

HEAT DISSIPATING BEHAVIOR OF FIN BASED MAGNESIUM ALLOY WHEEL BY FEA

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering Degree in
Automobile engineering

By

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**DEPARTMENT OF AUTOMOBILE ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC | 12b status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KUMRESH N** (Reg. No. **37860017**) and **SIVA DHARSHAN I** (Reg. No. **37860035**) who carried out the project entitled “**HEAT DISSIPATION BEHAVIOR OF FIN BASED MAGNESIUM ALLOY WHEEL RIM BY FEA**” under my supervision from **2020** to **2021**.

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Submitted for Viva voce Examination held on _____

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DECLARATION

We, **KUMRESH N (37860017), SIVA DHARSHAN I (37860035)** hereby declare that the Project Report entitled “**FINITE ELEMENT ANALYSIS OF A CAR DOOR SEAL FOR BETTER PERFORMANCE**” done by under the guidance of **Mr. S. YUVARAJA, M.E., Department of Automobile Engineering** is submitted in partial fulfillment of the requirements for the award of **Bachelor of Engineering** Degree in **Automobile Engineering**.

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ABSTRACT

A tire experience a temperature increase of roughly 80 degree Celsius after running in the highway for an hour but this carcass temperature varies due to external factor such as road surface, climate and surface temperature In tire different thread pattern and tire compound can contribute to varying tire temperature. When the brakes applied the heat generated from the brake disc because the brake is to, convert kinetic energy into heat energy due to this change in energy the surface of brake disc temperature will be high. The heat formed in tire due to friction in from the road surface and heat produced from the brake when the brake applied. This high temperature in the rim increase the tire pressure, brake wear and degrade tire compound this causes brake fade and tire blowout. With increase in the tire temperature, the friction reduces and increase in brake disc temperature brake fade occurs which increase the stopping distance. This high tire and brake disc temperature happens more in racing sports like formula 1, NASCAR. By referring the journal and pattern of heat dissipating wheel structure and heat transfer analysis respectively we came with 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, heat dissipating wheel rim is used to reduce the temperature and is compared to conventional setup.

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LIST OF SYMBOLS AND ABBREVIATIONS

CAD	– Computer Aided Design.
FEA	– Finite Element Analysis.
CFD	– Computational Fluid Dynamics.
LES	– Large Eddy Simulation.
AMG	– Algebraic Multi Grid.
FEM	– Finite Element Method.
ABS	– Acrylonitrile Butadiene Styrene.
CADD	– Computer Aided Design and Drafting.
KSI	– Kilo Pound per Square Inch.
GPA	– Giga Pascal.
MPA	– Mega Pascal.
AR	– Aspect Ratio.
D_w	– Wheel Diameter.
R_w	– Wheel Radius.
K.E	– Kinetic Energy.
HG	– Heat Generated.
Π	– Pie.
C_p	– Specific Heat.
M_d	– Mass of Disc.
M	– Mass of the vehicle.

V	– Linear Velocity.
M/S	– Meter per Second.
J/Kg K	– Joules per Kilogram Kelvin.
W	– Tire Width.
D	– Rim Diameter.
W/MK.	– Watt per Metre Kelvin.
Kg/m³	– Kilogram per Metre Cube.

CHAPTER 1

INTRODUCTION

A heat dissipation structure of wheel rim is mainly that a spoke of the wheel rim configures a plurality of heat dissipation slots on an inner surface facing towards configuration end of the brake calipers. By disposing the heat, dissipating slot a heat dissipation area between the wheel rim and air can be increased and it is taken as heat dissipation air passage. Peripheral high temperature environment caused by effect of the brake caliper and the brake disc can be rapidly eliminated when a vehicle is stopped.

1.1 HEAT AFFECTING THE TIRE

Pressure is directly affected by temperature. With increase in heat the pressure goes up, take heat away the pressure drops. Changes in the temperature of the air, the temperature road surface increases the tire temperature. When tires get super-hot they can become overinflated, which can cause handling issues and harsh ride quality.

1.2 BRAKE DISC TEMPERATURE

For vehicle applying brake under normal condition, brake discs reach around 130°C. However, if sudden brake is applied or if frequently braking, without allowing time for your brakes to cool back down, the brake disc temperature rise up to 400°C and we could experience brake fade.

1.3 COMPUTER AIDED DESIGN (CAD)

CAD software are used to design models in 2D and 3D these software increase design productivity and improve design quality. They are efficient and formats which can be easily read and edited or read from one software to another. Cad output is often in the form of electronic file for print, machine, or other manufacturing operations. These software allow user to create, edit, reverse engineering and analysis the models. The cad software used for this project is solid works 2020.

1.3.1 Solidworks

Solid works is a solid modeling computer aided design and computer sided engineering computer program published by dassault systems.

1.4 ANSYS

Ansys develops and markets engineering simulation software to use across the product life cycle. finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing strength, toughness, elasticity, temperature , electromagnetism, fluid flow, and etc. it is also used to determine how a product will function with different specifications, without building test products or conducting crash tests. i.e Ansys software can simulate how a bridge will hold up after years of traffic or how to design a slide that uses less material which doesn't affect safety.

Most Ansys simulations are performed using the Ansys Workbench system, which is one of the company's main products Typically Ansys users break down larger structures into small components that are each modeled and tested individually A user may start by defining the dimensions of an object, and then adding weight, pressure, temperature and other physical properties. Finally, the Ansys software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency and other effects over time.

1.5 FLUID FLOW (FLUENT)

1.5.1 Efficient and flexible workflow

Fluent is fully integrated into the Ansys Workbench environment, a platform designed for efficient and flexible workflows, CAD associativity and powerful capabilities in geometry modeling and meshing. The built-in parameter manager makes it easy to rapidly explore multiple design options.

1.5.2 Solve complex models with confidence

Ansys Fluent can solve most sophisticated models for multiphase flows, chemical reaction and combustion. complicated viscous and turbulent, internal and external flows, flow-induced noise predictions, heat transfer with and without radiation can be modeled with ease.

1.5.3 Geometry design modeler

The ANSYS Geometry Tools are specifically designed to provide powerful CAD neutral capabilities to users of the entire suite of ANSYS, Inc. Products that allow users to import, repair, modify, simplify, and create.

1.5.4 Boolean function

Boolean operations are the functions which computations combinations of geometric entities. Boolean operations include add, subtract, intersect, divide, glue, and overlap.

1.5.5 Enclosure

The Enclosure feature is a tool used to enclose the bodies of a model so that the material enclosing the bodies can be assigned to something such as a gas or fluid in the ANSYS Mechanical application.

1.5.6 Meshing

Meshing is an integral part of the engineering simulation process where complex geometries are divided into simple elements that can be used as discrete local approximations of the larger domain. The mesh influences the accuracy, convergence and speed of the simulation.

1.5.7 Tetrahedral mesh

An all-tetrahedral mesh can consist of only isotopically shaped tetrahedral elements with no special boundary clustering. Such meshes can be used for inviscid Euler flow simulations where there is no need for special elements near the wall surfaces. They can also be used for Large Eddy Simulation (LES) simulations. Destructured Prisms or Hexahedra.

1.5.8 Fluent amg solver

The AMG solver is used to solve linear transport equations using implicit discretization from coupled systems such as flow variables for the density-based solver, pressure-velocity variables for the coupled pressure-based schemes and inter-phase coupled individual equations for Eulerian multiphase flows.

CHAPTER 2

LITERATURE SURVEY

2.1 Heat Degrades Rubber

Tae-Sok Song, Ju-Wan Lee, Han-Jong Yu, Rolling Resistance of Tires - An Analysis of Heat Generation, SAE Technical paper 980255, Feb 23 1998.

Form the technical paper we found that the tires are made up of both natural and synthetic rubber compounds, but these compounds are full of natural oils that keep the rubber flexible and supple. As tires age, the heat of direct sunlight and friction with the road can bake out and cause the rubber to become brittle. Brittle rubber can crack, split or leak. This condition is called heat rot and is one of the reasons tires have a date code on the side. Weathered tires with lots of tread may still not be road worthy. Even if plenty of tread left on tires, heat-related damage can be dangerous and can cause a sudden catastrophic blowout.

2.2 Heat Disassembles Tires

Flavio Farroni, A real time thermal model for the analysis of tire/road interaction, MDPI Article, Feb 28 2020.

By analysing the above article we found out all tires are made from two distinct layers of rubber, the outer band or tread section and the inner liner or carcass. When the tire manufacturer makes tires, they squeeze these two layers together while they are still sticky, fresh rubber. In Hot road surfaces, under inflation can cause these two layers to come away from each other this is called tread separation. If tread separates, you can experience sudden disintegration of tires and loss of vehicle control, both very dangerous conditions.

2.3 TIRE TEMPERATURE

F.S. conant, Tire Temperatures, Rubber chemistry and technology, Research Article, May 01 1971.

From this article quote, "Tire operating temperature is of vital concern to tire engineers because it relates to both 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 do automobile tires. Adhesion failures are generally be caused by excessive heat. He was unable to 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.

In high speed, the high temperature develop weaken the bonds in the tire, which will be then separated by a combination of centrifugal force and fatigue. If the temperature reaches 350 to 400° F, tire separations will occur before fatigue this type failures are evident. We gained knowledge that tire temperature is vital to engineering cause it affects the traction and cornering ability and the operating factor and the behaviour of rubber compound under heat and load.

2.4 BRAKE DISC SYSTEM

Faramaraz talati, salman jalalifar, Analysis of heat conduction in a disk brake system, DOI: 10.1007/s00231-009-0476-y, Jun 6 2009.

In this paper, we are able to transient heat equation for disk and brake pad, which is dependant to time and space, and 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.

CHAPTER 3

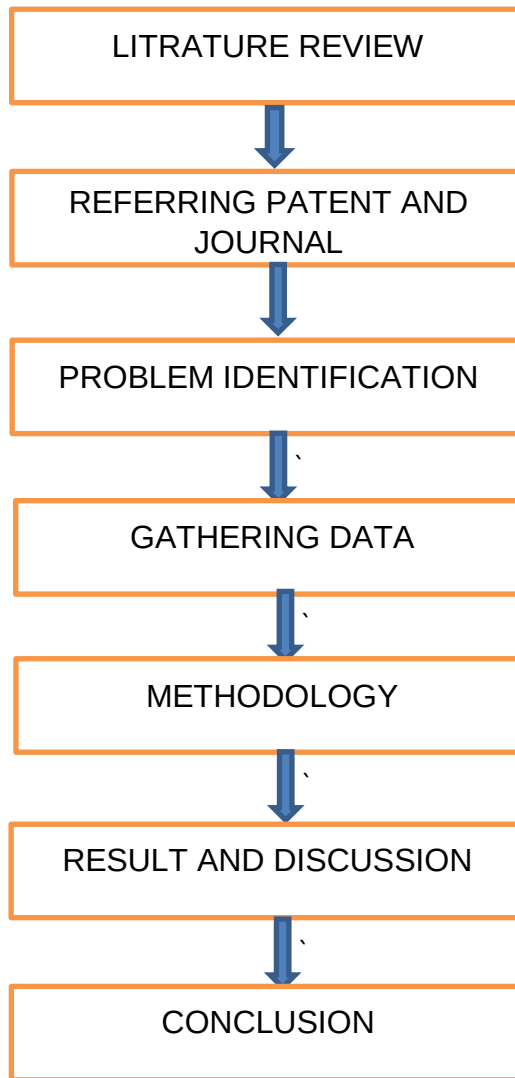
OBJECTIVE AND INNOVATION

3.1 OBJECTIVES

The objective is to design and analysis a wheel rim that is efficient and fast enough to dissipate heat from the tire and brake. In present work ,attempts has been made in formula 1 racing series which has heat dissipating wheel rims with brake ducts where the air flows through brake ducts and comes out from wheel hub to wheel rim where the fins is used to push the air out. This reduces the temperature in brake disc and maintain the wheel temperature. We gone design and analysis of wheel rim fins using magnesium alloy as rim material cause it is more efficient than aluminum alloy and to compare with conventional system.

The slotted gap in the fender is to be designed in such a way where it is used to channel air to back side of the wheel. The designed rim must be able to reduce the temperature in brake disc.

3.2 WORK TO BE DONE



3.3 INNOVATION

3.3.1 Fins

The fins are placed inside the wheel rim from the back portion of leading edge to inside of 110.2 mm and inside area is 467.8mm². There are around 20 fins are placed inside the wheel rim in equal distances of each other.

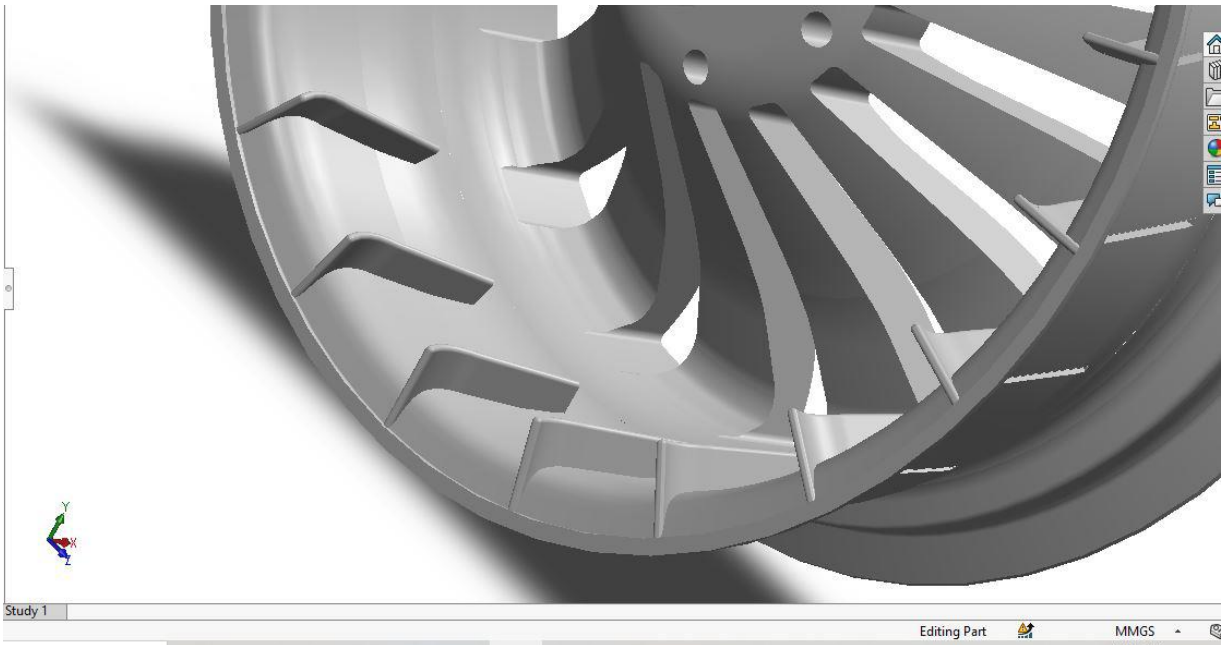


Fig 3.3.1: Rim with hollow fins

These fins are hollow fins so that the hot air inside the tire can come inside the fins and their heat gets transferred to the surrounding atmosphere air these hot air when they cooled they return to wheel rim area and remaining hot air comes in and gets cooled and circulated this method comes under the principle of conduction.

The fins are placed in an angle and curved so that when the wheel rotates the fins in the rim acts as a compressor and sucks the air behind the wheel and pushes out these air molecules touch the brake disc surface, the rim and fin area. Thus keeps the brake disc and rim in optimum temperature and which is more efficient to transfer heat from brake disc.

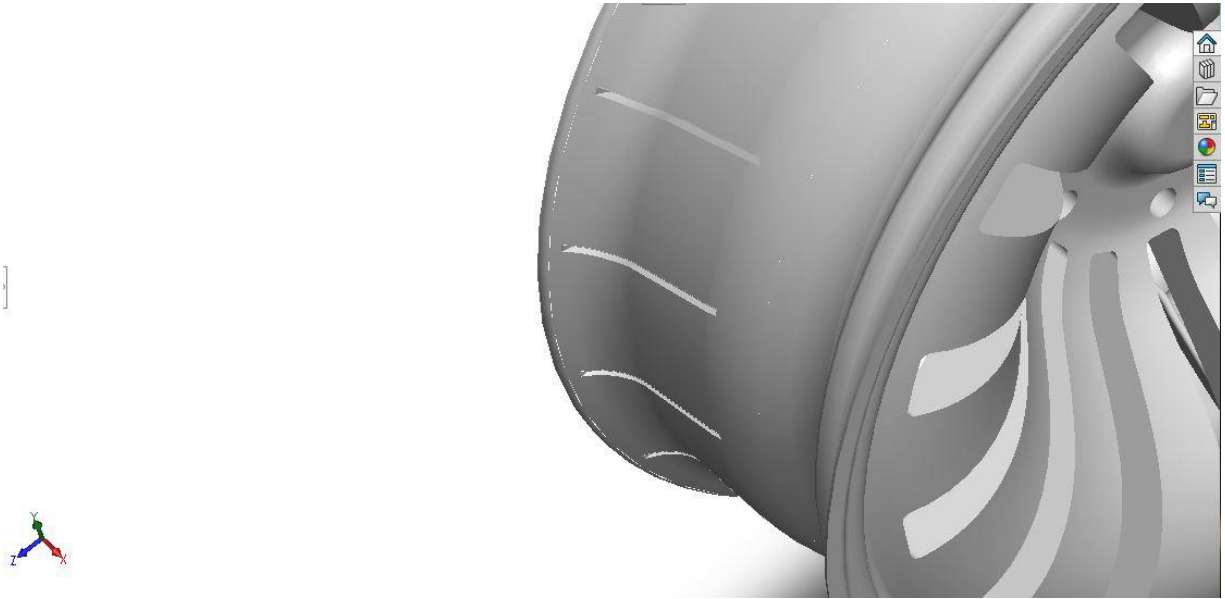


Fig 3.3.2: 3d model of rim with fins

The spotted gaps in the fender allows the air easily move to behind of the wheel rim which gives and advantage for the fins to suck more air.

CHAPTER 4

MATERIAL AND DESIGN METHOD

4.1 ALUMINUM ALLOY WHEEL

4.1.1 History of aluminum car wheels

The first light-alloy sheet aluminum car 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 nave. The first high-volume production of wheels in Europe started in 1979 for Mercedes Benz cars destined for the America.

Through further development of the production process for wheel rims and naves, the manufacturing costs were reduced markedly so that an aluminum sheet wheel has been produced in large numbers for the BMW 5 Series since 1995.

Using aluminum wheels on passenger cars began with the upper class or flagships models in order to give them a distinctive personal touch. Mainly at this time, they started to be factory-fitted to mass-produced cars.

Wheels are now representing about 15% of the average aluminum content in passenger cars and light trucks, and if the main motivation has been styling with mainly cast solutions, weight reduction requirements have led to the development of more technical cast but also forged and fabricated solutions.

These components have critical safety functions and must meet high standards of design, engineering and craftsmanship.

4.1.2 Physical properties

Stiffness

Structural stiffness is the basic value to consider when designing an aluminum wheel , material stiffness is very little depending on alloy.

Crash worthiness

Crashworthiness is beginning to be simulated recently. However, impact tests systematically check the resistance to accidental collisions such as pavements impacts and etc.

Dimensionnel

A perfect mass balance is a key parameter to avoid significant vibrations. As a result, cast and forged wheels are mostly machined. Lightness also reduces vibrations of aluminum wheels.

Corrosion

Cast and forged wheels are painted or lacquered after chemical conversion. Strip wheels are polished and varnished or also painted. This methods prevents the wheel from corrosion.

4.1.3 Manufacturing process

Two types of process are used to manufacture aluminum alloy wheel they are:

Casting process

Forging process

4.2 MAGNESIUM ALLOY

4.2.1 History of magnesium alloy wheels

The original cast magnesium wheels were made in the 1930 and their production continues till today. Some of the biggest brands producing magnesium wheels in the past include Hali brand, American Racing, Campagnolo, Commodore, Ronal, Technomagnesio, and Watanabe. The popularity of magnesium wheels peaked from 1950 to 1960. Magnesium wheels are prone to corrosion, So they were mostly used in racing sports.

After 1960's magnesium, aluminum alloy wheels on the mass market, but not from the competition wheels market gradually replaced wheels. Many companies continued production after 1960 is although in lower quantities. Modern scientific and engineering development which led to significant improvements in quality, including improved anti-corrosion treatment that extends the lifecycle of a wheel which matches or exceed the life cycle of aluminum alloy wheel.

Forged magnesium started to displace sand and gravity die-cast magnesium wheels in 1990s. DYMAg and Marvic has been supplying cast wheels to the elite motorbike racing market. DYMAg has also supplied all eh Lola and Reynard Indy cars until 1998.

4.2.2 Manufacturing process

There are two types of magnesium wheels made, they are:

Cast magnesium wheels

Forged magnesium wheels

4.3 CHOOSE OF MAGNESIUM ALLOY

We choose magnesium alloy wheels because it has the following advantage over aluminum alloy.

4.3.1Weight

Magnesium wheels are much lighter than steel wheels or aluminum wheels. Which means they will give better mileage for car compared to steel wheels in car because there is less weight to move. They are less prone to bend or buckle. This lighter weight requires less wheel balancing over the life of the magnesium wheels. It also helps in more responsive steering and handling, both of which are important factors in their favor. They corner very well with low profile tires. Mostly all the racing vehicles use magnesium wheel.

4.3.2Heat

There is less overheating with magnesium wheels because they spread the heat from the brakes much more efficiently than aluminum wheels. So there is minimum brake overheating as well as it helps to maintain the tire temperature.

4.3.3 Cooling

Whatever the type of wheel magnesium dissipates heat more quickly than steel/ aluminum. Further, magnesium wheels act as a very efficient heat sink. This results in significant improvements of braking efficiency, and a reduced risk of tire overheating.

4.3.4Looks

The advantage that magnesium wheels offer is in the look of vehicle. They are aftermarket wheels so they give the chance to customize the vehicle and make it stand out from the crowd.

4.4 RADIAL TYRE

4.4.1 History of radial tire

Following the announcement of the superiority of the radial design began an inexorable climb in market share reaching 100% of the North Americas market in the 1980s. Radial tire technology has been the standard design for all automotive tires.

Radial tire construction utilizes of ply cord which extends from the beads and goes across the tread so that the cords are laid at right angles to the centerline of the tread, and are parallel to each other, the stabilizer belts which is directly beneath the tread. The belts can be cord or as well as steel.

The advantages of this construction includes mainly longer tread life and better steering control it also reduces fewer blowouts and improves fuel economy, and lower rolling resistance. The radial tire has also have disadvantages such as, they are a harder ride at low speeds on rough roads. The design allows the entire tire body to flex easily, providing the main advantage of this construction, a smooth ride on rough surfaces.

A belted bias tire starts with two or more bias-ply to which stabilizer belts which are bonded directly beneath the tread. This construction provide smooth ride similar to the bias tire, while lessening the rolling resistance because of the belts and increased tread stiffness. Goodyear made it popular with the tire featuring a polyester carcass with belts of fiberglass.

4.5 MATERIAL PROPERTIES

Table 4.5.1: Aluminum alloy a356

Atomic number	13
Valency	3
Crystal structure	FCC
Thermal conductivity	200 w/mK
Density	2698 kg/m ³
Poisons ratio	0.34
Yield strength	24 ksi
Shear strength	26 ksi
Specific heat	963 j/kg k
Modulus of elasticity	68.3 gpa

Table 4.5.2: Magnesium alloy az31b

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

Table 4.5.3: Grey cast iron

Density	7000 kg/m ³
Yield strength	142 Mpa
Thermal conductivity	54 w/mk
Specific heat	586 j/kg k
Young's modulus	100 Gpa
Poisson ratio	0.28
Coefficient of expansion	8.1 x 10 ⁻⁶ m
Modulus of elasticity	80 Gpa

Table 4.5.4: Radial tire

COMPONENT	CONSTITUE MODEL	C10	C01	E	V
tread	hyper elastic	0.003940	0.862791	-	-
sidewall	hyper elastic	0.152081	0.555920	-	-
apex	hyper elastic	0.645362	0.873692	-	-
plies	linear	-	-	3,800	0.48
Steel belts	linear	-	-	110,316	0.46
Cap ply	linear	-	-	3,800	0.48
Bead wire	linear	-	-	200,000	0.30

Table 4.5.5: Rubber

density	850 Kg/m ³
Specific heat	2005 j/kg k
Thermal conductivity	0.16668 w/m k

Table 4.5.6: Abs plastic

Density	1050 Kg/m ³
Specific heat	1.80 j/Kg C
Thermal conductivity	0.145 w/m K

4.6 METHOD

4.6.1 Dimensions and 3D modeling

By referring journals and paper, we got the dimensions for 20-inch alloy wheel and the dimension of low profile radial tire.

Apply these dimensions values in solid works (3d modeling software) we have created the below models using tools like,

- Exclude boss/base
- Revolve
- Cut exclude boss/base
- Reference plan and axis
- Hole wizard
- Fillet and chamber
- 2d Sketch
- Circular pattern

After creating these models (rim, tire, brake disc, fender) we went into solid works assemble mode and assembled the components using mate function.

LOW PROFILE RADIAL TIRE

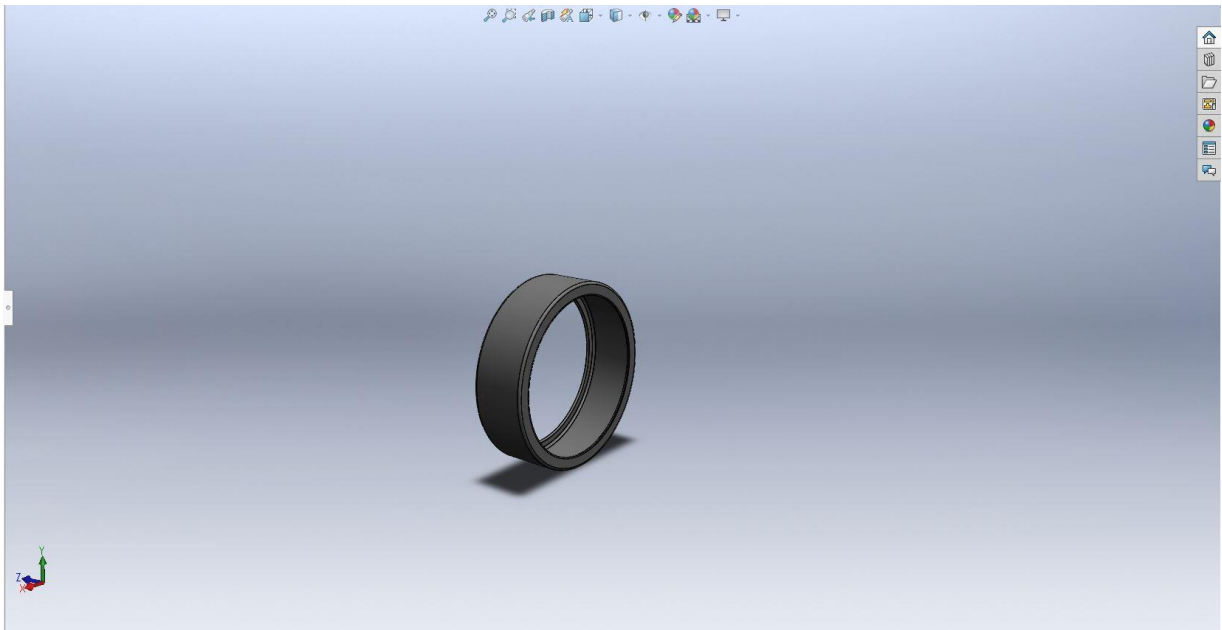


Fig 4.6.1: Low profile radial tire

The low profile tire is designed in solid works with revolve tool.

ALUMINUM ALLOY RIM

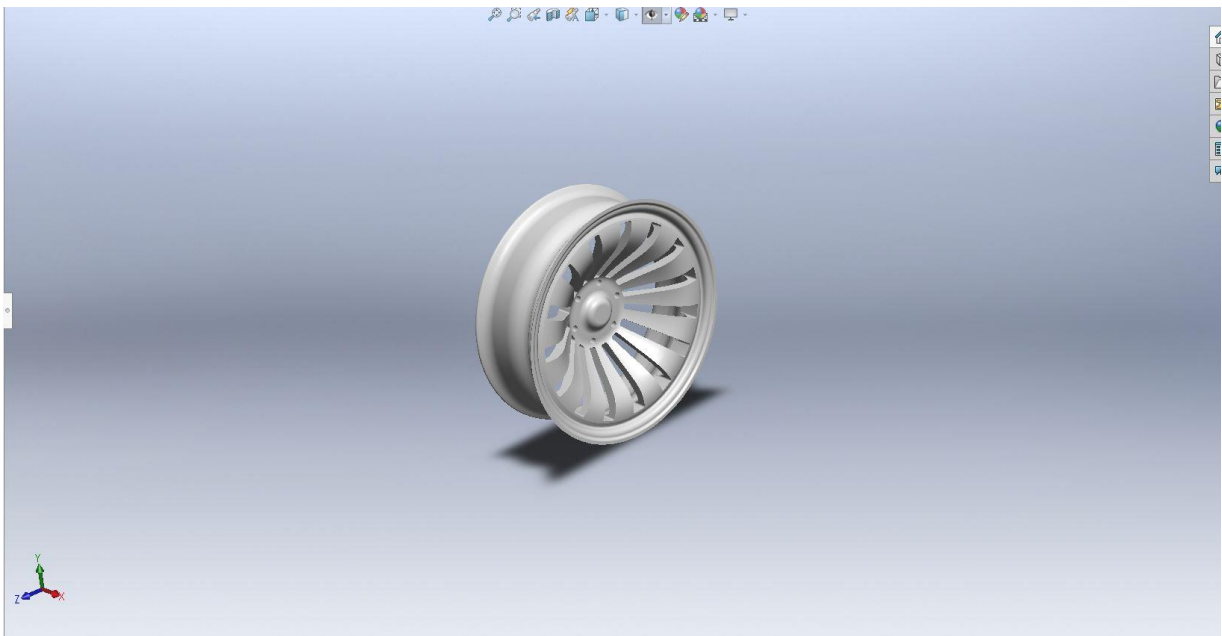


Fig 4.6.2: Aluminum alloy rim

This image picture shows the front side of aluminum alloy wheel which has been 3D designed with the help of wheel design/ dimension paper.

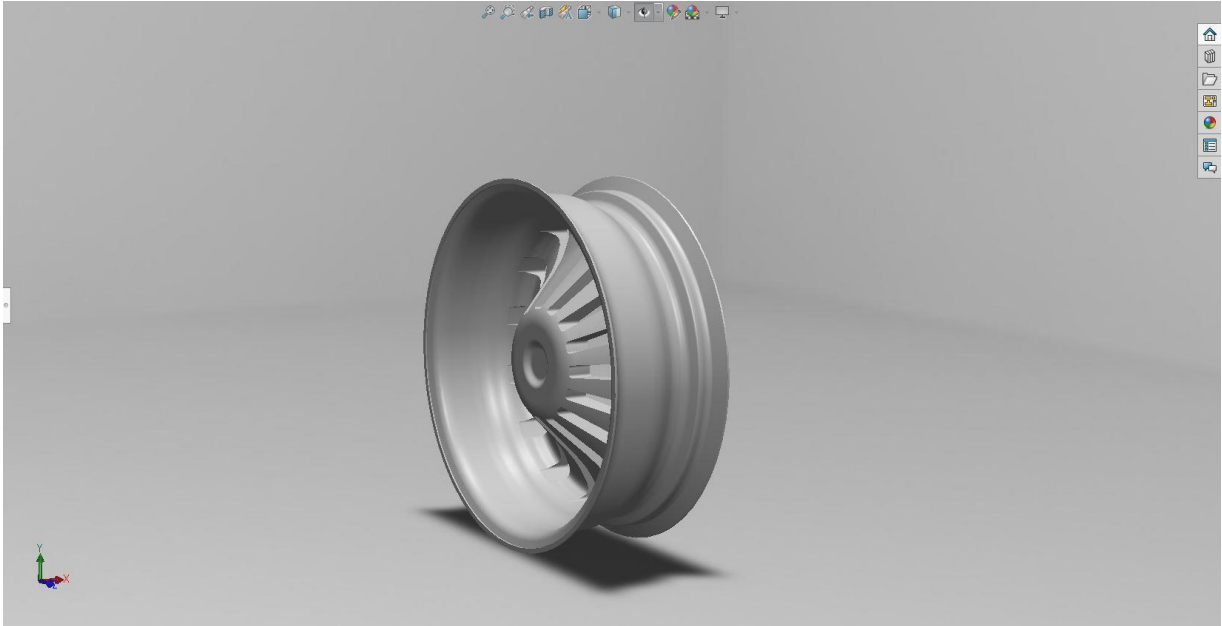


Fig 4.6.3: Rear side alloy rim

The 20 inch wheel rim is made so that it can be able to support the low profile radial tire with center bore.

MAGNESIUM ALLOY RIM WITH FINS

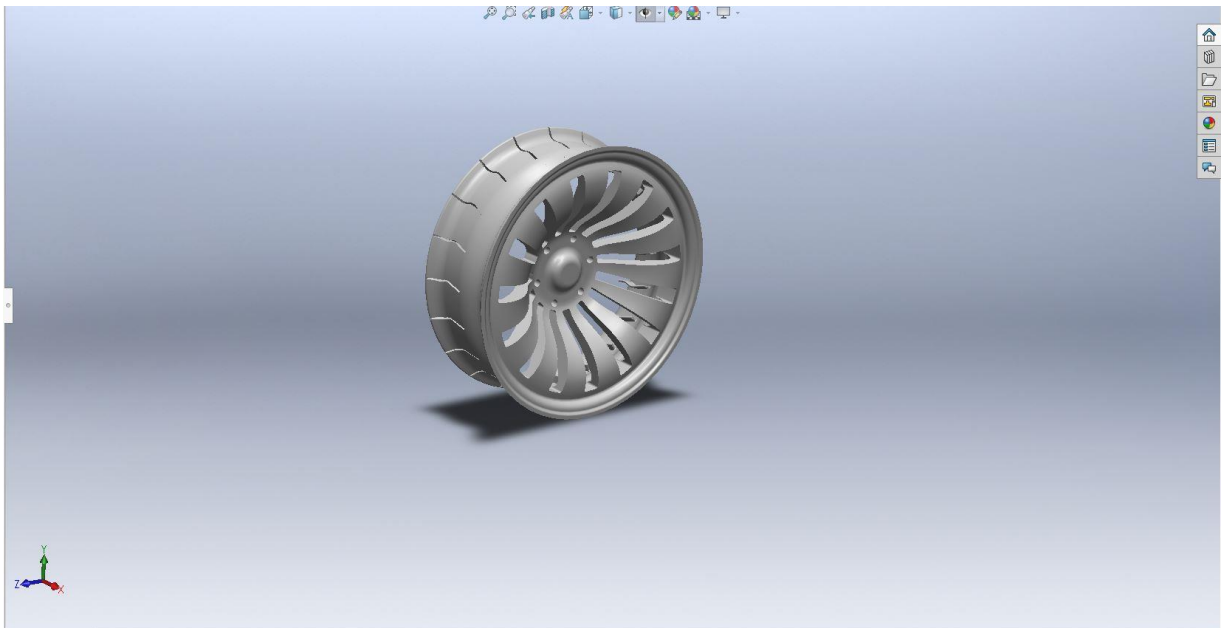


Fig 4.6.4: Magnesium rim with fins

In this above image we can see the magnesium alloy rim with hollow fins these hollow fins have been placed rear side of the wheel rim.

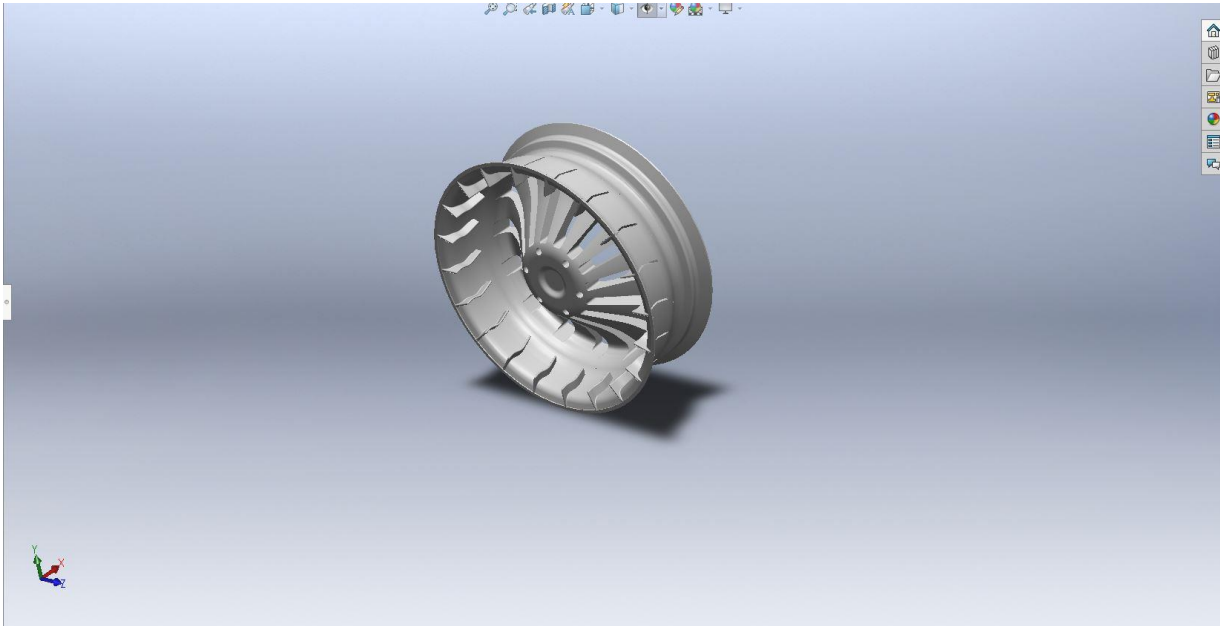


Fig 4.6.5: Hollow fins in the rim

The hollow fins are placed in curved shape so that the fins direct the incoming air through fender to outside of the wheel rim these fins height are measured and placed such that the brake rotor or disc will not rub each other when the rim is placed in the hub.

BRAKE ROTOR

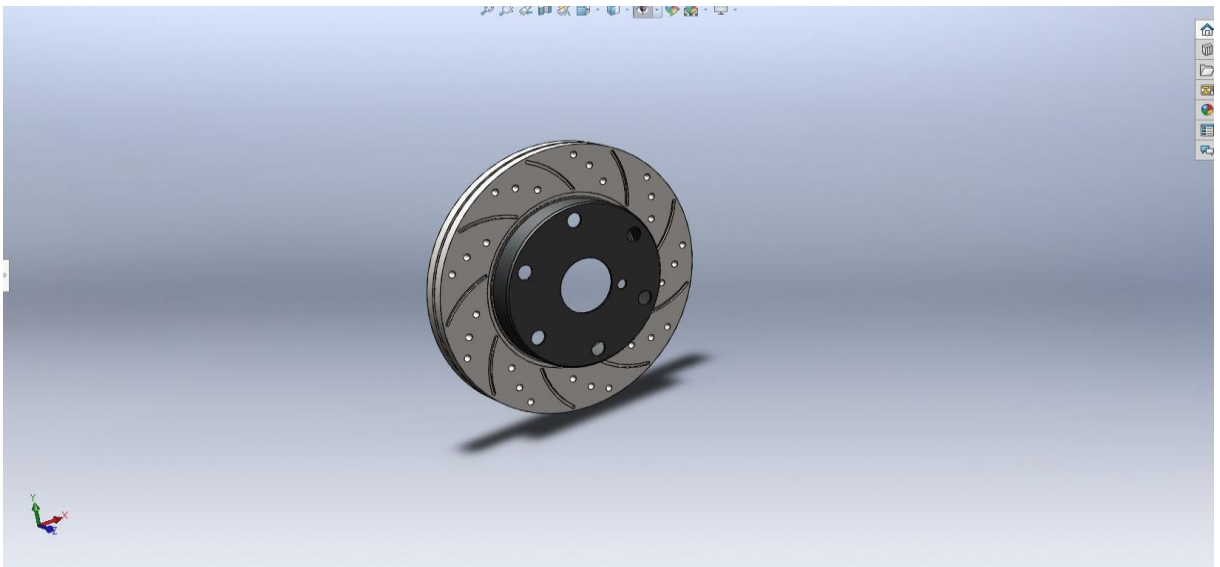


Fig 4.6.6: Brake disc rotor

The brake disc rotor has the outer diameter of 328mm and has the mass of 7kg. The holes are placed for the disc to slide into hub and the center bore is cut.

ALUMINUM ALLOY WHEEL ASSEMBLY



Fig 4.6.7: Conventional design

Fully assembled and running model of conventional wheel, which 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 are attached to the main component with the help of mates option which is solidworks assembly mode. The tire is hollow inside so that we can simulate pressure difference. This above assembled part will be imported to ansys and analyzed.

MAGNESIUM ALLOY WHEEL ASSEMBLY



Fig 4.6.8: new design

In this above image we can see that new fender and magnesium alloy wheel with fins has been used instead of conventional aluminum alloy.

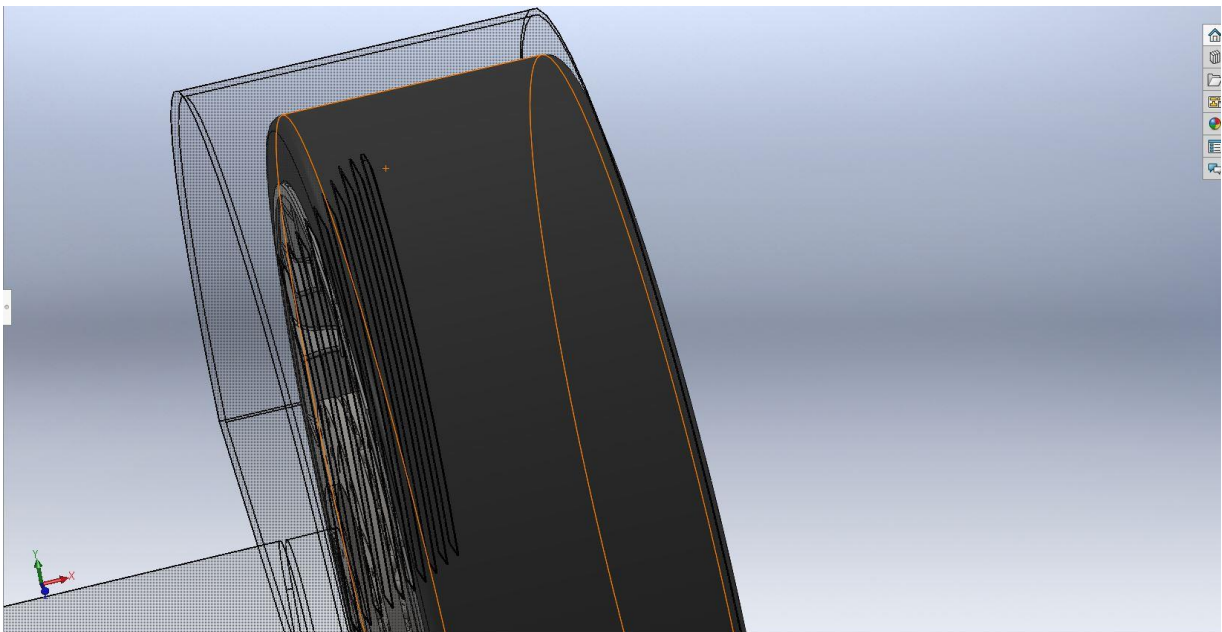


Fig 4.6.9: Fender with slotted gaps

This image shows the fender which has vertical slots and has been placed in angle of 14 degree.

CHAPTER 5

CALCULATION AND ANALYZING

5.1 CALCULATION

For tire and rim design calculation are mentioned below,

Tire and Rim

Tire Width – **227.37 W (mm)**

Tire Height – **49.59 H (mm)**

Rim Diameter – **22 D (in)**

$$AR = H/W \times 100$$

21.08

Where

AR – aspect ratio

H – tire side wall height

W – Tire width

D – Rim diameter

Side Wall Height,

- $H = AR \times W/100$

49.59

Wheel Diameter,

$$D_w = D + 2H$$

664.18

Wheel Radius (free static),

$$R_w = d_w / 2$$

332.09

To take into account the deformation of the tire we can apply a coefficient of 0.95 which means that the free static radius will decrease with approx. 5% under vehicle load in this case static radius

$$R_w = 0.95 \times d_w / 2$$

315.4

Circumference of wheel,

$$C = \pi \times d_w$$

2,086.58

Disc Brake Rotor

Outer diameter of the rotor disc - **328 mm**

Inner diameter of rotor disc - **214 mm**

Hole diameter – **18 mm**

Thickness of rotor disc – **28 mm**

Calliper piston diameter – **57 mm**

Mass of disc – **7kg – 68.67N**

Kinetic energy of vehicle,

$$K.E = (m \times v^2) / 2$$

1392439.52

Where,

K.E – Kinetic Energy (j)

M – Mass of Vehicle (kg)

V – Linear Velocity of Vehicle (m/s)

To determine the heat produced in the brake disc while braking the brake calculation has been shown below.

Heat in a braking system, the mechanical energy is transformed into Heat energy. The energy dissipated in the form of heat can generate rises in temperature ranging from 300 °C to 800 °C. Generally, the thermal conductivity of material of the brake pads is smaller than that of the disc. We consider that the heat quantity produced will be completely absorbed by the brake disc.

Heat generated when applying braking action on disc brake = kinetic energy

$$H_g = K.E$$

$$H_g = M_d \times C_p \times \Delta t$$

340 c

Where,

M_d – Mass of Disc (kg)

C_p – Specific Heat (j/kg.K)

ΔT – temperature difference (c°)

Vehicle Parameters,

Mass of the vehicle (M) - **1600 kg**

Top speed - **200 km/hr**

Wheel diameter – **664.14 mm**

5.2 ANALYSING USING ANSYS FEA

The model has been Imported to geometry and opened in design modeler. Using Boolean enclosure and named section commands we have created wall and rotating body.

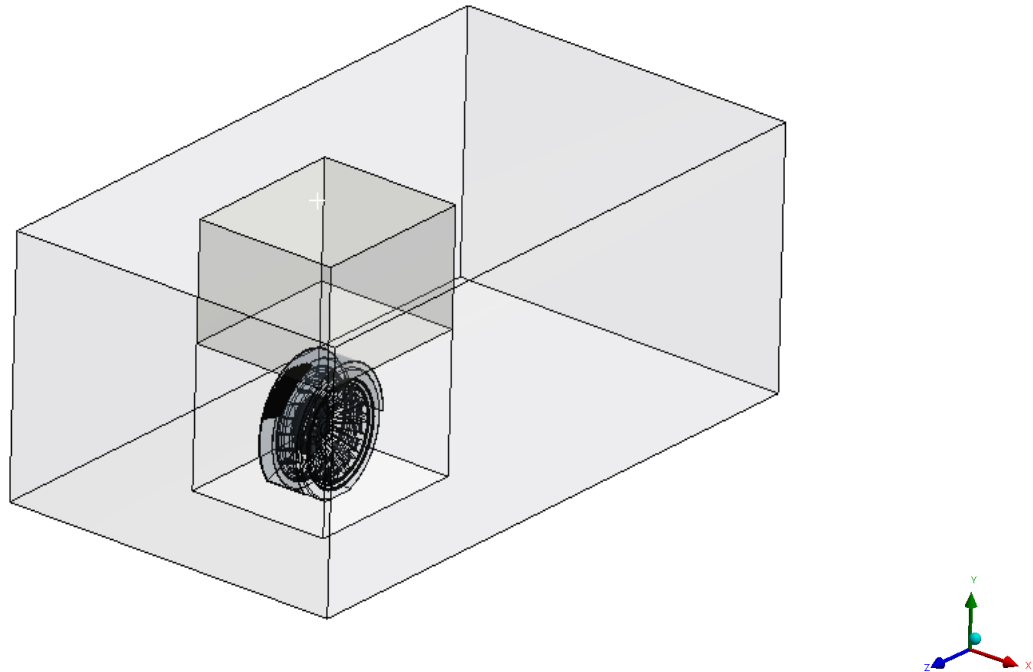


Fig 5.2.1: Enclosure

The dimensions are,

- X axis – 2500 mm
- Y axis – 1600 mm
- Z axis – 4000 mm

Opening mesh and checking contact region. The contact region has been set to friction the Co- efficient of friction is 0.4 the mesh element values has been given and the skewness value is below than 0.85 and the max skewness is below 0.9. The skewness ensure the equilateral of the triangles. Tetrahedral mesh has been used to mesh the geometry.

For aluminum alloy wheel

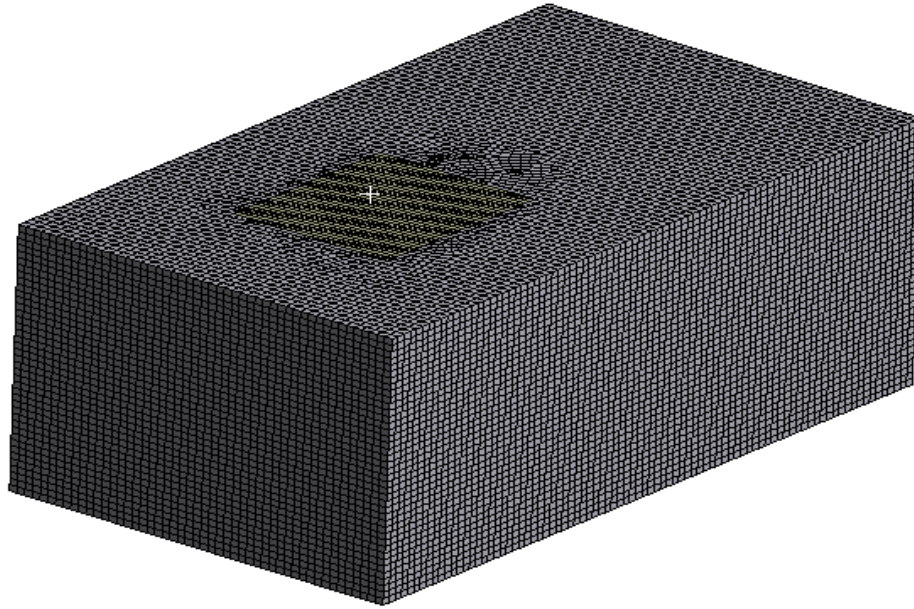


Fig 5.2.2: Outer wall mesh

The outer wall mesh for aluminum alloy wheel, which also represents both inlet and outlet wall.

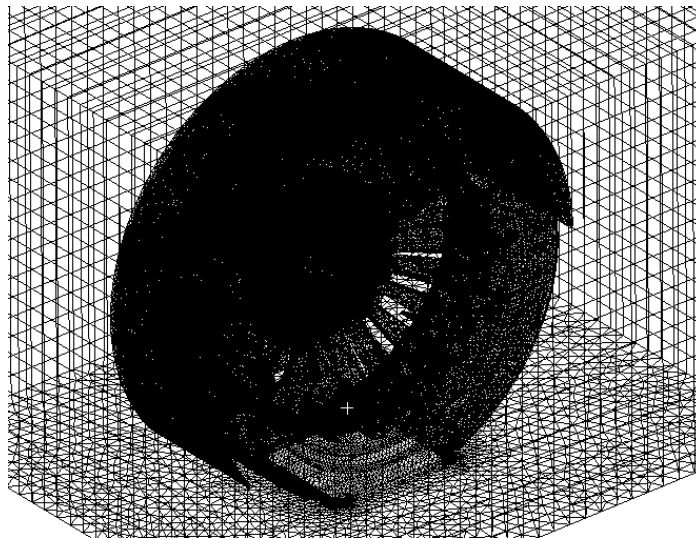


Fig 5.2.3: Wheel mesh

This image shows the mesh of aluminum alloy wheel is placed inside the outer wall.

For magnesium alloy wheel with fins

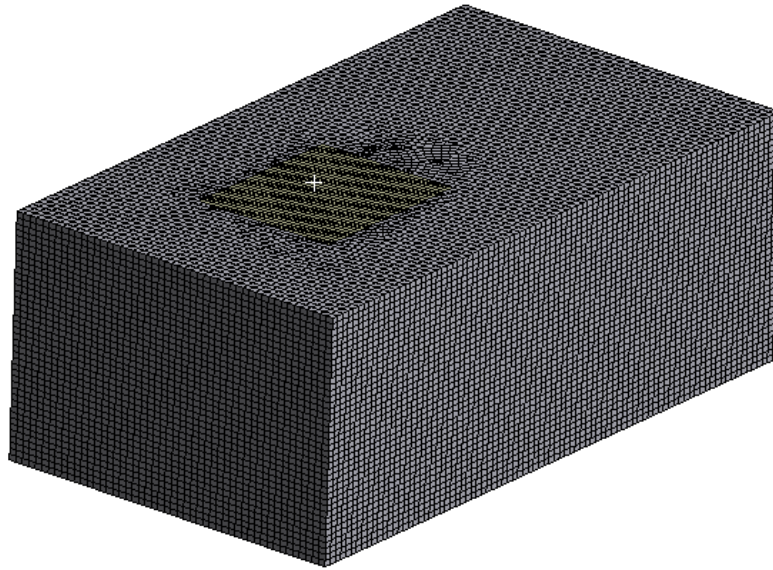


Fig 5.2.4: Outer wall mesh

Tetrahedral mesh is used to mesh this magnesium alloy wheel. This outer wall consist of inlet, outlet and road surface.

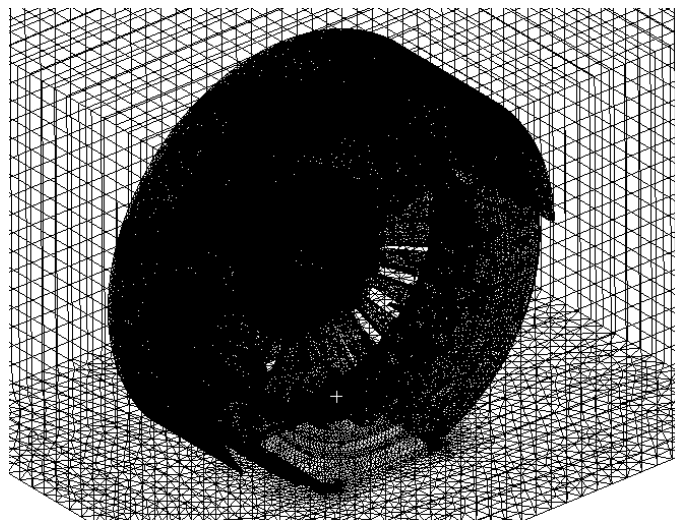


Fig 5.2.5: Wheel mesh

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 base model,

No of elements – 2804845

No of nodes – 718845

For model with fins,

No of elements – 4417082

No of nodes – 990513

After meshing in the setup double precision mode is used with Solver Processor count as 16. Energy equation and the Viscous – k epsilon is used. The rotational axis is kept as z axis.

Gravity,

- X axis – 0
- Y axis – -9.81
- Z axis – 0

Rotational Axis,

- X axis – 0
- Y axis – 0
- Z axis – 1

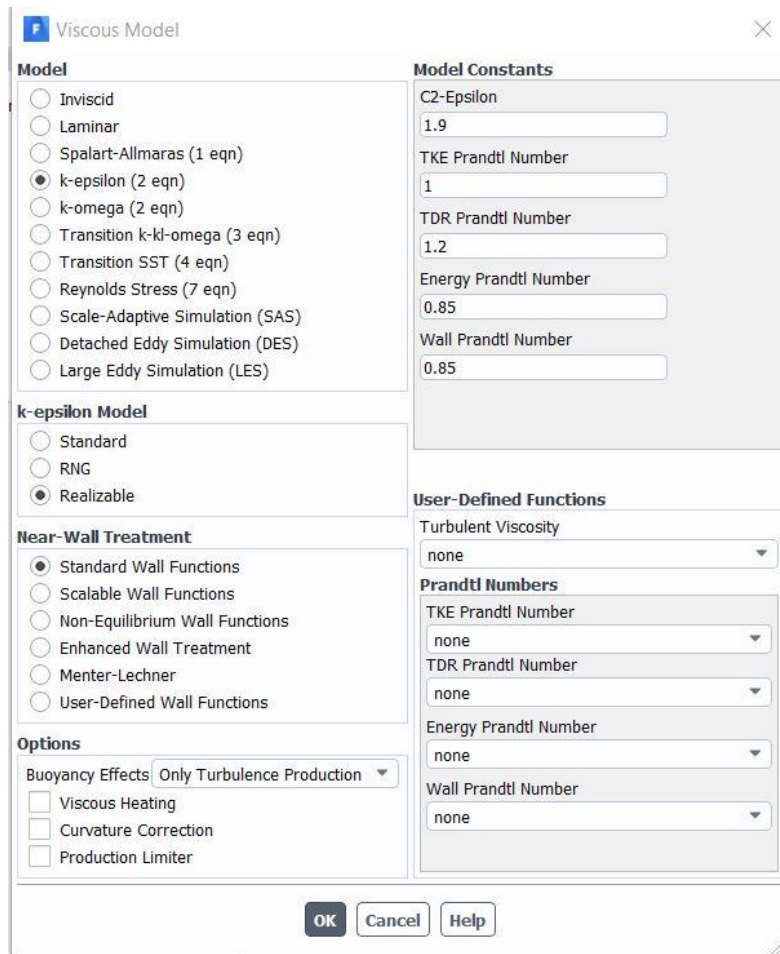


Fig 5.2.6: Viscos model

In this image we can see k-epsilon (2eqn) and realizable model is used.

The boundary conditions for

For aluminum alloy wheel,

 Inlet

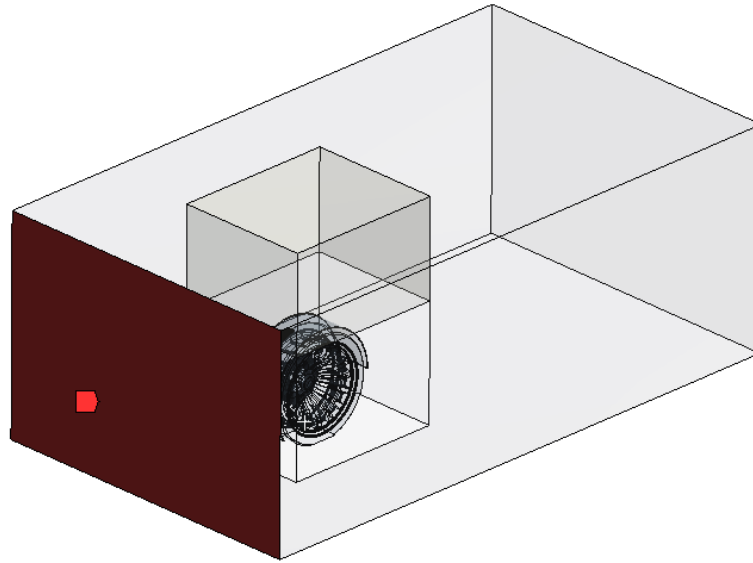


Fig 5.2.7: Inlet

The inlet is placed in the front side of the wall and velocity inlet is used.

 outlet

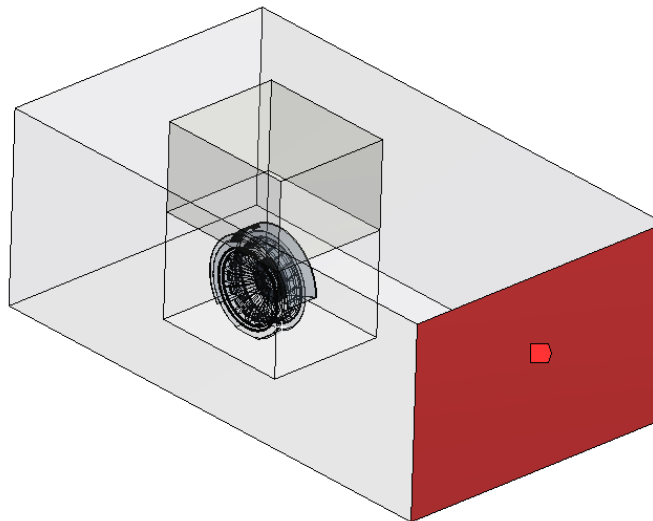


Fig 5.2.8: Outlet

The outlet is placed in the rear side which is in +^{ve} Z direction and pressure outlet is chosen.

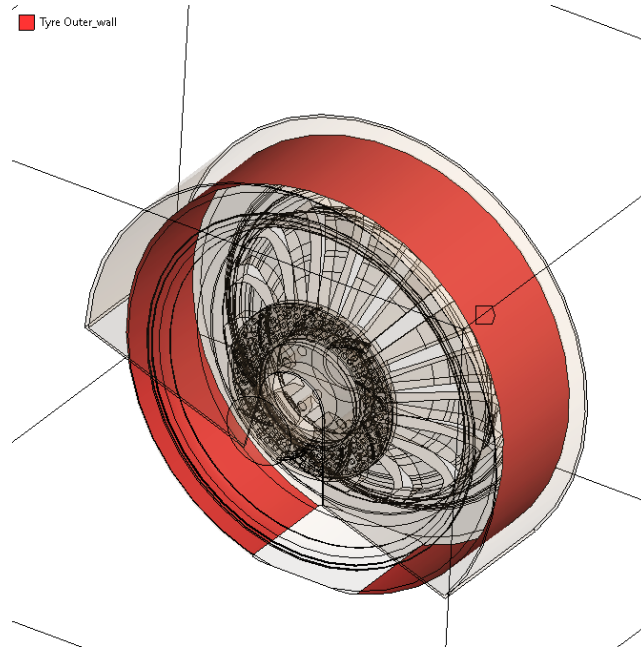


Fig 5.2.9: Tire

The tire surface is selected and the value is given.

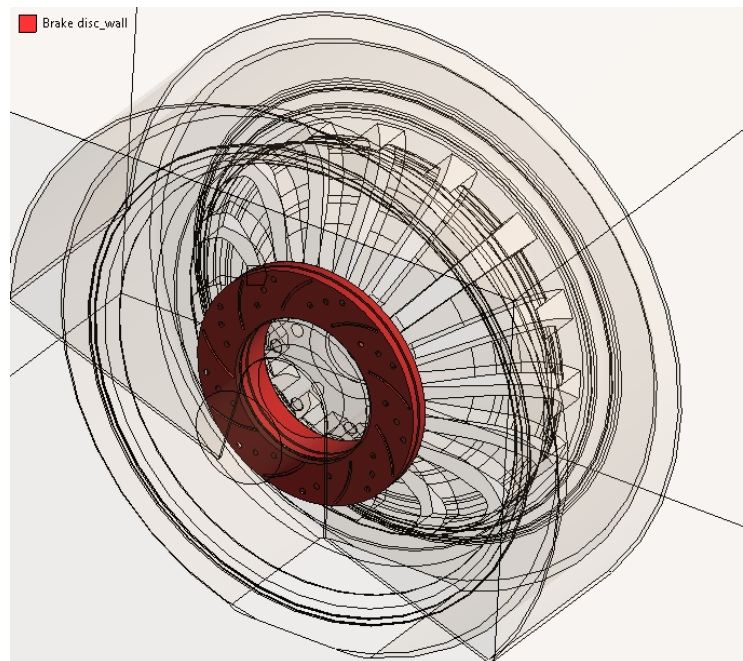


Fig 5.2.10: Brake disc

To apply brake disc temperature we have selected the brake disc outer surface wall in which the brake pad comes in contact with the disc.

- Inlet – velocity inlet **22.22 m/s**
- Outlet – pressure outlet (open to atmosphere)
- Tire wall caucus temperature – **80° c**
- Disc surface temperature – **340° c**

For magnesium alloy wheel,

 Inlet

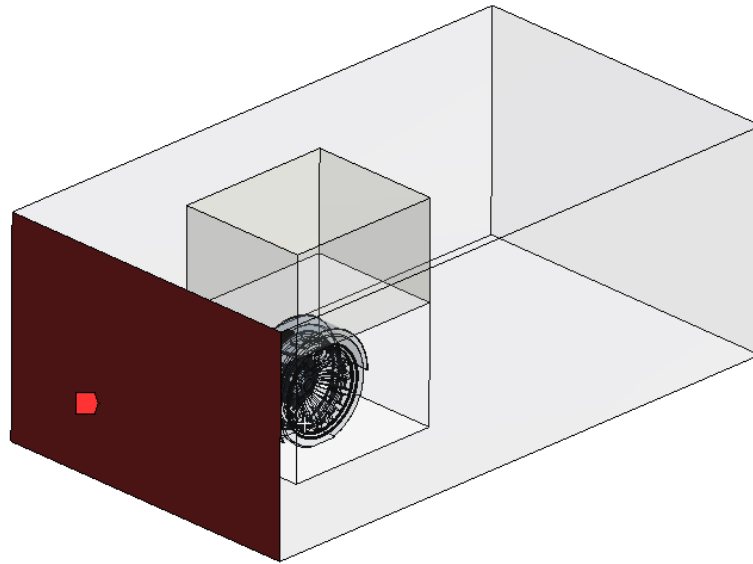


Fig 5.2.11: Inlet

The same method and setup which has been used in aluminum alloy wheel is used for the magnesium alloy wheel. The inside wall is the enclosure for the wheel body and the outside wall is for the total body. The wheel body is also known as rotating body the Boolean helps to separate these two bodies.

■ outlet

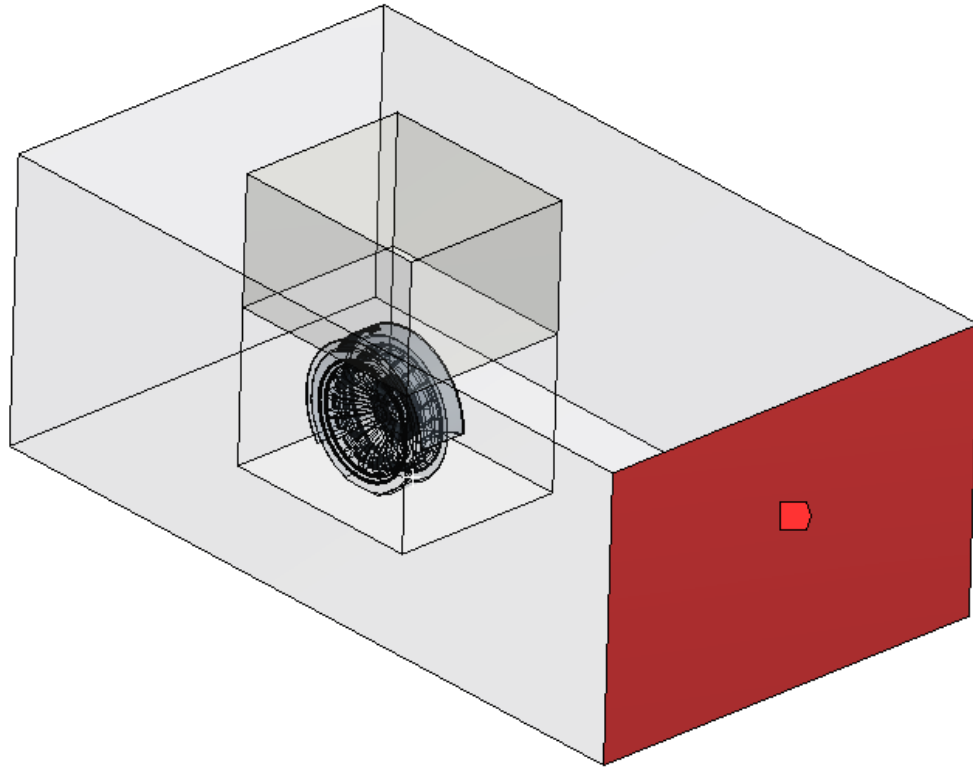


Fig 5.2.12: Outlet

The outlet is selected in the rear side of the outer wall so that we see the air temperature and compare the inlet and outlet air temperature.

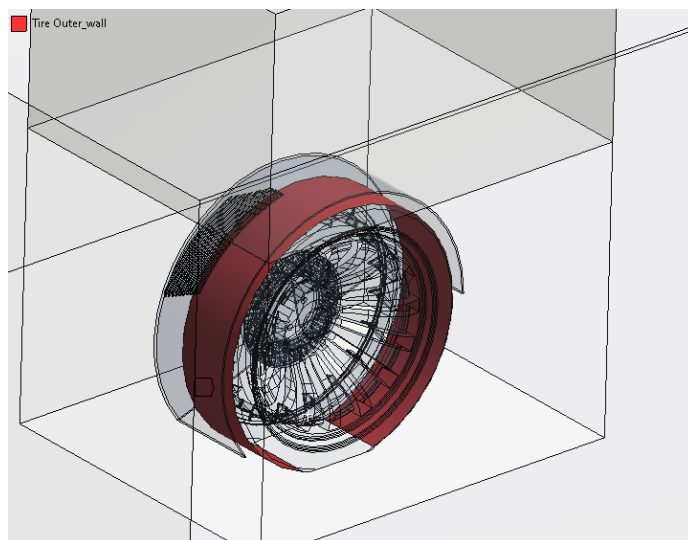


Fig 5.2.13: Tire

This image shows the tire surface wall is selected for the boundary condition.

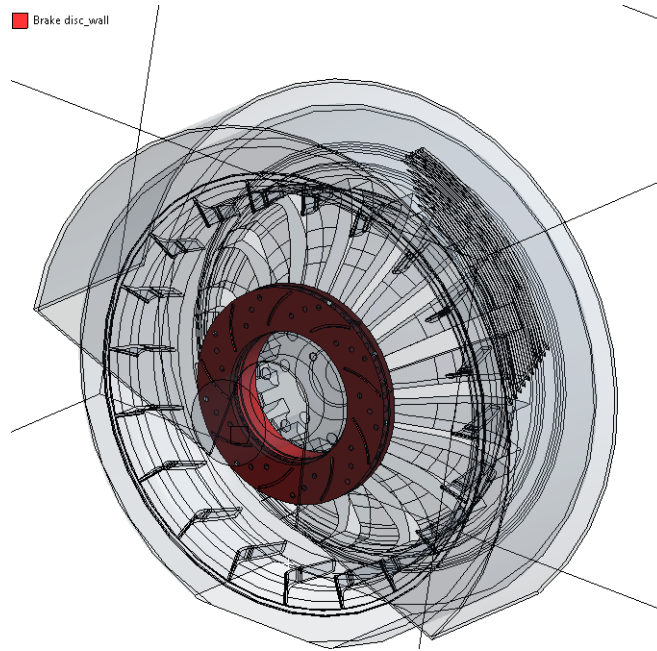


Fig 5.2.14: Brake disc

The brake disc wall is selected for the boundary condition and we also see the hollow fins the wheel rim.

- Inlet – velocity inlet **22.22 m/s**
- Outlet – pressure outlet (open to atmosphere)
- Tire wall caucus temperature – **80° c**
- Disc surface temperature – **340° c**

The materials is added for each parts,

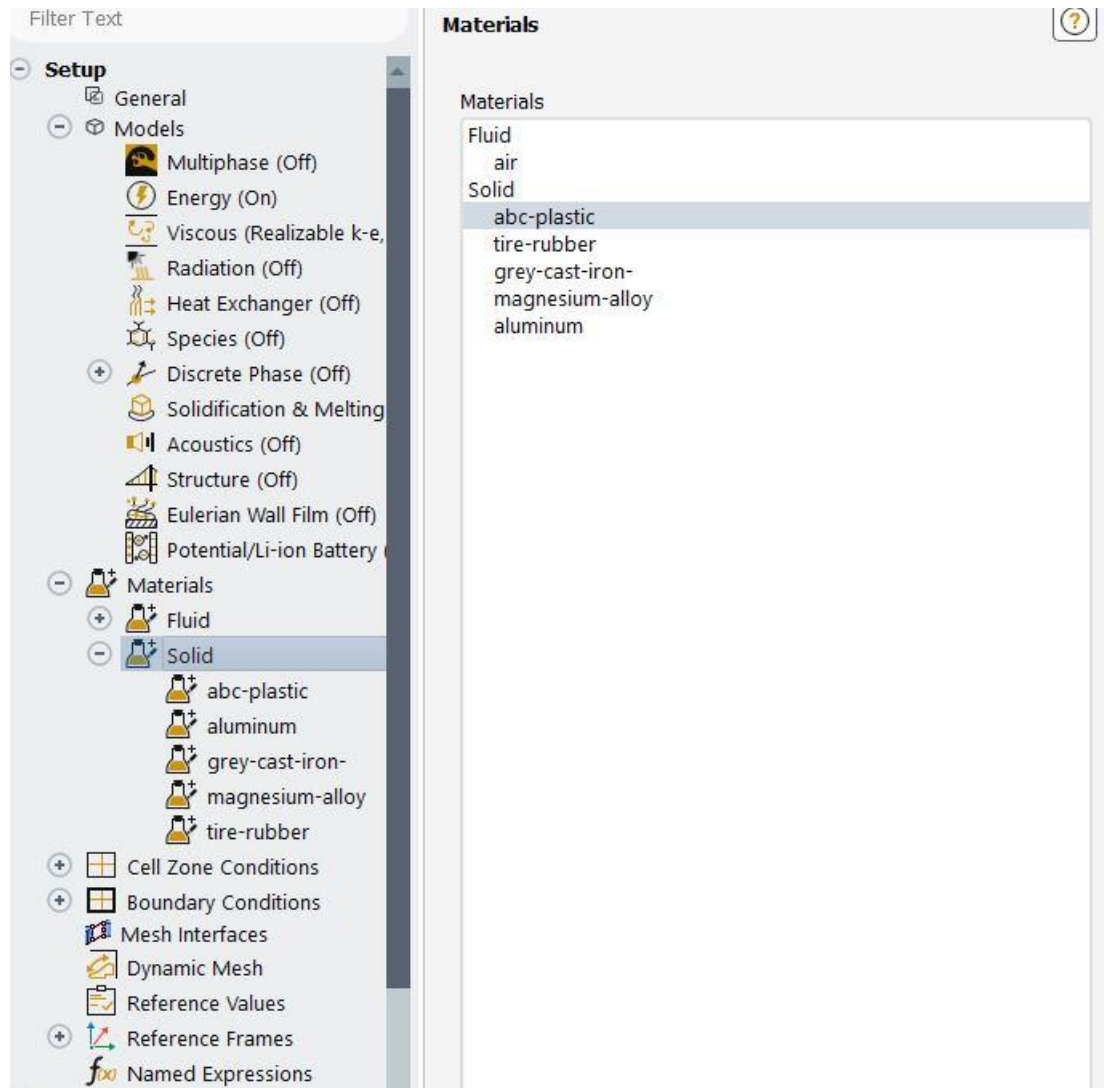


Fig 5.2.15: Addition of material

Initializing – using hybrid initializing we initialized the above solver and 2000 number of iteration is given and the calculated.

CHAPTER 6

RESULTS

The CFD simulation is done for aluminum alloy wheel and magnesium alloy wheel in steady state. The carcass temperature of the tire is 80 degree Celsius when the vehicle is running at 200km/h. The brake is applied for 4 sec and the vehicle speed is reduced to 80km/h, which produce the heat energy of 340 degree Celsius. Using the slotted gaps in the fender and the fins inside the rims the overall temperature of the brake disc and the rim is reduced more in the space of less time compared to conventional setup.

6.1 RESIDUAL GRAPH

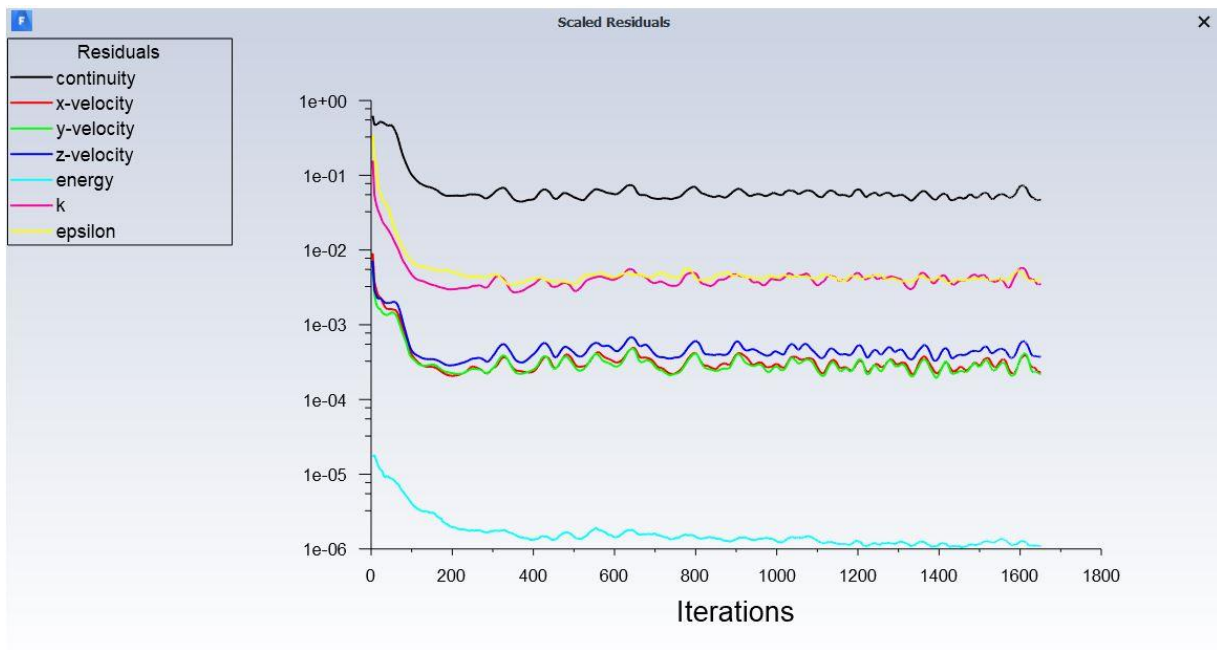


Fig 6.1.1: Conventional design

The residual graph for conventional design. In which we can see the velocity , energy and k epsilon for each iteration.

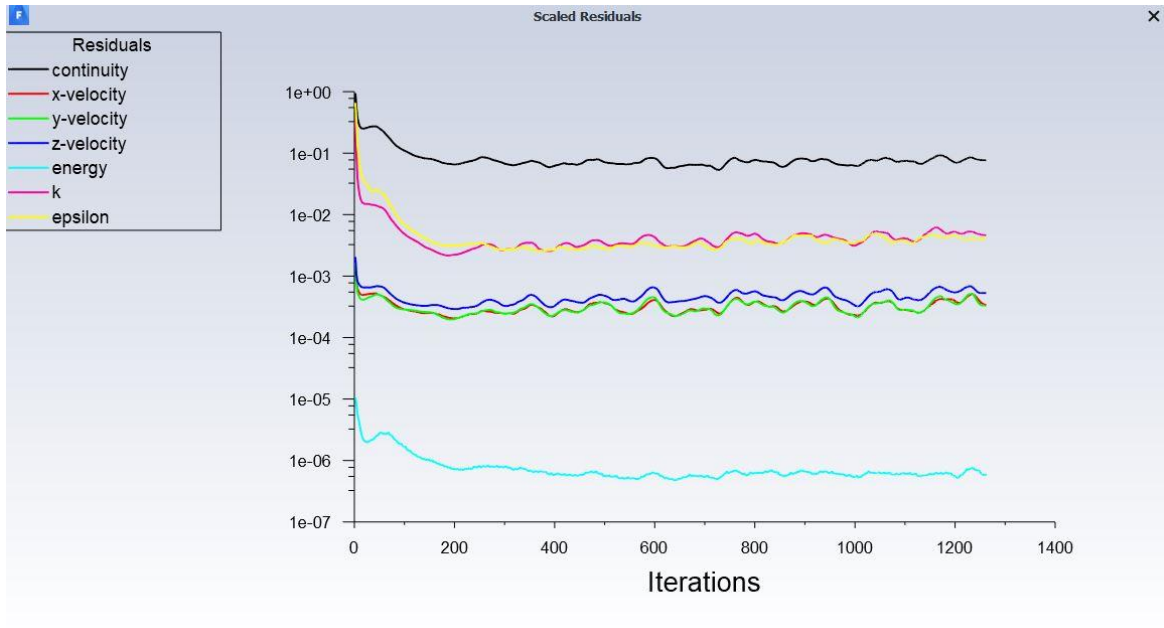


Fig 6.1.2: New design

By seeing the above two graph we can the residual graph for both conventional design and new design. For conventional design 1650 iteration has run, each iterations is a time interval of 1 second. In the same way for new design it took 1238 iterations. Once the equation has been reached convergence the iterations stops.

6.2 RESULT OF CONVENTIONAL DESIGN

Pressure contour

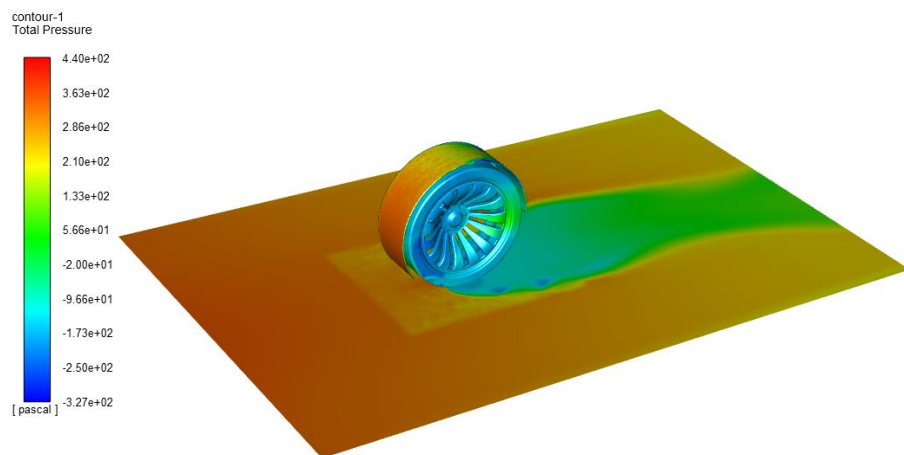


Fig 6.2.1: Pressure contour

The above image shows the pressure contour for the conventional design (aluminum alloy wheel).

Velocity contour

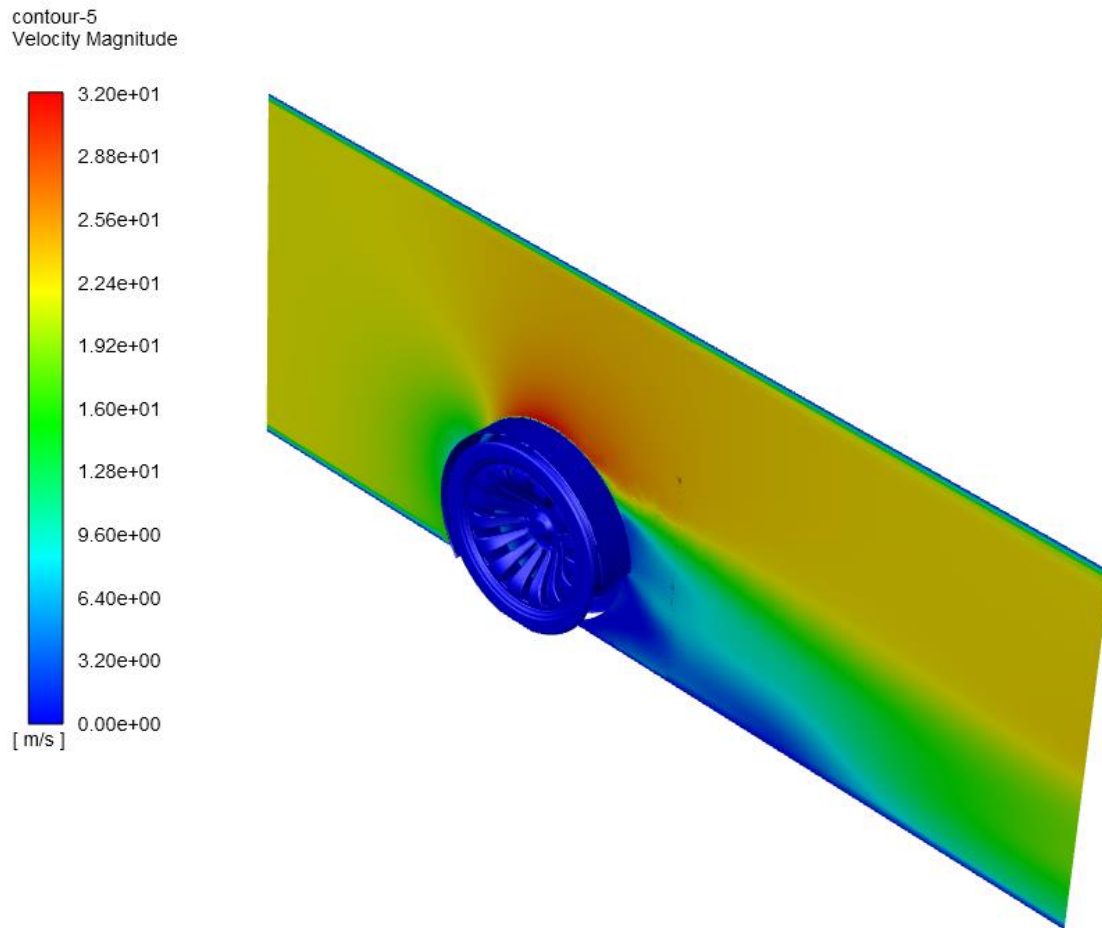


Fig 6.2.2: Velocity contour

The velocity contour shows where the velocity is high and the velocity is low behind the wheel cause the wheel produced the wake turbulence while its rotating.

Temperature contour

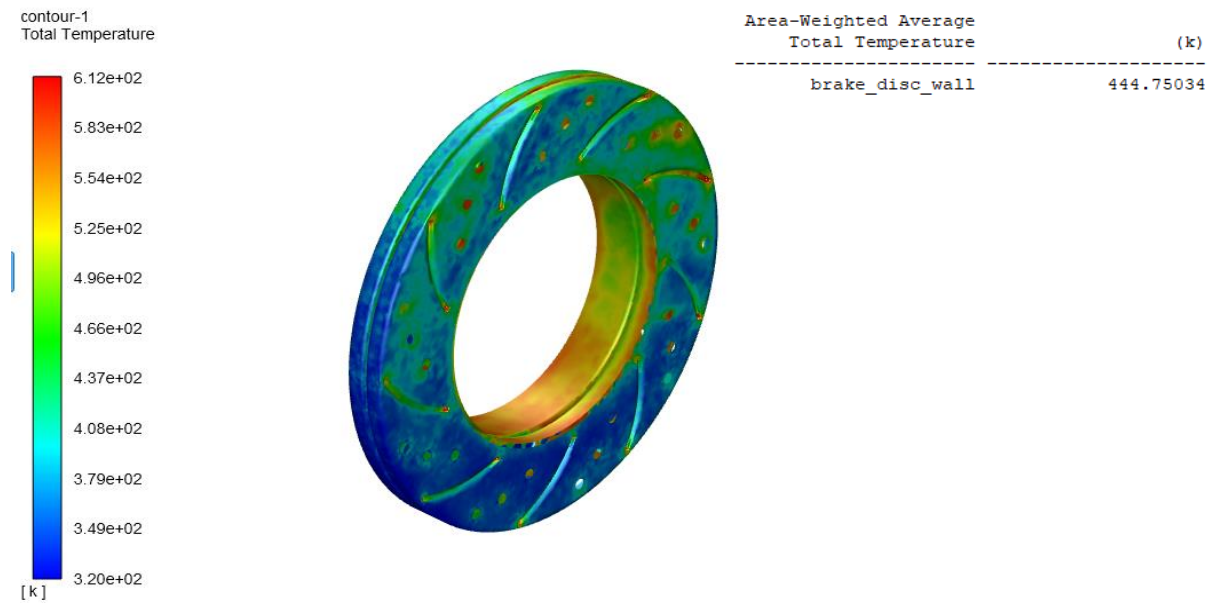


Fig 6.2.2: Brake disc temperature contour

This image shows the temperature after the air flow, due to obstacle (fender) the air flow is unable to reach the brake disc.

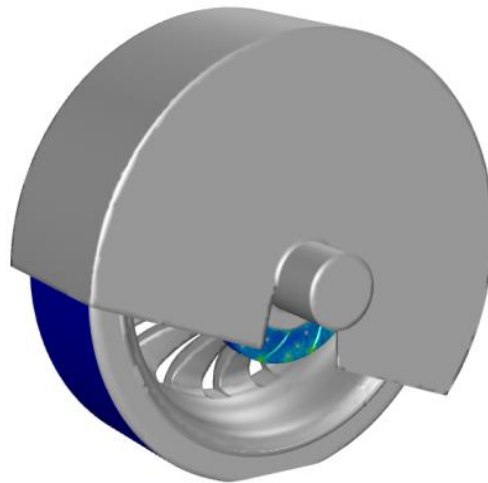


Fig 6.2.4: Wheel temperature contour

In this above image we can see the both the tire and brake disc surface temperature contour.

Vector velocity contour

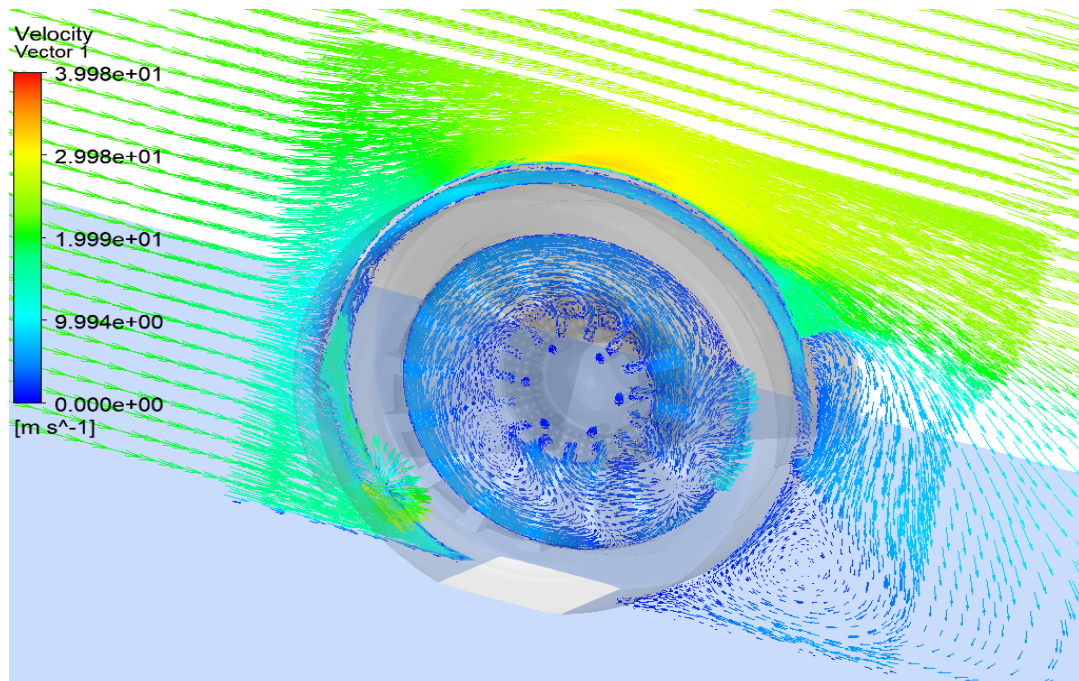


Fig 6.2.5: Vector velocity

In this vector velocity, we can see the airflow is heavily disturbed by the conventional fender design.

Velocity streamline contour

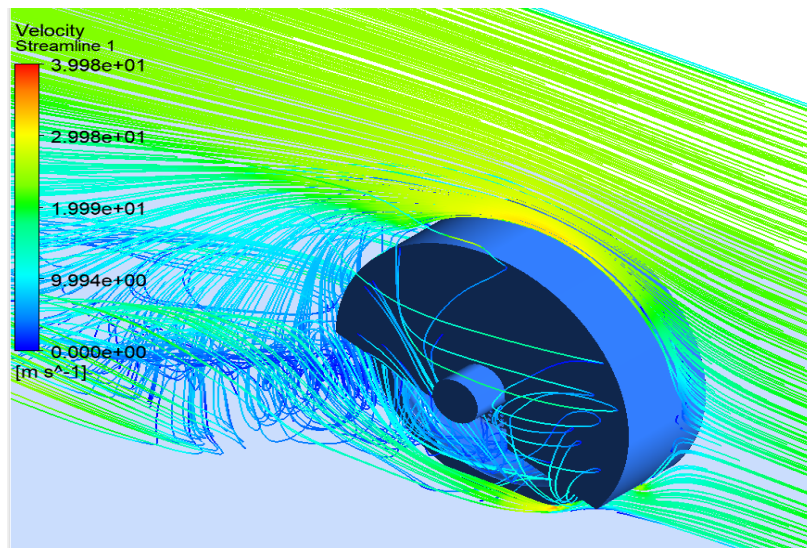


Fig 6.2.6: Streamline velocity

This streamline flow contour shows the flow of air coming from the inlet of the inlet wall.

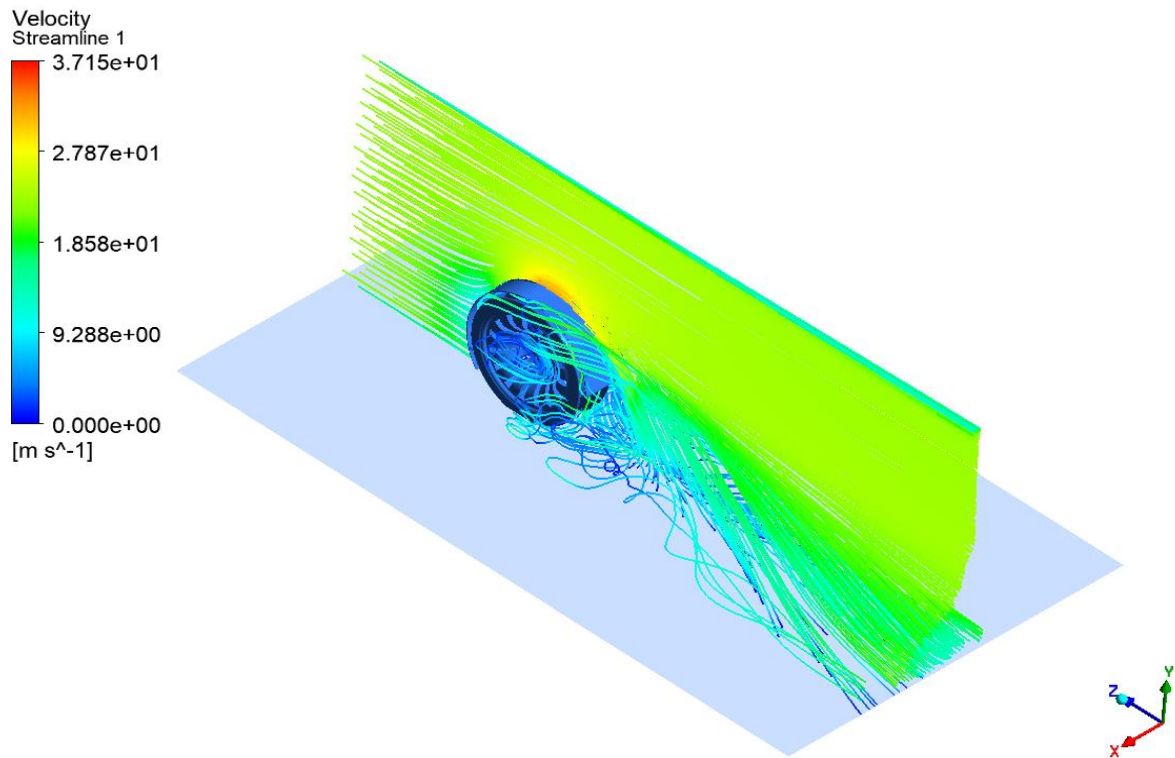


Fig 6.2.7: Streamline velocity flow

This streamline flow shows a huge amount of air flow disturbance created by the wheel when its running.

Tire temperature contour

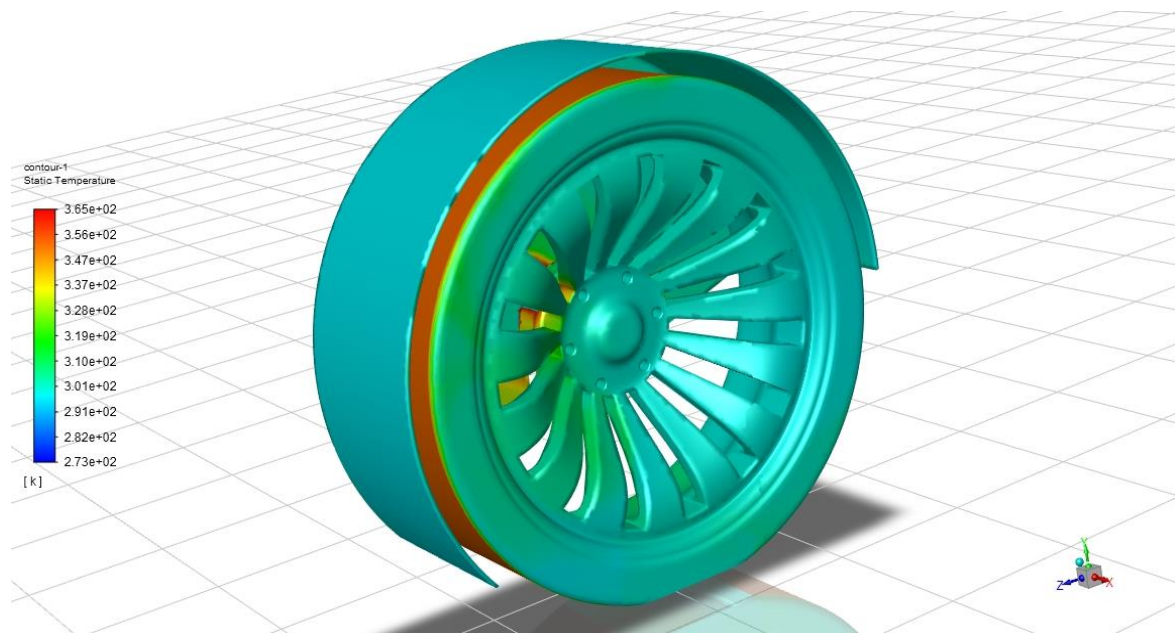


Fig 6.2.8: Tire temperature contour

Once we removed the brake disc temperature we can clearly see the tire temperature.

6.3 RESULT FOR NEW DESIGN

Pressure contour

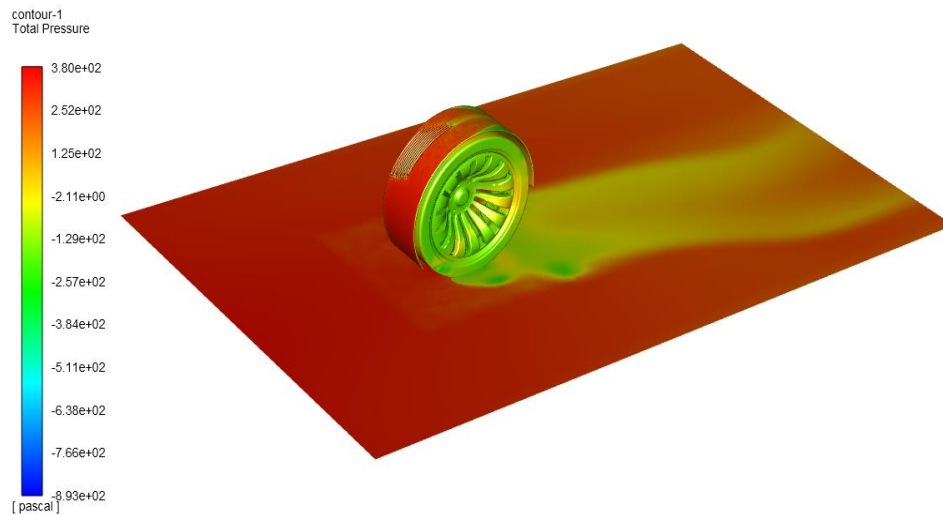


Fig 6.3.1: Pressure contour

This image shows the pressure contour for new design. The pressure is high compared to conventional design.

Velocity contour

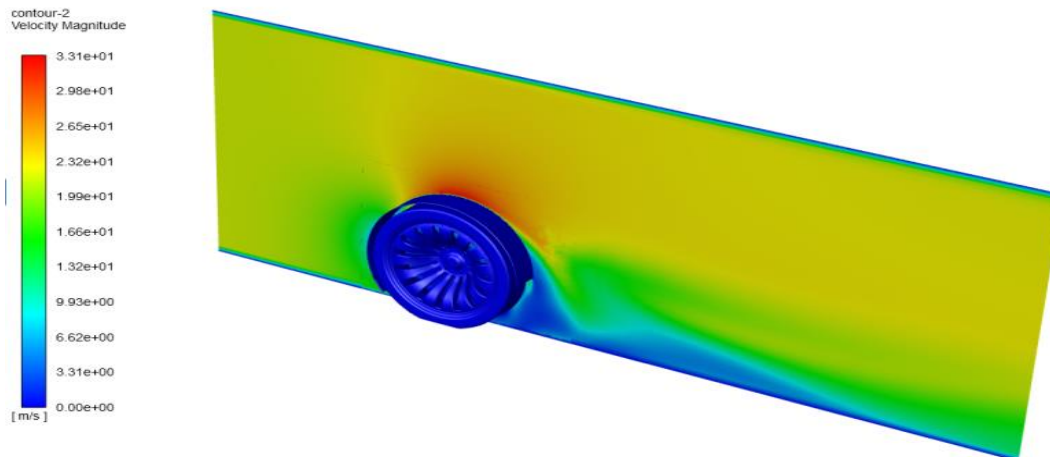


Fig 6.3.2: Velocity contour

In this image we can see the changes in velocity across the whole system. We can also see the velocity is high near the slotted gaps in the fender.

Temperature contour

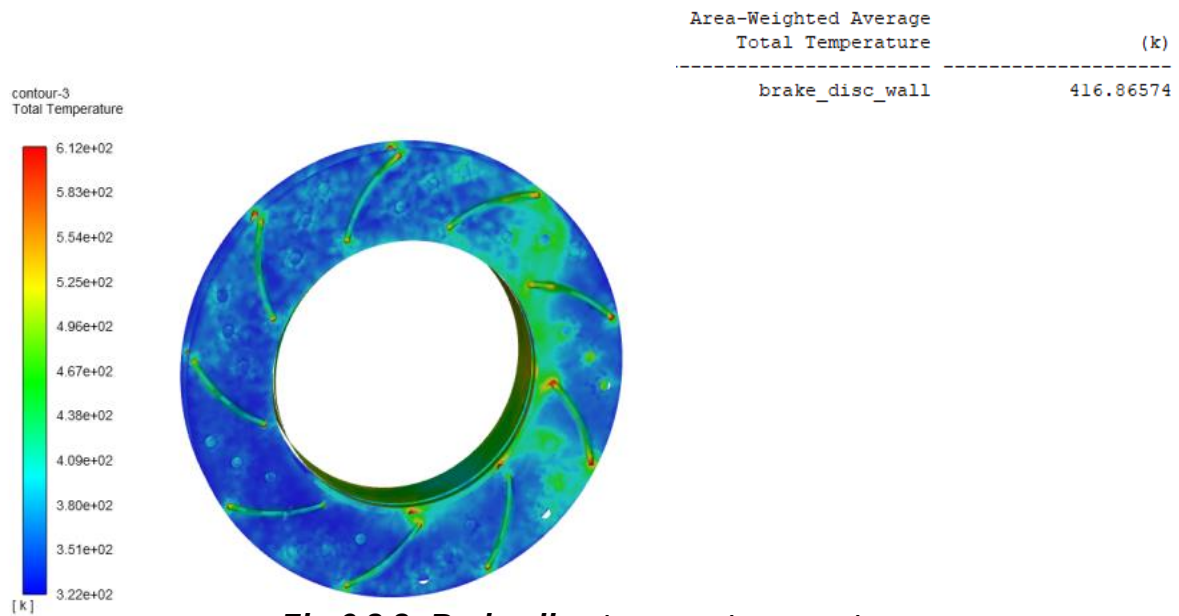


Fig 6.3.3: Brake disc temperature contour

Due to increase in air flow to brake disc which is helped by the slots in fender we can reduce in brake disc surface temperature.

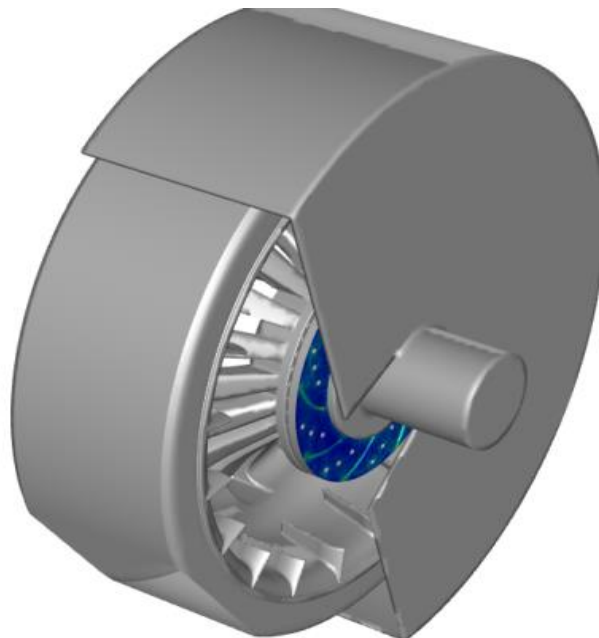


Fig 6.3.4: Wheel temperature contour

This image shows the wheel tire temperature of magnesium alloy rim with hollow fins.

Velocity vector contour

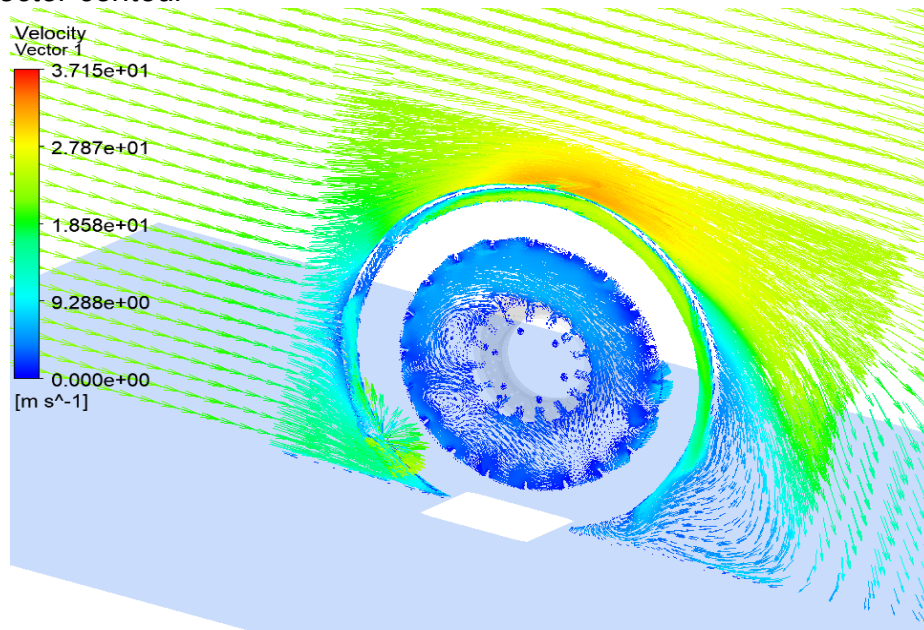


Fig 6.3.5: Vector velocity

In this vector velocity contour we can see increased number of vectors in the brake disc and we can also see the change in velocity at slots in fender.

Velocity streamline contour

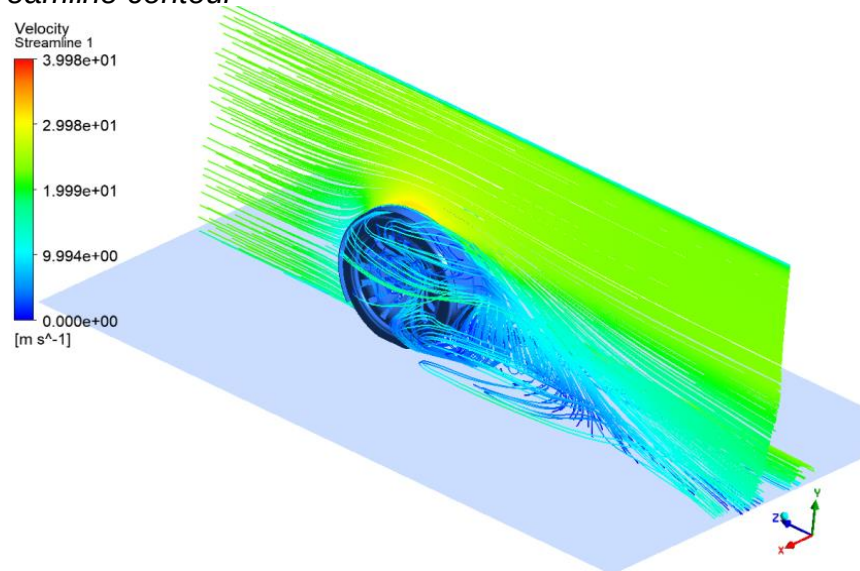


Fig 6.3.6: Streamline velocity flow

In the above image we can see the air flow coming out of the wheel this is due to the fins, where they are acting as compressor when the wheel rotating the slots in fender helps the air flow easily.

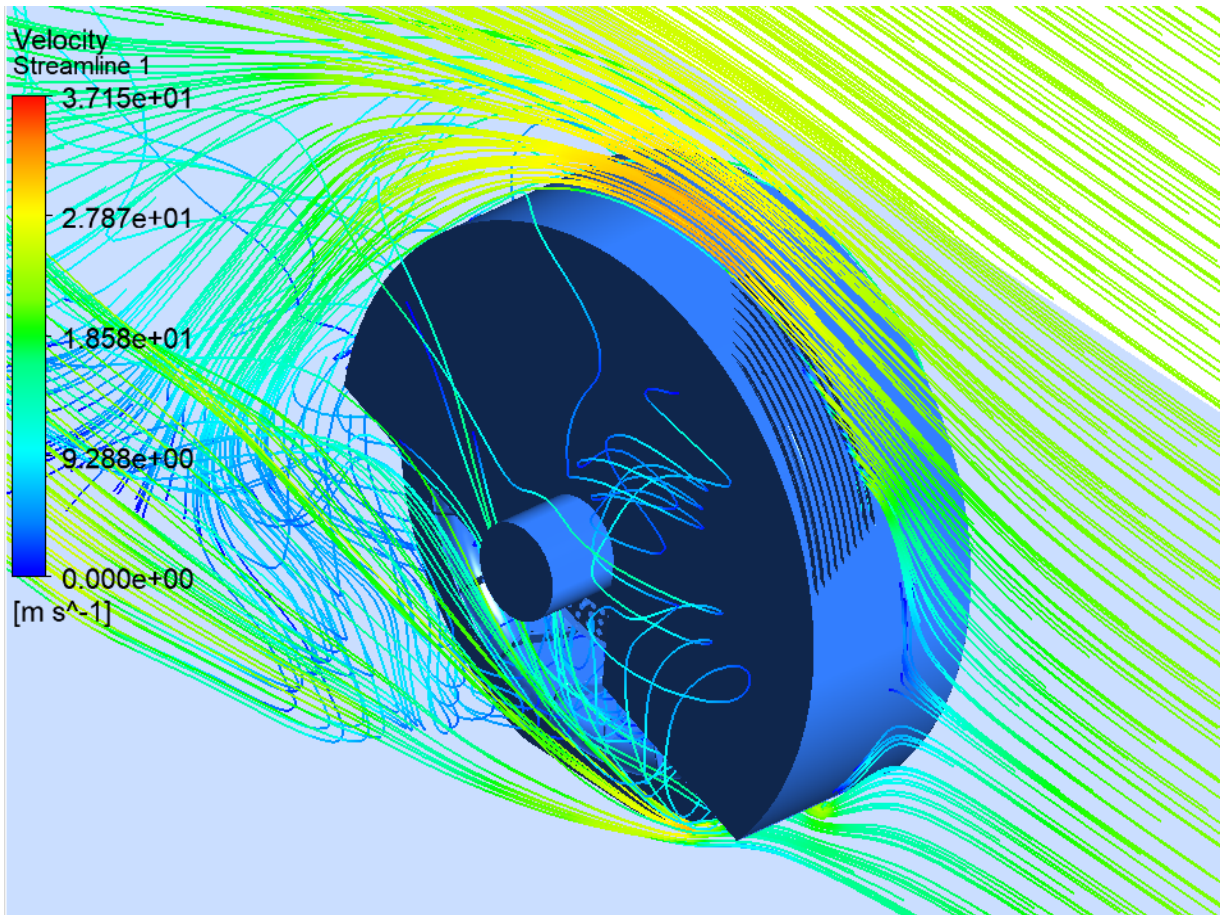


Fig 6.3.7: Streamline velocity contour

In the streamline flow we can see the flow of air coming through the inlet and passing through the slots in 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 compared to conventional design.

Tire temperature contour

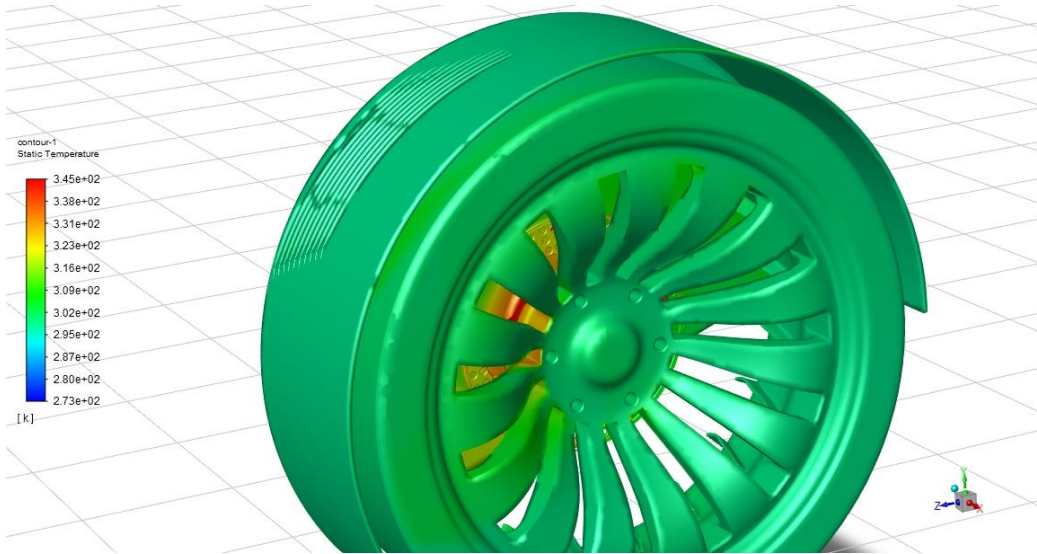


Fig 6.3.8: Tire temperature contour

The above image shows the tire surface temperature of the magnesium alloy wheel.

6.4 COMPARING THE CONVENTIONAL AND NEW DESIGN

By comparing the heat change in brake disc of both system. For the conventional

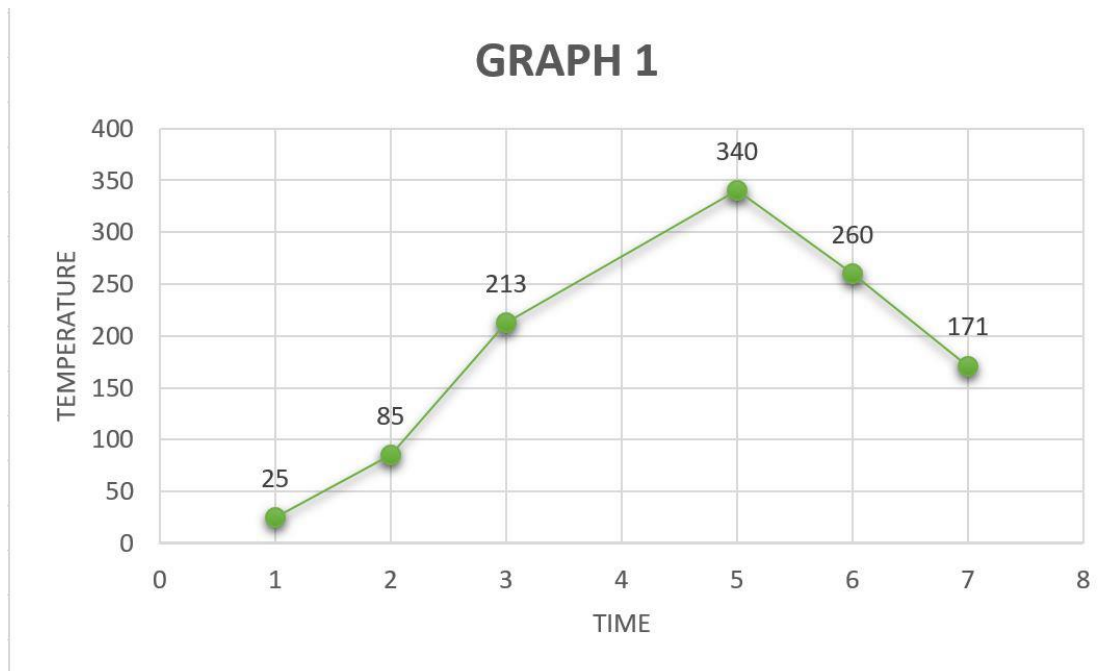


Fig 6.4.1: Conventional design

design from the temperature contour, we can see that the temperature across the brake disc was 444.750k (171.75 degree C).However, with the slotted fender and hollow fins in the wheel rim we can see that the temperature was reduced to 416.86k (143.8 degree C).

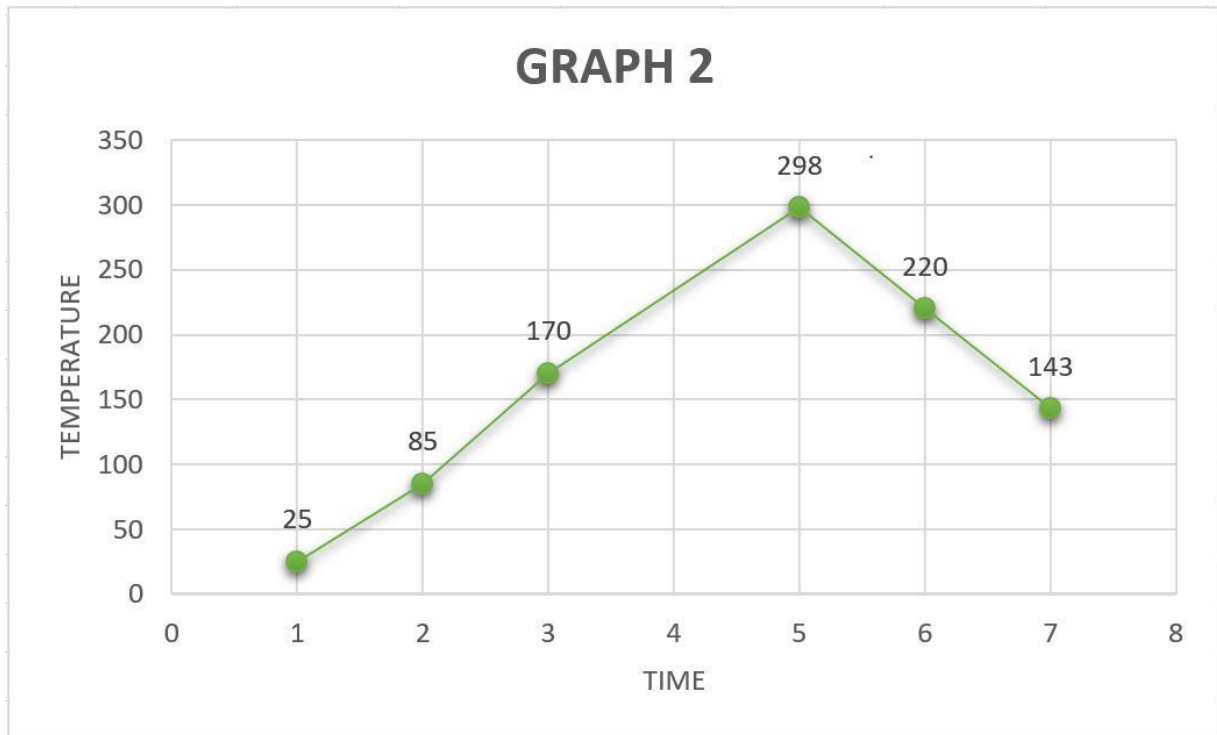


Fig 6.4.2: New design

In the above conventional design we can see that when the brake is applied the temperature of the brake disc rise from 25 degree to 340 degree with the time period of five seconds and the temperature reduces slowly.

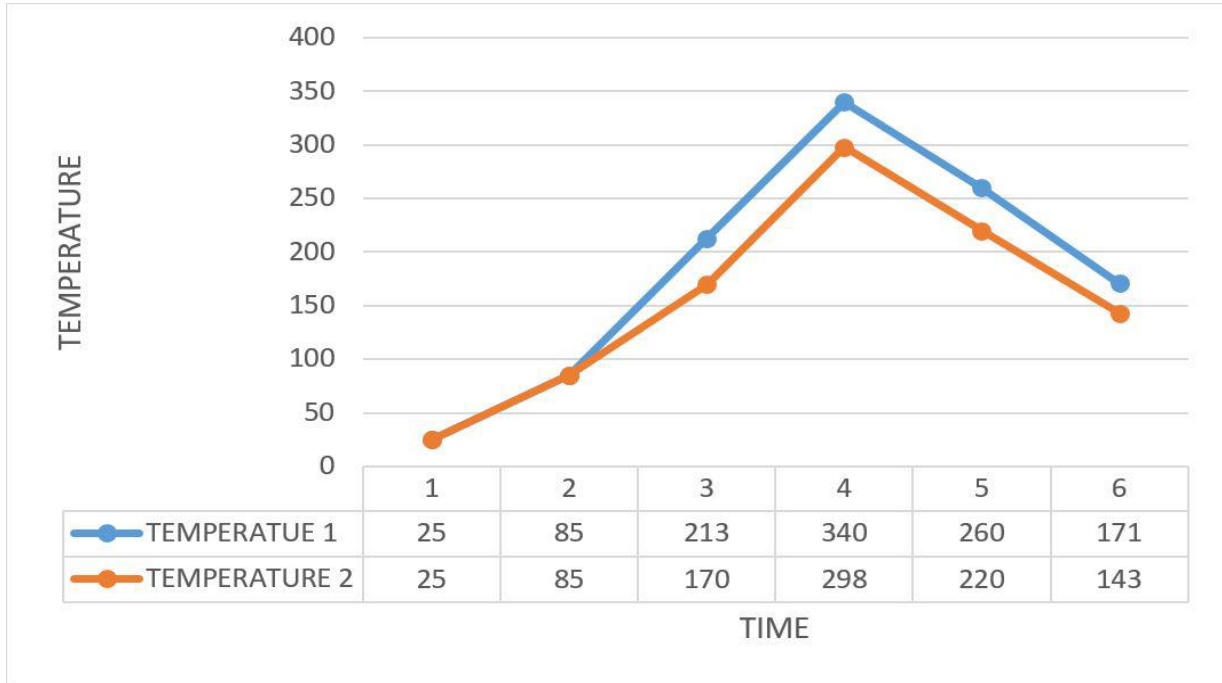


Fig 6.4.3: Comparison graph for rim

As we compared both the temperature readings of conventional design and New design we can see that the rise in temperature is reduced when the brake is applied and heat is transferred efficiently so that the temperature of the brake disc surface is reduced more compared to conventional design.

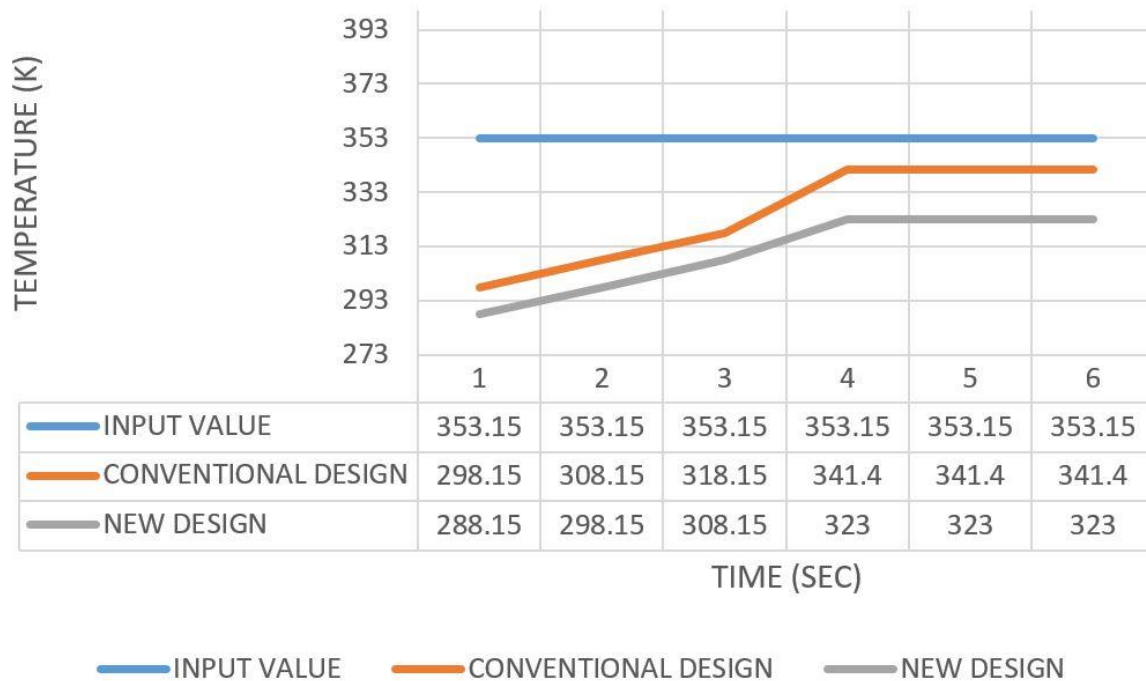


Fig 6.4.4: Comparison graph for tire temperature

By comparing the tire surface temperature we can see that for the conventional design the surface tire temperature is 341.4 k (68.25 degree C). In addition, the tire temperature for the new system which has slotted gap in fender and rim with hollow fins which helps to reduce the surface temperature of the tire and we can see the reduce in temperature of the tire surface is 323k (49.85 degree C). This reduce in temperature maintains the tire pressure and surface temperature in optimal range.

Even the input is set at constant 353.15k the flow of air through the rim and slotted gaps in the fender keeps the tire in optimum condition which helps to maintain the rubber compound and does not separate the rubber layer inside the tire.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

We conclude that the magnesium alloy wheel with fins have improved by reducing the tire temperature and brake disc temperature compared to conventional system this reduce in overall temperature. The magnesium alloy wheel has higher tendency to transfer heat and with the help of hollow fins tire temperature can be maintained over a period of time, which reduce the risk of tire blow out and decrease the tire wear.

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

7.2 FUTURE SCOPE

With the help of transit flow analysis, we can get more accurate value of the turbulent flow. The next step is try to implement the fins in aluminum rim to reduce the cost of manufacturing ,With the help of transit analysis we can make the fins more effective and even reduce the number of fins and change the angle of fin placement inside the rim so that more air can be pushed from the rim. The sizing of the fins can be reduce with more accurate analysis. We can also determine the carcass tire temperature and model analysis can be done for the tire.

CHAPTER 8

REFERENCES

- [1] Chen jerry han-chieh, European Patent No: EP 3 578 386 A1, Heat dissipation structure for composite material wheel rim, Dec 11 2019.
- [2] He Kaiwen, Patent No: CN104669925A, Wheel rim with heat dissipating structure, Dec 14 2011.
- [3] Chao-Ying Chen, Patent No: TW200831311A, Rim with the structure of ventilation and heat dissipation, Mar 21 2010.
- [4] Huang Fangfu, Patent No: CN102275459A, Heat-dissipating wheel hub for automobiles, May 24 2017.
- [5] Casba cserea, look behind the tire hysteria, the steering column, Dec 1, 2000.
- [6] Chen Shian Li Xuan He Ren Jiang, Patent No: CN102407729A, Wheel casing for forced ventilation/heat radiation to rim and brake, Feb 12 2014.
- [7] AZOM, Material properties of magnesium alloy az31b, Nov 13 2012.
- [8] Carpal aluminium, Aluminium and aluminium alloy characteristic and properties, May 01 2008.
- [9] Anthony Starks, design calculation of wheel rim, X-engineer.org.
- [10] Emmanouilides, Krystina, Heat transfer analysis of formula 1 wheel assembly, June 05 2015.
- [11] Prof Mit Patel, Mansi Raval, Jenish Patel, Paper No: IJEDR1604140, Design of disc brake's rotor, June 15 2016.
- [12] Falvio Farroni, MDPI Article, A real time thermal model for the analysis of tire/road interaction, Feb 28 2020.
- [13] F.S. conant, Tire Temperatures, Rubber chenistry and technology, Resarch Article, May 01 1971.