IMPACT ANALYSIS ON ALUMINIUM AND MAGNESIUM 5 SPOKE ALLOY WHEEL USING FEA

Abhinas.k. Faisal [1], Niju Jayan [2]

[1, 2]UG Scholars, Al Azhar College of Engineering and Technology, Thodupuzha, India

---***---

Abstract- *The wheel rim is the one of the most critical components in that vehicle. So, a number of tests have to be performed on it so that it could meet the safety requirement, But the inspection of wheel during the development and physical testing are both time consuming and costly. So, Finite Element analysis (FEA) has developed as a major tool for their analysis. In this paper, we studied the simulation of impact test for cast aluminium alloy and magnesium alloy to find the difference between them in the value total deformation, equivalent stress and strain, life, damage, safety factor, etc. during an impact. This test is carried out by using 3D explicit finite element analysis. The modelling of 5 spoke wheel has been done using SOLIDWORKS 2022 SP2.0 and analysis is done by ANSYS 2023 R1.*

Key words: *Aluminium alloy wheel, magnesium alloy wheel, impact analysis, tensile strength, 5 spoke alloy wheel, finite element analysis, ANSYS, SOLIDWORKS.*

1. INTRIDUCTION

In automotive industry, alloy wheels are wheels that are made from an alloy of aluminium or magnesium. Alloy are mixtures of a metal and other elements. They generally provide greater strength over pure metals, which are usually much softer and more ductile. Alloy of aluminium or magnesium are typically lighter for the same strength, provide better heat conduction, and often produce improved cosmetic appearance over steel wheels. Although steel, the most common material used in wheel production, is an alloy of iron and carbon, the term “alloy wheel” is usually reserved for wheels made from nonferrous alloys.

The earliest light-alloy wheels were made of magnesium alloys. Although they lost favour on common vehicles, they remained popular through the 1960s, albeit in very limited numbers. In the mid-to-late 1960s, aluminium-casting refinements allowed the manufacture of safer wheels that were not as brittle. Until this time, most aluminium wheels suffered from low ductility, usually ranging from 2-3% elongation. Because light-alloy wheels at the time were often made of magnesium (often referred to as "mags"), these early wheel failures were later attributed to magnesium's low ductility, when in many instances these wheels were poorly cast aluminium alloy wheels. Once these aluminium casting improvements were more widely adopted, the aluminium wheel took the place of magnesium as low cost, high-performance wheels for motorsports.

2. MATERIAL PROPERTIES

2.1 Aluminium Alloy

The most widely used aluminium alloy for the production of wheels by low pressure die casting is the A356 alloy. A356 aluminium alloy is made up of 92.05% Aluminium, 7% Silicon, 0.35% Magnesium, 0.20% Iron, 0.20% Copper, 0.10% Manganese and 0.10% Zinc. It is lightweight and extremely corrosion resistant like stainless steel. A356 alloys naturally have an elastic modulus of about 70 GPa, which is about one-third of the elastic modulus of the majority kinds of steel and steel alloys. Therefore, for a specified load, a part of an A356 alloy will experience a greater elastic deformation than a steel part of the identical size and shape. Though there are A356 alloys with somewhat-higher tensile strengths than the usually used kinds of steel. Aluminium alloys are far more resistant to rust and corrosion than ordinary metals. This makes the cost of ownership much lower over time. It also allows you to worry less about a wheel related malfunction due to corrosion and deterioration.

PROPERTIES	A356 ALUMINIUM ALLOY
Elongation at Break	3-6%
Fatigue Strength	50-90 MPa
Shear Modulus	26 GPa
Ultimate Tensile Strength	160-270 MPa
Yield Tensile Strength	83-200 MPa
Melting Onset	570 °C
Thermal Conductivity	150 W/m-k
Thermal Expansion	21 µm/m-k
Density	2.6 g/cm3

Table –1: Properties of A356 Aluminium Alloy

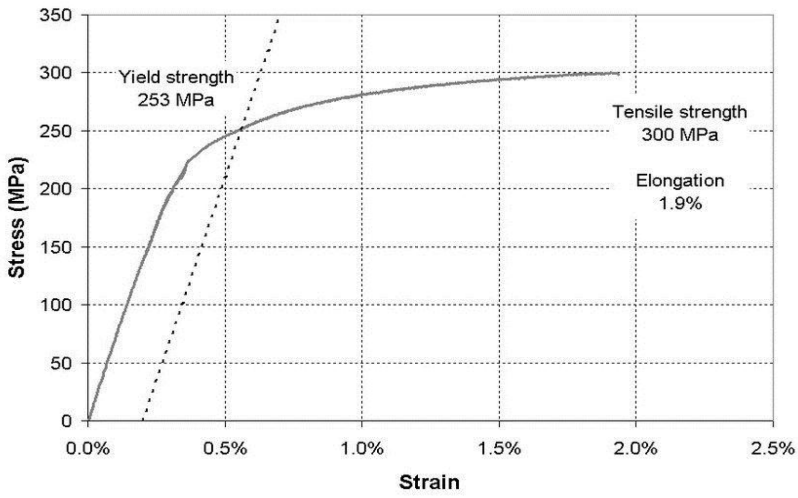

Chart -1: Stress-Strain Curve of A356 Aluminium Alloy

2.2 Magnesium Alloy

The most commonly used magnesium alloy for wheel manufacturing is AZ91 magnesium alloy. An AZ91 Magnesium alloy consists of Aluminium (8.3% - 9.7%), Silicon (0% - 0.5%), Manganese (0% - 0.2%), Zinc (0.35% - 1%), Magnesium (Bal) as primary components. Additionally, AZ91 alloy may have Copper (0% - 0.1%) in trace amounts. AZ91 magnesium alloy have many advantages including low density, high specific strength and stiffness, excellent machinability and good recyclability, which generates application value in many fields such as aerospace, automotive, and telecommunication industries. AZ91 Magnesium alloys are materials of interest mostly due to their high strength-to-weight ratios, exceptional machinability and low cost. They have a low specific gravity of 1.74 g/cm3 and a relatively low Youngs modulus (42 GPa) compared to other common alloys such as aluminium or steel alloys. They suffer, however, from brittleness and poor formability at room temperature. Their formability increases with increasing temperature, but that requires high energy. Furthermore, studies have shown that formability can be enhanced at the expense of strength, by weakening the basal texture of the Mg alloys.

PROPERTIES	AZ91 MAGNESIUM ALLOY
Elongation at Break	4 – 10%
Fatigue Strength	60 – 85 MPa
Shear Modulus	17 GPa
Ultimate Tensile Strength	160 – 210 MPa
Yield Tensile Strength	80 – 180 MPa
Melting Onset	431°C
Thermal Conductivity	51.2 W/m-k
Thermal Expansion	26 µm/m-°C
Density	1.81 g/cm3

Table -2: Properties of AZ91 Magnesium Alloy

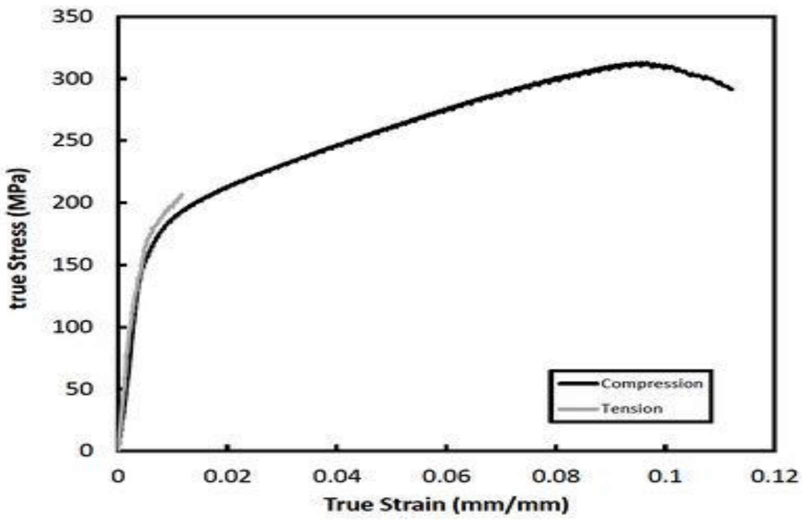

Chart -2: Stress-Strain Curve of AZ91 Magnesium Alloy

3. MODEL OF 5 SPOKE ALLOY WHEEL

The different steps that followed for a new wheel rim design are as follows,

1. Drawing rim profile

2. Drawing spoke profile

3. Drawing lug nut hole

4 Edge Filling

5. Review the Wheel Rim design

Save the model with an IGES file format by this the model geometry should cleanly import into ANSYS for the analysis process.

Fig -1: Model Of 5 Spoke Alloy Wheel Using SOLIDWORKS

4. FINITE ELEMENT ANALYSIS USING ANSYS

The modelling of 5 spoke alloy wheel is carried out in SOLIDWORKS software, and the it is converted into IGES/STP format. It is then imported to ANSYS and its finite element analysis was done in ANSYS.

The mesh is generated (Fine meshing), The boundary conditions are applied to the model for the impact test those are: fixed supports, remote force and pressure.

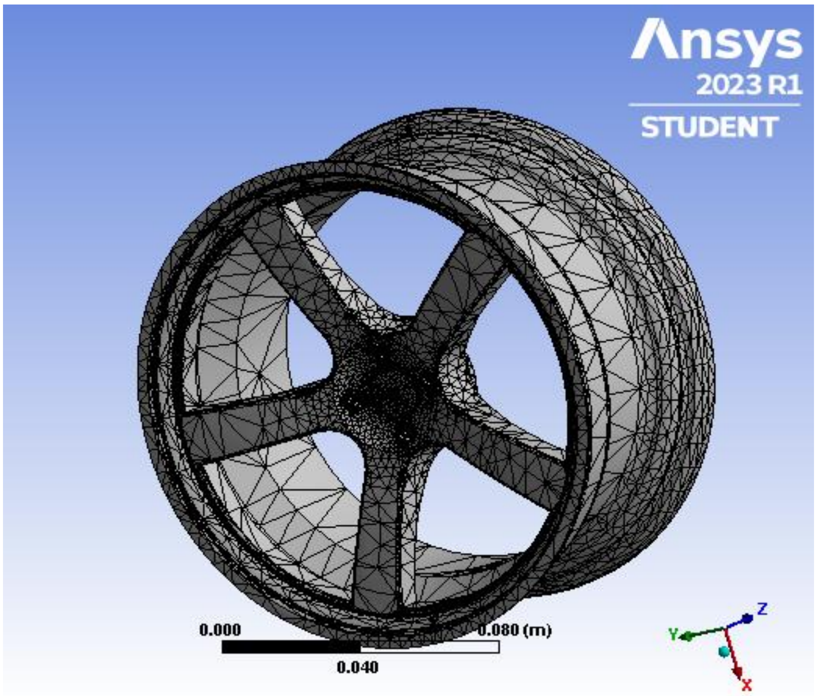

Fig -2: Meshing in Alloy Wheel

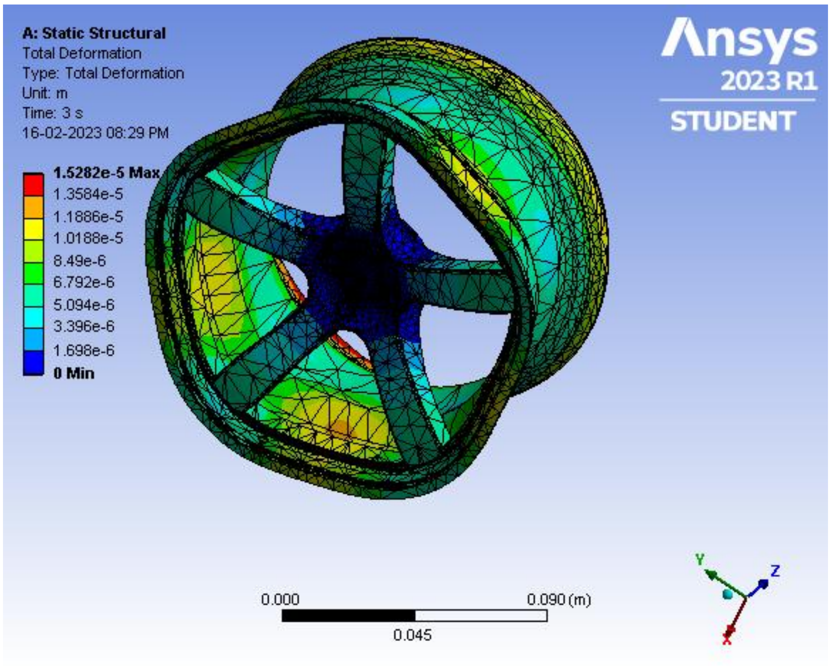

Fig -3: Deformation in 5 Spoke Aluminium Alloy Wheel

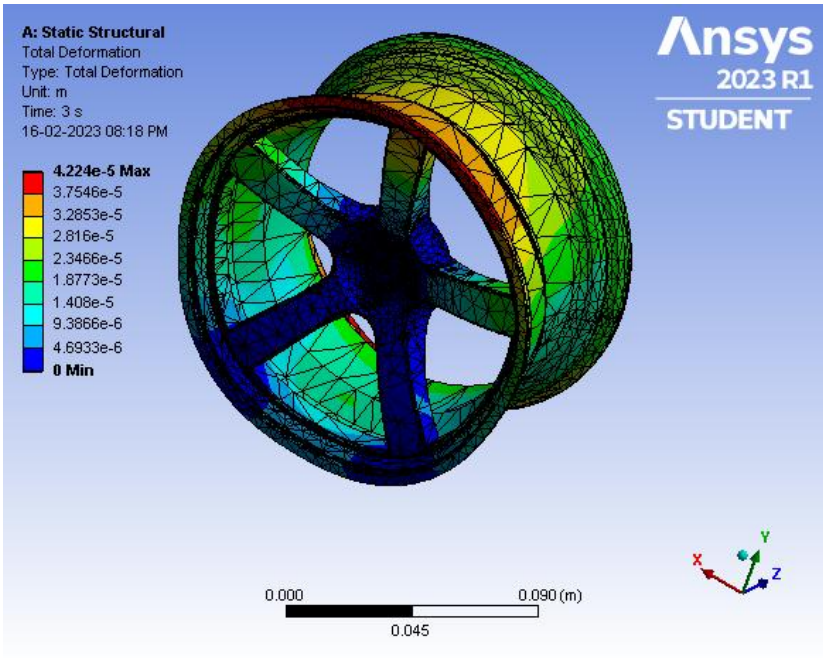

Fig -4: Deformation in 5 Spoke Magnesium Alloy Wheel

5. RESULT AND COMPARISON OF Al AND Mg ALLOY WHEEL

Pressure [MPa]	Deformation		
	Minimum [m]	Maximum [m]	Average [m]
0.2	0.	7.6944e-006	2.3726e-006
0.3		1.1488e-005	3.5384e-006
0.4		1.5282e-005	4.7061e-006

Pressure [MPa]	Equivalent Elastic Strain		
	Minimum [m/m]	Maximum [m/m]	Average [m/m]
0.2	6.6692e-007	2.3731e-004	4.3357e-005
0.3	1.1333e-006	2.5461e-004	5.8778e-005
0.4	1.9482e-006	3.3756e-004	7.4412e-005

Pressure [MPa]	Equivalent Stress		
	Minimum [Pa]	Maximum [Pa]	Average [Pa]
0.2	16587	1.6848e+007	2.9625e+006
0.3	40534	1.788e+007	4.0273e+006
0.4	85862	2.3708e+007	5.1058e+006

Table -3: 5 Spoke Aluminium Alloy Wheel

Pressure [MPa]	Deformation		
	Minimum [m]	Maximum [m]	Average [m]
0.2	0.	2.136e-005	6.3276e-006
0.3		3.18e-005	9.3207e-006
0.4		4.224e-005	1.2317e-005

Pressure [MPa]	Equivalent Elastic Strain		
	Minimum [m/m]	Maximum [m/m]	Average [m/m]
0.2	1.1436e-006	5.1311e-004	7.5364e-005
0.3	1.4002e-006	5.5435e-004	1.0383e-004
0.4	1.7344e-006	6.6742e-004	1.3277e-004

Pressure [MPa]	Equivalent Stress		
	Minimum [Pa]	Maximum [Pa]	Average [Pa]
0.2	40461	2.3089e+007	3.257e+006
0.3	46979	2.4945e+007	4.4989e+006
0.4	57740	3.0031e+007	5.7615e+006

Table -4: 5 Spoke Magnesium Alloy Wheel

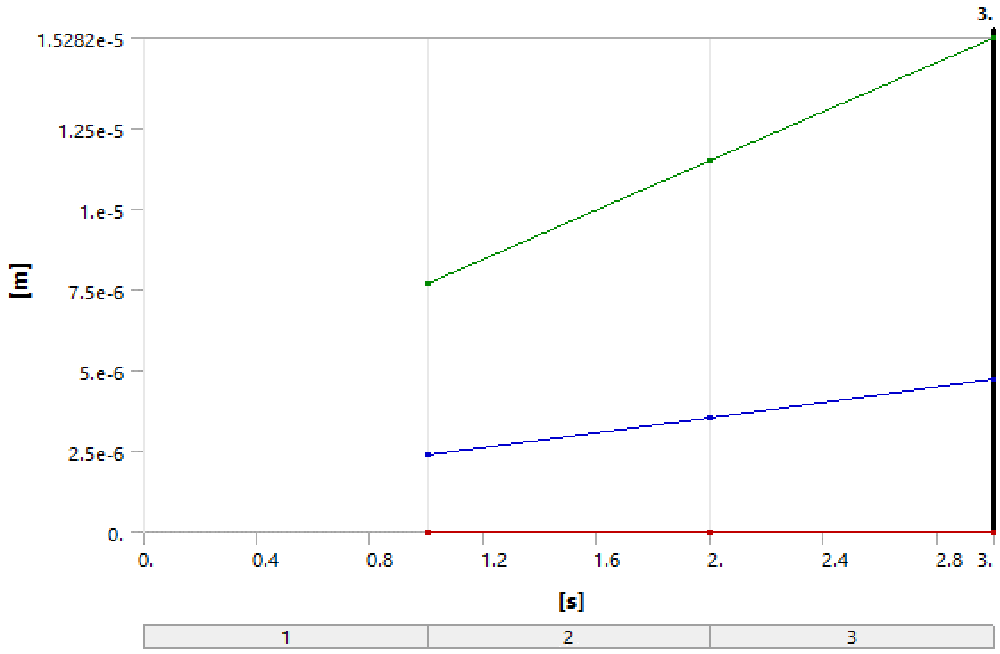

Chart -3: Total Deformation on 5 Spoke Mg and AL Alloy Wheel

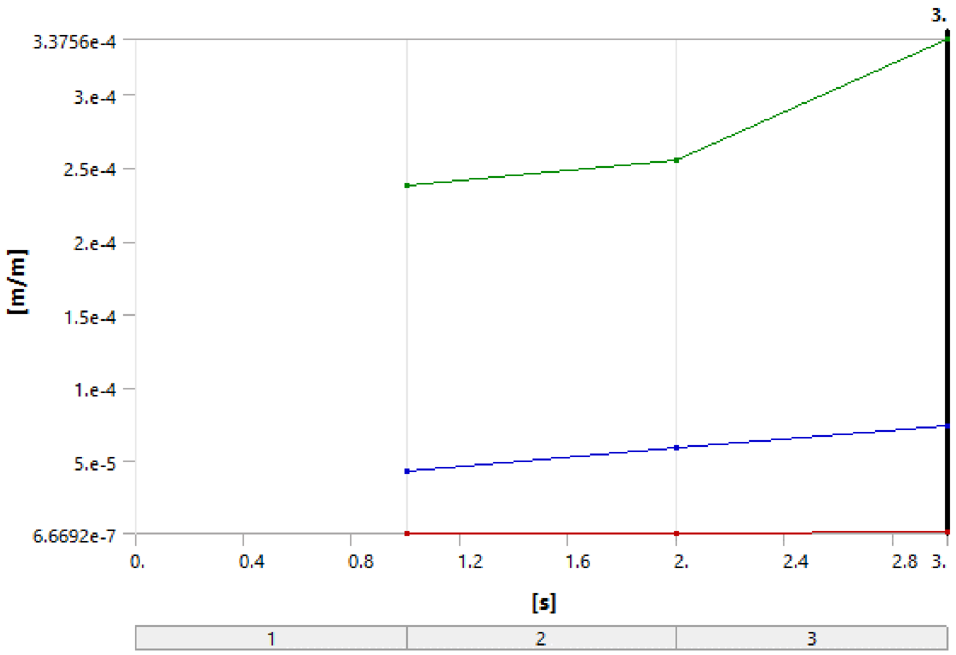

Chart -4: Equivalent Elastic Strain on 5 Spoke Mg and AL Alloy Wheel

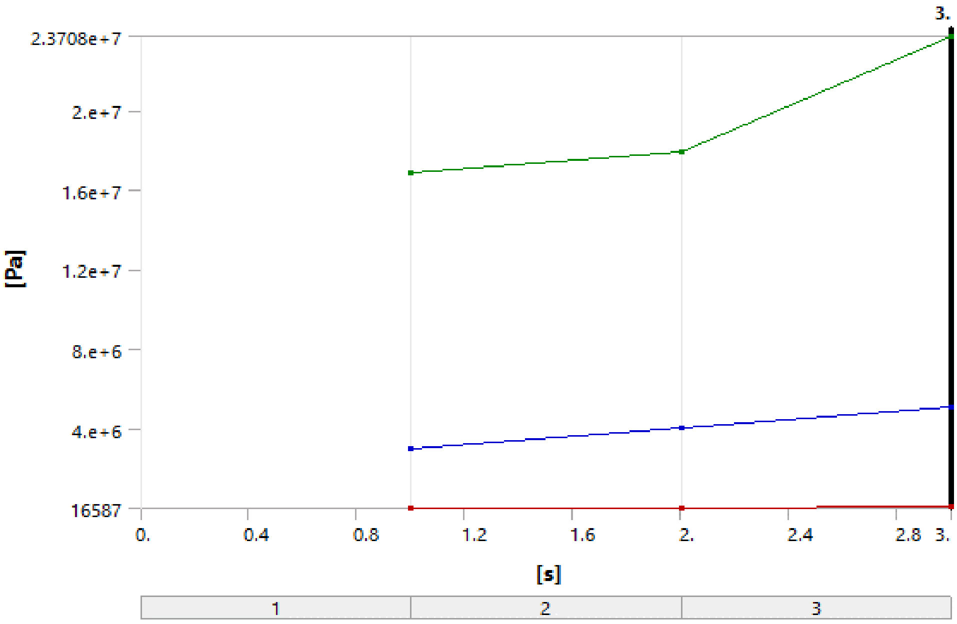

Chart -5: Equivalent Stress on 5 Spoke Mg and AL Alloy Wheel

6. CONCLUSION

Compared to magnesium wheels, aluminium wheels are more durable and will last longer than other materials. Aluminium wheels are stronger than magnesium wheels, with the latter being more delicate and more difficult to make. They are strong enough for use with your car without suffering significant wear and tear in the process. They come as standard on some vehicles, making them suitable for regular cars while other types are more suited to specialized cars, such as those used for racing. Magnesium wheels are light wheels, much lighter than steel or aluminium wheels. That means they will give better mileage for your car because there's less weight to move. You'll also find that they're less prone to bend or buckle if you dip into a pot hole. This lighter weight requires less wheel balancing over the life of the magnesium wheels. It also translates into more responsive steering and handling, both of which are important factors in their favour. They corner very well with low profile tires. On the downside, once your magnesium wheels do bend, they can't be straightened again. Because of this you have to be more thoughtful when you drive. Magnesium wheels are usually applied to racing cars as they provide slightly better strength/weight ratio than aluminium alloys. The stress and strain formation are more in magnesium alloy wheel than aluminium alloy wheel. Aluminium Alloy's tensile strength is 230 Mpa, Magnesium Alloy is 220 Mpa. The same volume of magnesium alloy material is not as strong as aluminium alloy.

7. REFERENCES

1. Mustafa Kemal Kulekci, "Magnesium and its alloys applications in automotive industry", 2007.
2. T. Siva Prasad, T. Krishnaiah, J.Md. Iliyas, M. Jayapal Reddy, "A review on modelling and analysis of car wheel rim using CATIA & ANSYS", May 2014.
3. K. Venkateswara Rao and Dr. T. Dharmaraju, "Analysis of wheel rim using finite element method", 2014.
4. M. Sabri et.al, "Deformation behaviour analysis of car wheel rim under different loading using finite element method", March 2015.
5. Karthik A.S, Praveen S. Ullagaddi, "Static analysis of alloy wheel using FEA", May 2016.
6. Sahil Bandral, Satnam Singh, "Impact analysis of car alloy wheel rim using finite element analysis", 2018.
7. Xin Jiang, Hai Lui, Rui Lyu, "Optimization of magnesium alloy wheel dynamic impact performance", Sep 2019.

8. Suraj L. Gondhali et.al, "Static structural analysis of car rim by finite element method", 2019.

9. P Santosh Reddy, Dr. R Ramesh, "Analysis of alloy wheel rim styling structure using aluminium and magnesium alloys", Aug 2020.

10. Md Rahamath Ansari, S Rajesh, P Rama Murty Raju, "Sinite element analysis on alloy wheel using different materials", Oct 2021.

11. Aaksh patil, dr. Suman sharma, "Design and analysis of alloy wheel rim using finite element analysis", December 2022.

12. S. Rajasekaran, "Finite element analysis in engineering design", S. Chand & Company LTD.

13. C S Krishnamoorthy, "Finite element analysis theory and programming 2nd edition".

14. R K Rajput, "Automobile engineering", Laxmi publications (P) LTD.