Applications – Chassis & Suspension – Wheels

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3 Wheels

3.1 Introduction

The three basic elements of a wheel are the hub, the spokes and the rim. Sometimes these components will be one piece, sometimes two or three. The hub is the centre portion of the wheel and is the part where the wheel is attached to the suspension through the wheel carrier (or knuckle). The spokes radiate out from the hub and attach to the rim. The rim is the outer part of the wheel that holds the tyre.

Steel wheels are usually pressed from sheet metal and then welded together. They are still found on many cars since they are inexpensive, durable and flexible, but also heavy. In the beginning, aluminium wheels were generally marketed as optional add-ons or as part of a more expensive trim package. Today, however, aluminium wheels are found on more and more car models as standard equipment.

The use of aluminium wheels on passenger cars did not start primarily as a lightweighting measure. Aluminium wheels were introduced for styling reasons, to give upper class or flagships models a distinctive personal touch. The forged aluminium wheel was invented by ALCOA in 1948. In Europe, the success story of the aluminium wheel began with the development of the Porsche 911 in 1962. Porsche looked for a special wheel which should have outstanding qualities and present new dimensions, also visually. The forged aluminium wheel from OTTO FUCHS offered an attractive appearance. In addition, its low weight and thus the resulting reduction in the unsprung mass ensured also a superior ride quality. In the 1970s, cast aluminium wheels started to be factory-fitted to mass-produced cars.

Aluminium penetration in wheels was in the year 2000 for European vehicles about 30 to 35%, compared to largely more than 50% in USA and Japan. Today, about 50% of the vehicles produced on a worldwide basis use aluminium wheels, i.e. wheels are representing nearly 15% of the average aluminium content in passenger cars and light trucks. Some car manufacturers furnish over 80% of their production with aluminium wheels. In North America, the market penetration of aluminium wheels approaches 70%, in Japan about 60% and in Europe about 50%. Nowadays, the growth rate of the aluminium wheel market has slowed down, but the market volume is still increasing. The development of new, high strength steel grades and sophisticated manufacturing methods have enabled significant weight reductions for steel wheels and also allowed to meet the intricate aluminium wheel designs.

Wheels have to provide critical safety functions and must meet high standards of design, engineering and workmanship. Almost all modern aluminium wheels are made by one of two processes: casting and forging. Their performance is a direct result of the employed manufacturing technique. Whereas styling has been the main motivation for cast solutions, forged wheels are usually lighter and stronger, but also more expensive than cast wheels. Nevertheless, with proper attention to material quality and process control, cast aluminium wheels can be made to a high standard and provide many years of good service.

Today, cast aluminium wheels are most common with a market share of more than 80% in North America, more than 90% in Europe and close to 100% in Japan. In North America, the share of forged wheels is about 15%, in Europe only 5%. Increasing weight reduction requirements present a good chance for the further growth of forged aluminium wheels, despite their higher price. On the other hand, the lightweighting trend has also led to the development and application of more sophisticated casting methods as well as the consideration of fabricated solutions made using sheets and/or extrusions. Many new developments are on the way to further reduce the weight of present aluminium wheels without sacrificing the styling advantages. An attractive compromise could consist of cast or forged central discs and subsequently assembled (mainly by welding) to extruded or rolled rims.
Aluminium wheels produced by different technologies:

a) cast wheel (Source: Montupet), b) forged wheel (Source: Otto Fuchs), c) 2-piece sheet wheel (Source: Kronprinz), d) 3-piece with an extruded rim and a cast hub (Source: Speedline SpA)

3.2 Requirements

Car producers ask from their wheel suppliers a high quality product that meets all the requirements of standard driving conditions, but is also able to withstand severe misuse. The most important characteristics of aluminium wheels are styling flexibility and cosmetic appearance, even after long term use. Another important factor is the generally reduced weight and thus the related low rotary moment of inertia, although there are specific aluminium wheel styles which are not significantly lighter than steel wheels. Lighter wheels improve car handling and riding comfort through the reduction of the unsprung mass, allowing the suspension to follow the terrain more closely and thus improve grip. The reduction of the overall vehicle mass also helps to reduce fuel consumption. Furthermore, the better heat conduction of aluminium leads to a faster dissipation of the heat from the brakes, which improves braking performance in highly demanding driving conditions and reduces the chance of brake failure due to overheating.

In the design phase of an aluminium wheel, the following characteristics must be considered:

- **Stiffness**
  The structural stiffness is the basic engineering parameter to be examined when designing an aluminium wheel which offers at least the same vehicle performance as an equivalent steel wheel. The structural stiffness is determined by the final shape of the wheel; the material stiffness (Young's modulus) is more or less given and little depending on alloy and temper.

- **Static performance (strength)**
  In order to avoid any deformation under maximal axial (accelerations and braking) and radial stresses (turning), the yield strength of the material must be considered. Misuse cases have to be evaluated in relation to the tensile strength. Yield tests under pressure are also conducted to check this behaviour. An additional, important factor is the temperature resistance, i.e. the wheel must be able to tolerate...
temporarily 200°C due to the proximity of the brakes and temperatures around 100°C over longer periods.

- **Fatigue behaviour**
  The fatigue performance is the most important parameter for wheel dimensioning. Numerical simulation methods are systematically used during design. Service stresses, including also multi-axial stresses are considered. Rotary bending and rim rolling tests are used to verify these calculations.

- **Crash worthiness**
  Numerical simulation methods are more and more used for the design of wheels for crashworthiness. However, impact tests are still systematically carried out to check the resistance to accidental collisions, such as pavements impacts.

Apart from the mechanical characteristics, there are also other important design considerations:

- **Thermal aspects**
  Whatever type of wheel (cast, forged, mixed wrought-cast…) is used, aluminium dissipates heat more quickly than steel. Furthermore, aluminium wheels act as a very efficient heat sink. This results in a significantly improved braking efficiency, and a reduced risk of tyre overheating.

- **Style and weight saving potential**
  The reduction of the weight of the unsprung mass of vehicles is a key priority in any design consideration. On the other hand, styling aspects are generally a decisive factor for choosing an aluminium wheel. Thus, a compromise has to be accepted if the styling requirements dictate the selection of specific production technologies and therefore the realization of less than the maximum achievable weight reduction potential.

- **Dimensional tolerances**
  A perfect mass balance is a key parameter to avoid significant vibrations of the wheel. As a result, both cast and forged aluminium wheels are finally machined. Compared to steel wheels, the lower weight of aluminium sheet wheels also reduces the intensity of vibrations.

- **Corrosion resistance**
  There are various surface treatment options for aluminium wheels offering different qualities and benefits. Wheel appearance, durability and maintenance requirements must be considered when choosing a wheel surface. More details can be found in the section “Surface treatment”. Galvanic corrosion effects present generally no problems. Even at the uncoated iron/aluminium hub interface, no significant corrosion has ever been noticed.
3.3 Cast aluminium wheels

The main advantage of cast aluminium wheels is the high styling versatility. Cast wheels also offer a high dimensional accuracy (i.e. homogeneous mass distribution) and adequate static and dynamic mechanical characteristics. An important reason for choosing cast aluminium wheels is their attractive visual appearance. The weight reduction potential compared to steel wheels is a benefit, but often not the major objective. Thus, in some cases, the weight of cast aluminium wheels is equal or only slightly less than a standard steel wheel without any styling.
3.3.1 Casting processes

Different aluminium casting technologies are suitable for wheel production. High productivity casting methods are primarily applied for the production of aluminium wheels to be used for factory production cars (supply to the OEM market). On the other hand, the aftermarket is looking for more versatile designs, but relatively small series, i.e. specialty casting processes are more useful. However, depending on the applied casting process, also the quality of the cast aluminium wheels varies. The selection of the specific casting methods largely determines the quality of the as-cast microstructure (e.g. porosity) and influences the choice of the applicable types of alloys and heat treatments. Thus, it determines not only the strength and durability of the wheel, but also affects the quality level which can be achieved in the various surface preparation steps and thus the final appearance. Consequently, the selection of the optimum casting methods depends on many different factors.

The main casting processes used for the production of aluminium wheels are:
- low-pressure die casting (mainly)
- gravity permanent mould casting (less used)
- squeeze-casting process (marginally used)

In addition, a few other casting processes have been or are used:
- counter pressure die casting
- casting-forging (Cobapress)
- thixocasting.

In general, pressure casting, where the metal is pumped into the mould, is preferable to just pouring. However, gravity permanent mould casting is still a relevant casting process for aluminium wheels. Gravity casting offers reasonable production cost and is a good method for casting designs that are more visually oriented or when the reduction of the wheel weight is not a primary concern. Since the process relies only on gravity to fill the mould, the cast structure usually shows more defects (porosity, etc.) than that produced by some other casting processes. Consequently, gravity cast wheels will generally have a higher weight to achieve the required strength.

Most cast aluminium wheels are produced by low pressure die casting using a multi-part mould. Low pressure die casting is the standard process approved for aluminium wheels sold to the OEM market, but it offers a good value for the aftermarket as well. Low pressure die casting uses a relatively low pressure (around 2 bar) to achieve a fast mould filling and to produce a dense microstructure resulting in a finished product that has improved mechanical properties compared to a gravity cast wheel. On the other hand, it results also in slightly higher production cost than gravity casting.

Apart from the conventional low pressure die casting, there are numerous process variants optimized for the production of wheels with special designs or improved performance. As an example, even lighter and stronger wheels are produced when using special casting equipment and applying a higher pressure. Another variation of the manufacturing process leads to cast wheels with undercuts for weight reduction. This casting process is similar to standard low pressure die casting, but the design of the mould is modified and the solidification conditions must be specifically controlled.
An interesting new development is the patented “air-inside technology” of BBS. The basic idea is the utilization of hollow chambers and spokes instead of solid material in the construction of the wheels. The result is a significantly lighter wheel offering better driving...
dynamics and comfort. In production, the wheels are first cast with a flange in the middle of the rim. The inner and outer shoulders are then shaped into hollow chambers by flow-forming and sealed by laser welding. The spokes are hollow cast using hydraulically actuated inserts. With such a design, the stability of the wheel is increased by up to 60%. At the same time, the wheel weight is significantly compared to the conventional low pressure die cast wheel.

![Wheel produced using the BBS Air-Inside technology](image)

**Wheel produced using the BBS Air-Inside technology**

*Source: BBS*

### 3.3.2 Flow-formed cast wheels

The flow forming or rim rolling technology is a specialized wheel production process that begins with a low pressure die casting and uses a special machine that spins the initial cast blank while heating its outer portion to a temperature between 300 and 350 °C and then uses steel rollers pressed against the rim area to pull the rim to its final width and shape. The combination of the heat, pressure and spinning creates a thinner rim wall with mechanical characteristics close to that of a forged wheel, but without the high cost of the forging. Some special wheels produced for the OEMs high performance or limited production vehicles utilize this type of technology resulting in a light and strong wheel at a reasonable cost. The cast wheel centre offers interesting design possibilities whereas the flow-formed rim affords the realization of reduced wall-thicknesses and, thus, a lower wheel weight. But even highly sophisticated cast wheels with undercuts and flow-formed rims cannot reach the weight saving potential of forged wheels. Forged wheels are lighter and, in large production quantities, also more economical.
3.3.3 Finishing and inspection

After casting, the cast wheels are 100% X-ray inspected (a) and then eventually heat-treated prior to machining. This step is followed by a pressure tightness testing before drilling valves and bold nut holes.

After an additional visual inspection, the wheels are surface finished (e.g. painted or varnished (b), this operation including an appropriate pre-treatment). 3D dimensional controls (c), dynamic balance checking, (d) bending and rim roll fatigue as well as (e) impact tests are statistically performed.
3.3.4 Casting alloys and heat treatments

The alloys employed have to meet a range of sometimes conflicting requirements:

- Good casting characteristics while using metal moulds (excellent mould filling, no adherence to mould, little susceptibility to hot tearing and shrinkage)
- Strong ability to withstand physical impact (crash worthiness, ductility, impact strength)
- Excellent corrosion resistance (in normal and saline atmospheres)
- High fatigue resistance

These requirements have led to the widespread use of hypoeutectic Al-Si casting alloys with a silicon content of 7 to 12%, varying levels of magnesium (to achieve a good strength-elongation compromise) as well as low iron and other minor impurity concentrations.

Up to the 1980s, non-heat treatable, near eutectic AlSi11Mg alloys with 11 – 12 % Si were used in particular in Germany and Italy. These alloy types show very good casting characteristics, specifically with respect to mould filling and shrinkage behaviour. On the other hand, it is an alloy composition which is less favourable in terms of strength and fatigue limit.
Today, AlSi7Mg0.3 (A356) modified with Sr is the standard aluminium casting alloy used for wheels. In the beginning, non-heat-treated wheels were produced with this alloy in France. The advantage of the alloy AlSi7Mg0.3 is, however, its heat treatability and thus the ability to fulfil the increasing technical requirements on wheels. In North America and Japan, this alloy was used exclusively from the beginning in the heat treated T6 temper. Also in Europe, cast aluminium wheels are now more and more heat treated.

### 3.3.5 Mechanical characteristics of heat treated wheels

The following graph shows the static mechanical properties and the fatigue strength for the AlSi7Mg primary alloy in the T6 temper and various Mg contents. The material characteristics were measured on representative permanent mould (P.M.) test specimens. In every case, the alloy was modified with Na. The results clearly show that the AlSi7Mg0.3 alloy offers the best compromise between fatigue strength and elongation. An increase in magnesium content does not clearly improve fatigue strength, but significantly reduces elongation. The same investigation has been carried out with different silicon contents. It was clearly demonstrated that an increase in Si content has an adverse effect on ductility, particularly at low rates of solidification (thick hubs). Nevertheless, alloys with 9-11% Si are still acceptable if better castability is required.

![Graph showing static strength, fatigue and elongation properties as a function of the Mg content for an AlSi7Mg-T6 primary casting alloy](image)

In addition, the fatigue limit was measured for permanent mould (P.M.) cast test specimens (rotating bending tests). The alloy was a Na-modified, heat-treated AlSi7Mg0.3. Micrographic examinations indicated a close correlation between the fatigue limit and the maximum pore size in the test specimens.
Fatigue limit as a function of pore size for an AlSi7Mg-T6 primary casting alloy

3.3.6 Mechanical characteristics of non-heat-treated wheels

"Rial" cast wheel
Source: Villingen

The following graphs compare the mechanical properties of the primary casting alloys AlSi7Mg (modified with Sb) and AlSi11Mg (modified with Sr). The tensile strength and the yield strength vary almost in parallel with the increasing magnesium content over the range of 0 to 0.3% Mg.
The elongation varies inversely with tensile strength and yield strength, and clearly proves the superiority of AlSi7Mg modified with Sb.

The fatigue characteristics reflect the same trend. An increase of the magnesium content significantly enhances the fatigue strength and the AlSi7MgSb alloys exhibits clearly higher fatigue values than the AlSi11MgSr alloy.
3.4 Forged wheels

Forged aluminium wheels are one-piece wheels formed from a single block of metal by hot forging, followed by hot or cold spinning and the necessary machining operations. The forging process permits flexibility in design of the styled disk, almost similar to cast wheels. One-piece forging is considered superior to other forms of wheel manufacturing in providing ultimate strength while reducing weight compared to cast and multi-piece aluminium wheels (and of course steel wheels).

- Forged wheels are typically around 25% lighter than cast wheels (and potentially even more).
- While casting may be a less expensive process, cast wheels exhibit significantly lower mechanical properties than forged wheels.
- Multi-piece wheels are formed from two or more pieces which are fixed together by some sort of joining system. Some multi-piece wheels use fasteners while others use welds or other adhesives. The joints of multi-piece wheels act as stress concentrators and thus fatigue cracks can start. Fasteners can also develop vibrations and often fail.
Forged aluminium wheels for high performance applications

Source: Alcoa

Forged wheels outperform cast aluminum wheels in particular with respect to impact and fatigue performance. Generally forged wheels do not fail in impact tests whereas complying with the impact test requirements may be a tougher problem for cast wheel designers. The impact test is not only representative for hitting curbs, but also for pot holes in roads. Cars with low profile tyres are most at danger as there is less side wall to protect the wheel. Pot holes can create a large impact which can create cracks, resulting in tyre leaks, or even worse. Forged wheels offer far more protection from impact and thus keep the driver safer. Regarding fatigue performance, some OEMs have moved towards a biaxial fatigue test (although this test does not suit all applications). The improved fatigue characteristics allow for a lighter forged wheel to achieve the same level of test performance as a cast wheel.

3.4.1 General characteristics and examples

The forging process enables the full exploitation of the material properties in terms of:

- mechanical properties
- toughness
- fatigue strength.

The manufacturing process permits a maximum brake calliper room in combination with tight dimensional tolerances and a low weight. Forged wheels are free of porosity and cavities, which means higher safety. They also offer a greater variety of applicable surface finishes than cast wheels.
3.4.2 Materials aspects

The standard alloys used for forged aluminium wheels are the heat treatable wrought alloys of the AlMgSi system, in particular:

- EN AW-AlSi1MgMn (6082) in Europe,
- AA 6061(AlSiMgCu) in North America.

Forging aligns the microstructure of the aluminium metal along the direction of the flow of the material, thereby permitting the full exploitation of the strength and toughness characteristics of the alloy.

While cast wheels are performing according to the same load and durability specifications as forged wheels, the latter are more damage tolerant with respect to overloads and misuse.
Compared to cast aluminium wheels, forged components exhibit also a higher fatigue resistance due to absence of porosity and the presence of a fine, homogeneous microstructure. In addition, the dense wrought microstructure permits high gloss diamond machining and polishing of the decorative hub faces.

### 3.4.3 Manufacturing process

The traditional wheel forging concept included several forging operations, rough machining, splitting, flow turning, heat treatment, final machining and numerous additional finishing steps, depending on design requirements. As a result, styling dominates weight and costs are considerable. On the other hand, if low weight and low cost are the primary targets, then fabrication technologies must dictate the styling limits.

The production concept "Light Forged Wheel" developed and introduced originally in 1995 by Otto Fuchs includes the following steps:
Production steps for light weight forged wheel
Source: Otto Fuchs

The wheel is forged as a disk with a centre and a flange of metal around the outside, which is then split and rolled outward to form the rim halves. This step is similar to the flow forming (rim rolling) process used for cast wheels (see above). The centre is formed by coining and piercing in line with the forging process. The formed wheel is then solution heat treated and aged. Finishing steps include machining, drilling, deburring, optionally diamond turning and finally surface pre-treating and painting.

The Alcoa forging process starts with AA 6061 extrusions in the T6 temper, optimized for wheel design and production. The aluminium billet is prepared and subjected to large forging presses, ranging up to 50,000 tons and extensive heat treatment and curing processes for optimal wheel strength.

3.5 Surface finishing

Cast and forged wheels are often painted or polished and lacquered with a clear coat after a chemical conversion surface treatment. But in particular forged wheels can be subjected to a wide range of alternative surface treatments. Extreme care is taken in the machining and finishing processes resulting in a complete wheel that is not only optimally balanced and strong but also superior in appearance and more durable.

Examples of specific surface options are outlined below:

Dura-Bright® technology
Alcoa’s proprietary Dura-Bright® technology surface treatment has been offered in the commercial vehicle market since 2003. More recently it was brought to the automotive OEM market. Traditional aluminium wheels rely on lacquer as a finish and
protection against the elements. During heat cycling, brake dust and grime can penetrate the lacquer to create a yellow discoloration or black specks that cannot be removed. In contrast, the Dura-Bright® technology penetrates the surface of the wheel to become an integral part of the aluminium itself. It resists peeling, cracking and corrosion while offering a premium finish.

- Chrome wheel finish
  A chrome finish provides a mirror-like appearance to complement the look of many of today's vehicles. Chrome finish also offers maintenance benefits with some ease of washing. However, special care should be given to durability in off-road or winter driving conditions.

- Polished clear coat wheel finish
  A two-step surface finishing process is used to develop polished clear coat wheels. First, the forged wheel is polished to a smooth and attractive appearance. Then a premium clear coat is applied to protect the aluminium. Polished clear coat wheels provide additional durability and ease of maintenance. A clear coat wheel offers a similar appearance to a polished aluminium wheel without the need to polish the aluminium.

- Polished wheel finish
  A polished aluminium wheel offers a brilliant shine that is durable for rugged use.

3.6 Fabricated wheels

![Toyota mixed wheel (cast hub, laminated rim)](image)

Fabricated wheels utilize two or three components assembled together to produce a finished wheel. Multi-piece wheels can use many different methods of manufacturing. Centres can be either cast (using various methods) or forged.

3.6.1 Three piece wheels

Three-piece aluminium wheels (or composite wheels) were first developed for racing application. In the 1970s, they were introduced for street use and reached their peak of application in the 1980s. In the beginning, they provided several benefits. At that time, forged one-piece wheels were very expensive. In comparison, the smaller one-piece centres could be forged and then bolted to rims produced by other methods at a significantly lower cost, but still providing a strong, lightweight wheel. The rim sections for three-piece wheels are spun from aluminium disks. The rim sections are bolted to the centre and normally a sealant is applied in or on the assembly area to seal the wheel. Generally, spun rim sections offer the
ability to custom-tailor wheels for special applications that would not be available otherwise. Rims can be built for nearly any width or offset and a damaged rim can be replaced separately. On the other hand, manufacturing a composite wheel is extremely labour intensive. A one-piece forged wheel requires comparatively higher tooling cost, but the manufacturing process is simpler and faster. Furthermore, in a one-piece forging, all the material serves a structural purpose. Thus, a one-piece wheel will always be somewhat lighter than an equivalent three-piece fabricated wheel.

3.6.2 Two piece wheels

Today, there are different options for two-piece wheels in the market. The two-piece wheel design does not offer such a wide range of application as the three-piece wheel, however, two-piece wheels are generally cheaper. Some two-piece wheels have the centre bolted into a cast or cast and spun rim section. Other manufacturers press cast or forged centres into spun rim sections and weld the unit together. When BBS developed a new two-piece wheel to replace the previous three-piece street wheel, they used the special rim-rolling technology to give the rim section the weight and strength advantages similar to a forged rim. On the high-end of the two-piece wheel market, there are wheels using forged rims and forged centres.

Two piece forged wheel with Ti bolts

Source: BBS

A special type of a two-piece wheel is the sheet wheel, see below. Sheet wheels belong to the lightest types of aluminium wheels. Other aluminium wheel variants have been examined too, for example using rims formed from extruded sections

3.7 Aluminium sheet wheel

The first lightweight aluminium alloy sheet wheels were used in Daimler-Benz and Auto-Union racing cars in the 1930s. In the 1960s, Porsche began the batch production of sheet wheels, which consisted of a wheel rim and a hub. The first high-volume production of sheet wheels in
Europe started in 1979 for Daimler-Benz cars destined for export to the US. Further developments of the production process for both the wheel rims and hubs enabled a significant reduction of the manufacturing costs so that an aluminium sheet wheel has been produced in large volumes for the BMW 5 series starting in 1995. Compared to the 6.5Jx15" steel wheel with a weight of 8.7 kg, the weight of the similar aluminium sheet wheel was only 5.7 kg allowing a total weight reduction of 15 kg per car.

### Aluminium sheet wheel

![Aluminium sheet wheel](image)

**Source:** Michelin Kronprinz Werke GmbH

### Materials

The good mechanical properties and corrosion resistance of aluminium sheet wheels are ensured by the use of established rolled materials. Rim and disc are fabricated from hot rolled AlMgMn alloy sheet stock. This alloy has a stable microstructure resisting thermal effects during service. The typical as-received materials properties are listed in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Rim</th>
<th>Nave</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical alloy</strong></td>
<td>AlMg2.7Mn EN AW 5454</td>
<td>AlMg2.7Mn EN AW 5454</td>
</tr>
<tr>
<td><strong>Material thickness</strong></td>
<td>4.2 – 5.0 mm</td>
<td>8.0 – 9.0 mm</td>
</tr>
<tr>
<td><strong>Tensile strength</strong></td>
<td>approx. 245 MPa</td>
<td>approx. 245 MPa</td>
</tr>
<tr>
<td><strong>Yield strength</strong></td>
<td>approx. 125 MPa</td>
<td>approx. 125 MPa</td>
</tr>
<tr>
<td><strong>Elongation $\varepsilon$</strong></td>
<td>approx. 22%</td>
<td>approx. 22%</td>
</tr>
</tbody>
</table>

### Manufacturing process

The manufacturing process for two-piece sheet wheels is based on the use of well-known technologies:

- A strip of sheet metal, cut to the required length, is formed to a circle with the ends butt welded together using a pressure welding machine. After removal of the weld flash, the rims are shaped by a series of rolling operations.
The wheel nave is formed in several steps on a transfer press using a deep drawing process or stamped on a forging machine.

Joining the rim to the nave is done by means of a pulsed MIG process. After joining, the wheels are surface treated, i.e. pre-treatment to produce a conversion coating followed by an electro-dip coating.

Configuration of the two-piece aluminium sheet wheel
Source: Michelin Kronprinz Werke GmbH, Solingen, Germany

Most interesting is the also the so-called “split wheel” concept. The starting point is a circle cut from a rolled sheet. First the wheel disc is formed by stamping. Then the edge is split and the rim is formed by a rolling process similar to the flow forming of forged wheels. The applied materials were heat treatable alloys of the type EN-AW 6082. But up to now, all fabricated aluminium wheel variants showed little success in the market.

3.8 Future developments

Cast and forged one-piece aluminium wheels have reached today a high technical development level. However, there is still some potential for further improvement. This is demonstrated for example by the recent introduction of the “air-inside technology” developed by BBS. In addition, the future potential of fabricated multi-piece aluminium wheel designs should not be ignored although at the moment, they play only a negligible role in the marketplace.

Magnesium alloy wheels are sometimes used on special cars (sports cars, upper class models) for better performance instead of heavier steel or aluminium wheels. These wheels are produced by hot forging or casting from magnesium alloys such as ZK60, AZ31 or AZ91. Their typical mass is about 5–9 kg (depending on size). But apart from the high price, magnesium wheels have also additional disadvantages for normal road use (flammability, corrosion resistance).

Steel wheels are mainly of interest when cost considerations are top priority. Nevertheless, the introduction of improved steel grades with significantly higher strength levels and the development of more attractive steel wheel designs could initiate a certain comeback of steel wheels. New steels including micro-alloyed HSLA, dual-phase, and bainitic steels allow the manufacturing of lighter steel wheels. Also new steel wheel designs are feasible which include large ventilation openings that mimic the thin-spoke appearance of some aluminium wheels.

Nevertheless, the future looks bright for aluminium wheels!