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Michelin Uptis - Are airless tires the future of the automotive industry?

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Abstract. Problem. *The paper addresses the question of whether the conversion of the entire automotive industry to airless tires, specifically focusing on the Michelin Uptis concept, is economically realistic and technically feasible for high-performance vehicles.* ***Goal.*** *The goal of the paper is to investigate and analyze the technical feasibility and economic impacts of airless tires, specifically the Michelin Uptis, through expert interviews, literature review, and research methodology.* ***Methodology.*** *The research methodology involves various research methods, including expert interviews, literature research, journal articles, press releases, and expert opinions. The paper relies on current and relevant sources to provide a comprehensive understanding of the topic. Expert interviews with industry professionals, such as Philipp Kranich from Mercedes Benz Consulting and Jochen Konrad, a tire developer at Pirelli, provide additional insights.* ***Results.*** *The technical feasibility of airless tires, specifically the Michelin Uptis, is examined, highlighting advantages such as puncture protection and environmental friendliness. However, concerns are raised regarding the structure's resilience, potential damage to spokes, weight and energy efficiency, and suitability for high-performance vehicles. The economic impacts of airless tires are also discussed, including the potential reduction in tire orders, changes in aftermarket services, logistical adaptations, and the pricing challenges associated with the Uptis concept.* ***Originality and Practical Value****. This paper offers an analysis of the technical and economic aspects of airless tires, specifically focusing on the Michelin Uptis concept. It provides expert insights, reviews relevant literature, and addresses the original research question. The findings contribute to the understanding of the feasibility and potential implications of airless tires in the automotive industry, aiding decision-makers in assessing the practical value and viability of adopting this tire technology.*

Key words: *airless tires, Michelin Uptis, technical feasibility, economic impacts, automotive industry*

Introduction

At the International Motor Show (IAA) 2019, Michelin caused a stir with the introduction of a new tire concept. As part of the "New Mobility World," the Michelin Uptis was showcased. This is an airless tire concept that is ready for mass production and is expected to be introduced to the market in 2024 [1, 2]. Michelin even received the "Golden Steering Wheel" award in 2019 for this innovation. A year later, on the occasion of the 2020 Golden Steering Wheel awards, Michelin presented the first, press driveable prototype. Although this prototype was only allowed to be driven at a maximum speed of 50 km/h in these tests, the press's response to the driving behavior was positive [3]. After a few years of silence on the Uptis, Michelin announced at the beginning of 2023, and already partially implemented, the equipping of 50 DHL vehicles in Singapore with the Uptis this year [4]. Thus, airless tires as mass-produced tires are becoming more and more real. However, is a conversion of the entire automotive industry to this type of tire economically realistic? Is it technically feasible for high-performance vehicles? This paper attempts to get to the bottom of these questions with the help of expert interviews.

Literature review and hypothesis development

The first part of this chapter provides an overview of the essential characteristics of tires and the goals of tire development and construction. Additionally, it delves into the history and construction of traditional air-filled tires and the evolution of airless tires leading up to the Michelin Uptis, which helps to better understand the implications of airless tires on the automotive industry.

Tire Properties and Objectives in Development.

Tires must withstand various forces to carry vehicles and safely navigate curves, including wheel loads, lateral forces, and longitudinal forces that transmit both motor power and braking forces to the road. Additionally, tires should provide the greatest possible road grip under all weather conditions and have suspension and damping properties to support the vehicle's steering behavior. Furthermore, the tire should have good running performance with low rolling resistance and noise development, and be dimensionally stable, safe, and durable throughout its lifespan. It is important that the tire does not jump off the rim and is robust enough to withstand external influences while remaining as airtight as possible. However, since all of these properties involve trade-offs, the goal of every tire development is to find an optimal compromise. The determination of this optimal compromise is the responsibility of vehicle manufacturers, while the tire manufacturer is responsible for the technical implementation [5].

History of air tires.

The history of the car tire officially began two years after the publication of Carl Benz's patent for his gasoline-powered automobile in 1888. Scottish veterinarian Dr. John Boyd Dunlop put his idea into practice and mounted air-filled tires on his son's tricycle. This invention first found industrial application in bicycle tires and was soon also used in automobiles. The history of tires is associated with many well-known manufacturers such as Continental, Dunlop, Goodyear, Michelin, and Pirelli, all of whom have contributed to the development and progress of tires at various times [6].

Today, highly complex scientific methods, computer programs, and experts from many fields are required to develop and manufacture a high-tech tire. In the early days of mass motorization around the turn of the century, however, there were fewer demands placed on tires. Over time, the rubber compound was reinforced, the tires lasted longer and were more durable, and numerous new technologies, such as detachable rims and tubeless tires, were developed. Synthetic rubber was introduced in 1936 and significantly increased the level of performance. By the 1950s, a standard for car tires had been established that still exists today. Over time, the tire has evolved along with the motor vehicle and adapted to the needs of customers [7]. Over time, the tire has steadily evolved alongside the motor vehicle, adapting to the needs of customers. This is evident, for example, in the continuously increasing average tire width, the decreasing aspect ratio, and the change in the profile, as illustrated in Figure 1 [8].

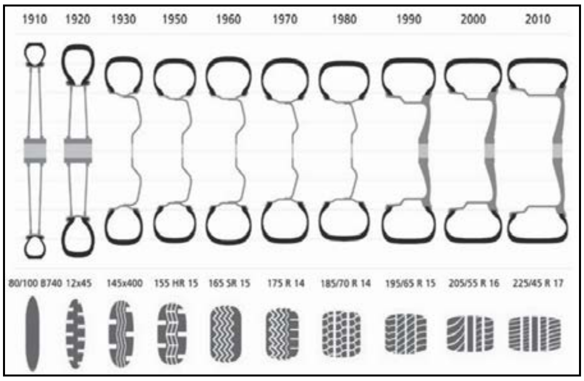

Fig. 1 Development of tire dimensions and tire profile [8]

Overall, tire development has played a crucial role in mass motorization over the decades and is still in constant change and progress. Without air-filled tires, the modern automotive world would not be conceivable [9].

Structure of an air tire

The production of modern passenger car tires is almost exclusively done in radial construction. A schematic representation of the basic structure of such a radial tire can be seen in Figure 2 [10].

A tire is made up of a variety of materials, including various rubber compounds, steel wire (also known as "steel cord"), and various synthetic fibers such as nylon and aramid. The tread of the tire is the surface that rolls on the road and is profiled to improve the tire's grip and self-cleaning ability. Underneath the tread are several layers of support material that contribute to the stability and strength of the tire.

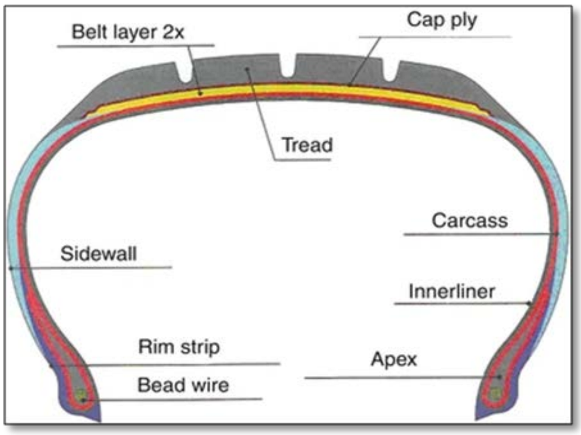

Fig. 2. Structure of a radial tire [10]

The carcass forms the tire's load-bearing framework and is made up of steel wire embedded in the rubber. The tire beads, the thickened areas at the inner edge, form the connection to the rim and consist of circumferential steel wires embedded in the rubber. To prevent air and moisture diffusion, the inside of the tire is coated with a special rubber layer called a liner or inner liner [11].

The profiling of the tread and the labeling of the sidewall only take place during the "baking" process of the tire. In the last step of tire production, the tire blank is heated to up to 200°C in a steel mold under pressure, which irreversibly bonds the individual raw components of the tire together (vulcanization). The mold contains a negative form of the desired tread and sidewall, which is transferred onto the rubber [8].

The dimensions of a tire can usually be described by three measurements: the section width, the aspect ratio, and the nominal diameter of the wheel. The width is measured without labeling, protective strips, or similar features. A tire can be simplified as a torus. The aspect ratio is a dimensionless quantity for the tire height that provides information on the tire's cross-sectional shape regardless of the tire size. For example, a distinction can be made between balloon tires and low-profile tires. A diagram of the mentioned sizes is shown in Figure 3 [12].

The law requires that the tire size, among other information, must be permanently marked on the tire sidewall. For this purpose, a "technical zone" has been defined as a circular ring at the inner edge of the tire sidewall, in which the required data must be provided. The position and size of the technical zone are marked in yellow in Figure 4.

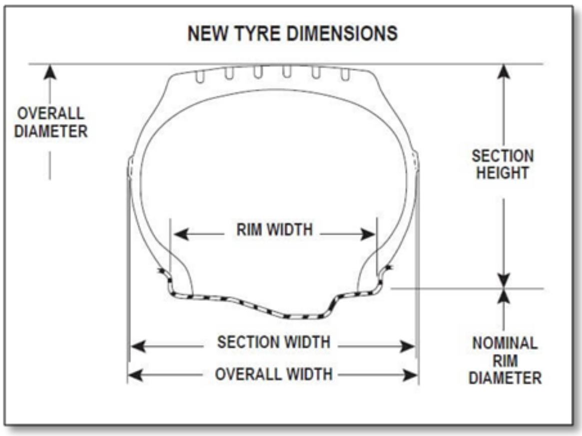

Fig. 3. Tire dimensions [12]

Fig. 4. Tire sidewall information [13]

Specific step sizes (10 mm and 5%) are used when indicating the cross-section width and the aspect ratio, respectively. The area above the technical zone is referred to as the "commercial zone" and can be freely designed by the tire manufacturer. Here, the brand and tire type, as well as the tire size, are often displayed in large font sizes [8].

History of airless tires

The origin of the idea of an airless tire is difficult to trace. The first known attempt to produce an airless tire began in the 1960s when NASA and the Goodyear Tire and Rubber Company started developing airless tires for use on the moon. These tires consisted of a wire mesh structure connected to metal links and surrounded by a layer of elastic silicone. These tires offered the advantage of not puncturing or losing air, which was a crucial factor on the rugged terrain of the moon. They were successfully used on the Lunar Roving Vehicle (LRV) deployed during the Apollo missions to the moon [14].

The use of these airless tires in space had a decisive influence on the development of airless tires for use on Earth. In the 1970s, tire manufacturer Sumitomo began developing a hybrid tire concept called Runflat, which had airless properties [15]. Tires with this construction can travel a limited distance even when fully deflated or experiencing significant pressure loss. Unlike conventional tires that need to be replaced or immediately repaired in the event of a flat tire, run-flat tires can continue to travel a limited distance, typically up to 80 km at a maximum speed of 80 km/h. The secret behind run-flat tires lies in their special construction. Inside the tire, there is a reinforcement that prevents the tire from completely collapsing in the event of pressure loss. The sidewalls of the tire are also stronger than in conventional tires to provide additional support. Another advantage of run-flat tires is that they can reduce the risk of accidents due to a flat tire since the driver can maintain control of the vehicle and slow down instead of coming to an abrupt stop [16].

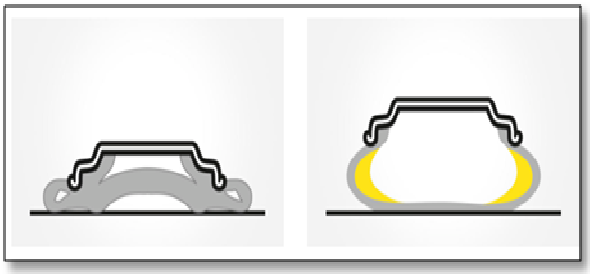

Fig. 5. Difference in pressure loss between conventional tires (left) and run-flat tires (right) [17]

This concept was introduced to the mass market in the early 2000s, and despite the advantages mentioned, it has had problems fully competing with traditional air-filled tires in the market. Because although this concept has its benefits, it also has some disadvantages [18].

Overall, the history of airless tires has undergone remarkable development, from its origins at NASA to the Runflat tire, and now even further to the Michelin Uptis.

Purpose and Tasks

The purpose of the paper is to investigate and analyze the technical feasibility and economic impacts of airless tires, specifically the Michelin Uptis, through expert interviews, literature review, and research methodology.

Introducing the Michelin Uptis

The Michelin Uptis is a new airless tire concept introduced by Michelin, with the acronym standing for "Unique Puncture-proof Tire System". According to Michelin, this tire represents a technological breakthrough in the field of airless solutions, as it combines nearly infallible puncture protection with excellent driving performance and energy efficiency at the highest level. Unlike existing airless solutions, the Uptis is perfectly suited to the needs of passenger cars and can be used in a variety of ways. The concept, introduced in 2019, combines an aluminum wheel with a flexible load-bearing structure made of glass fiber-reinforced plastic (GRP) to meet all the performance requirements of a Michelin tire. As the Uptis does not require any air pressure, it is more puncture-resistant than conventional tires and thus offers a particularly high level of reliability. After quick and easy installation, no further air pressure control is necessary, making the tire virtually maintenance-free. The Michelin Uptis also has exemplary environmental properties: currently, about 200 million tires are replaced annually, even though they have not yet reached the end of their lifecycle. The reason for this is damage caused by low tire pressure or loss of pressure due to punctures. According to Anish K. Taneja, CEO of Michelin Northern Europe, this is no longer an issue with the airless Michelin Uptis [19, 20].

Michelin emphasizes three key points with the Michelin Uptis. Carefree: Thanks to the Uptis, drivers no longer have to worry about the effects of road conditions on their tires. The danger of losing control of the vehicle or having to stop by the side of the road due to a tire puncture no longer exists. Increased productivity: With the Uptis, fleet owners would increase their efficiency as the risk of vehicle breakdowns would be reduced and maintenance related to tires (such as pressure checks and tire inflation) would be unnecessary. More environmental protection: The airless technology would drastically reduce the number of tires that need to be disposed of due to tire punctures [20].

Fig. 6. Appearance of the Michelin Uptis [20]

In Figure 6, the 2021 prototype of the Michelin Uptis can be seen. The most obvious difference between the Uptis and a conventional air-filled tire are the open sidewalls and spokes that connect the rim to the tread. The tread pattern is no different from Michelin's conventional tires. The Uptis is not mounted on the rim like conventional tires, but the spokes are directly connected to the rim. The spokes are made of polyester resin and glass fiber and are said to have high resilience, excellent load-carrying capacity, and vibration-damping properties, which improve driving comfort [21]. Michelin has confirmed on their German Instagram account (@michelingermany) that the Uptis will be replaced only as a wheel, not as an individual tire [22]. It is not yet officially known how the spokes are connected to the rim, and information on pricing is not yet available [23].

As shown in Figure 7, the Michelin Uptis prototype 2021 was presented in the tire size 215/45 N17 84H [20]. The same tire size was also used during test drives on the Chevrolet Bolt in 2019 [24]. During press test drives with the Michelin Uptis on the Chevrolet Bolt in 2020, the press reported that there was hardly any difference at the allowed speeds of 40-50 km/h. The steering precision and comfort were also remarkable [3].

Fig. 7. Tire size of the Michelin Uptis prototype 2021 [20]

Since the beginning of 2023, Michelin has been testing the Michelin Uptis on DHL delivery vehicles on the streets of Indonesia in cooperation with DHL [4, 25]. The tire dimension used for this purpose differs from the presented prototype and is 215/65 N16 93T [22]. Thus, the load has been increased for this prototype and, as shown in Figure 8, the spokes have become significantly longer.

Fig. 8. Michelin Uptis 2023 prototype DHL [22]

Research methodology

To answer the research question, various research methods were employed. These included expert interviews, literature, journal articles, press releases, and expert opinions. Literature research was conducted through various sources such as textbooks, online articles, and scientific publications. Special attention was paid to current and relevant sources to ensure a comprehensive presentation of the topic. Journal articles were also considered to identify current research findings and new developments in the field of the research question. In particular, articles from renowned academic journals were used. Press releases were also used as a research method to obtain information about current developments and innovations in the industry, with a focus on press releases from companies and industry associations. Finally, the opinions of experts were included in the research to obtain a broader perspective on the topic. Experts from various areas of the industry were interviewed to obtain their opinions and assessments of the research question. The two expert interviews with Philipp Kranich from Mercedes Benz Consulting and Jochen Konrad, a premium segment tire developer at Pirelli, are particularly noteworthy. Overall, a variety of research methods were used to ensure a comprehensive and well-founded answer to the research question.

Results and discussions

The aim of this chapter is to answer the research questions formulated in the first chapter using literature, expert opinions from the automotive industry, and the author's expert interviews. Special attention is paid to two aspects: firstly, the technical components of airless tires are examined, their influence as well as advantages and disadvantages in the automotive industry. Secondly, the economic impact of introducing airless tires in the automotive industry is investigated, which is also influenced by technical components.

Technical Feasibility

The characteristics and benefits of the Uptis presented by Michelin in chapter three sound very good and promising at first glance. However, upon closer examination, some implementation questions arise that Michelin has not yet answered and that are viewed critically by experts.

Michelin promises almost flawless puncture protection with the Uptis [20]. However, it is questionable whether this statement can really be true. Due to the design of the Uptis, the risk of air loss and carcass breakage caused by, for example, potholes is definitely eliminated. But it would have to be tested how well the spoke structure holds up in the same extreme situations [26]. Furthermore, the spokes can also be damaged by a nail puncture and thus affect the structure, as shown in Figure 9.

Fig. 9 Simulation of a nail puncture on the Michelin Uptis [21]

The consequences for the tire are still to be clarified [26, 27]. Due to its open-sided design, the same risk of damaging the structure through high curbs as with air-filled tires still exists [26]. Michelin also advertises the environmental friendliness of its airless tire concept. One main argument is that due to the puncture resistance against impacts and punctures, no 200 million tires per year would have to be replaced [1]. The aforementioned points also cast doubt on this statement. In addition, it should be noted that the Uptis would likely not be repairable with simple methods in the event of damage, which could lead to immediate disposal of the tire, unlike a conventional tire [27]. Also, the clearly visible higher material input of the Uptis compared to conventional tires raises doubts about the environmental aspect that Michelin highlights.

However, the high material usage of the Uptis could also lead to problems in other aspects. One of the main goals of tire development is energy efficiency, which is often achieved through weight reduction. The higher material usage compared to traditional air-filled tires will likely increase weight and therefore rolling resistance. To counteract this, the structure of the spokes would have to be designed extremely hard, which in turn strongly affects the tire's suspension behavior. Furthermore, the open design of the Uptis could also have a negative aerodynamic impact on energy efficiency, particularly with regards to the detachment of airflows [26]. The reason for the open design of the Uptis is likely the strong heat generated by the working of the spokes. Air is needed to cool the spokes, which is why a closed sidewall would be an even greater trade-off for the Uptis [27].

A point that could support the announced environmental friendliness of the Uptis would be the renewal of the tire. Michelin has already announced that the Uptis will only be available on the market as a wheel-tire combination. This leads to the assumption that a type of retreading will take place when renewing the Uptis, as is already known from air-filled tires [26]. However, this can only be definitively determined when it is clear how the different components of the Michelin Uptis are interconnected. According to Mazur, who has compiled various papers on airless tires from Russian and American universities, the airless wheel-tire concept consists of six different main components [28].

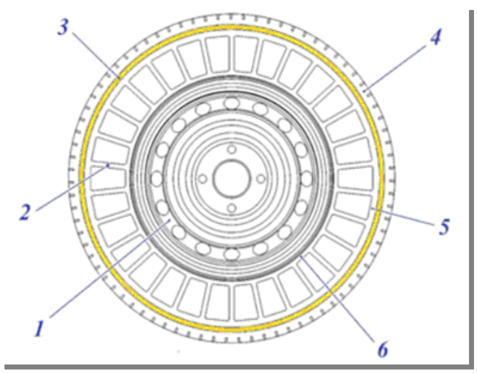

Fig. 10. Components of an Airless Wheel [28]

Three of these components can also be clearly seen in pictures of the Uptis, namely the rim (1), the flexible spokes (2), and the rim protector (4). In addition, there are said to be three different types of rings in the structure: an adaptation ring (5), a mounting ring (6), and a support ring (3). The support ring, in conjunction with the flexible spokes, provides the tire's elastic resilience and load-bearing capacity [28]. Although these insights from Mazur do not provide any information on how the spokes are connected to the rim and the tread, they do point to another problem that experts have mentioned. This concerns issues with the load-bearing capacity of airless tires or the flexible spokes. As mentioned earlier, the spokes of the tire would have to be extremely rigid to achieve a certain load-bearing capacity. However, this would mean sacrifices in the spring effect and performance of the tire [26]. By using a support ring, following the example of the existing variant in run-flat technology (see Figure 11), this problem could be counteracted [28].

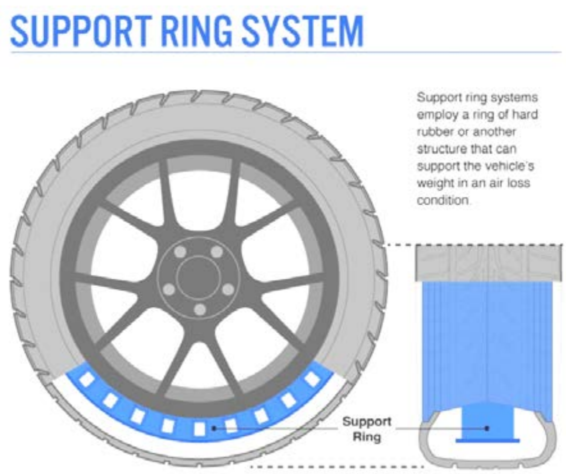

Fig. 11. Run-flat tire with a support ring [29]

There is another aspect that experts, including former racing driver Scott Mansell, have identified as the biggest criticism of airless tire concepts: their use in high-dynamic applications. This is attributed to the structure of the design. The experts assume that the structure cannot meet the high demands of such vehicles [26, 27, 30].

Further unanswered questions exist regarding the connection between the spokes of the Uptis and the rim, as well as the tread. At this point, only speculations can be made about how the spokes are attached to the rim and the tread, such as that they may be bonded or possibly clamped [26].

In addition, there is the issue of what mass production of such a concept would look like. The fact is that this concept is far removed from conventional tire manufacturing [26]. Therefore, in order to ensure mass production, new machines, and processes would have to be developed, which in addition to the already expensive development costs, would cause further high costs [26, 27]. Another complicating factor in mass production lies in the weight differences of the various vehicle derivatives. With conventional tires, the weight differences of these derivatives do not pose a problem as the tire pressure can be adjusted accordingly. With the Uptis, however, the factor of tire pressure is eliminated and therefore, it is thought that different tires would have to be developed in order to cover all vehicle derivatives [26].

Economic Impacts

New technology in the market also leads to new synergies. Michelin's claim that the Uptis or airless tire could reduce the need to dispose of 200 million tires per year and also reduce the need to renew 200 million tires would have an impact on many parties in the supply chain. Whether it is tire manufacturers, retailers, or waste disposal companies, it would mean fewer orders for all concerned. The promised higher efficiency that Michelin offers with the Uptis, in conjunction with the ongoing progress in mobility, could further reduce the aftermarket for tires [31].

Furthermore, the aforementioned renewal process also plays a role. Due to the fixed connection of the tire and rim with the Uptis and Michelin's announcement that the Uptis will only be available as a complete wheel, the traditional mounting process for wheel renewal in the automotive industry would be completely eliminated. Thus, the revenue potential for the service of wheel renewal by repair shops would be completely swallowed up by Michelin [31].

Another factor that should be mentioned is the logistical impact that the Uptis concept brings with it. Due to the many new properties that the Uptis brings, the logistics processes would have to be adapted and probably presented in a more complex manner. The increased weight of the Uptis compared to an air-filled tire also plays a role in logistics [31].

The biggest economic question arising from the Uptis concept is the price. The elaborate and lengthy development process, combined with the fact that the Uptis is only available as a unit with a rim, suggests a higher price in the market [26, 31]. This raises the question of who in the market would find such a tire economically feasible. Michelin's test runs in cooperation with DHL in Indonesia provides a clue. Fleet vehicles that generate losses due to downtime could benefit from the puncture-proof feature of the Uptis. However, this can only be determined conclusively when data on the total cost of ownership of the Uptis is available. Furthermore, it is conceivable that the Uptis could initially be offered as an optional extra by vehicle manufacturers in order to integrate itself into the market [26, 31].

Conclusions

In conclusion, it can be said that Michelin's vision of airless tires on automobiles is becoming a reality. However, in the form that they have announced, there are some doubts. As shows, there are still many technical uncertainties that need to be explained in order to fully understand the concept of the Michelin Uptis. The goal of tire development is to find the perfect compromise, and the Uptis makes many compromises that an air-filled tire does not have to make. Therefore, the first research question of whether the concept is suitable for high-performance vehicles is more likely to be answered in the negatively. However, the Michelin Uptis will certainly find its place in the market, probably more in the fleet sector, with vehicles or industries that benefit from the puncture resistance of the Uptis and where performance plays only a small role. However, for private customers, the compromises that are made are too great. Especially for small car owners, the price would probably be a decisive factor. The coverage of the different vehicle derivatives also plays a major role in this respect. In these areas, the concept loses out to conventional tires in the market. One of the few ways to establish itself in the private customer sector would be to collaborate with manufacturers in the form of a special equipment line. The second research question of whether a switch to this type of tire by the entire automotive industry is economically realistic is still to be answered in the negative. Another reason for this is the completely new design of the Uptis. The entire automotive industry is geared toward the design of conventional tires. Complex new structures and processes would have to be created for airless tires in order to ensure a regulated process in the automotive industry.

Limitations and study forward

This research is based purely on opinions and assessments from experts in the industry and literature. Only a few facts are known about the Michelin Uptis and absolutely no practical data has been published. It remains to be seen when further facts and, above all, data will be released in order to make more informed statements and gain further insights.

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Michelin Uptis - Майбутнє автомобільної промисловості за безповітряними шинами?

Анотація. Проблема. *У статті розглядається питання про те, чи економічно реалістичним і технічно можливим для високопродуктивних транспортних засобів є перехід усієї автомобільної промисловості на безповітряні шини, особливо зосереджуючись на концепції Michelin Uptis.* ***Мета.*** *Метою статті є дослідження та аналіз технічної здійсненності та економічного впливу безповітряних шин, зокрема Michelin Uptis, за допомогою експертних інтерв'ю, огляду літератури та методології дослідження.* ***Методологія.*** *Методологія дослідження включає різні методи дослідження, включаючи експертні інтерв'ю, дослідження літератури, журнальні статті, прес-релізи та експертні думки. Стаття спирається на актуальні та відповідні джерела, щоб забезпечити всебічне розуміння теми. Експертні* *інтерв'ю з професіоналами галузі, такими як Філіп Краніч з Mercedes Benz Consulting і Йохен Конрад, розробник шин у Pirelli, надають додаткову інформацію.* ***Результати.*** *Розглядається технічна доцільність безповітряних шин, зокрема Michelin Uptis, підкреслюючи такі переваги, як захист від проколів і екологічність. Проте виникають занепокоєння щодо стійкості конструкції, потенційного пошкодження спиць, ваги та енергоефективності, а також придатності для транспортних засобів високої продуктивності. Також обговорюється економічний вплив безповітряних шин, включаючи потенційне скорочення замовлень на шини, зміни в послугах післяпродажного обслуговування, логістичні адаптації та проблеми ціноутворення, пов'язані з концепцією Uptis.* ***Оригінальність і практична цінність.*** *Ця стаття пропонує аналіз технічних і економічних аспектів безповітряних шин, особливо зосереджуючись на концепції Michelin Uptis. Він надає експертну думку, огляд відповідної літератури та розглядає оригінальне дослідницьке питання. Отримані результати сприяють розумінню доцільності та потенційних наслідків використання безповітряних шин в автомобільній промисловості, допомагаючи особам, які приймають рішення, оцінити практичну цінність і життєздатність впровадження цієї технології шин.*

Ключові слова: *безповітряні шини, Michelin Uptis, технічна можливість, економічні наслідки, автомобільна промисловість*

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