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Formula for the future

TireDesigns.com

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*Tyre Guru **TK Tio's** design journey started from ATV to UTV and then LTR: that is from off-road to on-road and then off-road. And from lightweight ATV of about 450 lbs (204kg) to UTV of about 2000 lbs (907kg), he now has 5700 lbs (2585kg) Rubicon for testing his designs. Heavy weight class OTR/TBR are his dream that is in line with his constant thinking of bigger and yet bigger tyres as marvels of tyre engineering. In an interview to **Tyre Asia** , he speaks of his tyre design journey and the future of tyre science*

TA News Bureau

At every major global tyre events and technology conferences, Dr TK Tio will certainly be present. The veteran tyre designer with a PhD in engineering physics is a hands-on, butts-on innovator who runs a successful industrial consultancy for the tyre industry worldwide.

In an interview to ***Tyre Asia*** he speaks of the challenges in the science and art of designing the next generation innovative tyres. He also spoke about the scientific testing of various kinds of Utility Task Vehicle or Utility Terrain Vehicle tyres, All Terrain Vehicle and Light Truck All-Terrain tyres for drivers who want to go wherever the road leads - from main streets to the woods. In this context, he said the US Department of Transportation (DoT) and National Highway Traffic Safety Administration (NHTSA) have no regulation on LTR for off-road use.

"The scientific tyre-terrain test is still in the early mobility test using a single wheel terramechanics test rig on controlled terrain bed," he said adding that the tyre design journey will never end as it is a continuum.

> ***The terrains and terramechanics of a wide-range and different kinds of roughness and topologies are the new frontiers and the challenges facing most of today's tyre and chassis designers and engineers***

The LTR Tyre Classification Table that he has made is a summary of his 10 years of R&D in ATV/UTV and LTR tyre designs. "The old table is still good today even without any state-of-the-art updates," he said. He is currently engaged in checking his brand new Rubicon third Test Rig.

Dr Tio says by controlling the tyre air pressure inflation one could control the vehicle's riding behaviour.

Pneumatic rubber tyre is the rolling contact interface between the vehicle and terrain. "All of the supporting/flotation on soft terrain/isolation from rough terrain, driving/braking, and cornering forces of the vehicle are generated at the four small viscoelastic rubber contact patches." By adjusting the inflation air pressures of the two front tyres and the two rear tyres properly, one could control the size and the flexibility deflection, chemical, and mechanical grips of the contact patches.

This allows the driver or racer to handle the vehicle in stable, slightly understeer or unstable oversteer/drifting/power slide driving style. "The terrains and terramechanics of a wide-range and different kinds of roughness and topologies are the new frontiers and the challenges facing most of today's tyre and chassis designers and engineers."

Today engineers are familiar with the low aspect ratio, square shoulder, flat contact surface, chemical grip, fixed inflation pressure, PCR tyre design for the low centre-of-gravity 2WD chassis passenger car on the flat smooth pavement roads, Dr Tio explained. The subject is complex and challenging.

The big science and technology of the contact interface of the relative motion between vehicle and the terrain is called tribology or contact mechanics. It is in line with the legacy of French military engineer and physicist Charles-Augustin de Coulomb (1736-1806) whose phenomenological law of friction and traction still rules the engineering science.

Interdisciplinary knowledge

Cutting-edge tyre designer requires the interdisciplinary and collective knowledge from the legendary giants and grandmasters of the tyre design science and art in addition to vehicle dynamics propounded by Maurice Olley (1889-1972), the founding father of chassis engineering and design, who first coined the terms understeer and oversteer.

Dr Tio feels that many tyre designers have learned tyre mechanics and vehicle dynamics as part of their engineering courses but mostly the focus has been only on the force and moment on the smooth pavement road applications.

"It's fine for PCR, SUV, LTR (on-road), and TBR. But for off-road tyre designers, the challenges are terramechanics and traction physics and chemistry, including chemical and mechanical grips."

In the off-road tyre design, one needs to understand the interplay of the parameters of the formula 'L' vs 'p' where 'L' is the corner load or vertical force and 'p' is the inflation pressure. In the case of PCR, SUV, and LTR on smooth pavement, the 'L' vs. 'p' are nicely tabulated in the ***Tire & Rim Association Yearbook***.

It is critically important to note that the 'L' vs. 'p' vs. Terrain vs. Application for the smooth pavement is very different from the mud, deep snow, rock crawling or King of the Hammers, desert sand or Baja 1000, which are considered the world's toughest races.

"This is the central concept of my Variable Inflation Pressure (Variable 'p' or VIP) tyre design. And it's the first step in any on-road/off-road tyre designs such as ATV, UTV and LTR, etc."

After traction design and the art, the tyre is produced. Then the inflation pressure 'p' is the only variable parameter which can adjust the contact envelope for the best optimum traction performance.

Traction design or tread pattern design, as is commonly known within the contact envelope, is the secondary process. But it is a tough balancing act especially in the utility case of a drawbar pull requirement. It's no contact no traction!

Design innovation

Commenting on the latest innovations in such design issues and manufacturing, Dr Tio said

Common LTR / ATV / UTV Tire Classification

(Dr. T.K. Tio, September 8, 2010) ©

On-Road (Smooth) / Off-Road (Rough)	Land Ratio	Tread Depth
100% On-Road – Race / Track Tire, Drift Racing Tire, UHP Tire, and Summer Tire such as Yokohama Advan Neova AD08, Michelin Pilot Super Sport.	70% or Larger	9/32" or Less
90% On-Road / **10% Off-Road** – All Season Tire such as Goodyear Eagle F1 Asymmetric All Season & Michelin LTX M/S2. Also Winter / Ice Tire.	65%	10/32"
75% On-Road / **25% Off-Road** – Misleading "All-Terrain or A/T" Tire for Rough Desert / Sand Terrain, Baja Racing & Dakar Rally such as BF Goodrich Baja T/A, General Tire Grabber. Also 3PMSF Snow Tire (Mountain Snowflake).	55%	18/32"
50% On-Road / **50% Off-Road** – True All-Terrain or Any-Terrain Tire also called Commercial Traction such as Dick Cepek Radical Fun-Country (F-C) II & Goodyear Wrangler DuraTrac, Cooper Discoverer S/T MAXX.	50%	18/32" or Deeper
25% On-Road / **75% Off-Road** – Mud-Terrain (M/T) Tire for Soft Mud, Dirt / Loamy, Deep Snow & Rocks are O.K. Such as BF Goodrich Mud-Terrain T/A KM2, Goodyear Wrangler MT/R with Kevlar, KANATI Mud Hog.	45%	19/32" or Deeper
100% Off-Road – Extreme Traction, Off-Road Competition Tire for Deep Mud and Rock Crawling with Soft Compound. Usually Special Bias Tire and Non-DOT such as Interco Tire, Pit Bull Tire.	35% or Less	25/32" or Deeper

Force (Load & Traction), Flexibility, Flotation, & Fashionable (4Fs) are the keys to the next generation innovative LTR / ATV / UTV tire designs. Inflation pressure is the only adjustable parameter available for the end-user to control the 3Fs of the fashionable tire. Sand is a cohesionless frictional soil and the traction on soft sand is friction. Traction on hard pavement is also friction. Whereas, mud or snow is a frictionless cohesive soil and the traction is paddle force. Friction traction increases with the land ratio (& soft compound). Whereas paddle traction increases with the sea ratio (or void ratio) and tread depth. Traction is a force, which has both magnitude and direction. Land ratio & tread depth (& rubber compound) determine traction's magnitude, which is the basis of the above table. Direction of the traction (not included / considered in the table above) is as important as the land ratio & tread depth, especially in water, mud, & snow. And also in the case of steer, drive & trailer tires.

Note that as the terrain type and terrain geometry change from the smooth even, hard pavement on-road to uneven rough, soft terrain off-road:

- The land ratio decreases and the tread depth increases.
- The tire's aspect ratio increases from low-profile PCR of 35% with square shoulder to high-aspect- ratio high flotation LTR of 80% with round shoulder.
- Inflation pressure decreases from high 40 psi to low operating pressure of 10–15 psi (human's footprint) for flotation. And the tire's deflection from low 15% to high 35%.
- High-speed DOT-139 applies to the PCR or LTR with tread depth of less than 18/32". **For the tread depth of 18/32" or larger, lower speed but higher load DOT-119 applies.**

before any innovations or renovations, it is important to understand the first principle of the 'L' vs. 'p' vs. Terrain vs. Application basic scaling laws which will lead to quantum-leap in off-road tyre design from the time-consuming cut-and-try craftsman approach to the cutting-edge scientific approach.

The latest innovations in LTR, ATV or UTV tyre traction design are the wraparound tread design with natural contour of the carcass. "This is the central concept of my Variable Inflation Pressure (Variable 'p' or VIP) Tyre Design for terrain compliance and high flotation, tread blades and fins for enhanced mud and snow clearing," Dr Tio said. And the state-of-the-art traction design such as Goodyear's TractiveGroove Technology is the key to pass the Mountain Snowflake (3PMSF) bracking test on the medium packed snow, the tough US Standard not thee easy Europe Standard.

The Variable 'p' LTR Tyre Design is very different from the commonly known PCR tyre design, which is basically fixed inflation pressure, low aspect ratio, lightweight, square shoulder tyre profile/flat contact patch design for the smooth pavement roads.

"The coming innovation in LTR tyre construction and design could be the use of aramid and hybrid fibres and cords for the extreme, pushing to the limit racing military applications such as the King of The Hammers, Baja 1000, Desert Storm Operation, etc."

Dr Tio said there are four issues that need to be addressed: force or traction, flexibility, floatation and fashionable as they will be the keys to next generation innovation in LTR/ATV/OTR.

"As in industrial design, the motto in tyre design is Form (Art) Follows Function (Science). Force, Flexibility, and Flotation are the keys of tyre science. And Fashionable is the tyre art in the legacy of Dutch graphic artist Maurits Cornelis Escher (1898-1972).

Dr Tio says force is braking and cornering traction forces or grips (both chemical and mechanical) and also the vertical force or load (static and dynamic). Flexibility is the tyre's compliance to the rough terrain to achieve maximum contact patch and hence traction. Flotation is driving on the top of the soft terrain to reduce tyre sinkage and hence less motion resistance. Fashionable is the rotation symmetric aggressive looking of the wrap-around tread design, which also enhances the sidewall traction and also the puncture resistance.

"The governing formula is simply force+flexibili ty+flotation+fashionable = L vs. p vs. Terrain vs. Application+Traction Design and Art. It is the formula that will keep driving tyre innovation.

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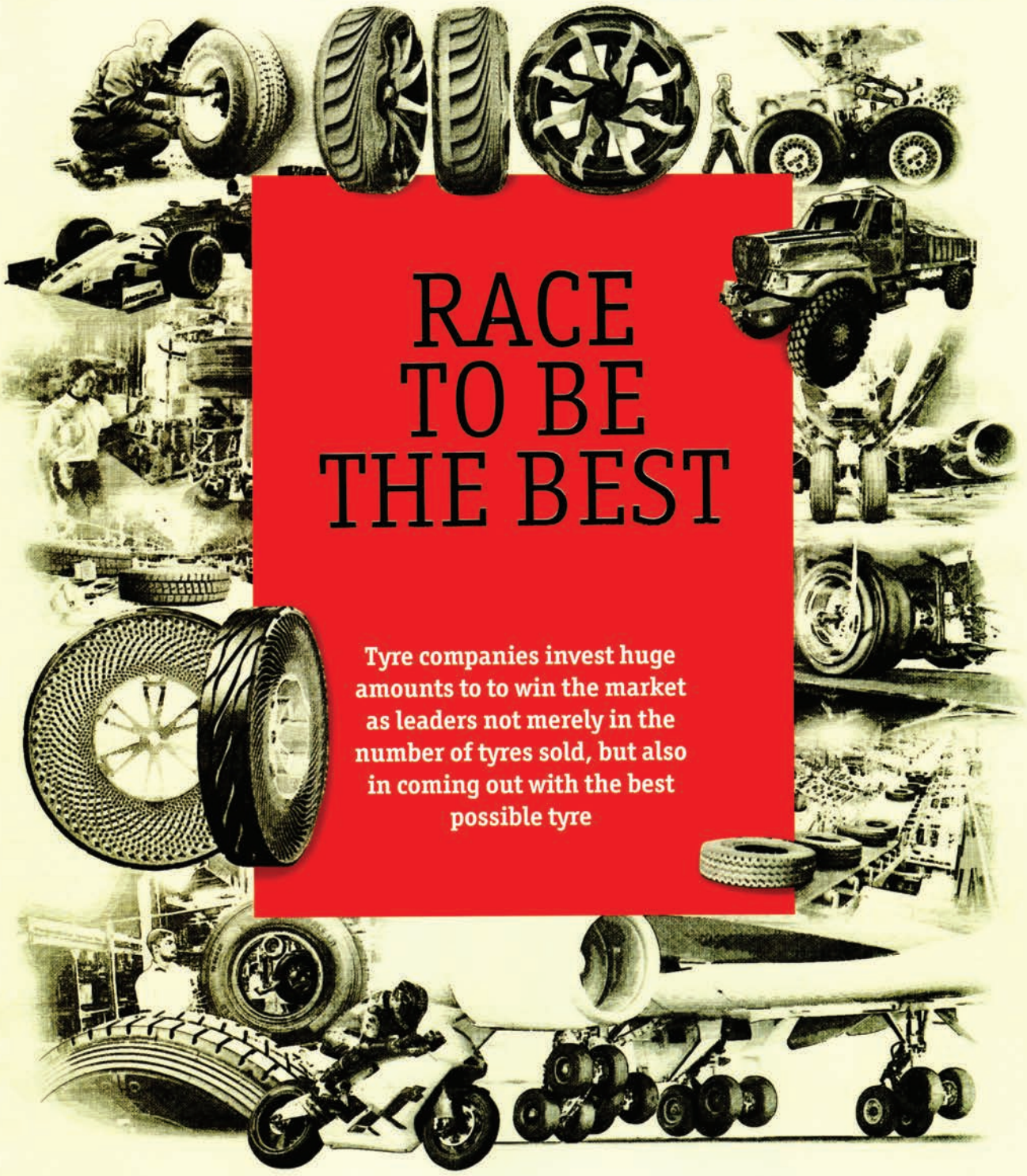

RACE TO BE THE BEST

Tyre companies invest huge amounts to to win the market as leaders not merely in the number of tyres sold, but also in coming out with the best possible tyre

First
The ATV Tire That Won The 2008 UTV Baja 1000 Racing Champion

First
DOT-Certified Ultra High Performance ATV Street / Track Tire

First
State-of-the-Art Third Generation LTR Mud Terrain Tire

The Science & Art of Designing
The Next Generation Innovative Tires

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Tire Designer, Scientist, & Consultant

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