HEAT DISSIPATING BEHAVIOR OF FIN-BASED MAGNESIUM ALLOY WHEEL BY FEA

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Abstract

Tyres are one of the crucial parts of the vehicle. The heat formed in the tire due to friction in the road surface and heat produced from the brake when the brake is applied. This high temperature in the rim increases the tire pressure and brake wear and degrades the compound, causing brake fade and tire blowout. With the increase in the tire temperature, the friction reduces an increase in the occurrence of brake fade, which increases the stopping distances. We devised an innovation of implementing hollow fins in the wheel rim so that the wheel rim acts as a compressor to suck the air from behind the wheel. Therefore, the heat-dissipating wheel rim is used to reduce the temperature. Using solid works, the magnesium alloy wheel model is designed by using Ansys. The various factors like pressure contour, velocity contour, temperature contour, Velocity vector contour, and velocity streamline flow are analyzed. We achieve that the magnesium alloy wheel with fins reduces the tire and brake disc temperature. By this, the overall performance of the tires can be increased.

Keywords: alloy wheel rim, Fins ally rim, pressure distribution, velocity profile

1. INTRODUCTION

The heat dissipation structure of the wheel rim is mainly that a spoke of the wheel rim configures a plurality of heat dissipation slots on an inner surface facing towards the configuration end of the brake calipers. A heat dissipation region between the wheel rim and air can be enhanced by disposing of the heat, and it is used as a heat dissipation air passage [1]. When a vehicle is stopped, the effect of the brake caliper and the brake disc on the surrounding high-temperature environment can be quickly reduced. Flavio Farroni et al. [2] described how heat disassembles tires with a real-time thermal model for analysis. He states that two layers are compressed together during tire production while the rubber is still sticky and new. Under-inflation on hot road surfaces can cause these two layers to separate, referred to as tread separation. Tread separation can result in abrupt tire disintegration and loss of vehicle control, both hazardous situations.

Another article states, **“**Tire operating temperature is vital to tire engineers because it relates to service life and power loss in a tire.**”** Which affects the performance in areas like traction and cornering ability. Operating temperature is a limiting factor in the choice of construction material for truck tires, which run at much higher temperatures than automobile tires. Adhesion failures are generally caused by excessive heat. He could not produce separation by heat alone, even though he held a tire at 300° F for two hours and then tried to pull the components apart F.S. Conant et al. [3]. It also says that, at high speed, the high temperature weakens the bonds in the tire, which will then be separated by a combination of centrifugal force and fatigue. If the temperature reaches 350 to 400° F, tire separations will occur before fatiguing. This type of failure is evident. We learned that tire temperature is vital to engineering because it affects the traction and cornering ability, the operating factor, and the behavior of rubber compounds under heat and load. Emmanouilides et al [4]. Showed the wheel assembly of formula 1 car, this paper focuses on the heat transfer through a wheel.

Faramaraz talati et al [5]. Able to transient heat equation for disk and the brake pad, which is dependent on time and space, we learned in which part brake system rise in temperature is critical. We concluded that the heat generated due to friction between the disk and the pad should be ideally dissipated to the environment to avoid decreasing the friction coefficient between the disk and the pad. Advancement is done in the wheel hub to reduce the heat from the wheels [6].

There are 20 fins placed inside 110.2 mm in an area of 467.8mm^2 placed inside the wheel rim at equal distances from each other. These fins are hollow, so the hot air inside the tire can come inside the fins, and their heat gets transferred to the surrounding atmosphere air [7]. This hot air, when it cools, returns to the wheel rim area, and the remaining hot air comes in and gets cooled and circulated. This method comes under the principle of conduction. The fins are placed at an angle and curved so that when the wheel rotates, the fins in the rim act as a compressor and suck the air behind the wheel and push out these air molecules to touch the brake disc surface, the rim, and the fin area. This keeps the brake disc and rim at optimum temperature and is more efficient in transferring heat from the brake disc [8].

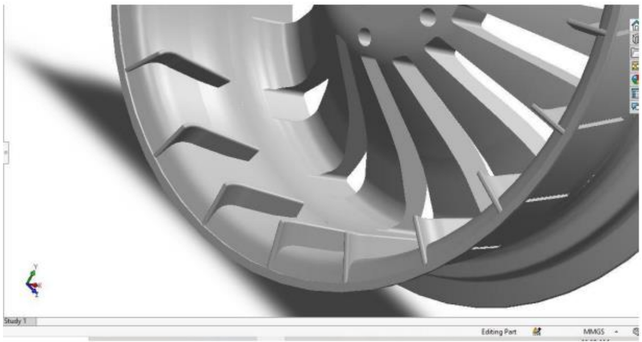


Figure 1: Rim with hollow fins

2. MODELLING AND ANALYSIS

2.1 Material Selection

Magnesium wheels are much lighter than steel wheels or aluminium wheels. This means they will give better mileage for the car than steel wheels because there is less weight to move. They are less prone to bend or buckle. There is less overheating with magnesium wheels because they spread the heat from the brakes much more efficiently. The material properties of magnesium alloy are mentioned in table 1[9].

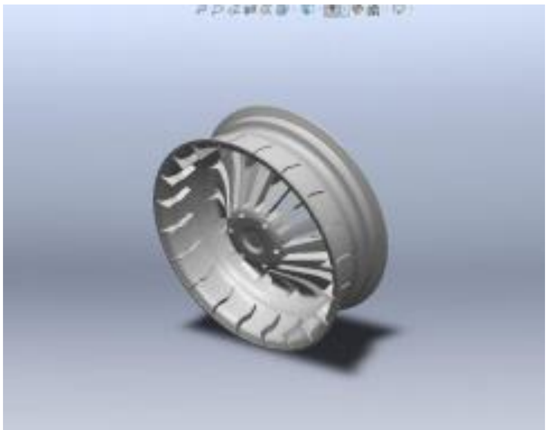
Table 1. Material properties of magnesium alloy

Density	1770 kg/m^3
Tensile strength	260 Mpa
Yield strength	200 Mpa
Shear strength	17 Mpa
Elastic modulus	44.8 Gpa
Poison ratio	0.35
Thermal conductivity	96 w/mK
Specific heat	1024 j/kg k

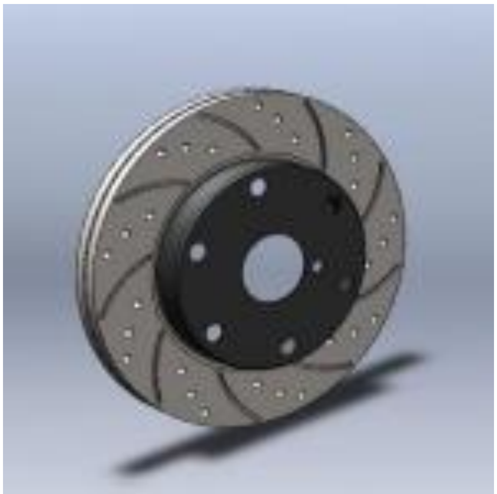
2.2 3D Modelling Of Magnesium Alloy Rim Assembly

Figure 2 shows the front side of magnesium alloy with a fins wheel which has been 3D designed with the help of wheel design/ dimension paper. The width is 20 inches. The brake disc rotor has an outer diameter of 328mm and a mass of 7kg. The holes are placed for the disc to slide into the hub, and the center bore is cut [10]

(a)



(b)

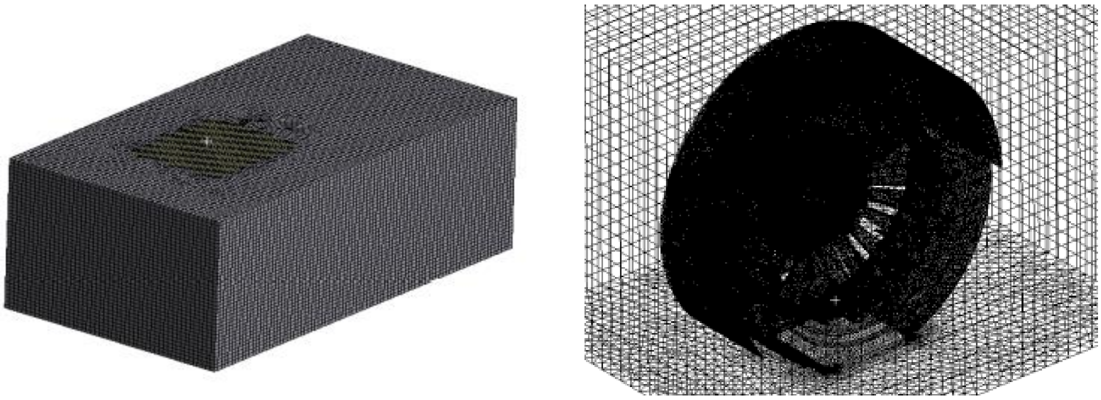


(c)

Figure 2: 3D Modelled Magnesium Alloy with Fins (a) Inner Side and (b) Outer Side (c) Brake Disc Rotor

2.3 Boundary Conditions of Wheel Mesh

Figure 3 shows the mesh of the magnesium alloy wheel with fins. Tetrahedral mesh is used to mesh this magnesium alloy wheel. This outer wall consists of an inlet, outlet, and road surface. Wheel mesh of magnesium alloy wheel which sits on the bottom wall, i.e., road surface. Quadrilateral mesh is used to mesh the wheel. For the base model, no of elements – 2804845 No of nodes – 718845. For the model with fins, no of elements – 4417082 No of nodes – 990513. After meshing in the setup, the double precision mode is used with the Solver Processor count as 16. The energy equation and the Viscous – k epsilon are used. The rotational axis is kept as the z-axis. Gravity, X-axis – 0 Y axis – -9.81 Z axis – 0 with Rotational Axis, X axis-0, Y axis-0 and Z axis – 1.

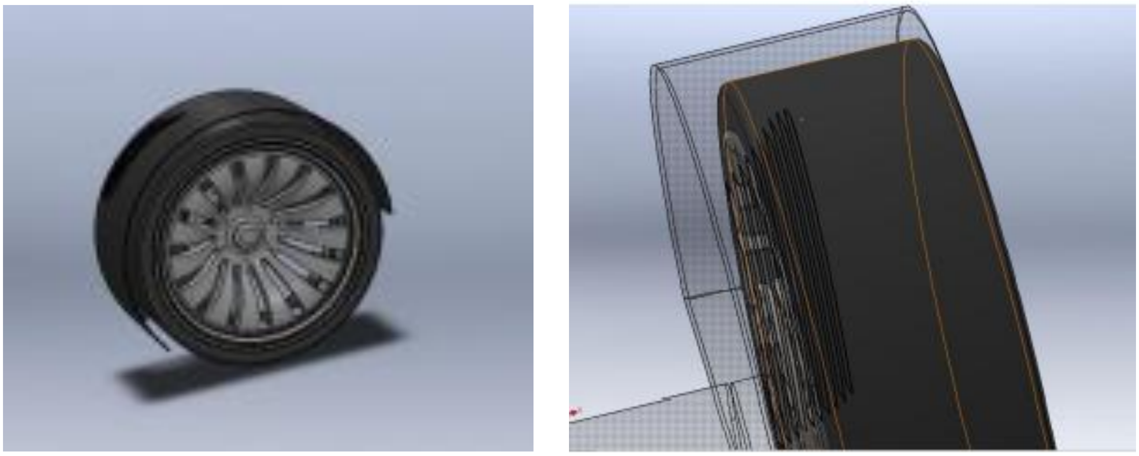


(a) (b)

Figure 3: (a) Outer Wall Mesh and (b) Wheel Mesh.

2.4 Assembly of Magnesium Alloy Wheel

The magnesium alloy wheel's fully assembled, and running model is placed under the fender. The brake rotor and wheel are attached to the wheel hub and bolted. The origin axis is placed in the center of the wheel hub. Each part is attached to the main component with the mate option's help, solid works assembly mode. The tire is hollow inside so that we can simulate pressure difference. The assembled parts are imported Ansys workbench and shown in figure 4.



(a) (b)

Figure 4: Modified Design (a) and Fender with Slotted Gaps (b)

Figure 4(b) shows the fender, which has vertical slots and has been placed at an angle of 14 degrees. To determine the heat produced in the brake disc during braking, the mathematical expression shown in equation 1 was used. During braking, the mechanical energy is transformed into Heat energy. The energy dissipated in the form of heat can increase the temperature from 300 °C to 800 °C. Generally, the thermal conductivity of the brake pad material is smaller than that of the disc material. During analysis, it was assumed that the brake disc completely absorbs the total heat developed during braking. So the heat developed during braking equals the kinetic energy available on the disc. The kinetic energy available of the disc can be expressed as

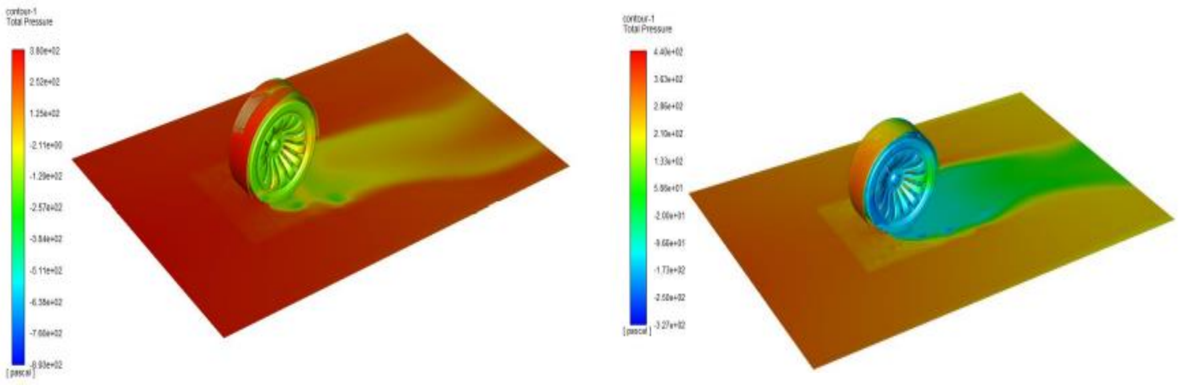
$$H_g = M_d x C_p x \Delta t \text{----------------------} (1)$$

M_d – Mass of Disc (kg), C_p – Specific Heat (j/kg.K), Δt – temperature difference (c)

3. RESULTS AND DISCUSSION

The CFD simulation is done for the modified design of the magnesium alloy wheel in a steady state. The carcass temperature of the tire is 80 degrees Celsius when the vehicle runs at 200km/h. The brake is applied for 4 sec, and the vehicle speed is reduced to 80km/h, which produce a heat energy of 340 degree Celsius. Using the slotted gaps in the fender and the fins inside the rims, the brake disc's overall temperature and the rim are reduced in less time than in conventional design. The model is analyzed and compared in Ansys under various factors like pressure contour, velocity contour, temperature contour, Velocity vector contour, and velocity streamline flow are analyzed.

3.1 Pressure contour

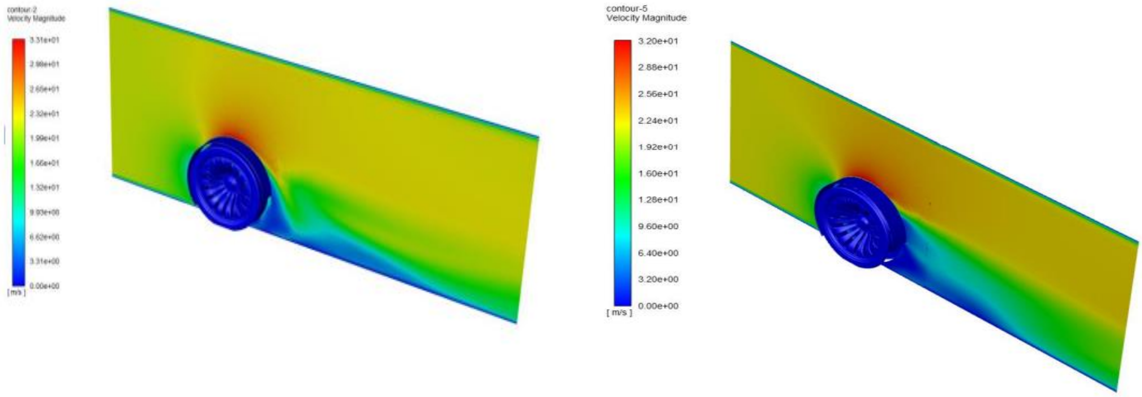


(a) (b)

Figure 5: Pressure Contour Conventional Design (a) and Modified Design (b)

The pressure counter for the conventional design rim and the modified design of the magnesium alloy rim is shown in Figure 6. Figure 6a confirmed the high-pressure development in conventional design compared to the modified one (refer to figure 6b). The maximum pressure is 3.80e+02, and 2.86e+02 values are seen in the conventional and modified designs of the wheel rim, respectively.

3.2 Velocity Contour

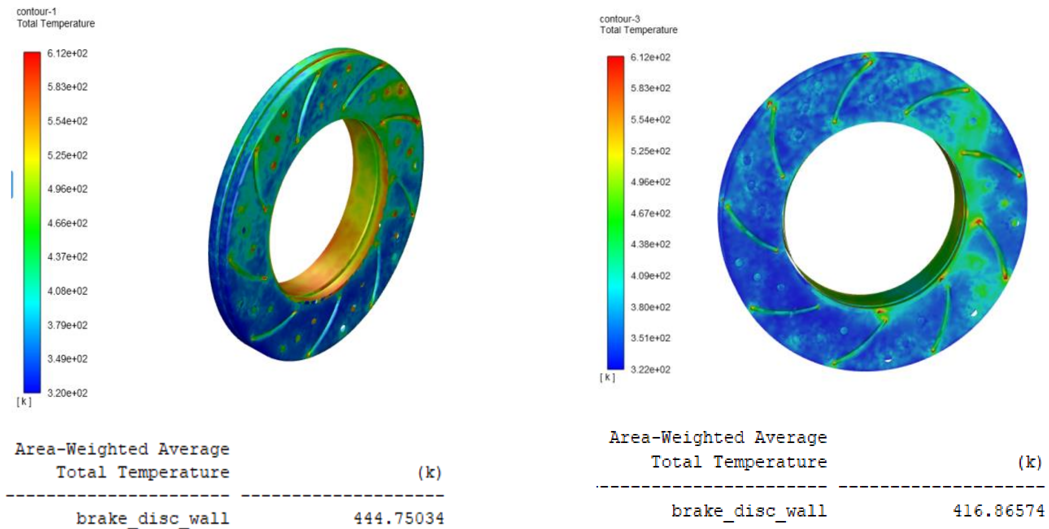


(a) (b)

Figure 6: Velocity Contour Conventional Design (a) and Modified Design (b)

Figure 6(a) describes that the conventional design has more turbulence flow than the 6(b) modified design. In the modified design, the airflow across the rim is linear, and there is a change in velocity across the whole system. We can also see the velocity is high near the slotted gaps in the fender. The maximum velocity is 3.31e+01, and 3.20e+01 values are shown in the conventional and modified design of the wheel rim, respectively.

3.3 Temperature Contour

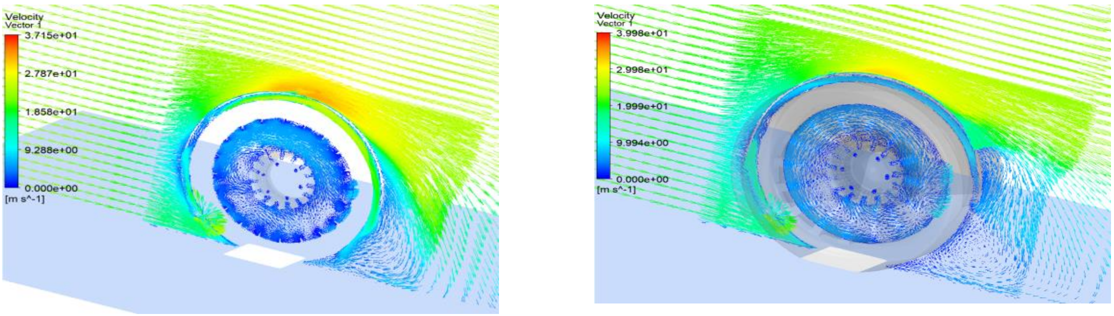


(a) (b)

Figure 7: Temperature Contour Conventional Design (a) and Modified Design (b)

Figure 7(a) confirmed that Conventional Design has a higher temperature than the modified design. Due to the increase in airflow to the brake disc, which is helped by the slots in the fender, we can reduce brake disc surface temperature, as shown in figure 8b. The maximum temperature 444.75034 and 416.8574 values are shown in the brake disc's conventional and modified designs, respectively.

3.4 Velocity Vector Contour

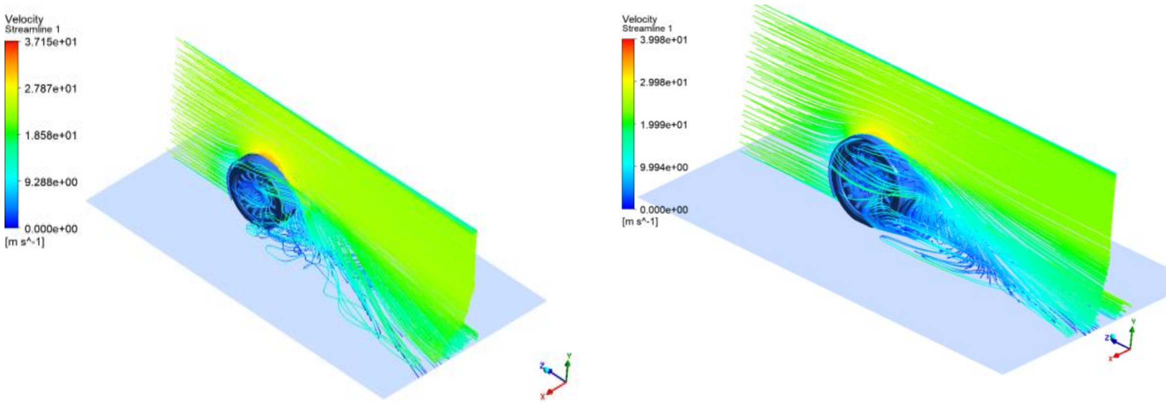


a **b**

Figure 8: Velocity Vector Contour Conventional Design (a) and Modified Design (b)

From figure 8, we developed that the vector velocity contour of a modified design increased the number of vectors in the brake disc, and we can also see the change in velocity at slots in the fender. In conventional design, the velocity vector is low as there are no fins

3.5 Velocity Streamline Flow

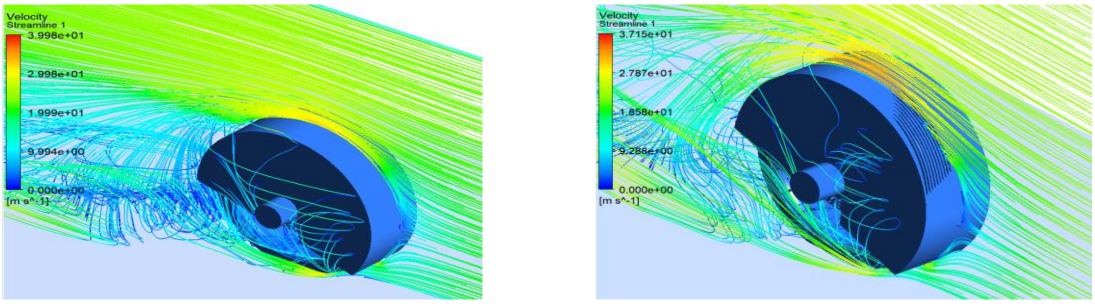


a **b**

Figure 9: Velocity Streamline Flow Conventional Design (a) and Modified Design (b)

Figure 9 shows the velocity streamlining the flow of conventional and modified designs. The airflow coming out of the wheel is exceptional due to the fins, where they are acting as a compressor when the wheel is rotating, and the slots in the fender help the air flow quickly.

3.6 Streamline velocity contour



a **b**

Figure 10: Streamline velocity contour conventional Design (a) and modified design (b)

Figure 10 compares the difference between conventional and modified designs. In a modified design, air comes through the inlet and passes through the slots in the fender, which then gets pulled out of the wheel rim with the help of fins. This also reduces the wheel turbulence and wake. This flow helps to reduce the low-pressure region behind the wheel, as shown in figure 10(b).

4. CONCLUSION

We conclude that the magnesium alloy wheel with fins has improved by reducing the tire and brake disc temperature; this reduces overall temperature. The magnesium alloy wheel has a higher tendency to transfer heat. With the help of hollow fins, tire temperature can be maintained over a period, reducing the risk of a tire blowout and decreasing tire wear.

This system increases the vehicle's safety and can be implemented for wide range and wheel sizes. Reducing brake disc surface temperature reduces the risk of brake fade and failure. This method can also be used for a racing vehicle where they use a slick tire, which gets heated up more than a standard road tire, and with their heavy braking, with the help of fins and slotted gaps in the fender, optimal brake disc temperature can be maintained. Reducing tire surface temperature helps maintain carcass temperature so that the tire pressure remains the same. The manufacturing of hollow fins in the wheel rim is a delicate process.

References

[1] Chen jerry can-Chieh, European Patent No: EP 3 578 386 A1, Heat dissipation structure for composite material wheel rim, Dec 11, 2019.
[2] Flavio Farroni, MDPI Article, A real-time thermal model for the analysis of tire/road interaction, Feb 28 2020.
[3] F.S. conant, Tire Temperatures, Rubber chemistry and technology, Resarch Article, May 01 1971.
[4] Emmanouilides, Krystina, Heat transfer analysis of formula 1 wheel assembly, June 05 2015.
[5] Faramaraz Talati et al (DOI: 10.1007/s00231-009-0476-y, Jun 6 2009) heat transfer from brake pad and disc dependent to time.
[6] Huang Fang, Patent No: CN102275459A, Heat-dissipating wheel hub for automobiles, May 24, 2017.
[7] He Kaiwen, Patent No: CN104669925A, Wheel rim with heat dissipating structure, Dec 14 2011.
[8] Chao-Ying Chen, Patent No: TW200831311A, Rim with the structure of ventilation and heat dissipation, Mar 21 2010.
[9] AZOM, Material properties of magnesium alloy az31b, Nov 13 2012.
[10] Prof Mit Patel, Mansi Raval, Jenish Patel, Paper No: IJEDR1604140, Design of disc brake's rotor, June 15, 2016.