THE HISTORY OF COMPONENTS

This section of the journal deals with one of the metal components used in the automotive industry, recording the changes in its design. At the same time, the many ways in which the techniques and materials employed in its manufacture have developed will be described.
This approach helps to emphasize the vital role played by metal component manufacturers in developing the basic materials and working out production processes.
The article in this issue deals with the wheel.

Wheels

Giovanni Riccio

Abstract
In the early days of this century, automobile pioneers were still arguing about whether wooden or metal wheels gave the better performance. But soon, in 1924, the first wheel in light alloy, mounted on a Bugatti, made its appearance on the occasion of the French Grand Prix. The article, following the evolution of wheels for cars and heavy vehicles, focuses on their characteristics and the innovations brought in, affecting both the materials used and the manufacturing process.

Riassunto
Le ruote
Nei primi anni del secolo, i pionieri dell'automobilismo disputavano ancora sulla maggior convenienza delle ruote in legno o in metallo. Ma già nel 1924, in occasione del Gran Prix di Francia, la prima ruota in lega leggera, montata su una Bugatti, faceva la sua comparsa.
L'articolo ripercorre l'evoluzione dei vari tipi di ruote per automobili e veicoli industriali, evidenziandone le caratteristiche e le innovazioni apportate nella scelta dei materiali e nei processi di fabbricazione.

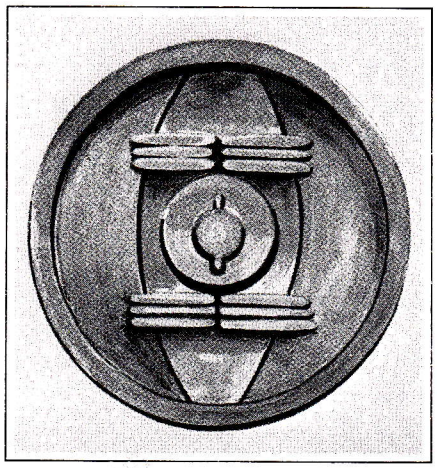


Fig. 1 - The prehistoric wheel (4000 B.C.).

According to Tchakravartin, a Tibetan sage, seven things were precious to the world: the wheel (Fig. 1), the horse, the elephant, woman, the pearl, the house-steward and the counsellor.
To-day, some things have changed in this list, but the wheel, and in particular the automobile wheel, retain its importance. This automobile component consists of a metal body, disc shaped or spoked, and a rim shod with a pneumatic tyre. Such a wheel can easily be mounted on a fixed hub, which generally carries the braking system.
The characteristics of the wheel are now stated on the basis of the experience and long history of the automobile. First of all we talk about lightness, inasmuch as the wheel represents the greatest unsprung weight and contributes to the quality of the suspension, the roadholding, etc. The wheel must be compatible with effective ventilation for cooling the brakes and the tyre itself, and must be particularly endowed with resistance to fatigue, especially when the vehicle is entering a curve or accidentally strikes an obstacle. Finally, the wheel has an important function in the general aesthetics of the automobile.
From the first years of the development of the automobile, solidity in the wheel was sought, to be able effectively to transmit the impulse of the engine, to resist the forces of sudden braking and to withstand impacts of various kinds. The most convenient diameter of the wheel was considered, relative to the weight of the vehicle and to its position, front or rear. The tractive effort, the weight of the vehicle, the radius of the wheel and the height of the obstacle to be surmounted are connected in a relation of the type

$T = P^{h}_{2R}$ where T = tractive effort,

P = weight,

R = radius,

h = height of the obstacle.

On the width of the rims, theory wasn't much exhaustive and account was chiefly taken of the state of the road bed. For example, given roads with a soft bed, the rims were made wider; but if the same roads were strewn with stones the wide rim increased the number of obstacles that had to be surmounted.
At the end of a competition for heavy vehicles, held in Liverpool in May 1898, it could be affirmed: "The irregularities of the ordinary roads are the main causes of very high costs of maintenance and depreciation of vehicles and the primary cause of risks in any public service with mechanically driven vehicles".
The argument about the convenience of wooden or metal wheels filled the first years of the life of the automobile (Fig. 2).
Metal is elastic while wood is not. Wood shows variations in volume with humidity and temperature, but in the opposite direction to that of metal. Therefore wooden wheels with metal hubs and tyres caused dangerous separations between these parts.
On the other hand, wood has a valuable characteristic that metal has only in a much reduced measure; that is, the capacity to absorb the shocks provided by the

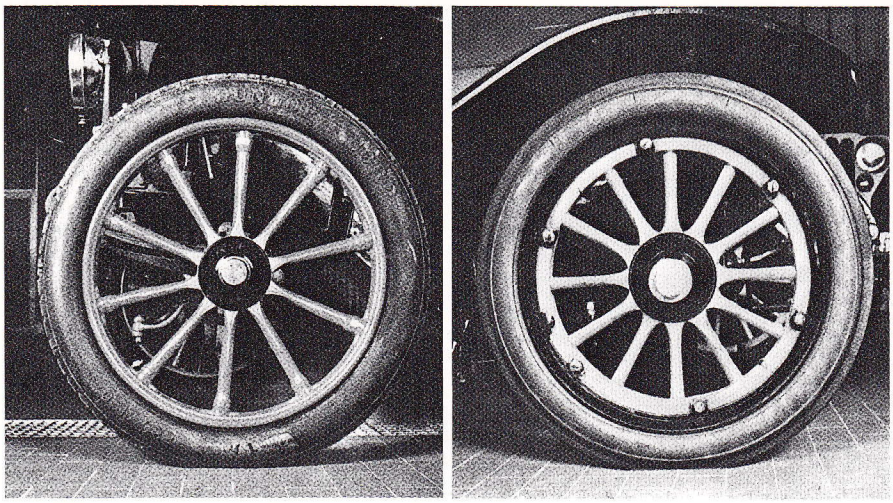
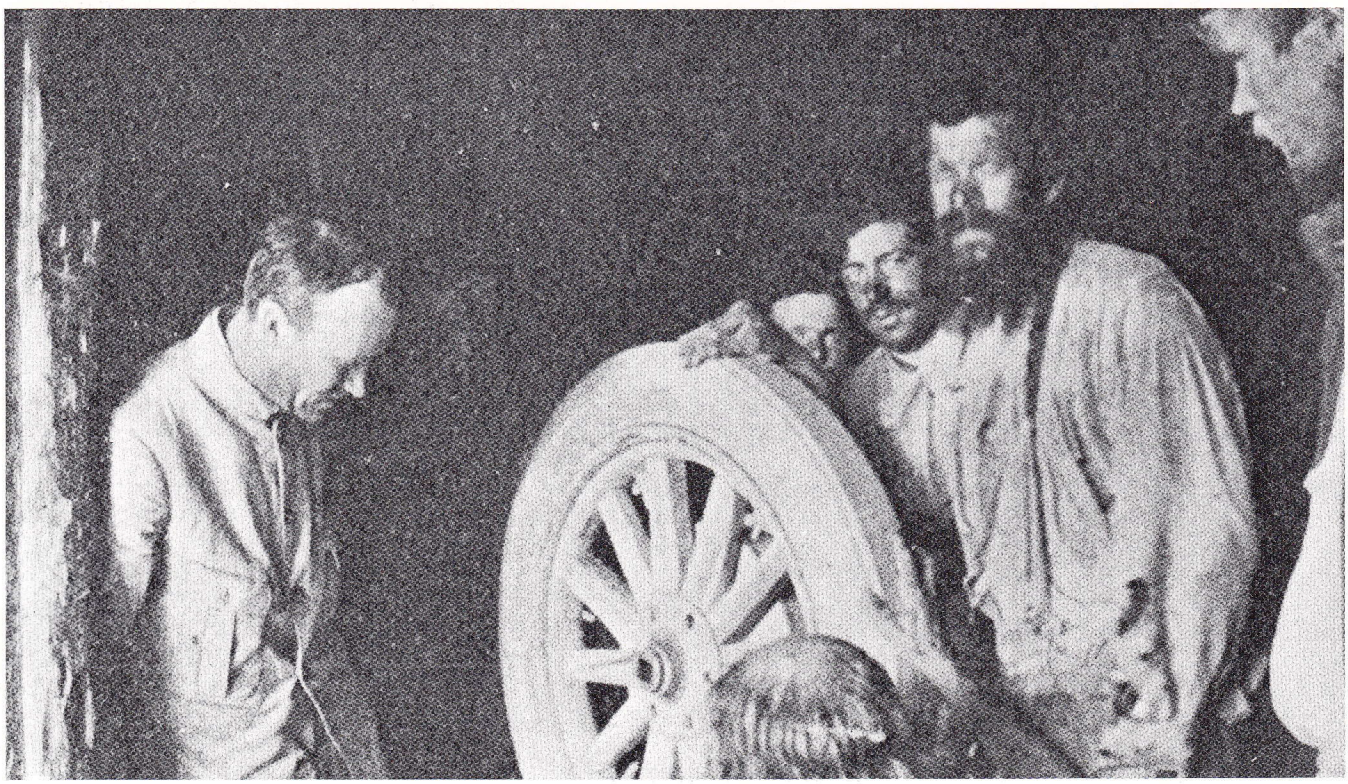


Fig. 2 - Automobile wheels in wood with metal reinforcement (1900).

road (irregularities, potholes, stones). The metal wheel in this case is subject to vibrations that are transmitted to other components of the vehicle.
The damping action of wood thus augments that of the outer elastic tyre on the rim.
A great advantage of the wooden rim appeared during the Peking-Paris "raid" (1907), during which a wheel was rebuilt by the work of a Central Asian artisan, enabling the journey to continue (Fig. 3).

At the start of the Century, wheels for motor vehicles were divided into three main categories: 1) wooden spoked wheels, 2) metal spoked wheels, 3) solid metal wheels.
Wooden spoked wheels were made with the hub of elm wood or more frequently of bronze, case-hardened and tempered iron or steel, the spokes were of acacia wood or, for very heavy vehicles, of oak. The rims were of elm or ash and occasionally of metal.
At that time, wooden wheels gave satisfactory results and were widely used.
Wheels with metal (steel) spokes were derived from those used on motorcycles and light cars. Metal spokes worked only in tension, in contrast to wooden ones, which worked in compression. Their section used to increase from the hub towards the rim, with a direct (radial) or tangential arrangement according to the circumference.
Solid metal wheels are an innovation

Fig. 3 - Wooden wheel rebuilt in 7 hours by a Siberian artisan (Peking - Paris "Raid", 1907).



of the last years of last century. To take an example, the wheels of New York taxis from the Electric Vehicle Co. had the spokes replaced by solid steel segments 4 mm thick, and arranged according to truncated cone surfaces like ordinary spokes. The rims were of wood with concave sections to receive the pneumatic tyres.
At the same time, for the comfort of passengers, and for adequate protection of the various mechanisms, the wheels of vehicles that must maintain high (relative) speeds were provided with elastic tyres. Heavy vehicles that maintained lower speeds were equipped with metal tyres. But the tendency to use rubber for the outer tyres of wheels was increasing rapidly (Fig. 4).
The solid rubber tyre had to be fixed solidy to the rim to avoid tearing away. One precaution was to make these tyres wide enough so as not to slot into tram tracks. Fitting the tyre was done by forcing, welding or with circular elements with or without bolts.
Hollow rubber covers had no success because the air in the cavity at atmospheric pressure was not enough to ensure an empty space that would support the weight of the vehicles. Their performance in practice was equivalent to that of a solid rubber tyre.
At the Paris Exhibition of 1899, 80% of the cars on show had adopted the pneumatic tyre with air at high pressure. Dunlop was starting to produce pneumatics for cars built with a weldless inner tube with the joint vulcanised, as also was the patch carrying the valve. A tape protected the inner tube from the heads of the metal spokes. The tyre was composed of 7-8 robust canvas webs with other supplementary webs for the tread, held together with a special rubber.
The whole was vulcanised once only, without the subsequent application of a tread. Four or five security bolts fixed the cover to the rim, which could be of metal or

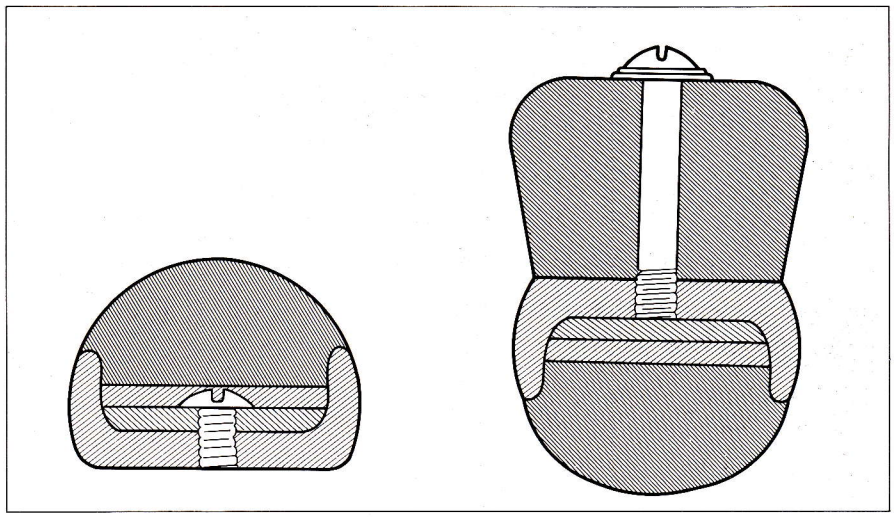
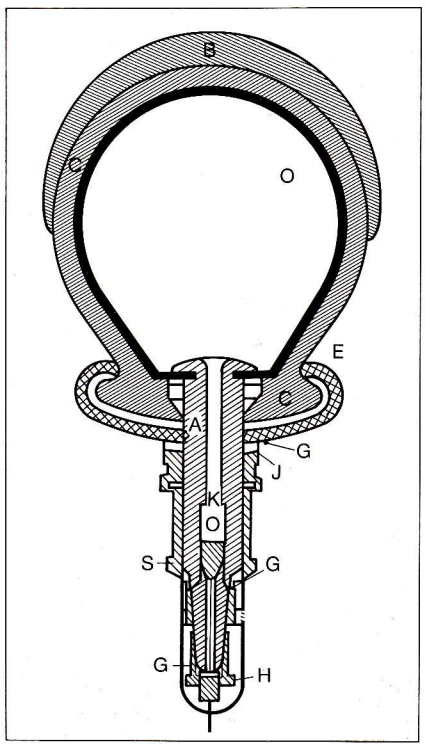


Fig. 4 - Solid rubber type (end of XIX Century).

wood. The air pressure was 4-5 kg/cm^2.
Arguments soon arose about the best pressure of inflation for pneumatic tyres in relation to rolling resistance presented by the new version of the wheel, compared with the others. A fundamental factor in this regard was presented by the variability of the road bed.
Despite the frequent punctures and their very costly maintenance, wheels equipped with pneumatic tyres spread rapidly (Fig. 5).
However, their weakness led to the realisation of some curious alternative solutions. A typical example was the so-called "elastic wheel". This consisted of a metal outer rim coated with rubber, connected to the hub by spings in place of the traditional spokes. Thus a certain elastic displacement of the outer rim was possible which simulated the behaviour of a pneumatic tyred wheel. A solution of the same type will then be adopted for the first lunar vehicle built in the USA in 1971.
Some interesting attempts were made to simplify production with integrally metallic wheels, like the Sankey wheel (Fig. 6), comprising two parts laminated from pressed steel and welded together so as to form a spoked wheel.
In 1914 appeared the disc wheel produced by Michelin (Fig. 7). Thanks to its lower cost, this type quickly replaced the spoked wheel which, however, was still retained on sports cars (Fig. 8).
The first wheel in light alloy made its appearance on the occasion of the French Grand Prix of 1924, mounted on a Bugatti. The innovation

Fig. 5 - Michelin pneumatic tyre (end of XIX Century).



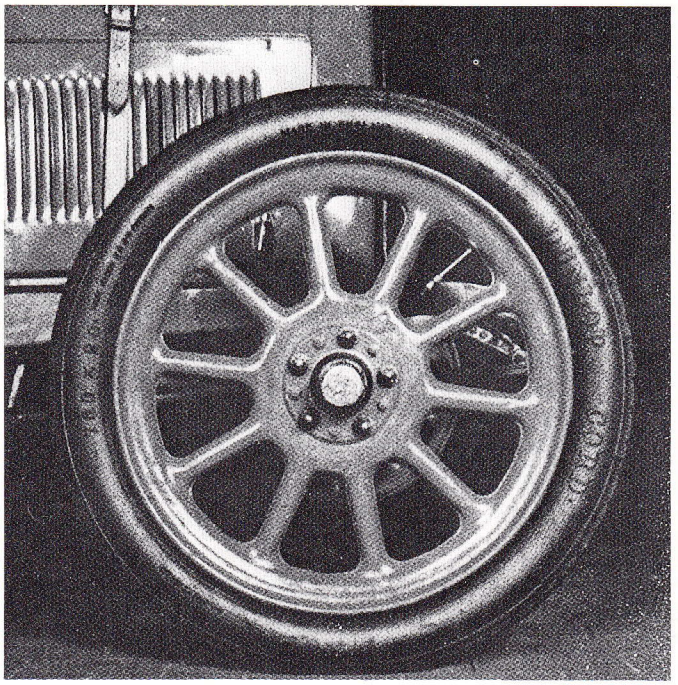


Fig. 6 - Sankey wheel, metal (1920).

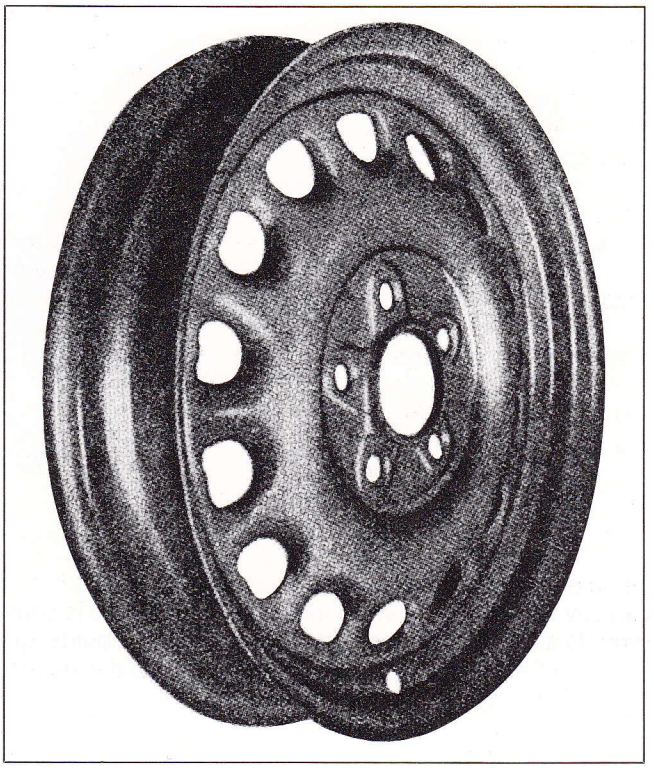
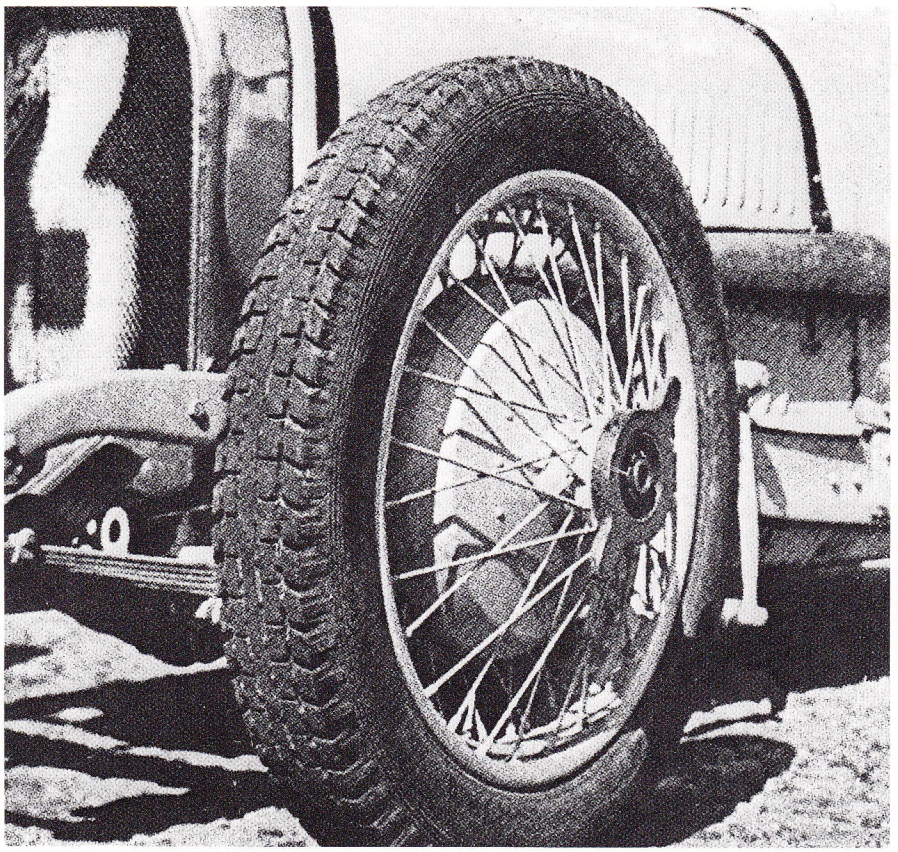


Fig. 7 - Sheet metal disc wheel (1925).

Fig. 8 - Spoked wheel for sports car, '30s.



awakened lively interest in the advantages offered by lightness. However, this solution did not have immediate success for reasons of cost.

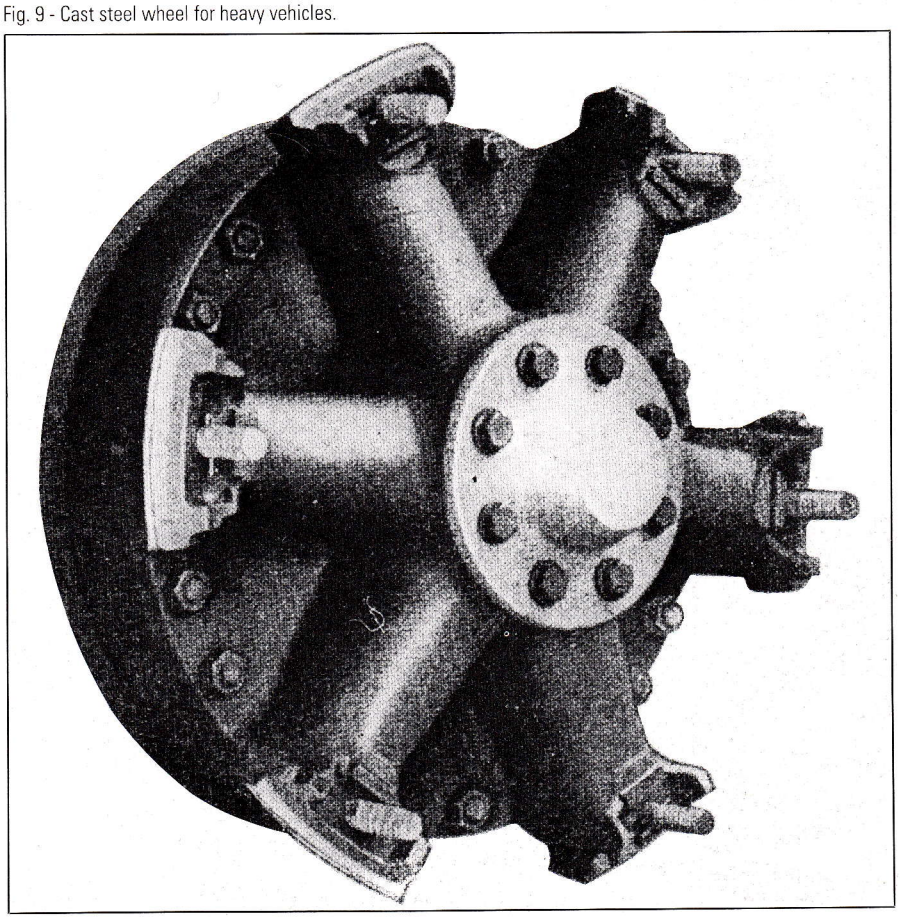
The first definitely to adopt the light alloy wheel were the Americans in the late '50s. In 1963-1964 Ferrari adopted wheels in light alloy both on his "monoposto" and his series production cars.

In the years between 1920 and 1930 a basic development of vehicles and pneumatic tyres occurred. The shape of the coachwork gradually moved away from the typical open car of pre-war days. Greater consideration was given to comfort and safety, and the pneumatic tyre became safer and more reliable. The first refined designs of tread in relief appeared and rims changed so that the "clincher" became "straightsided".

The "clincher" gripped the bead of the tyre like a pincer, while the "straightside" was characterised by a bead rendered undeformable by a

metal hoop supported and held in place by the pressure of inflation.
The spread of trucks introduced giant pneumatic tyres that replaced the earlier solid rubber ones.
In 1923 appeared the low-pressure pneumatic, which was generally adopted in the years immediately to follow. With a low inflation pressure the carcass no longer needed a massive construction ; from this resulted an increase in flexibility with greater passenger comfort.
The larger section of these tyres earned the popular name "Balloon".
Coming to the more recent years of the second and, we hope, the last post-war period, we can trace a panorama distinguishing the wheels for cars from those for heavy vehicles. With regard to cars, we can say that the most widespread wheels are those of disc type.
These are formed of a channel rim, welded or riveted to a pressed disc, shaped so as to enhance rigidity and resistance to transverse stresses.
The disc is of extra-soft steel plate for deep drawing, in a thickness of 3-5 mm. Generally the central part of the disc has a greater thickness and is ribbed in the zone where it mounts to the hub with the aim of increasing strength and avoiding complete contact between disc and flange. Often the disc has holes for lightness and to provide for cooling the brakes. This type of wheel owes its wide adoption to its characteristics of strength, long life and low cost.
The light alloy wheel (aluminium and magnesium), after a phase of use on competition and special cars, has seen the development of two markets. The first market is that of the light alloy wheel as an optional replacement for the steel wheel on series production cars, especially for the up-market sector. The second market is that of the wheel in light alloy covered by the firms manufacturing high-performance (sports or competition) cars where the advantages of the same are hold in high regard.
The styling of the light alloy wheel has always had great importance in these two markets; but it is necessary to consider the effective advantages as regards performance and safety, which have not always been in evidence.
These advantages are: 1) high dimensional accuracy, which ensures a better balanced wheel; 2) a machined sealing for the tyre bead, with consequent better contact between the tyre and the rim; 3) higher thermal capacity, which allows better dissipation of the heat from the tyre and brakes; 4) a reduction in the unsprung weight, with better handling of the vehicle.
When the processes of manufacture of wheels in light alloy are referred to, casting must rank first. This is subvided into casting in sand moulds, gravity casting in metal die and casting in metal die at high and low pressure. The choice of the most expedient method is taken bearing in mind that high quality and uniformity in the product are essential for a stressed component like a wheel, and the fact that we must operate under the most economic conditions.
To achieve the required mechanical characteristics of strength and elongation, we resort to heat treatment. To combat porosity in the castings, which would be disastrous for the heat treatment, pore-free processes have been adopted.
A recent system using aluminium wheels is that presented by Aluminia S.p.A. at the XIX Congresso Nazionale ATA (Modena, 1983). The rim is drawn out from a segment of tube extruded in aluminium alloy, and is then welded to the disc.
The latest innovation in aluminium

Fig. 9 - Cast steel wheel for heavy vehicles.



wheels is the "section wheel" carried out by Späth GmbH in West Germany. "Section wheels" have not yet gone into mass production but their design and manufacturing technology can be considered complete for the most part.
In the field of automobile wheels, attention must be drawn to products in resin reinforced with special fibres while other novelties can be foreseen in connection with different conditions of service.
In every case, the wheel has a role of primary importance in the operational safety and the roadholding of the vehicle.
Wheels for heavy vehicles, trucks, buses and trailers, because of the exceptional loads they carry, very soon began to adopt spoking in cast steel (Fig. 9) and subsequently in malleable cast iron and spheroidal graphite iron. The part in contact with the ground was originally made of solid rubber or semi-pneumatics fixed to the outer flat surface of the wheel. Later, from 1925 to 1930, even on lorries, pneumatic tyres came to be adopted, for which detachable rims were developed, like those still in use (Fig. 10).
To-day wheels for commercial vehicles present two typical solutions, that is: 1) disc wheels similar to those on cars but, of course, with adequate thickness for the greater stresses which they undergo; 2) spoked wheels, with a hub equipped with spokes to which the rubber tyred rims are directly attached. The choice between these solutions is made by firms building commercial vehicles in appreciation of the different factors, such as speed, capacity and the weight of the vehicle. In general, disc wheels are preferable for the light and medium classes, and those with spokes for the heavier classes.
The rims of these wheels are of two types: the so-called continuous with detachable rims which are the most widespread throughout the world and those radially divided into three segments, which prevail in Europe.
Various attempts to use light alloys to manufacture wheels for heavy vehicles have been made from the early '20s. The results obtained were not always satisfactory.
On the basis of past history and current trends, we can say that the future development of the wheel for automotive use will be evolutionary rather than revolutionary (Fig. 11).
We must not lose sight of the fact that motor vehicles are predominantly work tools, and must

Fig. 10 - Triplex rim for heavy vehicles (1934).

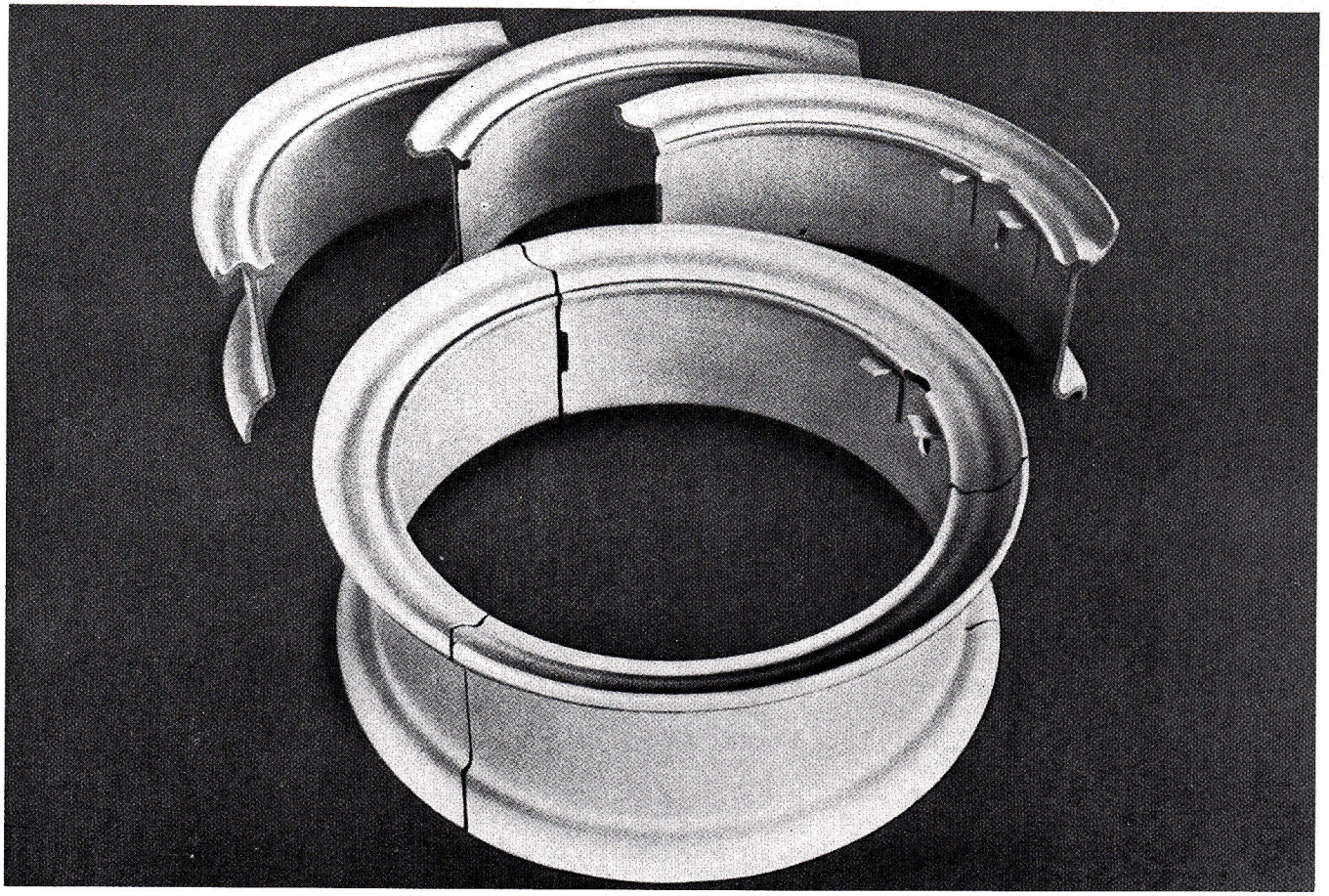


Fig. 11 - Rim for tubeless pneumatic tyre (Formula 1).

function in an efficient and economical way, with the minimum of downtime. Therefore every strongly innovative proposal must prove its validity on the whole normal life of the vehicles before it can be accepted in any degree.

REFERENCES

(1) Lavergne, G. **Manuel de l'automobile sur route,** *Librairie Polytechnique, Paris, 1900.*

(2) **OMNIA. Revue pratique de locomotion.** *Paris. 2 février 1907.*

(3) **Fifty years of growth,** *Dunlop Rubber Co., England, 1938.*

(4) Uccelli, A. **La ruota e la strada,** *Editoriale Domus, Milano, 1946.*

(5) **Encyclopédie Universelle Automobile,** *Edition du Livre, Montecarlo, 1951.*

(6) Lief, A. **Firestone story,** *Whittlesey House, New York, 1951.*

(7) Buss, H. **Aus der Entwicklung der Rader fur Lastungen und Omnibusse,** *Georg Fisher AG, Schaffhausen, 1952.*

(8) **Architettura della ruota,** *Gianetti S.p.A., Saronno, 1963.*

(9) Bencini, M. **La trazione anteriore,** *Ed. Automobile, ACI, Roma, 1967.*

(10) Matteucci, M. **Storia dell'automobile,** *Ediprint, Torino, 1967.*

(11) Ichimura, Y. **Automotive tires,** *Japan's Automotive Industry International, Suppl. of Ashai Evening News, Tokyo, 1969.*

(12) Ruote leggere, ruote veloci. **Tavola Rotonda Auto 70,** *Torino, aprile 1972.*

(13) **Milleruote,** *ed. Domus, Milano, 1974.*

(14) **Storia di un pneumatico.** *Industrie Pirelli S.p.A., Milano, 1980.*

(15) Sternberg E.R. A history of motor truck development. **SAE Paper 493** *(1981).*

(16) Späth W. Felgenfertigung aus Aluminium Strangpressprofilen. **ATZ Automobiltechnische Zeitschrift 88(10)** *(1986).*