Why Nitrogen Tire Inflation Extends Commercial Tire Tread Life

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Introduction

The author wrote an article titled "Nitrogen Tire Inflation for Commercial Fleets: The Business Case is Stronger Than Ever" in June 2005. In this article, the author demonstrates how tread wear increases when Nitrogen tire inflation is used instead of ordinary compressed air inflation.

Summary of Nitrogen Benefits for Commercial Trucking[1]

Nitrogen tire inflation has significant benefits over air inflation, and is undoubtedly the best maintenance strategy. There are three main benefits:

- Maintaining correct inflation pressures;
- Extending tire tread and casing life; and
- Reducing tire failure rates.

Correct inflation pressures are maintained due to the much slower rate of Nitrogen dissolution into tire rubber. This finding has been proven through extensive laboratory and field testing. Reduced tire failure rates were demonstrated during a field trial conducted over 12,000,000 km (7,500,000 miles). The purpose of this paper is to explain the mechanism of extended tread wear. This is a key finding which helps to dramatically lower the operating cost per km for long haul trucking fleets.

The mechanism that directly impacts tread wear is oxidation of the tire rubber. Oxidation in tire rubber is very similar to oxidation of unsaturated fats in packaged foods. In the food industry, many products that have a food-oil component are packaged in Nitrogen. Ground coffee, peanuts, salty snacks (e.g. potato chips), creamy pasta sauces, butter pats, cooking oils, and sandwiches are packaged in Nitrogen to extend shelf life and preserve the taste of the product. In normal air, Oxygen is the culprit because it attacks double chemical bonds in unsaturated fats. When Oxygen breaks down these double bonds, the taste of the product is degraded. Stale peanuts taste stale because Oxygen has attacked the peanut oil. Foods packaged with Nitrogen last longer, taste better, and increase profits for their manufacturers by reducing scrap. Tires also have unsaturated bonds in the rubber, and Oxygen attacks and breaks down these bonds. Nitrogen inflation virtually eliminates oxidative aging in tires, and this results in big cost savings for fleets.

Tire Rubber Chemistry, and Tire Rubber Oxidation

Rubber has single and double bonds. Double bonds are susceptible to oxidation. Tire manufacturers have recognized this for a long time. Tire rubber compounds now in use focus on minimizing the number of double bonds. Tire manufacturers

[1] For a complete treatment of benefits for Commercial fleets, including operating economics and integration into shop preventative maintenance routines, see Nitrogen Tire Inflation for Commercial Trucking Fleets, Konrad Mech, P.Eng. MBA, 4 June 2005.

add sacrificial anti-oxidants to bind free O2 so that the double bonds in the tire rubber are not attacked. However, as tire pressure decreases, the operators continually add more compressed air, thereby adding more O2. As the O2 is added, eventually all the anti-oxidant compounds in the tire rubber are consumed. These additives are a one-shot deal. When the additives are gone, the O2 is free to attack the double bonds in the tire rubber. Sperberg's study showed definitively that as time progressed, Oxygen was found deeper and deeper in the tire casing rubber, until it was finally found at the face of the tire tread.

Reference	Author	Date
Million Mile Truck Tires – Available Today	Lawrence R. Sperberg Probe Scientific Lab. El Paso, TX	1985
Long Term Durability of Tires	Tokita et. Al, Uniroyal Inc Research Centre	1985
Factors in Tubeless Radial Tires – 1993 Technical Yearbook, Rubber and Plastics News	David M. Coddington, Exxon Chemical Company	1993
Nitrogen Inflation for Truck Tires – Clemson Tire Conference	Guy Walenga, Bridgestone Firestone	2004
Effects of Nitrogen Inflation on Tire Aging and Performance	Baldwin, Bauer, Ellwood, Ford Motor Company	2004

A complete treatment of tire rubber chemistry and the effect of oxidation on tire rubber is found in the technical papers in the above table.

Quantifying the extension of tire tread wear

From a field trial standpoint, Lawrence R. Sperberg has performed the most important work in validating tread life extension[2]. Sperberg's trial provides conclusive proof that Nitrogen extends both tire tread and casing life. This analysis will focus on his findings about tread wear.

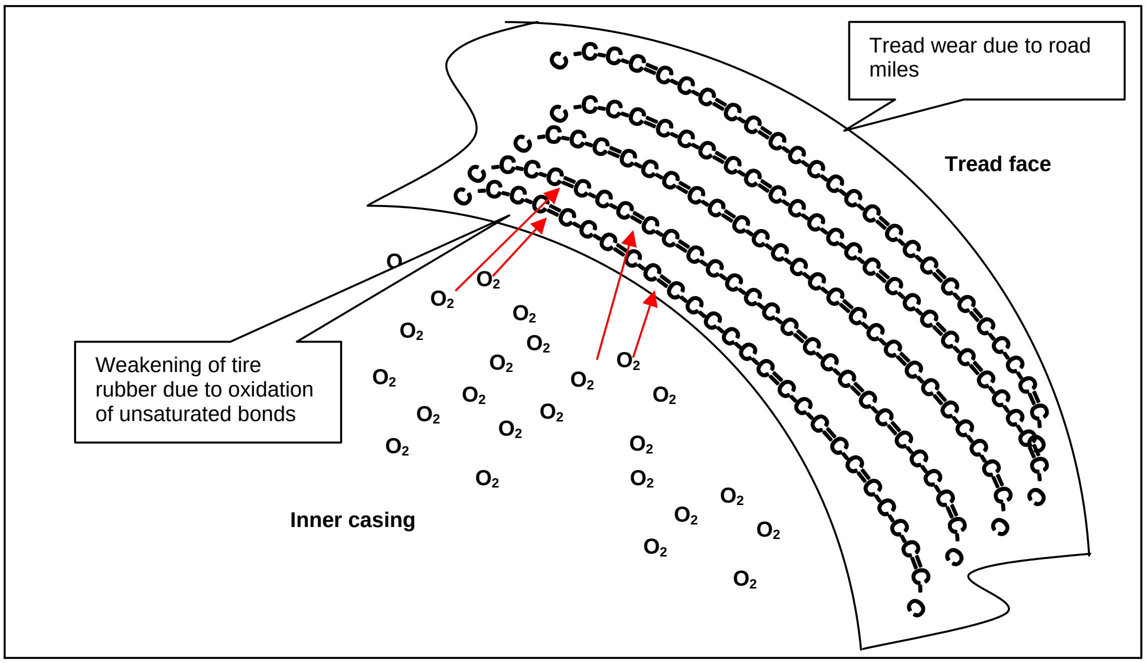
To quickly recap Sperberg's study, he ran tires on drive axles in matched pairs. Two pairs had Nitrogen inflation; the others had air inflation (with Oxygen). The trucks ran routes on the Eastern Seaboard and the Southern US. All tires were inspected at between 6,000 and 10,000-mile intervals. The trial ran for approximately 7,500,000 miles, or over 12,000,000 km. The trial was conducted using new casings, and retreads of air-aged casings. After the trial, all tires were inspected using an electron microscope to examine changes in the rubber chemistry of the casing and tread rubber. Sperberg was actually able to see the change in tire rubber properties, from the inside of the casing right to the tread face. Sperberg noted that the increased tread life for a Nitrogen inflated tire was because Oxygen was prevented from reaching the tread. Because the distance from the inner casing to the tread face is the longest distance for Oxygen to travel, he expected the tread face to be the last region to suffer Oxygen degradation. But at some stage, as the tread wears, the outer surface of the tread is going to contact the inner region that has been degraded by Oxygen, and the wear should accelerate. This is in fact what Sperberg showed.

[2] Lawrence R. Sperberg, Stronger Longer Tires of El Paso, Million Mile Truck Tires – Available Today: One of the World's Best Kept Secrets; Jan 9, 1985.

Sperberg explained the extension of tread life as follows. Oxidative aging occurs from the inside of the tire out, as compressed air at 100 psi works its way through the tire rubber to the outside atmosphere at 14.7 psi[3]. However, as tires roll in

operation, the treads wear from the tire face inwards toward the centre of the tire. In a new casing, the Oxygen in compressed air first gets consumed by any anti-oxidant additives. Once these are consumed (because it's impossible to replenish them), Oxygen attacks the unsaturated double bonds in the rubber, from the inside of the casing outward.

As the Oxygen breaks these double bonds, the tire is continually losing pressure. Aggressive maintenance with compressed air actually accelerates the decay of tire rubber. As the tires are topped up with new air, the newly introduced Oxygen molecules enter the rubber. However, these new molecules travel past already broken double bond sites to new double bonds that are deeper and deeper inside

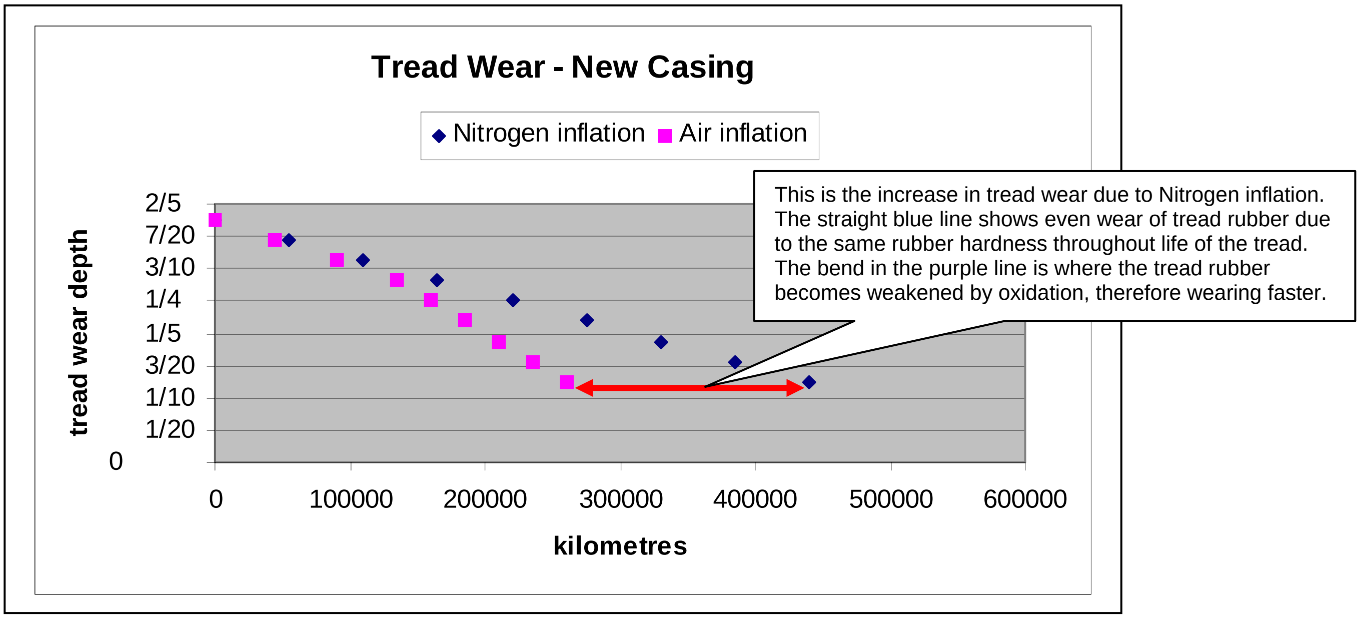


the casing, and closer towards the outside of the tire, including the tread face. At some stage the two surfaces meet. The outer tread wear face comes into contact with the degraded rubber layer. At this point, the durometer hardness of the rubber changes, and typically tread wear accelerates. The remainder of the tread wears at a much faster rate than the new tread did. This phenomenon is shown in the following chart.

Note that fleet operators using compressed air are on the horns of a dilemma. If they top up their tires frequently with compressed air, the Oxygen degrades the

[3] This pressure is at sea level. Ambient pressure decreases with altitude.

tire rubber. But if they do not top up their tires with air, they pay a fuel consumption penalty (1% per 10 psi underinflated per Cummins, 2-5% on



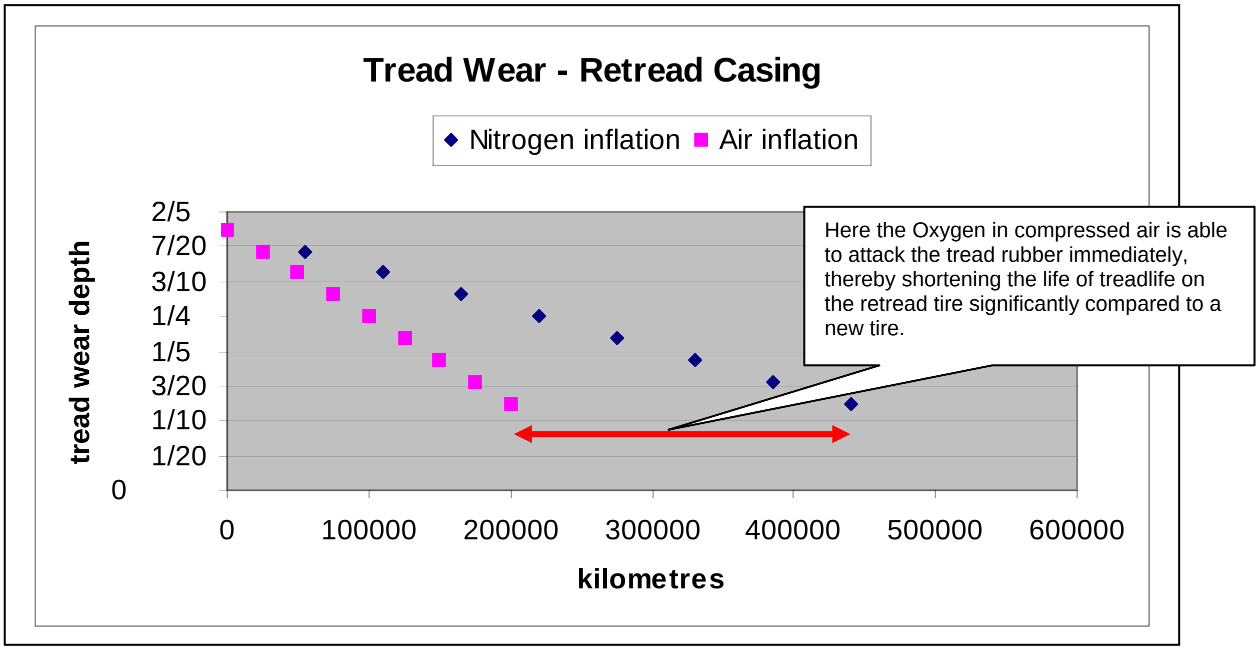
average per Goodyear), a tread wear penalty due to uneven tread contact, and a casing life penalty due to hotter casing running temperatures.

The tread life results of Sperberg's trial were nothing short of astounding. Tread life on a new casing increased on average by 26%. However, tread life on a retreaded casing increased on average by 54%. And the failure rate of casings in service was reduced by 50%, for both new casings and retreaded casings.

It should be noted that Sperberg's study was performed in 1985, on bias ply drive tires, not steel belted radials. Also, tire rubber compounds have changed since 1985. However, the chemical reaction between Oxygen and the rubber compounds is exactly the same as described above. So while tire life has increased due to better compounds and tire casings last longer due to steel belt radial construction, oxidation of tire rubber still occurs. What we have seen in limited trials in Canada is exactly as predicted by Sperberg. Trailer tires, previously reaching between 200,000 and 220,000 km with air inflation, are currently trending to achieve over 400,000 km when inflated with Nitrogen.

The above discussion and chart was for a new casing. The second chart on the following page shows why tread life is significantly lengthened for nitrogen-inflated casings. When an air filled casing is retreaded, the majority of double bonds in the casing have already been oxidized. This is why an air aged casing is weaker than a new one. So the time for Oxygen to reach the new retreaded face in contact with the road is much less than for a new tire, and the retread wears faster than a new tread. Sperberg's trial showed that for an air aged casing, the tread rubber on a nitrogen inflated retread lasted as long on average as the tread on a new nitrogen inflated casing.

The key point for fleet owners and fleet managers is this. Sperberg proved that when an air aged casing is retreaded and then inflated with Nitrogen, the tread



wear of the retread <u>is the same as it is for nitrogen-inflated new casings</u>. This means that fleets should incorporate nitrogen inflation in their entire fleet (new tires, new retreads, and old retreads) all at once. Once retreads start to be put on new tires that started their life cycle with nitrogen inflation, then not only will tread wear be longer, but the casings will be much stronger, and failures on the road will be dramatically reduced.

<u>Additional benefits to Commercial Fleet Operations from Nitrogen Inflation</u>

The main objective of this article was to explain why commercial truck tires get longer tread wear with Nitrogen tire inflation. However there are four other significant benefits to commercial truck fleet operators.

<u>Maintenance of Correct Tire Inflation.</u>

Tire manufacturers agree that underinflated tires waste between 2-1/2% and 4% of fuel in increased rolling resistance[4]. For a fleet with 500 tractors and 1000 trailers running an average of 240,000 km a year and getting 6.9 mpg, this translates to an annual fuel usage of over 49,000,000 litres of diesel a year. At a spot price of 90 cents a litre, that is a total fuel bill of almost $44,100,000.00 a year. 2% loss in efficiency is equal to almost $882,000.00 excess costs per year, every year. Tires inflated with Nitrogen maintain correct inflation pressure longer than air inflated tires – up to five times longer. This reduces rolling resistance of

[4] Goodyear Radial Truck Tire and Retread Service Manual p. 40

the tire and reduces fuel consumption. This means that these lost costs are recouped and drop to the firm's bottom line as pure profit. Also, when correct tire pressure is maintained, the tread lasts as long as the manufacturers intend. Under-inflated tires wear faster.

Extending Casing Life.

Sperberg showed that Nitrogen inflation increases tread life on a new casing up to 26% on average. Nitrogen inflation increases tread life on retreads up to 54% on average. Also, casings retain their strength longer. A casing filled with Nitrogen will retain over 80% of its original strength after two years, while an air filled casing will only have 40% of its original strength[5]. That is a 100% increase in casing strength for Nitrogen over compressed air. This translates to significant tire savings. A stronger casing can be retreaded more times, and the tread wear on each casing lasts longer than tread wear with air inflation. For the same fleet details as above, potential tread savings can increase from a current average life of 908,000 km to a life of 1,650,000 km with Nitrogen inflation. Most retreaders use non-destructive testing to verify casing integrity before retreading. Fleet managers will be able to verify whether to retread a casing an additional time or sell it to another user.

Reducing Tire Failure Rates.

Just like the food industry's experience, Nitrogen can actually extend tire and casing life and can reduce the number of tire failures in service, by reducing oxidative aging of the rubber. Nitrogen inflation not only extends tread wear and casing life, it reduces the casing failure rate. Tests on new and retreaded casings show that the rate of failure for Nitrogen-inflated tires is 50% lower than for air-inflated tires. For a large fleet this saving alone can pay for an entire program. Please note that Nitrogen will not turn tires into Kryptonite –failures on the road will still occur. However, failures will drop substantially, saving the cost of replacement tires, and unscheduled roadside repair costs, which can be quite unreasonable at times.

Simpler maintenance due to elimination of condensed water in tires.

A lot of compressed air is wet. Water causes rim rust, and can cause chronic leaks through the valve stem. Rust also gets pushed under the bead of the tire, creating micro leak paths. In winter, if a tire needs to be aired down, moisture in the tire casing can freeze in the valve stem. Since Nitrogen is a dry gas, all these maintenance problems are eliminated.

[5] Baldwin, Ford; Tokita, Uniroyal; Coddington, Exxon Chemical; op. cit.

Summary of Fleet Maintenance Savings

Fleet maintenance managers are increasingly turning to Nitrogen tire inflation to reduce their operating costs and increase their fleet up time. Direct and indirect savings to fleets are:

- Fewer tire failures in service
- Lower costs per km in service for steering tires, drive tires, and trailer tires
- Fewer scrap casings (by allowing additional retreads)
- Higher casing value for resale
- Lower retreading costs
- Lower fuel costs due to proper inflation
- Lower tire costs due to proper inflation when running
- Reduced roadside service calls
- Reduced late delivery charges (for guaranteed delivery services)
- Less lost revenue due to breakdowns
- Lower accident liability due to fewer blowouts and collateral accident claims
- Reduced spare tire inventories

Drexan Corporation specializes in the specification and supply of nitrogen tire inflation and compressed air solutions, including industrial gas solutions, from Parker Hannifin Corporation. Drexan is staffed with a technically trained inside, outside and technical support sales team in Vancouver, Calgary, Edmonton, the GTA, and Ste-Therese QC.

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