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Tire Inflation Rate Modeling

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Abstract

This paper will examine in detail the conditions of correctly inflated tire pressure that gives appropriate support from the contained air pressure to provide an even distribution of load across the footprint and help stabilize the tire's structure which has a significant impact on tire wear, rolling resistance, durability and allows drivers to feel acceptable vehicle comfort, and adequate performance. Tire industry load and inflation standards are in a constant state of change and all tires manufacturers continually updates their product information to reflect these changes. Therefore the printed information's may not reflect the latest load and inflation standards, so tires users will be in need of continuous following for information updating and this is one of the main problem for the most tire dealer. In this paper we have taken into consideration all factors and the condition of tire work that have direct effect on tires performance, stability and safety. Also the paper is presenting all technical procedures to guarantee better performance, stability, safety and long duration. Finally, the paper will introduce the risks faced by the use of improper pressure inflation and worn tires.

Keywords: Tire size, Tire load, Tire cold inflation pressure rate, pressure rate modeling.tion.

Introduction

Tires now manufactured in around 455 tire factories in the world with over 1 billion tires manufactured annually [1]. According to high number of manufactures and due to the pure economical interests tendency rather than quality technical specifications, tires performance has been declined at the last decade as a result of considerable low quality production [2,3].While tires appear solid, the molecular structure of the rubber used to manufacture them actually looks like strands stuck together. These molecular strands are stretched and returned to their relaxed state every time the tire rolls (about 800 times every mile) [4] this result to a very high excessive stresses and strains then to wear and finally to a failure.

It's an important issue in planning and managing vehicle's safety and economical running to know how to select a proper load and cold inflation pressure of vehicles due to tires size. Choosing the correct load rating of a tire can be very confusing. There are many things to be considered when selecting a load rating due to maximum inflation rate, payload and vehicle type and in addition industry load and inflation standards. [5]. Tires support the weight of the vehicle by means of the air pressure inside them that actually supports the weight. Maintaining sufficient air pressure is required if the tires are to provide all of the handling, traction and durability of which they are expected to good performance. Tires should be applied to appreciate designing procedures. Failure of the tire would endanger human life, and since the tire is made in extremely large quantities; consequently, an elaborate testing program is justified during design and even after the production [6]. However, even if tires are correctly inflated, setting of tire pressure has to be checked periodically to assure that the influences of time; change in ambient temperatures or small tread punctures have not caused it to drop. However, even if tires are correctly inflated, setting of tire pressure has to be checked periodically to assure that the influences of time; change in ambient temperatures or small tread punctures have not caused it to drop [7].

The tire load and cold inflation pressure per axle for road vehicles there are standard tables to be used. It's always recommended weighing each axle end

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separately and using the heaviest end weight to determine the axle's cold inflation tire pressure. **For control of the road vehicles inflation rate it is critical that the tire pressures should be the same across all axles, while never exceeding the maximum air pressure limit stamped on the wheels but in fact tire fitter men and vehicle drivers are so far not interested to do so properly [8].**Tires are normally inflated with air (a combination of gasses comprised of about 78% nitrogen (N_2), 21% oxygen (O_2) and 1% argon (Ar) along with some traces of other gasses) from the local gas station. Unfortunately, using air permits moisture and the amount of water vapor in the air that varies from place to place, time of the year and due to weather conditions. While air is all around the world is extremely different sometimes, finding a convenient source of an ideal compressed air is becoming difficult, and finding a source of "dry," vapor free compressed air is even more difficult and this as a result has a negative influence to tire performance and its time life. Correctly inflated tires receive appropriate support from the contained air pressure to provide an even distribution of load across the footprint and help stabilize the tire's structure. And while most drivers recognize that proper inflation rate has a significant impact on tire wear, rolling resistance and durability, only a few realize that under inflation also has a noticeable influence on how quickly and precisely the tires respond to the driver's work commands [9].

Since typical tire pressures range from 30 to 35 psi for cars (with light truck tire pressures often higher), there is a constant force trying to push the air through the tire. This allows some of the air to escape (called permeation) right through the microscopic spaces between the rubber molecules and somewhat like a rubber balloon; the air will eventually escape if it is not replenished. Generally, a tire's inflation pressure rate will go down by about 1 psi every month. This means that if air isn't added for two to three months, the tire's inflation pressures will probably be 2 to 3 psi low, but normal car owners are not paying great attention to that. In order to help maintain more constant tire pressures, tires should be checked more frequently, once a month and before trips is the minimum but once a week is preferred. This will allow refilling lost pressure that escapes over time, as well as discover any pressure losses due to slow leaks caused by minor punctures before significant pressure is lost and the tire's internal structure is damaged [10]. An underinflated tire will tend to wear the shoulder areas of the tread faster than the center. This is because there is insufficient air pressure to allow the center of the tread to carry its fair share of the weight. A correctly inflated tire receives appropriate support from the contained air pressure to provide an even distribution of load across the footprint. While most drivers recognize that proper inflation rate has a significant impact on tire wear, rolling resistance and durability, only a few realize that also has a noticeable influence on how effectively the tires can resist hydroplaning to maintain wet traction. An underinflated tire can't maintain its shape and becomes flatter than intended while in contact with the road. If a vehicle's tires are underinflated by only 6 psi it could lead to tire failure. Additionally, the tire's tread life could be reduced by as much as 25%. Lower inflation pressure will allow the tire to deflect (bend) more as it rolls. This will build up internal heat, increase rolling resistance and cause a reduction in fuel economy of up to 5%. Drivers would experience a significant loss of steering precision and cornering stability. While 6 psi doesn't seem excessively low it usually represents about 20% of the tire's recommended pressure [11]. An overinflated tire is stiff and unyielding and the size of its footprint in contact with the road is reduced that increasing a local stress. If a vehicle's tires are overinflated by 6 psi, they could be damaged more easily when running over potholes or debris in the road. Higher inflated tires cannot isolate road irregularities well, causing them to ride harsher. However, higher inflation pressures usually provide an improvement in steering response and cornering stability up to a point. This is why participants who use street tires in autocrosses, track events and road races run higher than normal inflation pressures. The pressure must be checked with a quality air gauge as the inflation pressure cannot be accurately estimated through visual inspection. In order to evaluate the influence of inflation pressure on response and handling, the tire rack conducted a performance test track drive, comparing properly inflated tires to purposely underinflated tires [12].

Objectives of this study were taken in the study all needed materials and statistical analysis to assess their potential impact on tires performance, stability, safety, time life and operational comforts. Having summarized the factors that influence the tire cold pressure air inflation rate that are considered in this study they can be: - tire size, tire load rating, vehicle mean speed rating, vehicle regime of service rating and air pressure with respect to temperature fluctuation.

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Materials and methods

Tire production starts with bulk raw materials such as rubber, carbon black, and chemicals and produces numerous specialized components that are assembled and cured. Many kinds of rubber are used; the most common materials are styrene-butadiene copolymer. So these are generally the article describes the components assembled to make a tire like, the various materials, the manufacturing processes , machinery and the overall business model (see figure 2). Regardless of how well a product meets design specifications and quality standards, it also must meet economical criteria in order to be competitive in the domestic and global marketplace. The first strict liability concept of product liability generally prevails in the United States. This concept states that the manufacturer of an article is liable for any damage or harm that results because of a defect and it doesn’t matter whether the manufacturer knew about the defect, or even could have known about it [13].

Figure (1)

Styrene-butadiene copolymer (chemical structure pictured) is the most popular material used in the production of rubber tires. In 2004, $80 billion of tires were sold worldwide; in 2010 it was $140 billion. The top five tire manufacturing companies by revenue are Bridgestone, Michelin, Goodyear, Continental, and Pirelli [14].

Many tires used in industrial and commercial applications are non-pneumatic, and are manufactured from solid rubber and plastic compounds via molding operations. Solid tires include those used for lawn mowers, skateboards, golf carts, scooters, and many types of light industrial vehicles, carts, and trailers. One of the most common applications for solid tires is for material handling equipment (forklifts). Such tires are installed by means of a hydraulic tire press.

Semi-pneumatic tires have a hollow center, but they are not pressurized. They are light-weight, low-cost, puncture proof, and provide cushioning. These tires often come as a complete assembly with the wheel and even integral ball bearings. They are used on lawn mowers, wheelchairs, and wheelbarrows. They can also be rugged, typically used in industrial applications and are designed to not pull off their rim under use. Tires that are hollow but are not pressurized have also been designed for automotive use, such as the Towel (a portmanteau of tire and wheel), which is an experimental tire design being developed at Michelin. The outer casing is rubber as in ordinary radial tires, but the interior has special compressible polyurethane springs to contribute to a comfortable ride. Besides the impossibility of going flat, the tires are intended to combine the comfort offered by higher-profile tires (with tall sidewalls) with the resistance to cornering forces offered by low profile tires. They have not yet been delivered for broad market use.

Aircraft tires are designed to withstand extremely heavy loads for short durations. The number of tires required for aircraft increases with the weight of the plane (because the weight of the airplane has to be distributed better). Aircraft tire tread patterns are designed to facilitate stability in high crosswind conditions, to channel water away to prevent hydroplaning, and for braking effect.

Tires often overheat if maximum braking is applied during an aborted takeoff or an emergency landing. The fuses provide a safer failure mode that prevents tire explosions by deflating in a controlled manner, thus minimizing damage to aircraft and objects in the surrounding environment [15]. The requirement that an inert gas, such as nitrogen, be used instead of air for inflation of tires on certain transport category airplanes was prompted by at least three cases in which the oxygen in air-filled tires combined with volatile gases given off by a severely overheated tire and exploded upon reaching auto ignition temperature. The use of an inert gas for tire inflation will eliminate the possibility of a tire explosion.

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Drivers usually have no ability to know the actual pressure with naked eyes to pay attention for that. Therefore a test is done to confirm this issue. The first part of the test was visual. The drivers were asked to look at the tires and decide which of the two vehicles was equipped with the underinflated tires. While perhaps this visual test might have been easier with taller tires of the past, today's low profile tires fitted to the car demonstrated how difficult it has become. The drivers agreed that the tire appearance alone did not provide irrefutable confirmation of the tire pressure contained inside see figure (2).

Figure (2)

Therefore person can't use his naked eyes as a tire pressure gauge. While driving at the edge of a tire's ability in wet conditions is challenging, the car with the properly inflated tires provide handling that was predictable. Driving the car with the underinflated rear tires proved to be much more difficult to drive and forced the driver to slow down to retain control, producing lap times that were several seconds slower than the properly inflated car. While tire manufacturers can develop tires with great hydroplaning resistance and wet traction, poor maintenance of tire inflation pressures can make a great tire awful like excessive wearing and car disorder resulting even to car accident. Therefore adjusting tires pressures as indicated on the vehicle tire placard or in the owner's manual is very important. Checking tire inflation pressures at least once a month and before highway trips is a must. Driving at high speeds certainly helps make a trip go faster, however with the exception of events like the road rally or a driver's school on a racetrack; so it's difficult to find a place that allows unlimited speeds. The tires on the vehicle should be properly sized, inflated and inspected when planning to drive fast because the tires will be subjected to tremendous stresses.

Because of the weight they bear, pneumatic tires' sidewalls bulge and their treads flatten as they roll into contact with the road. The tires flatten treads results in dimensional difference between the tire's "unloaded" radius and its "loaded" radius). Increasing vehicle speed will cause the tires to deflect quicker and increasing vehicle load will cause the tires to deflect farther (if tire pressure isn't increased). The European Tire and Rim Technical Organization (ETRTO) establishes the standards for tires sold in Europe, and recognizes that the tire's deflection must be minimized and controlled in order to surpass high speed driving stresses. In order to accomplish this, the tire inflation pressure recommendations and the tire's rated load capacities are customized when speeds exceed 160 km/h (99 mph) for all tires up to be nominate as a V-speed rating, and when speeds exceed 190 km/h (118 mph) for all tires that are Z-speed rated. Beginning with the vehicle manufacturer's recommended tire pressure for normal highway conditions, tire cold inflation pressures are initially increased and then the tire's rated load capacities (branded on the sidewalls) are reduced as speeds climb up. As an example shown below, the vehicle manufacturer's recommended 35 psi for a 225/45R17 91W Standard Load tire installed on a vehicle initially rises in 1.5 psi increments for every 10 km/h (6.2 mph) increase in speed until the inflation pressures max out with an increase of 7.5 psi when the vehicle's top speed has increased 50 km/h (31mph). Then as the vehicle's top speed continues to climb, the rated load capacity of the tire is reduced in 5% increments for every additional 10 km/h until the vehicle's top speed has increased an additional 30 km/h (18.6 mph). In this case the 225/45R17 91W standard load size's rated load capacity of 1,477 lbs. is reduced to 1,255 lbs. when applied to a vehicle with a 270 km/h (168 mph) and general condition Tire safety:

Proper vehicle safety requires specific attention to inflation pressure, tread depth, of the tires. Over-inflated tires run the risk of explosive decompression. On the other hand, under-inflated tires tread wear particularly on the edges of the tread. As tire treads decreases, there inflated tires have a higher rolling resistance and suffer from overheating and rapid tread wear more traction between the tire and the road resulting in better grip. However, there is an increased risk of hydroplaning, so as the tire wears the performance in the dry generally improves, but

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gets worse in the wet. Tires worn down past their safety margins and into the casing run the very real risk of rupturing. Also, certain combinations of cross ply and radial tires on different wheels of the same vehicle can lead to vehicle instability, and may also be illegal [15].

Tire Load and Inflation Standards:
The load range or ply rating branded on a tire's sidewall helps identify how much load the tire is designed to carry at its industry specified pressure. Passenger tires feature named load ranges while light truck tires use load ranges that ascend in alphabetical order (letters further along in the alphabet identify stronger tires that can withstand higher inflation pressures and carry heavier loads). Before load ranges were adopted, ply ratings and/or the actual number of carcass plies were used to identify the relative strength with higher numeric ratings or plies identifying tires featuring stronger, heavier duty constructions. Today's load range/ply ratings do not count the actual number of body ply layers used to make up the tire's internal structure, but indicate an equivalent strength compared to early bias ply tires. Most radial passenger tires have one or two body plies, and light truck tires, even those with heavy-duty ratings (10-, 12- or 14-ply rated), actually have only two or three fabric plies, or one steel body ply.
In all cases, when changing tire sizes or converting from one type of size to another, it is important to confirm that the Load Index in the tire's s service description of the new tire is equal to or greater than the Load Index of the original tire and/or that the new tire's rated load capacity is sufficient to carry the vehicle's Gross Axle Weight Ratings.

Tire pressure monitoring systems (TPMS) are in some cases used as electronic systems that monitor the tire pressures on individual wheels on a vehicle, and alert the driver when the pressure goes below a warning limit. There are several types of designs to monitor tire pressure. Some actually measure the air pressure, and some make indirect measurements, such as gauging when the relative size of the tire changes due to lower air pressure.

Since air is a gas, it expands when heated and contracts when cooled. In most parts of North America, this makes fall and early winter months the most critical times to check inflation pressures...days are getting shorter...ambient temperatures are getting colder...and your tires' inflation pressure is going down. The rule of thumb is for every 10° Fahrenheit change in air temperature, your tire's inflation pressure will change by about 1 psi (up with higher temperatures and down with lower). In most parts of North America as an example, the difference between average summer and winter temperatures is about 50° Fahrenheit...which results in a potential loss of about 5 psi as winter's temperatures set in and a 5 psi loss is enough to sacrifice handling, traction, and durability. Additionally, the difference between cold nighttime temperatures and hot daytime temperatures in most parts of the US country is about 20° Fahrenheit. This means that after setting tire pressures first thing in the morning, the vehicle's tire pressures will be almost 2 psi higher when measured in the afternoon (if the vehicle was parked in the shade), while that is expected, the problem is when setting the vehicle's tire pressures in the heat of the day, their cold pressures will probably be 2 psi low the following morning. So if the vehicle is parked in the sun, the sun's radiant heat will artificially and temporarily increase tire pressures. We put some of these theories to the test at the Tire Rack. First, we mounted two tires on wheels. We let them sit overnight to equalize and stabilize their temperatures and pressures. The following morning we set them both to 35 psi. One tire and wheel was placed in the shade while the other was placed directly in the sun. We then monitored the ambient temperatures, tire temperatures and tire pressures through all the day. As the day's temperatures went from 67° to 85° Fahrenheit, the tire that was kept in the shade went from our starting pressure of 35 psi to a high of 36.5 psi. The tire that was placed in the sun and subject to the increase in ambient temperature plus the sun's radiant heat went from our starting pressure of 35 psi to a high of 40 psi. In both cases, if we had set our tire pressures in the afternoon under the conditions of our evaluation, they would have been between 2 and 5 psi low the following morning.

Next we evaluated the effects of heat generated by the tire's flexing during use. We monitored the changes in tire pressure in 5-minute intervals. The test tires were inflated to 15 psi, 20 psi, 25 psi and 30 psi. Running them all under the same load, the air pressure in all of the tires went up about 1 psi during every 5 minutes of use for the first 20 minutes of operation. Then the air pressures stabilized, typically gaining no more than 1 psi of additional pressure during the next 20 minutes. This means that even a short drive to inflate your tires will result in tires that will probably be under-inflated by a few psis the following morning. Adding all of these together, we can understand why the conditions in which vehicle's tire pressures are set are almost as important as the

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fact that we do set it. It's important to remember that the vehicle's recommended tire pressure is its cold tire inflation pressure. Tires should be frequently checked in the morning before driving more than a few miles, or before rising ambient temperatures or the sun's radiant heat affects it.

The tire contact patch is readily reduced by both overinflated and under inflation. Over-inflation may increase the wear on the center contact patch, and under-inflation will cause a concave tread, resulting in less center contact. Most modern tires will wear evenly at very high tire pressures, but will degrade prematurely due to low (or even standard) pressures. It has been found, that an increased tire pressure almost exclusively results in shorter stopping distances, except in some circumstances that may be attributed to the low sample size. If tire pressure is too low, the tire contact patch is changed more than if it were over-inflated. This increases rolling resistance, tire flexing, and friction between the road and tire. Under-inflation can lead to tire overheating, premature tread wear, and tread separation in severe cases [16].

In some cases drivers may tend to increase or to decrease tire mean pressure to insure expected comfort. So for high performance and dynamic drivers often increase the tire pressure to near the maximum pressure as printed on the side wall. This is done to sacrifice comfort for performance and safety. A tire at higher pressure is more inclined to keep its shape during any encounter, and will thus transmit the forces of the road to the suspension, rather than being damaged it. This allows for an increased reaction speed, and “feels" the driver perceives of the road. Modern tire designs allow for minimal tire contact surface deformity during high pressures, and as a result the traditional wear on the center of the tire due to reasonably high pressures is only known to very old or poorly designed tires. Therefore very high tire pressures have only two downsides: The sacrifice in comfort; and the increased chance of obtaining a puncture when driving over sharp objects, such as on a newly scraped gravel road. Many individuals have maintained their tire pressures at the maximum side wall printed value (inflated when cold) for the entire lifetime of the tire, with perfect wear until the end. This may be of negative economic value to the rubber and tire companies, as high tire pressures decrease wear, and minimize side wall blow outs [17].

It is dangerous to allow tire pressure to drop below the specification recommended on the vehicle placard. Low pressure increases the amount of tire wall movement resulting from cornering forces. Should a low-pressure tire be forced to perform an evasive maneuver, the tire wall will be more pliable than it would have been at normal pressure and thus it will "roll" under the wheel. This increases the entire roll movement of the car, and diminishes tire contact area on the negative side of the vector. Thus only half the tire is in contact with the road, and the tire may deform to such an extent that the side wall on the positive vector side becomes in contact with the road. The probability of failing in the emergency maneuver is thus increased. When driving on sand or in deep snow, tire pressure is sometimes lowered to reduce the chance of bogging down.

Furthermore, the tire will absorb more of the irregular forces of normal driving. With this constant bending of the side wall as it absorbs the contours of the road, it heats up the tire wall to possibly dangerous temperatures. Additionally, this flexing degrades the steel wire reinforcement; this often leads to side wall blow-outs.

Low pressure tires can be subjected to pinching. If the vehicle drives into a pot-hole, the side wall can temporarily collapse, thereby pinching the tire between the steel wheel and road. This can result in a tire laceration and blow-out, as well as a damaged wheel. Feathering occurs on the junction between the tire tread and side wall, as a result of too low tire pressures. This is as a result of the inability of the tire to perform appropriately during cornering forces, leading to aberrant and shearing forces on the feathering area. This is due to the tire moving sideways underneath the wheel as the tire pressures are insufficient to transmit the forces to the wheel and suspension. One of the most important issues is how to set properly tire cold mean pressure with relative to applied force. Tires are specified by the manufacturer with a maximum load rating. Loads exceeding the rating can result in unsafe conditions that can lead to steering instability and even rupture. The work load of a tire is monitored so that it is not put under undue stress, which may lead to its premature failure. Work load is measured in Ton Kilometer per Hour (TKPH). The measurement's appellation and units are the same. The recent shortage and increasing cost of tires for heavy equipment has made TKPH an important parameter in tire selection and equipment maintenance for the mining industry. For this reason, manufacturers of tires for large earth-moving and mining vehicles assign TKPH ratings to their tires based on their size,

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construction, tread type, and rubber compound. The rating is based on the weight and speed that the tire can handle without overheating and causing it to deteriorate prematurely. The equivalent measure used in the United States is Ton Mile per Hour (TMPH).
Speed rating:

The speed rating denotes the maximum speed at which a tire is designed to be operated. Nowadays for passenger vehicles these ratings range from 99 to 186 miles per hour (159 to 299 km/h). The study obtained results as a reported standard as its shown bellow.

Vehicle Top Speed		Required Tire Pressure Increase		Tire Load Capacity % of Branded Maximum	W-Speed 35 psi O.E.	Rated Tire Example
mph	km/h	psi	Bar	% of value branded on sidewall	psi	lbs.
118	190	0	0	100%	35.0	1000
124	200	1.5	0.1	100%	36.5	1000
130	210	3.0	0.2	100%	38.0	1000
136	220	4.5	0.3	100%	39.5	1000
143	230	6.0	0.4	100%	41.0	1000
149	240	7.5	0.5	100%	42.5	1000
155	250	7.5	0.5	95%	42.5	950
161	260	7.5	0.5	90%	42.5	900
168	270	7.5	0.5	85%	42.5	850

Table (1)

In our example shown below, the vehicle manufacturer's recommended 35 psi for a 225/45R17 91W Standard Load tire installed on a vehicle initially rises in 1.5 psi increments for every 10 km/h (6.2 mph) increase in speed until the inflation pressures max out with an increase of 7.5 psi when the vehicle's top speed has increased 50 km/h (31mph). Then as the vehicle's top speed continues to climb, the rated load capacity of the tire is reduced in 5% increments for every additional 10 km/h until the vehicle's top speed has increased an additional 30 km/h (18.6 mph). In this case the 225/45R17 91W Standard Load size's rated load capacity of 1,477 lbs. is reduced to 1,255 lbs. when applied to a vehicle with a 270 km/h (168 mph) top speed see table (1).
Work load:

The work load of a tire is monitored so that it is not put under undue stress, which may lead to its premature failure. Work load is measured in Ton Kilometer per Hour (TKPH). The measurement's appellation and units are the same. The recent shortage and increasing cost of tires for heavy equipment has made TKPH an important parameter in tire selection and equipment maintenance for the mining industry. For this reason, manufacturers of tires for large earth-moving and mining vehicles assign TKPH ratings to their tires based on their size, construction, tread type, and rubber compound. The

rating is based on the weight and speed that the tire can handle without overheating and causing it to deteriorate prematurely. The equivalent measure used in the United States is Ton Mile per Hour (TMPH)
Tire Load and Inflation Standards:

Load inflation tables for passenger cars and light trucks are based on various standards organizations including The Tire and Rim Association, (TRA) the European Tyre and Rim Technical Organization (ETRTO) and The Japan Automobile Tyre Manufacturers Association (JATMA). The sizing systems and a brief explanation of each component of the size from each standard are listed below in figure (3):

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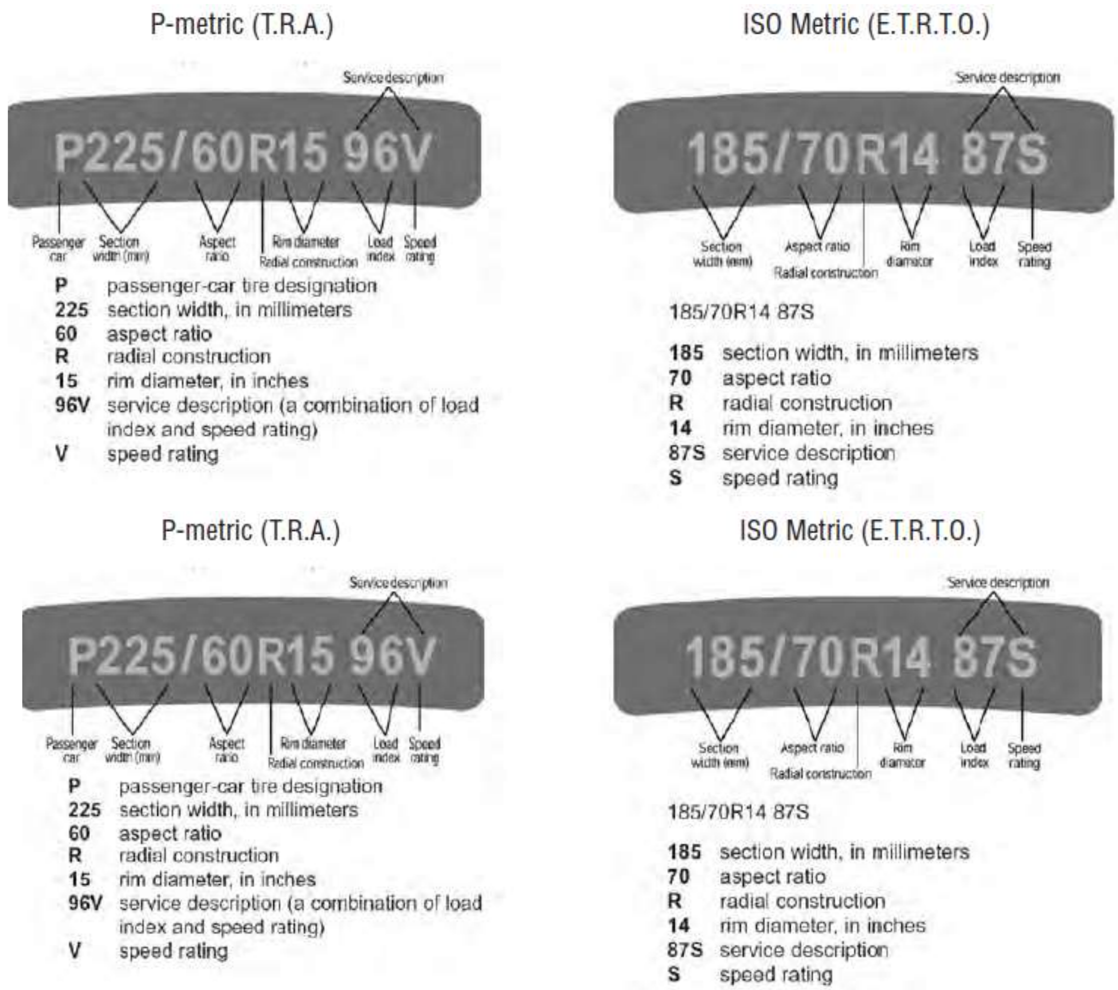

Figure (3)

Reinforced (RD) or Extra Load (XL):
'Reinforced' and 'Extra Load' both refers to the tire's ability to carry additional load capacity at a higher inflation pressure compared to standard load tires. The sidewall of the tire is marked with either "REINFORCED" or "EXTRA LOAD" as shown in Figure 4. Figure 5 shows the added load capacity of a reinforced of the same size.

Figure 4

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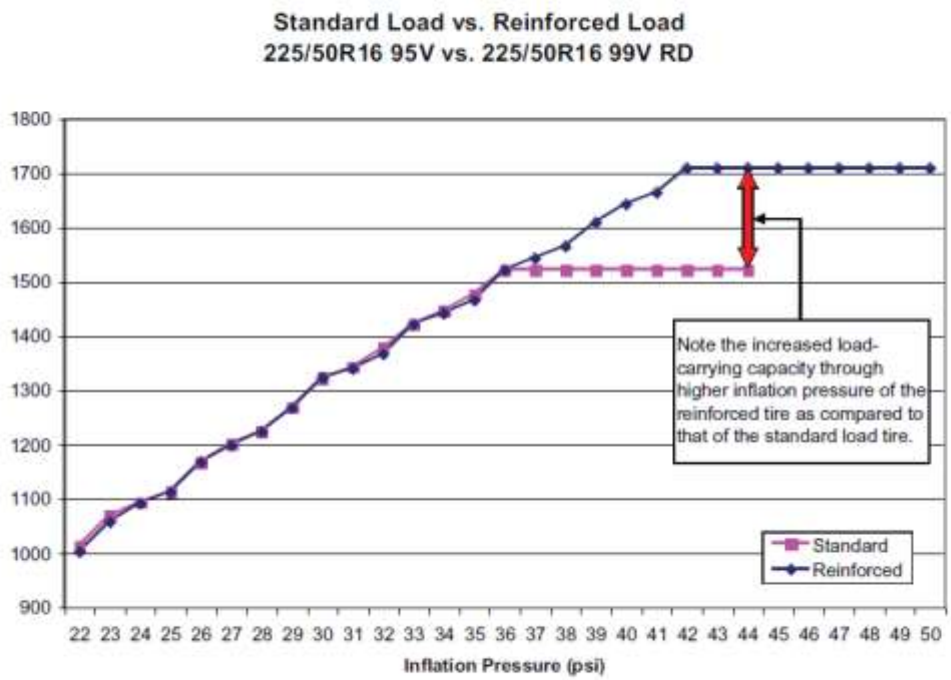

Figure (5)

Service rating:

Tires (especially in the U.S.) are often given service ratings, mainly used on bus and truck tires. Some ratings are for long haul, and some for stop-start multi-drop type work. Tires designed to run 500 miles (800 km) or more per day carrying heavy loads require special specifications.

Tread wear rating:

The tread wear rating or tread wear grade is how long the tire manufacturers expect the tire to last. A Course Monitoring Tire (the standard tire that a test tire will be compared to) has a rating of "100". If a manufacturer assigns a tread wear rating of 200 to a new tire, they are indicating that they expect the new tire to have a useful lifespan that is 200% of the life of a Course Monitoring Tire. The "test tires" are all manufacturer-dependent. Brand A's rating of 500 is not necessarily going to give you the same mileage rating as Brand B's tire of the same rating. The testing is non-regulated and can vary greatly. Tread wear ratings are only useful for comparing Brand A's entire lineup against itself. Tread wear, also known as tire wear, is caused by friction between the tire and the road surface. Government legal standards prescribe the minimum allowable tread depth for safe operation [18].

The study had been done by descriptive method and collecting the data through visiting the Khartoum capital in different petrol station where tires maintenance workshops are available in service clock the time. Also data is collected through specialized tire maintenance centers at the boarder limit of the capital and at the automobiles central parks. We have observed common problem in their activities, and they were always established and sited beside the civilian regions. The worn tires and their wastes are polluted it, beside the following general observations:

- Most of tire maintenance centers are private owned, with poor designing as auto tire repair workshop area.
- Work is done inside or outside workshop, e.g. on footpaths or road and in inadequate to safety, performing the job with missed special skillful technician and technical knowledge.
- The pressure is checked with a low quality air gauge and also area subjected to exposure and to harmful chemicals or other risks since it's sited in petrol station or around maintenance mechanical workshops.
- Lifting equipment suitable for the task is not supplied by employer and is not available at the breakdown scene. Service person manually handles heavy tires, and mostly there is no monitoring of the service persons health, safety and welfare. The service person has no means of emergency

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communication with the workshop or emergency services.

- Vehicle ramps and stands have no rated capacity marked and the safe working load is unknown. Vehicles on ramps not secured in such a way as to prevent movement. Lack of stock control leads to excess tires-parts – crowding storage area.
- Using air lines to clear away dust from engines, filters this will release large quantity of asbestos fibers into the breathing zones of employees and causing a serious damage to social health and to the environment.
- Qualified fitter men are using constant tire pressure rating depend on only tire size with the means of low quality gauges, while most car drivers using their sense to check their tire pressure. As a result of that according to data collected from Khartoum car park center daily for a week we took a hundred light car and a hundred heavy trucks as a sample to check the tire pressure rate at morning to record and to obtain the following results:

- 33% of heavy trucks samples are underinflated,
- 8% are overinflated,
- 3% improper alignment,
- 2% dissimilar pair and with
- 11% misbalanced tire. For light cars samples
- 23% are underinflated,
- 27% are overinflated,
- 13% improper alignment,
- 22% dissimilar pair and with
- 8% misbalanced tires.

Results and discussion

According to data obtained from general common standards the cold tire pressure rate can be easily calculated. At the first stage it is important to know which standard is applicable for any given tire size designation as the load capacity may differ at any inflation pressure value. The TRA developed the P-metric standard and the ETRTO developed the ISO Metric/Hard Metric standard. For example, TRA P225/55R17 95T has a maximum load capacity of 1521 lbs. and 35 psi while 225/55R17 97T has a maximum load capacity of 1609 lbs. and 36 psi see table (2).

Table 2. E.T.R.T.O. Load Inflation Table 97 load index.

load Index	Inflation Pressure (PSI)										
	26	27	28	29	30	31	32	33	34	35	36
97	1235	1272	1290	1345	1400	1421	1455	1510	1530	1554	1609

Tires with the same load index, regardless of tire size, may carry the same load, but not always, and they may require substantially different inflation pressures.

The load index may not be used independently to determine replacement tire acceptability for load capacity. An equal or greater load index does not always correspond to equal or greater load capacity at all inflation pressure settings, particularly when comparing P-metric and Euro-metric passenger car tires.

Basic procedures for reading and applying the load inflation tables:

Original Equipment:
1. Locate tire information placard to confirm OE tire size and cold inflation pressure. (The tire information placard can be found on the vehicle door edge, door jam, glove-box door, or inside of the trunk lid.)
2. Identify the standard used (TRA for P-metric, LT-metric, and flotation sizes and ETRTO for Euro metric sizes) and refer to the appropriate load inflation table. An example to that the OE size is P225/60R18 (P-metric), so we would refer to the TRA Load Inflation Table.
3. Find the corresponding load for the OE tire size(s) at the recommended cold inflation pressure.

In case the standard tires are to be replaced by other standard the following additional steps should be preceded:
1. Use the appropriate load inflation table for the replacement tire size(s).
2. Find the inflation pressure to which the corresponding load is equal to or greater than the OE tire.
3. Inflate tires to the appropriate inflation pressure.

ISSN: 2277-9655
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4. If the replacement tire requires a different inflation pressure than OE, the installer should inform the owner of the new required inflation pressure and should also place a sticker or decal over the vehicle tire placard showing the new tire size and recommended inflation pressure for future reference. Generally never use an inflation pressure lower than what is recommended by the vehicle manufacturer.6

Examples of implementing this procedure are carried out in the following:

Example 1:
Replace O.E. P235/45ZR17 93W with a Plus-1 245/40ZR18 97W reinforced on a 2006 Mitsubishi Lancer Evolution IX. The O.E. tire is P-metric; therefore use the TRA Load Inflation Table (see Table 3) to look up the load capacity at the O.E. inflation pressure. For the standard load P235/45ZR17 93W, at 32 psi the load carrying capacity of the front is 1354 lbs and the rear load at 29 psi is 1272 lbs according to table (3) TRA Load Inflation Table.

Table 3. TRA Load Inflation Table.

Load Index	Tire Size	Inflation Pressure (PSI)			
		26	29	32	35
93	P235/45R17	1188	1272	1354	1433

If replacing the O.E. tires with Proxies T1R245/40ZR18 97W RD which is a reinforced ETRTO spec; therefore, refer to the ETRTO Reinforced Load Inflation Table (Table 4). As indicated previously, always maintain any differences in inflation pressures front to rear that are shown on the vehicle placard. In order to maintain the same staggered inflation pressure from front to rear, while still carrying an equal or greater load, the front tire must be inflated to 35 psi (1378 lbs.) in the front, while the rear tires will need to be inflated to 32 psi (1290 lbs.).
Table4. ETRTO Reinforced Load Inflation Table.

Table 4. ETRTO Reinforced Load Inflation Table.

Load Index	Inflation Pressure (psi)														
	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
97	1146	1190	1246	126[illegible]	1290	1334	1359	1378	1433	1454	1477	1521	1547	1565	1609

In order to adequately support the load, the 2006 Mitsubishi Lancer Evolution IX with a plus 1 fitment of 245/40ZR18 97W RD must be inflated to front 35 psi and rear 32psi.9
Application of load inflation tables from LT-metric to LT-Metric

Example2:

Replace the O.E. LT315/70R17 121R with a plus zero LT325/70R17 122R on a 2006 Hummer H2.
The original equipment size is LT- metric; therefore use the TRA Light Truck Load Inflation Table (see Table5) to find the load carrying capacity at the recommended 37 psi.

Table 5. TRA Light Truck Load Inflation Table

Tire Size	Single/Dual	psi_35	psi_40	psi_45	psi_50	psi_50 load range
315/70R17	Single	2535	2685	2915	3195	D

It's seen that in this table that the 37 psi falls between the published values, so by extrapolation, the load is 2595 lbs. This can be calculated as follows [19]:

$$\frac{2685lbs.-2535lbs.}{40\,psi-35\,psi}=\frac{150lbs.}{5\,psi}=30 \text{ lbs. per each 1 psi increase from 35 to 40 psi}$$

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Therefore, add 60 lbs. to 2535 lbs. to calculate the load at 37 psi to get 2595 lbs.

Then if the O.E.tires also is to be replaced with the Open Country A/T LT325/70R17 122R D/8, so we use the Open Country A/T Load Inflation Table 6, we extrapolate again to find that the tires at 37 psi will sufficiently carry the O.E. load based on the O.E. inflation pressure. The corresponding load at 37 psi is 2667 lbs.

Table 6. Open Country A/T Load Inflation Table.

Tire Size	Inflation Pressure (PSI)			
	35	40	45	50
LT325/70R17 122R D/8	2555	2835	3085	3305 (D)

In order to adequately support the load, the 2006 Hummer H2 with a plus zero fitment of LT325/70R17 122R D/8 must be inflated to 37 psi (front and rear).

The cold inflation pressure is the inflation pressure of tires before the car is driven and the tires warmed up. Generally its recommended cold inflation pressure that displayed on the owner's manual and on the placard (or sticker) attached to the vehicle door edge, pillar, glove box door or fuel filler flap. Drivers are encouraged to make sure their tires are adequately inflated, as suboptimal tire pressure can greatly reduce fuel economy, increase emissions, increased wear on the edges of the tire surface, and can lead to premature failure of the tire. Excessive pressure, on the other hand, will lead to blowouts, decrease braking performance, and cause uneven wear (i.e. greater wear on the inner part of the tire surface). Anyhow there are many factors that have a direct effect on tire inflation pressure that make any normal vehicle driver unable to calculate all mentioned factors when he is setting the tire pressure rate. As a clear example it’s known that the ambient temperature affects the cold tire pressure. Cold tire pressure varies directly with the absolute temperature. The following table 7 shows the relationship between ambient temperature and cold tire pressure, where the volume of air in the tire remains constant.

Ambient temperature	**% change in pressure if originally filled at 75 °F (24 °C; 297 K)**	**Pressure change, tire originally filled to 32 psi (220 kPa; 2.2 bar) at 75 °F (24 °C; 297 K)**	**Pressure change, tire originally filled to 60 psi (410 kPa; 4.1 bar) at 75 °F (24 °C; 297 K)**
0 °F (−18 °C; 255 K)	- 14 %	−4.5 psi (−31 kPa; −0.31 bar)	−8.4 psi (−58 kPa; −0.58 bar)
20 °F (−7 °C; 266 K)	- 10 %	−3.3 psi (−23 kPa; −0.23 bar)	−6.2 psi (−43 kPa; −0.43 bar)
40 °F (4 °C; 278 K)	- 7 %	−2.1 psi (−14 kPa; −0.14 bar)	−3.9 psi (−27 kPa; −0.27 bar)
60 °F (16 °C; 289 K)	- 3 %	−0.9 psi (−6.2 kPa; −0.062 bar)	−1.7 psi (−12 kPa; −0.12 bar)
75 °F (24 °C; 297 K)	0 %	0.0	0.0
100 °F (38 °C; 311 K)	+ 5 %	1.5 psi (10 kPa; 0.10 bar)	2.8 psi (19 kPa; 0.19 bar)

Table (7)

Since the industry load and inflation standards are in a constant state of change, and the manufacturers are continually update their product information to reflect these changes the normal vehicle owner cannot follow these changes. Also the load and inflation tables for single or dual vehicle tires are different from one company to another. These tables are applicable for each company individually. Below

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are some tables (8) and (9) as examples. The first table indicates tire loads limits with relative to various cold pressure inflation by Michelin Company while the second table by Goodyear. It's clear that there is a big difference between the information delivered by Michelin Company and by Goodyear. The load by Michelin when the pressure is 35PSI is 1495LBS while for the same pressure by Goodyear table is 2090LBS both for the same wheel size 16in.

Wheel Diameter 16													
LT215/85R16 LRE XPS RIB®													
PSI		**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**Maximum load & pressure on sidewall**	
kPa		240	280	310	340	380	410	450	480	520	550		
LBS	**Single**	**1495**	1640	1785	1940	2055	2180	2335	2430	2550	2680	S	2680 LBS at 80 PSI
	Dual	2720	2980	3250	3530	3723	3970	4300	4420	4640	4940	D	2470 LBS at 80 PSI
Table 8													

LOAD/INFLATION INFORMATION FOR RV ST METRIC TIRES

TIRE LOAD LIMITS (LBS) AT VARIOUS COLD INFLATION PRESSURES (PSI) HIGHWAY STEER AND ALL POSITION TREAD DESIGNS USED IN NORMAL HIGHWAY SERVICE*

Tire Size	Max Speed Rating (MPH)	Inflation Pressure - PSI 15	20	25	30	35	40	45	50	55	60	65
ST175/80R13	65	670	795	905	1000	**1100(B)**	1190	1270	**1360(C)**			
ST185/80R13	65	740	870	990	1100	**1200(B)**	1300	1400	**1480(C)**			
ST205/75R14	65	860	1030	1170	1300	**1430(B)**	1530	1640	**1760(C)**			
ST215/75R14	65	953	1110	1270	1410	**1520(B)**	1660	1790	**1870(C)**			
ST205/75R15	65	905	1070	1220	1360	**1480(B)**	1610	1720	**1820(C)**			
ST225/75R15	65	1060	1260	1430	1600	1760	1880	2020	**2150(C)**	2270	2380	**2540(D)**
ST235/80R16	65			1720	1920	2090	2270	2430	2600	2730	2870	**3000(D)**

Table (9)

According to all mentioned factors that have direct effect on cold tire inflation it's clear that to select the proper load and inflation rate is still a problematic issue.

Conclusions

It can simply be summarized as follows:-

- It was observed that availability of information on tire specifications provided by all tire manufacturers is extremely poor, with a general absence of a central monitoring information management system.
- As a result of this it is impossible for tire fitter men and individuals' dealers to assess really the extent of good tire operation and maintenance and to formulate appropriate tire failures solutions.
- It was noted that there was poor networking and functional relations between industries, academic institutions, Non-Governmental Organizations and Community Based Organizations to transfer or share of needed tire properties information, dissemination of lessons learned from tire failure and to insure best practices among tire national and international stakeholders.
- Most countries are not heavily industrialized to produce any advanced technology for tire quality control, maintenance and tire waste processing.
- In some cases tire operation and maintenance management problems are due to poor technology of manufacturing of

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some tire manufacturers industries and outdated technology of maintenance in other cases and low trained cadre.

- Inadequacy of legislation for tire manufacturing industries and tire maintenance workshops in most part of the world as the result of that tire quality is continuously declined.
- Lack of trained personnel in most countries to establish, enforce, and implement strong tire quality control system in stage of manufacturing and in tire operation to standard limit tire failure is expected to be in continuous rising.
- Lack of experience cadre to understand and use latest technologies in tire maintenance especially in most small tire auto repair workshop to set a proper tire inflation rate is resulting severely in tire time life and safety.

To insure proper tire inflation pressure rate an effort should be done including the following:-

- Memorandum of a need to technical study for proper understanding of tire contracts on manufacturing and purchasing for different conditions of use.
- Need for investment in research and development for new technology of tire risk minimization options before it can be let in use in the country.
- Formulating easy funding mechanisms in studying tire quality control in all tire life stages according to different needed conditions if possible.
- To limit the use of high tire manufacturers mark number as far as possible to help in the process of quality assurance following.
- Good and efficient tire maintenance management will result to a reduction in earlier tire failure.
- Encouraging international standardization of all tire stages of designing, manufacturing and exploitation to guarantee high safety and acceptable tire duration.
- Persuade the use of latest technology in tire manufacturing and maintenance.
- Promote supportive relevant legislations and regulation in order to empower efficient management of tire quality control in all countries of the world.

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