Trends in Rubber Parts for Automobiles

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Personal History
- Graduated from Mechanical Engineering Department of Kyoto University in 1976.
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- Entered Toyota Motor Corporation in 1978 and worked mainly at R&D of Vehicle Dynamic Performance Fields.

Special field
- Evaluation of Total Vehicle Performance
- Research and Development of Vehicle Dynamic Performance
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Award
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Paper Title: Analysis of the Braking Performance of Straight-Running Vehicles on Uneven Roads

Abstract

"Rubber" is an indispensable material as an element for automobile, because of its original characteristics such as big transformation and restoration, which other materials do not have. There are no doubts that the technologies utilized in components such as tires, bushes, insulators and seals have supported the history of automotive evolution for more than 100 years. Due to the flexible property of "Rubber", automobiles have gained practicable durability and reliability in components such as bodies, power trains and axles etc. At the same time, automobiles have gained good comfort for passengers. It is also well known that automobiles have highly increased in their vehicle dynamics level, such as driving, handling and braking, by the ever improving road contact ability of the pneumatic tires. Now days, the current issues in automobile development are focused around minimizing the negative aspects such as environmental impact, traffic congestion and traffic accidents and maximizing the positive aspects such as fun, delight, excitement and comfort. "Rubber" must play more important part in such efforts. Expectations for the "Rubber" are discussed from an automotive standpoint, including author's personal ideas.

他の材料にはない大きな変形と復元という特性を持つ「ゴム」は、自動車の構成要素として必要不可欠存在であり、タイヤ、ブッシュ、インシュレータ、シールなどの要素技術が、この100年余りの自動車発展の歴史を支えてきたことは疑う余地がない。自動車はこの「ゴム」の柔軟性により、車体や原動機、車軸などの耐久性や信頼性を高め、乗客にとっての快適性をも向上させ、中でも空気入りタイヤによる接地特性の改善のお陰で、自動車が極めて高い運動性能（走る・曲がる・止まる）を獲得したことはよく知られている。現在の自動車開発の課題は、環境への負荷・交通渋滞・交通事故などのネガティブな側面の最小化と、楽しさ・喜び・感動・快適さなどのポジティブな側面の最大化に集約されつつある。ここにおいても「ゴム」はますます重要なもの役割を果たすに違いない。自動車の開発を開発の立場から、これからの「ゴム」要素に対する期待を、私見を交えながら紹介する。
1. Automobile Evolution with Rubber Material

"Rubber" is an extremely unique material with a capability to withstand repeated big transformation and restoration, which other materials do not have. Looking back at automobile history, it could be said that without the benefit of this unique property of rubber, more than 100 years history of automobile evolution would never have come to pass.

1.1 The beginning of the automobile

The first gasoline three-wheeled car invented by Karl Benz in 1886 is widely recognized as the root of the modern automobile. Looking at a replica, even it has leaf springs, its overall structure was rigid, and it considerably depended on its spoked wheels to absorb the bumps and dips on the roads.

One of extremely important requirement for pioneer cars must have been that they do not break down. Driven automobiles have continuous collisions with the bumps and dips on the road, and the shock of those impacts is transmitted to the wheels, axles, and body. The vehicle’s durability is not be ensured without shock absorbing material.

When an automobile runs, the engine rotates continuously at high speed to generate power, and the axles continue to support the revolution of the wheels even as they bear a sizable load. This makes lubrication essential. Sand and other foreign matter must not be allowed to mix with the lubricant. Here again, without the flexibility of rubber, effective sealing is not be ensured. Rubber's flexibility is also essential to the various hoses used in the engine's air intake system, fuel system, and cooling system.

Approximately 5% weight component parts in a modern automobile are made of rubber account. Every one is indispensable to the quality of the vehicle, and many are safety related parts as well. Thus, the reliability and durability of the rubber material itself is indispensable to the reliability and durability of the entire vehicle.

1.2 Evolution of the automobile

In the period after 1886, the automobile was initially regarded mostly as a means of recreation, and people still looked to the horse-drawn wagon for a working vehicle. And once the durability and reliability of the basic vehicle itself was established, the public's demand for even better driving performance only intensified.

Thus the dawn of automobile history was also the beginning of the competition for speed, and the competition for engine power to satisfy the demand for speed. To avoid damage to the auto body, it needed to be isolated not only from impacts with the road, but also from engine vibration. Then people started demanding comfort, too. So, flexible rubber parts now had to improve passenger comfort at the same time that they ensured durability, and reliability of automobile.

For passenger comfort, and especially for quietness, technology that isolates auto body from engine vibration is essential. On the other hand, the engine must be securely mounted to the body in order to transmit its power. One of the most important technologies of rubber material is resolving the conflicting requirements of mounting and isolation.

Then, as rubber material technology evolved, numerous breakthroughs were also appearing in automotive technology, and long-distance, high-speed travel became possible for the public. Even for parts such as tires that show no obvious changing, their technologies are evolving day to day, and innovative ideas are invested in the materials, to the construction, and to the principle of tires.

1.3 Roles of tires

Let me refer even more to the role of tires. If you were asked what supports the weight of an auto body, you might say the tires without thinking, but that would be a mistake. What really supports the weight of the vehicle is air itself, and the tires are nothing but containers for that air. In other words, tires play their role by how they flex and how they transmit power.

The flexing of the tires not only contributes to vehicle durability and passenger com-
fort, it actually contributes to generating the forces that drive, turn, and stop an automobile. The flexing of a tire allows the tread to grip the road with a force of several thousand newtons in only a post card size area.

The pneumatic tire invented by Dunlop in 1888 was used in an automobile race as early as 1895 and impressed everyone with the overwhelming speed it made possible. Although teams using pneumatic tire had to retire in the middle of races due to repeated punctures, the subsequent evolution of tires was astonishing. I'm sure the history of the pneumatic tire and the history of the automobile both span more than a hundred years, and in many ways, the history of functional improvements to this hunk of steel called an automobile is actually the history of how rubber has been used effectively.

1.4 The 21st century

The significance of an automobile continues to evolve. What was once only a means of recreation became a way to transport goods, and then a way to expand the freedom of the individual. And what was once a product only for the wealthy first became available to everyone and now is being integrated into the infrastructure.

At the start of a new year, people everywhere resolve in their hearts to make great strides in the year ahead. And when people greet a new century, it seems that they are motivated to achieve even greater things. When the gasoline-powered automobile and the pneumatic tire were unexpectedly invented just before the 20th century, the modern automobile was born. Now, 100 years later, which directions will our motivation for progress in the 21st century head for?

2. Zeronize & Maximize

The current issues in automobile development are focused around minimizing the negative aspects vehicles have such as environmental impact, traffic congestion and traffic accidents and maximizing the positive aspects vehicles have such as fun, delight, excitement and comfort. "Zeronize and Maximize" symbolizes the vision and philosophy of our persistent efforts in minimizing the negative aspects and maximizing the positive aspects.

2.1 Why people need automobiles?

It is said that a human being has the physical capacity to run at a maximum speed of only 30km/h. But since ancient times, humans have taken advantage of horses to exceed their own physical limitations, and today we are at ease driving automobiles at speeds over 100 km/h. So human capacities have definitely evolved dramatically. The human desire to expand our capacities is part of our essential nature as animals, and because the automobile is a way to travel faster and farther, as well as a means of transporting large amounts of cargo, it has become indispensable to us.

Human beings are social animals, but at the same time, animals lead an extremely selfish existence. Needless to discuss about instinctive behavior, animals living in the natural world act as they want when they want. Human beings, too, want to do something as soon as they decide, without waiting for public transportation. Ensuring this sort of freedom and privacy opens people's hearts and contributes to good mental health.

The modern automobile plays any number of other roles as well. It provides relaxation in a comfortable space, driving pleasure that heightens one's sense of the ability to move, the demand for creations to make, assemble, and adjust, as if playing with a toy, and the connections to other people and to society at large.

The reasons why people need automobiles are not explained without mentioning these benefits that automobiles bring.

2.2 World automobiles in use

Since the automobile was invented, improvements to its performance, durability, and convenience have made it more and more indispensable in people's
daily lives. However, even though there are currently 800 million automobiles in use worldwide, with a global population of 6.5 billion people, that means no more than 12% of the world's people have received the benefits of the automobile. In case that the motorization of Asia, including China, is taken into account, the total number of automobiles in use is expected to increase 50% by 2020, to 1.2 billion automobiles, and to 1.6 billion automobiles by 2030.

2.3 Negative aspects of motorization

The automobile has freed people from both physical and mental restraints and contributed to our advanced civilization, but it must not be forgotten that the world's 800 million automobiles have also brought with them many negative aspects. These can be broadly categorized under the headings of environmental impact and traffic accidents.

2.3.1 Environmental impact

Environmental impact must be understood from three perspectives.
- The total CO2 emissions and their effect on global warming, starting from the automobile and fuel manufacturing stage on through a lifetime of use to disposal.
- The consumption of resources and the environmental impact by automobile disposal.
- The air pollution that results from substances in exhaust-emissions, such as NOx and particulate matter.

2.3.2 Traffic accidents

A review of the history of traffic fatalities in Japan shows that after reaching a peak in 1970, the year of the "traffic wars," fatalities have continued to decline as a result of social and technological efforts. Nonetheless, traffic accidents must be understood from two vantage points.
- Even though traffic fatalities have declined in Japan, the total number of casualties has not.
- Worldwide traffic fatalities are increasing continuously.

2.4 Approaches to environmental impact

Environmental impact is a simple term that covers a wide range of issues. Activities to address these issues are divided into the three approaches described below. Targets are specified individually for the activities, but the ultimate goal is to build a 100% environmentally sustainable society, to use carbon-neutral technologies with zero CO2 emissions and complete car-to-car recycling.

2.4.1 Reducing CO2 emissions

The CO2 emitted every year by 800 million automobiles amounts to 5 billion tons and accounts for 22% of all greenhouse gas emissions. This equates to an increase of 3 ppm in the CO2 concentration of the atmosphere, and if this CO2 is not absorbed and fixed, it increases the Earth's mean temperature by approximately 0.03 degrees Celsius per year. Taking into consideration the total production and absorption of CO2, if the current trend continues, the density of CO2 in the atmosphere is forecast to be 970ppm by the year 2100.4) The agreement to reduce CO2 emissions under the Kyoto Protocol is a major first step toward confronting this impending reality.

Of the total CO2 that is emitted from the time an automobile is produced until it is scrapped, fully 86% is emitted during driving. So reducing the CO2 emitted during driving, which is to say reducing fuel consumption, directly reduces the total CO2 emissions. The market for hybrid vehicles, with their new power plant systems that combine a gasoline engine and an electric motor to reduce fuel consumption, is growing rapidly. And research and development is also being
promoted for the ultimate clean car, the fuel cell vehicle, which uses hydrogen fuel and emits only water.

Because of the carbon-neutral concept, it is also important to reduce CO₂ emissions substantially by converting to bio-energy fuels. And bioplastic materials made from plant-based raw materials are beginning to be used as a way to reduce CO₂ emissions in the automobile manufacturing process.

2.4.2 Promoting recycling

Recycling to make more effective use of global resources includes the reuse of parts, the physical recycling of materials, and the thermal recycling of substances to fuels.

The current recycling rate is around 85%, and the current recycling target of the European ELV directive and the Japan Automobile Manufacturers Association, Inc. (JAMA) is a recycling rate of 95% by 2015. However, it is important to stress material recycling over thermal recycling, and to aim for a horizontal recycling system that maintains the value of the materials, rather than a cascade recycling system, which tends to lower the value of the materials. The ultimate goal is to achieve a 100% car-to-car recycling rate through reuse and horizontal recycling.

2.4.3 Reducing environmentally harmful substances in exhaust emissions

Since 1970, when the Muskie Act took effect in the United States, better combustion control technology, catalytic converter systems, and better quality fuels have reduced the amounts of harmful substances in exhaust emissions to about 1%.

In near future, automobile exhaust emissions will be cleaner than the surrounding air in large cities, creating a situation in which the air will actually become cleaner as more cars are driven longer.

2.5 Approaches to traffic safety

The ultimate dream for traffic safety must be for people, cars, and society to work together to create a world free from traffic accidents. Traffic safety measures are fashioned in terms of active safety to prevent accidents and passive safety to minimize injury when an accident does occur.

2.5.1 Passive safety

Passive safety efforts have a long history. Seat belts were an early effort at occupant protection, and impact-absorbing body structures were among the first attempts to use the structure of the vehicle itself to counter frontal impact. By 1969, Japan required automobiles to be equipped with seat belts, and in 1979, NHTSA began publicly issuing the results of frontal impact tests.

In the area of protection from frontal impact, not only seat belts, but also driver’s-seat and passenger-seat air bags, have become standard equipment. Additional devices include knee air bags to protect the lower body and side air bags and curtain shield air bags to protect against side impact.

In Japan, vulnerable persons like pedestrians and bicycle-riders account for a high percentage of traffic fatalities. Pedestrians account for 28% of all traffic fatalities in Japan, so the development and implementation of pedestrian protection devices for automobiles is being pursued with special urgency.
2.5.2 Active safety

Improvements in the vehicle dynamics include not just improvements to the basic performance items of running, turning, and stopping, but also ABS to keep the wheels from locking when the brakes are applied suddenly on a slippery road, TRC to enhance stability during take-off and acceleration, VSC to ensure stability by sensing lateral slip, and VDIM to integrate all these systems for seamless control throughout the vehicle’s normal operating range. And these technologies continue to evolve even now.

To prevent accidents, a driver must be able to recognize hidden dangers promptly and avoid them. Efforts are underway to support the driver with appropriate technologies at each stage: recognition, judgment, and operation.

Technologies include anti-glare mirrors, raindrop-shedding mirrors, and water-repellent glass currently used to aid recognition by enhancing visibility and the field of vision. New systems that are starting to be adopted include cameras to eliminate dead angles, the Adaptive Front-Lighting System (AFS) to improve nighttime visibility during cornering, and night view systems that display near-infrared images of the road ahead. In the area of operation support, use the Brake Assist (BA) system, which shortens the actual braking distance by supporting the driver’s operation of the brakes in an emergency, is increasing rapidly.

2.5.3 Harmonizing with the infrastructure

There is inevitably a limit to how much traffic fatalities can be reduced just by safety technologies in vehicles. A more radical reduction in traffic accidents will require society-wide systems that prevent accidents by transcending the notion of the individual vehicle and utilizing interactive communication among groups of vehicles (car-to-car communication), widening the frame to include communication between people and vehicles and exchanges of information with the road infrastructure and society (road-to-car communication).

2.6 Working in Maximize

The idea of maximizing the comfort and convenience of the automobile for the sake of people’s happiness is widely held among the engineers who develop the market appeal of automobiles. But when it comes to how to achieve these goals, a competition in development naturally emerges as a result of different policies and approaches to creativity.

Rather than debate the various aspects of market appeal itself, I would like to discuss some of the ideas for how to produce market appeal in terms of five keywords.
2.6.1 Killing two birds with one stone

If an automobile is driven fast, the fuel consumption increases, creating an unavoidable conflict with environmental considerations. That’s just the way it is. But is it really? Mistakes are inevitably made in any human operation, so for safe travel, automated driving backed up by ITS is more important than driving pleasure. That’s just the way it is. But is it really? To achieve a quiet vehicle interior during driving, the engine mounting system is made softer to isolate vibration better, but then it becomes impossible to achieve a direct sensation of acceleration. That’s just the way it is. But is it really? Are there opportunities here to kill two birds with one stone?

2.6.2 Addressing problems at the source

Addressing problems at the source means not creating the causes of conflict between goals in the first place, and eliminating any causes that do exist. From this point of view, there is no conflict in reducing the weight of automobiles. And fuel consumption remains low even in quick response driving. Thus people can enjoy their cars and be environmentally friendly at the same time.

Much fuel consumption results in wasted energy, and approaches are being taken to eliminate this waste entirely. The conversion of kinetic energy into discarded thermal energy by the brakes is clearly a waste. If that energy could be recovered in the form of electrical energy, not only would waste be eliminated, but also the unit that recovers the energy could function as an electric motor to generate driving force. Thus, the same device that suppresses fuel consumption also significantly improves the vehicle driving performance.

Engine vibration is a cause of vehicle interior noise. Addressing this problem at the source means suppressing the vibration before trying to isolate it. Rotational balance is important for suppressing vibration. An engine with good rotational balance also has good durability. To be sure, fluctuations occur in the explosive force that constitutes the driving torque, but that is just operating noise, so for people, it is unexpectedly soothing.

2.6.3 Depth psychology

Being in an anechoic chamber creates a sensation of floating in a huge space that is very uncomfortable for a human being. At the same time, a silent environment in which all unpleasant noise has been suppressed is also somehow disturbing. Thus we can understand that human beings do not simply require silence, but rather a comfortable sound field.

When thinking about vehicle comfort, if we first think in a deeply psychological way about what people really want, rather than simply reducing discomfort, opportunities may appear to address the issue at the source in ways that achieve both goals.

2.6.4 Utilizing human’s ability

What is it about driving a car that people enjoy in the first place? As discussed earlier, there is unmistakably a point of view that says what people enjoy is having the freedom to transcend the limitations of their physical capacity for movement and being able to act as soon as the whim strikes them. But people’s motivations are also strongly influenced by their desire to make progress and a sense of accomplishment. In other words, the pleasure of driving includes one’s personal feeling that one has become a proficient driver.

On the other hand, it is said that the most direct cause of traffic accidents is the human mind. In other words, a vehicle that is produced to be driven proficiently is a vehicle that utilizes the driver to achieve safety and enjoyment at the same time.
Japan is said to have the longest life expectancy in the world, and in recent years the twin trends of fewer children and more elderly people have only become stronger. For elderly people, there is no substitute for the convenience of a car, and the issue of how to help the elderly use their cars as comfortably as possible is an important task in automobile development.

Here, too, it is important to utilize people's abilities, not simply enhancing convenience for the elderly, but also taking advantage of the anti-aging effects associated with the act of driving a car.

2.6.5 Electronic technology

In many cases, the best form for a given purpose can be achieved by mechanical means.

But electronic technology shows us new forms of a sort that is not achieved by mechanical means. The use of electronic technology in situations where it is truly needed can overcome conflicts and create new forms of value.

Electronic fuel injection plays a major role in making exhaust emissions cleaner, and nearly all cars now use it instead of a carburetor. New car navigation systems double the freedom that an automobile provides and are even being used as a new means of communication with society. Electronic technology is not just changing the automobile, it is clearly giving birth to a new kind of automotive society.

3. Trend in Rubber Parts for Automobiles

3.1 Rubber materials for automobiles

Looking at the changes in the mass ratios of the materials in automobiles, although the percentages of lightweight materials like aluminum and plastic have increased to meet the need for weight reduction, the amount of rubber material used per vehicle has not changed significantly. This is because a territory of rubber products has been established for which it is difficult to replace rubber with any other material. The tires account for roughly two-thirds of the mass of rubber used in a vehicle, while body seal parts, parts for damping and vibration isolation, and hoses each account for approximately 10%

Higher heat loads in the engine compartment have made EPDM rubber, which has good heat resistance, a better choice for accessory drive belts, brake booster diaphragms. The usage trend in the last ten years for individual rubber materials other than tire, shows that the use of EPDM has increased. But otherwise, no great overall change is apparent. This suggests that the material choice well meet the requirement and the parts designing have already come to maturity. Therefore, now the breakthrough technologies are strongly expected there.

3.2 Rubber parts with distinctive features

This section touches briefly on the trends in rubber parts with distinctive features that are used in automobiles.

3.2.1 Revolutionary evolutions in tire performance

The tires account for two-thirds of the mass of rubber parts used in an automobile, but the use of lightweight steel cord and technical improvements in rubber materials have reduced their weight by 15%, contributing not only to reduced vehicle weight, but also to better driving performance through improved road holding.

New technologies reducing rolling resistance are applied to recent tires.
in order to reduce fuel consumption, but if only the conventional rubber technology is used to reduce rolling resistance, the basic performance of the tires in terms of wet grip and other characteristics tends to deteriorate. But the material technology such as new synthetic rubbers and new filler materials, as well as the design technology such as improvements to the tire profile (cross section shape) and tread pattern, have made it possible to provide both basic performance and low rolling resistance.

From the standpoint of vehicle safety, one critical issue is to improve braking performance on roads that are slippery due to water, ice, or snow. In particular, the improvement in the braking performance of stud-less tires on icy, snowy roads has been surprisingly improved since studded tires were banned for generating too much dust. This has been accomplished by using compounding technologies that make it possible to remove the water film that reduces the coefficient of friction of the road surface, as well as by using advances in CAE analytical techniques to optimize the design of tread patterns.

Recent years have also seen an increase in the use of "run-flat" tires that can be driven for a given distance even if they are punctured. Two different kinds of structure are used for these tires. One is the sidewall-reinforced type, where the tire sidewall is reinforced with rubber and which is used mainly for tires with a low aspect ratio. The other is the support ring type, where a core ring is inserted into the tire and which is used mainly for tires with a high aspect ratio.

Although run-flat tires eliminate the need for a spare tire, creating advantages in terms of more effective use of space, lighter weight, and conservation of resources, still there is room for improvement, because they also provide a less comfortable ride than ordinary tires and increase road noise.

3.2.2 High performance engine mounts

The distinctive properties of rubber materials demonstrate their effects most dramatically in the area of improving riding comfort and interior quietness. For example, the vibration-isolating function of the engine mounts is a major contributor to the isolation of engine vibration and noise, but at the same time, the engine must be firmly supported by the auto body in order for the large driving torque to be transmitted. A variety of unconventional engine mounts have been developed to reconcile these conflicting requirements, including hydraulic engine mounts, active vacuum mounts, and highly responsive electromagnetic active control mounts.

3.2.3 Trends in use of premium rubber

The curtain shield air bags that are increasingly used to reduce injuries in side-impact collisions are coated with silicone rubber, which seals the bags against leaks and facilitates their smooth deployment. This is an example of a breakthrough where a highly functional material actually enhances a function of the vehicle itself. And even though the material is expensive, its sealing function and low friction make it indispensably valuable for this new system.

The hydrocarbons that are the main constituents of evaporative fuel emissions react with NOx in the atmosphere to cause air pollution. Evaporative emissions regulations were therefore instituted starting in the 1995
model year, and that led to the rubber parts in the fuel system, such as hoses and gaskets, being replaced with fluoric rubber parts, which are rather expensive, but hard for fuel to permeate. It may be of little significance to the user, but it can be said that high-priced rubber materials are absolutely indispensable for conforming to society's regulations.

The LEV2 regulations were strengthened in 2004, and rubber fuel hoses have been beginning to be replaced by fluorocarbon resin hoses, which are even less permeable by fuel. Fluorocarbon resin is expensive and has poor flexibility, but the evolution of design technologies for fuel tanks and hoses, including the use of processing methods to keep cost increases down and improve install-ability, is a good example of how functional improvements can be achieved without necessarily increasing the cost.

3.2.4 Recycling EPDM rubber to practical use

Due to the cross-linked structure of rubber molecules, recycling degrades the physical properties of rubber material and lowers productivity using current technology, so the uses for recycled rubber have been limited, and most of it ends up being used for thermal recycling. But in recent years, as the need to conserve petroleum resources and reduce energy consumption has increased, revolutionary technology has been developed that improve the physical properties of recycled rubber by selectively cutting the cross-links in the molecular chain of EPDM rubber. This technology yield physical properties equivalent to those of new rubber with 30 times better productivity than conventional technologies, and they are now used to recycle waste material from the manufacturing processes for weather strips and other parts into new automobile parts. The next step is to expand widely the use of this technology for recycling rubber materials.

3.2.5 Body seal parts for high quality

Rubber is the main material used for the body seal parts that prevent rainwater and outside air from penetrating the vehicle interior and ensure its quietness. That is because the elastic properties of rubber allow it to maintain proper contact pressure over a long period of time. In recent years, a double weather strip, which adds an opening trim weather strip to the door weather strip, has come to be used also in compact cars to make them quieter.

EPDM rubber is used for typical body seal parts like weather strips and glass runs because of its ozone resistance and weather resistance, but TPO material is starting to be used for some parts because of its recycle-ability and lighter weight. However, TPO material has not yet reached to be able to replace EPDM rubber because it is poor scratch resistance and initial compression set resistance.

3.3 Key words for future trends

Given the trends in automotive technology development described above, and the current state of rubber materials in relation to those trends, the viewpoints outlined below must be kept in mind when considering future trends in automotive rubber materials.

3.3.1 Quality (reliability, durability)

All rubber parts are essential to ensuring the quality of the automobile. That means that reliable and durable rubber materials are themselves essential to the reliability and durability of the automobile.
Vehicle life has gradually been extended as reliability and durability have improved. The total running distance during the life of a car has also been extended. In this manner, the warranty period and guaranteed running distance of a car have been extended significantly. But in fact, many vehicles are exported to other countries as used cars, so their true useful life and true running distance must be extended even longer.

Some rubber parts used in automobiles support the environment and the traffic safety. Given the broad range of considerations, from deterioration over time to properties such as weather resistance and chemical resistance, it is becoming increasingly important to maintain quality until the end of a vehicle's life (or establish a periodic replacement system for rubber parts).

For example, motor vehicles currently run mainly on gasoline and diesel fuel, but energy sources are expected to become more variedly in the future. Bio-fuels (derived from plants) and synthetic fuels are strong candidates, and ultimately, hydrogen is expected to become the main fuel. It is essential for the rubber materials that are used in future fuel systems to be studied for their compatibility with these alternative energy sources.

Recently, quality problems have shown themselves to be capable of shaking even the foundations of management in the manufacturing industry. For the future happiness of humankind as well, we must make automobiles whose performance is supported by reliable quality.

3.3.2 Cost

From the standpoint of the customer who uses an automobile, there are some parts that are extremely inexpensive for the value they provide, and others that are more expensive than the customer can understand. As explained earlier, the keeping cost for all rubber parts in an automobile have resulted mainly from improvements in the properties of general rubber and the development of highly functional rubber materials. In other words, the ability to keep costs should be recognized as nothing less than the ability to develop technology.

In addition to material technologies, design technologies for size reduction and modularization are continuing to evolve. Efforts to make the best possible products will continue amid competition and cooperation.

3.3.3 Recycling

Looking at the recycling rates for different types of materials, one sees that in contrast to metals, for which the material recycling rate is quite high, the recycling rate for plastic and rubber materials is still sustained mainly by thermal recycling. It is expected that plastic materials will be replaced by biomaterials eventually, however the outlook for non-petroleum-based rubber materials is still rather poor.

From the standpoint of suppressing CO₂ emissions and protecting resources, recycling technology is an extremely important field for automotive rubber materials, one to which a firm commitment must be made. Horizontal recycling is highly effective in maintaining the value of materials, and as we move forward, our efforts must be put into developing these recycling technologies, and into creating recycling systems and design technologies that take recycling into account.

3.3.4 Enhanced functions

Enhanced functions at the material level are an essential part of how automobiles make an impression on customers and how costs are kept. Enhanced functions for rubber materials have helped to address issues of the environment and safety, and they will become more important in the areas of comfort and driving pleasure as well.

Automobile ownership in Japan, the United States, and Western Europe has reached a plateau, and customers' requirements have also matured. It is only natural that their desires have turned more toward high-quality goods and those that make a new impression. This era is starting to dawn in many other countries as well.

The population of Japan is expected to peak in 2006 and then start to decline. Changes in the composition of the population indicate a steady yearly rise in the number of elderly citizens, so making automobiles amenable to older drivers has become an urgent task. But an aging population means longer life spans, and the number of healthy older people is

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X : good  XX : very good  XXX : excellent
increasing rapidly.

As the core of the customer base shifts to healthy older people, customers will naturally develop a more discerning eye and become choosier about getting good products at low prices and demanding substantially higher quality. Other countries are going to encounter the same phenomenon sooner or later. This is a point that must not be forgotten in enhancing the functions of rubber materials.

3.4 Appealing to people’s emotions

Just what does it mean to say that customers will demand substantially higher quality products? Customers exhibit this choosiness toward cars in any number of situations, whether looking, touching, riding, or driving.

It is necessary not just to show the effects of functions, but also to appeal to people's emotions, for example the high-quality visual feel and warm impression of rubber-based paint or its softness and warmth to the touch.

It is important to build in such qualities as a sense of security on straight line or accurate response matched with the steering action, which are affected by tire performance and by the balance of rubber bushings of the suspension and steering systems.

These qualities are difficult to quantify, and in many cases, those are composed or selected on subjective judgments. But at the same time, the evolution of qualities is continued by the technologies on objective analyses.

When material technology is considered as a basic technology, it might be far from the vehicle overall. But when working on basic technologies, one must get back to human emotions and the viewpoints of users, and must search for the ideal image of basic technology.

4. And Dreams

4.1 The automobile society of the 21st century

Where will the automobile society of the 21st century take us? It is difficult to look much beyond the current product plan, but the task becomes easier if we take it in 50-year or 100-year blocks.

The invention of the automobile and the pneumatic tire around 1900 was starting to create social problems 50 years later. The starting in electronics technology around 1950 ultimately made socially accepted the continuous rapid increase in automobile ownership around 2000.

In 2020, annual classic car races will be held. 20th century cars with no energy-recovery functions will compete there, but their performance will not be able to match that of the eco-cars that have already set the standard for the age. But the satisfied faces of the parents and children will tell of the good relationship between people and automobiles, as in every age.

It will be the next generation of people who decide what invention from around the year 2000 leads to free us from the negative impacts about fifty years after. But if a completely clean vehicle has actually been achieved by around 2050, then people’s living space and their vehicles will be fully integrated, and the ways in which vehicles are used will be undergoing revolutionary changes. And if complete active safety has been achieved, then passive safety devices will have become obsolete. The physical form of an automobile will itself be revolutionized, and the auto-
mobile will start to change from something to ride in to something to wear.
Then, around the year 2050, the basic technology to allow automobiles to fly in the 22nd century will be invented.

4.2 From something to ride in to something to wear

People who like automobiles generally like robots, too. And the affinity of the Japanese people for robots is particularly strong. If the automobile is what enlarges human capacities and expands our freedom, then it has many points in common with the robot as a way to follow our dreams, before we even consider the technological viewpoint.

Robots can be roughly divided into automatic types and controllable types, and an automobile is an example of a controllable machine. The automobile is gradually approaching an automatic form that will use ITS and other technologies for automated driving, but even then, depending on how "control" is defined, it will forever be a controllable machine.

An understanding of robotic culture will be essential to the task of maximizing an automobile's advantages through various control technologies, including object instruction-type control using by-wire technology, communication-type control using words, body movements, and facial expressions, and even a robot driver to take over when the human driver is tired, that is to say the car can be operated by a robot.

When the automobile starts to change from something to ride in to something to wear, the boundary between automobiles and controllable robots will be unclear.

4.3 High-function rubber in the 21st century

As the challenge under twin vision of Zeronize and Maximize continue, the evolution of the automobile and rubber will remain, as always, two sides of the same coin. Necessity is often the mother of technology, but sometimes the new approach to material technology itself unearths new functions.

I want to believe that the day will come when new rubber technologies produce a soft car, a transparent car, and even a body suit automobile.
4.4 TODAY for TOMORROW

More than 100 years have passed since the invention of the gasoline-powered automobile and the pneumatic tire, and as we begin the 21st century, automotive technology also is entering a stage where electronic technology will make new means available to open the way to new evolutions. The key technologies as a means will vary over time, but the spirit of craftsmanship that creates new ways to define human happiness and struggles with how best to serve the people of the future will not change. Drawing on the source of this spirit, the motivation of the world’s auto builder today is to make automobiles for the sake of human happiness.

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Table 2 High-function rubber in the 21st century (Dream)

| Deterioration Free / Full Recyclable |
| Energy Regenerative / Photosynthetic |
| Free to Colored (weather resistible) / Colorless Transparent (high strength) |
| Variable Characteristics / Muscular Function |

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