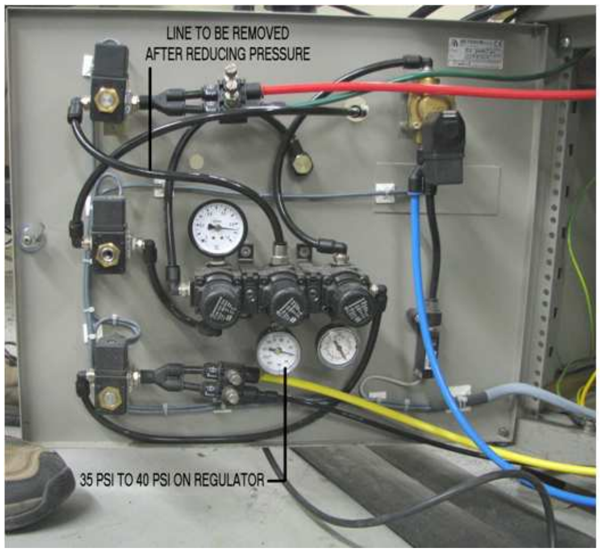


Figure B: Plug Installed

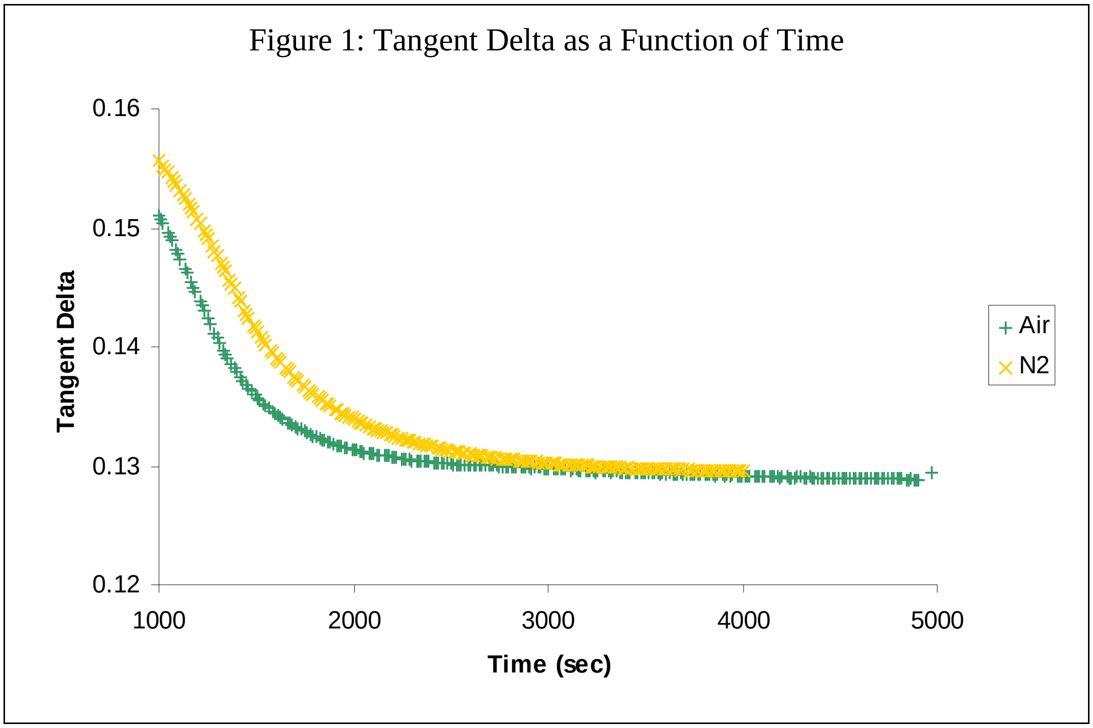
Figure C: Bottle Hose

Figure D: Bottle Pressure

Results and Discussion

Model Nitrile Compound

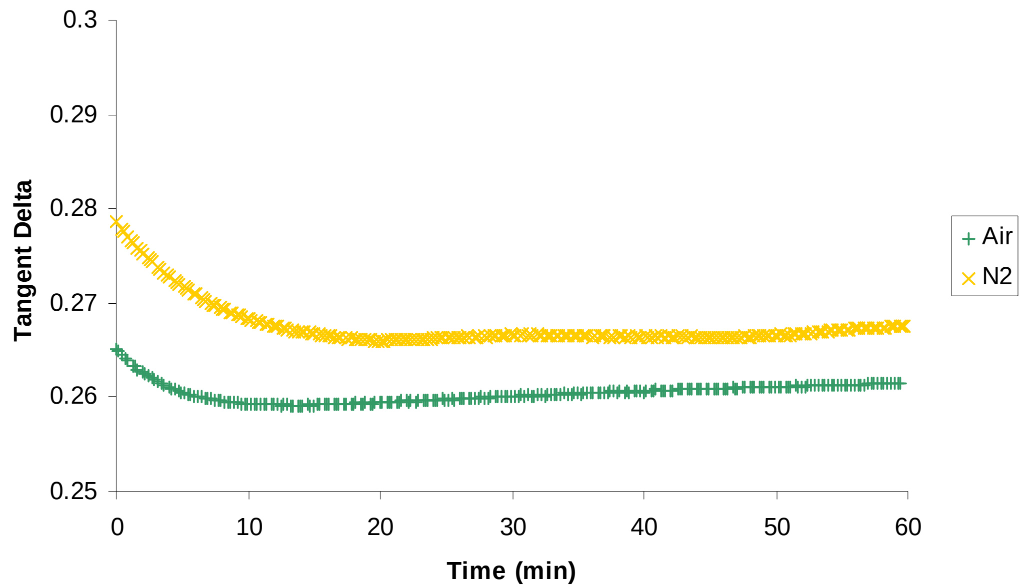
With the temperature at a constant 70°C, the tangent delta for both the sample exposed to air and the sample exposed to nitrogen approached and settled at a similar value (Figure 1).



Model Tread Compound

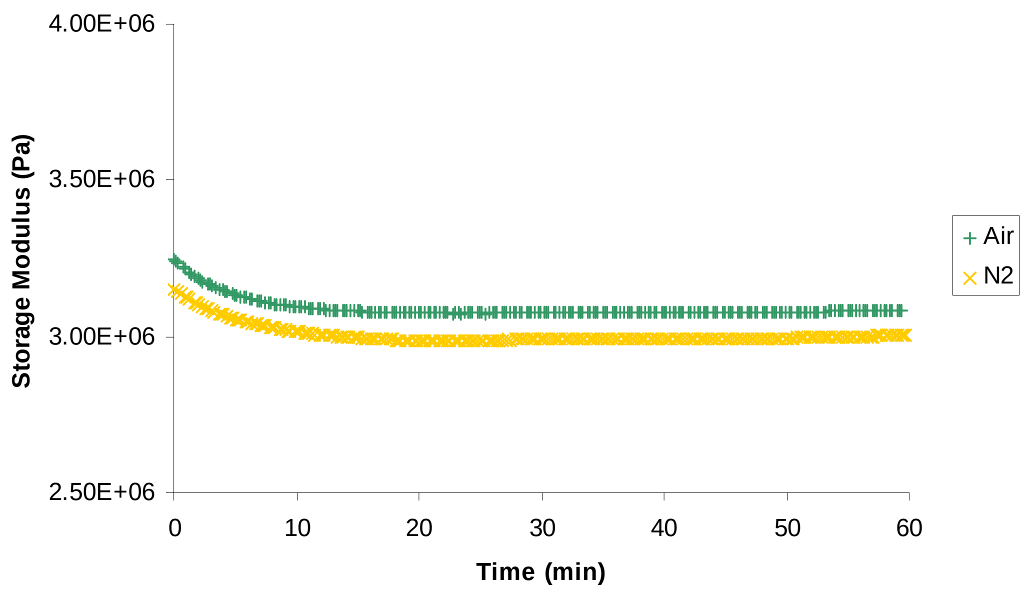
With the temperature at a constant 70°C, the tangent delta for the sample exposed to air approached and settled at a slightly lower value than the tangent delta for the sample exposed to nitrogen which was not significantly different (Figure 2).

Figure 2: Tangent Delta as a Function of Time



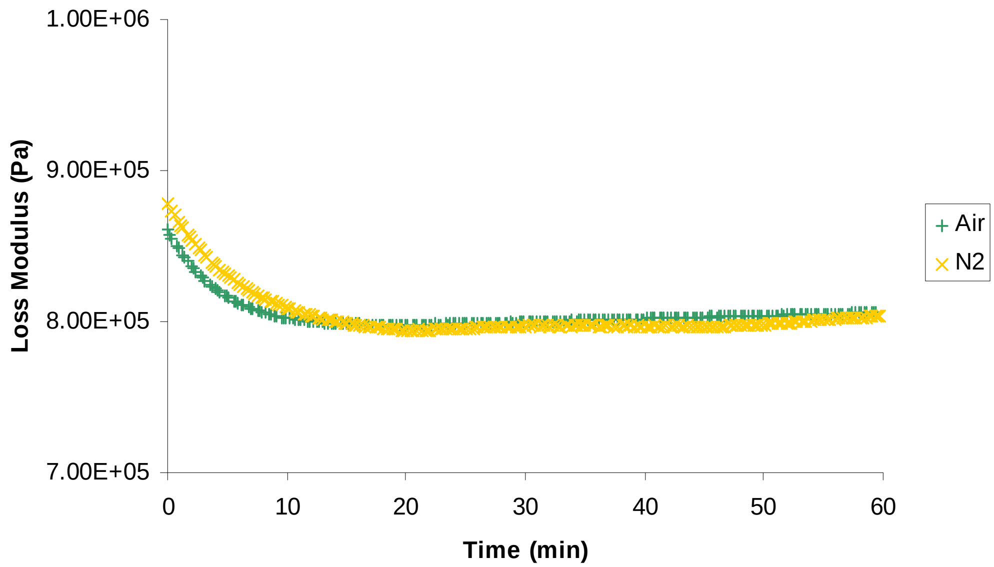
With the temperature at a constant 70°C, the storage modulus for the sample exposed to air approached and settled at a slightly higher value than the storage modulus for the sample exposed to nitrogen (Figure 3).

Figure 3: Storage Modulus as a Function of Time



With the temperature at a constant 70°C, the loss modulus for both the sample exposed to air and the sample exposed to nitrogen approached and settled at a very similar value (Figure 4).

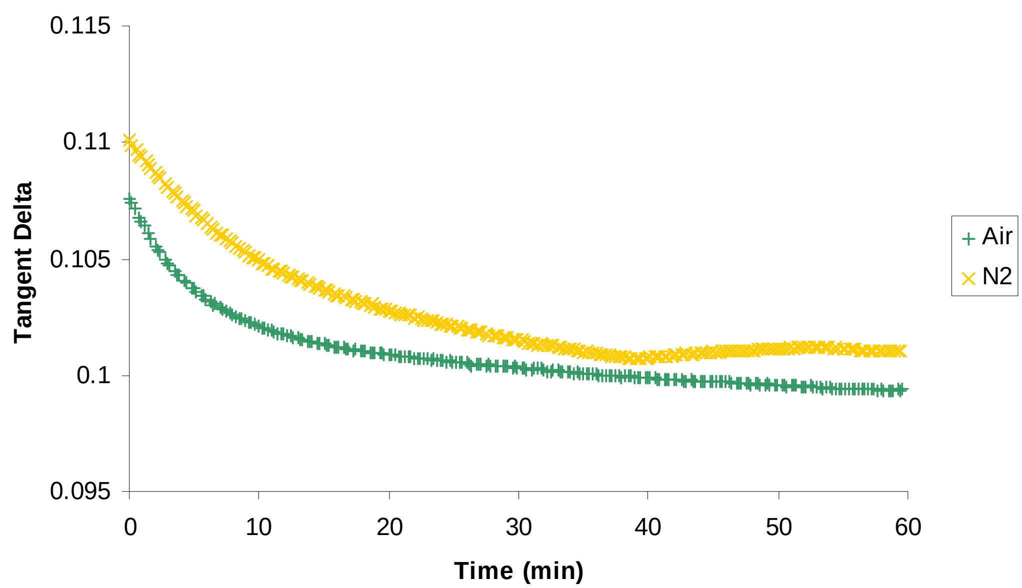
Figure 4: Loss Modulus as a Function of Time



Model Wirecoat Compound

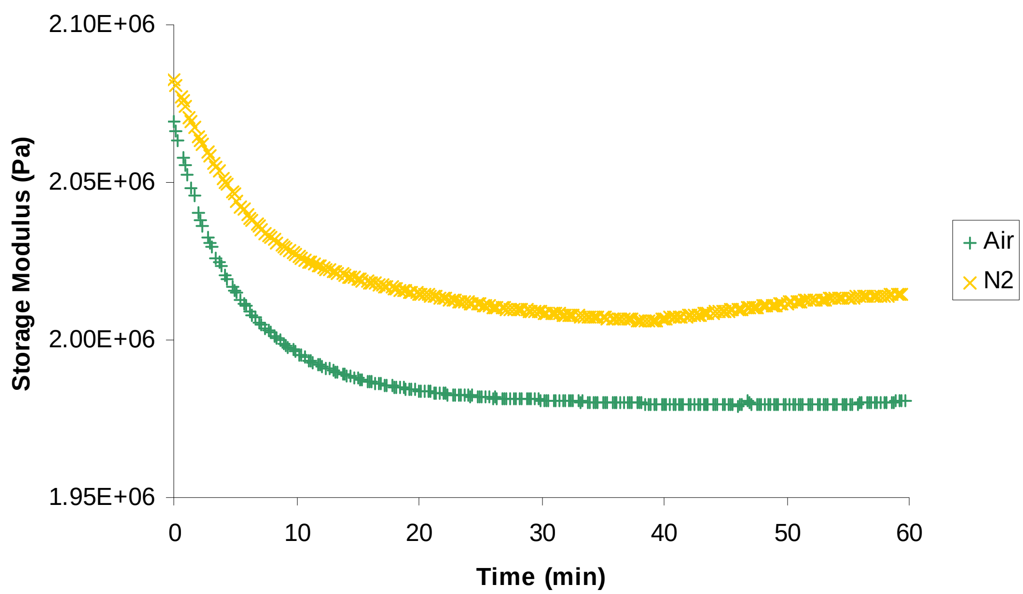
With the temperature at a constant 70°C, the tangent delta for the sample exposed to air approached and settled at a slightly lower value than the tangent delta of the sample exposed to nitrogen, but not significantly different (Figure 5).

Figure 5: Tangent Delta as a Function of Time



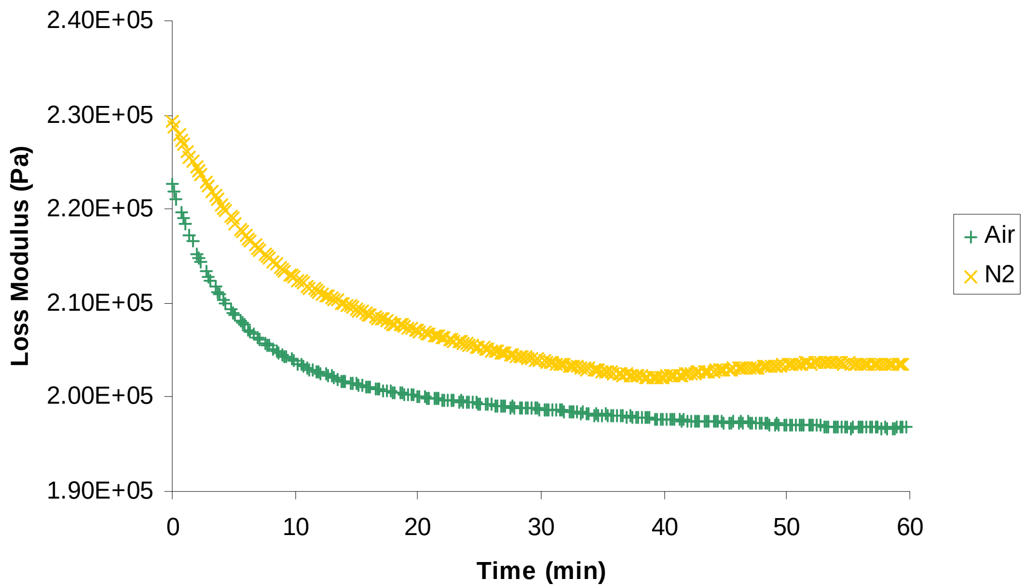
With the temperature at a constant 70°C, the storage modulus for the sample exposed to air approached and settled at a slightly lower value than the storage modulus for the sample exposed to nitrogen, but not significantly different (Figure 6).

Figure 6: Storage Modulus as a Function of Time



With the temperature at a constant 70°C, the loss modulus for the sample exposed to air approached and settled at a slightly lower value than the loss modulus for the sample exposed to nitrogen, but not significantly different (Figure 7).

Figure 7: Loss Modulus as a Function of Time



Conclusion:

The gas environment (oxygen concentration) did not significantly affect the dynamic mechanical properties of three compound types. This means that inflation gas composition would not be expected to affect the material contributions to tire rolling resistance (in the time scale of a rolling resistance test).

References:

1. N Jalili and P Venkataraman, "Tire Nitrogen Filling System" in a *Report to Ingersoll Rand Corporation*, Clemson University, 2007.
2. J M Baldwin and D R Bauer, *Rubber Chem. and Tech.* **81**, 338 (2008).
3. K Mech, "Why Nitrogen Tire Inflation Extends Tire Tread Life" in a *Drexan Corporation Report*, October 7, 2005.