

Design and Analysis of Two Wheeler Alloy Wheel Rim Using Composite Materials

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ABSTRACT: Alloy wheels are automobile wheels which are made from an alloy of aluminium or magnesium metals (or sometimes a mixture of both). Alloy wheels differ from normal steel wheels because of their lighter weight, which improves the speed of the vehicle, however some alloy wheels are heavier than the equivalent size steel wheel. In the design of automobile, the industry is exploring polymeric composite material is suggested as the best material to replace the aluminium alloy to reduce the weight without significant decrease in vehicle quality and reliability. By using this material the mass optimization is achieved. The reduction of weight of a vehicle directly impacts its fuel consumption. Thus in this project work the entire wheel design of two wheeler was modelled and analyzed by applying different loads and pressures on the following materials:-Aluminium Alloy, PEEK(polyether ether ketone) with 30% Glass Fiber, PEEK – 90 HMF 20, PEEK – 90 HMF 40. By comparing the results, Modification of materials and design can be considered for future development of two wheeler rim. This paper deals with the static & fatigue analysis of the wheel. A typical alloy wheel configuration of HONDA CB SHINE commercial vehicle is chosen for study. Finite element analysis has been carried out to determine the safe stresses and displacements using NX NASTRAN software.

KEYWORDS: Composite material, PEEK, HMF, HONDA CB SHINE, NX NASTRAN,

I. INTRODUCTION

The wheel is a part that enables efficient movement of an object across a surface where there is a force pressing the object to the surface. The spoke wheel rim assembly contributes the major weight addition in motorcycle after engine. To overcome this disadvantage alloy wheels are invented. While comparing all alloy materials aluminium alloy is the best of other alloy materials. The automotive industry faces increasing pressure to maximize performance while minimizing weight and cost to produce more fuel efficient vehicles.

Composite materials: A new kind of material which is formed due to combination of two or more metals or non-metals is known as composite materials. Generally composite materials are lighter and stronger than conventional metals. Thermoplastic composite materials consist of thermoplastic resins as matrix, reinforcement with traditional fibers as thermo sets matrix. They have shown great promise as materials for current and future automotive, aerospace and industrial applications. Composite material wheel is different from the light alloy wheel, and it is developed mainly for low weight. However this wheel has inadequate consistency against heat and for best strength. PEEK (polyether ether ketone) polymer continues to successfully replace steel, aluminium, bronze, titanium, and other high performance materials, because it offers an ideal combination of mechanical, thermal and aluminium spokes logical properties, combined with excellent resistance to grease, oils, acids and all other automotive fluids. PEEK is an ideal replacement for Aluminium alloy. PEEK is particularly useful in the automobile industry for its weight. Their Types are 1.PEEK with 30% Glass fiber, 2.PEEK-90 HMF 20% Carbon fiber and 3.PEEK-90 HMF 40% Carbon fiber

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II. LITERATURE REVIEW

This work comprises of composite materials and two wheeler rim, hence there are many journals, books and websites were referred. Since there is no research work and other studies about the designing and analysis of two wheeler rim for a commercial vehicle. This induces an idea to analyze a commercial vehicle. A typical commercial vehicle HONDA CB SHINE was chosen for this project work. The material properties, design calculations and analysis methods are taken from the following base papers.

2.1 Base Paper:

1. Ravi Lidoriya, SanjayChaudhary and Anil Kumar Mohopatra, "Design and Analysis of Aluminium Alloy Wheel using PEEK Material", International Journal of Mechanical Engineering and Research. ISSN No. 2249-0019, Volume 3, Number 5 (2013), pp. 503-516.

The above project is taken as the base project, concluded that PEEK 90HMF20 is the best material for the replacement of aluminium alloy by using the common dimensions and modified dimensions. From this project, material properties of original material and composite materials are referred.

2. M. Saran Theja, M. Vamsi Krishna, "Structural and Fatigue Analysis of Two Wheeler Lighter Weight Alloy Wheel", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE). e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 8, Issue 2 (Jul. - Aug. 2013), PP 35-45.

From the above project, the theoretical calculations to determine the maximum stress and displacements occurs during the analysis results are referred.

III. DESIGN PROCEDURE FOR TWO WHEELER RIM

3.1 Modelling of Wheel Rim:

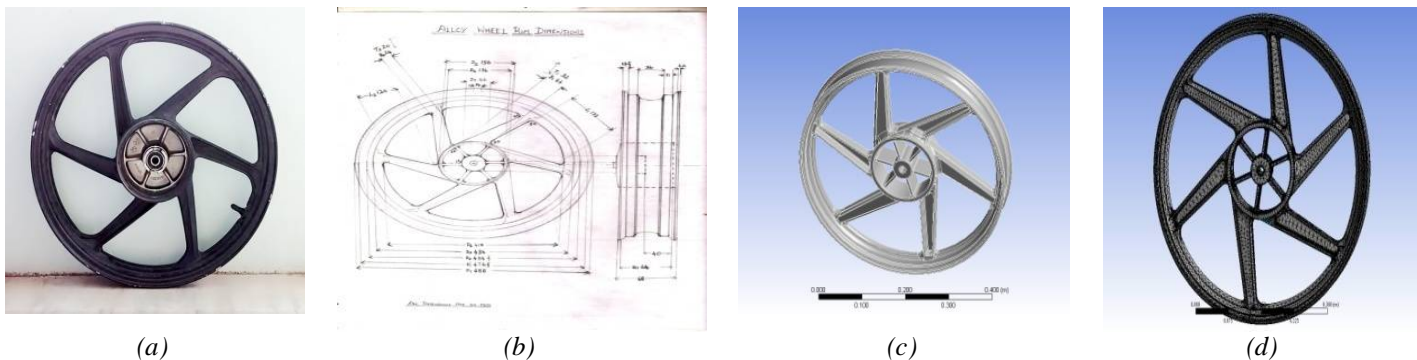


Fig. 1 Modelling of Wheel Rim (a) Wheel rim used (b) Dimensions of Wheel Rim (c) 3D part Model of Wheel rim (d) 3D Meshing of Wheel Rim

3.2 Theoretical Calculation:

Applying Loads:

Mass of Bike, Dead Weight of Bike = 143kg Other Loads = 20 Kg
 Load 0 = Total Gross Weight = 143 + 20 = 163 Kg = 163X 9.81 N = 1599.03N
 Load 1 = (163+65) kg = 228 kg * 9.81 = 2236.68 N (Rider) (Average weight of a man = 65kg)
 Load 2 = (163+65X2) kg = 293kg * 9.81 = 2874.33 N (Rider + 1 Person) up to 4 persons (Load 5).

Applying Pressures:

Number of Wheels: 2 Weight of the wheel rim = 5.86 kg.
 Rim surface area which is having 6 spokes: $A_6 = 48299.69 \text{ mm}^2$
 Pressure on the each rim for load 0 = 0.02321 N/mm^2 up to Load 5

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Tabulation of Loads and Pressures:

Table 1 Loads and Pressures Applied

No. of Loads	N	No. of Pressures by Load	N/mm ²
Load 0	1599.03	Pressure 0	0.02321
Load 1	2236.68	Pressure 1	0.0324
Load 2	2874.33	Pressure 2	0.0417
Load 3	3511.98	Pressure 3	0.0509
Load 4	4149.63	Pressure 4	0.0601
Load 5	4787.28	Pressure 5	0.0694

IV. ANALYSIS AND RESULTS


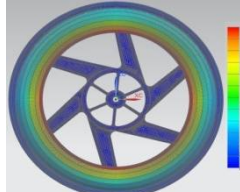
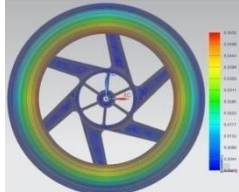
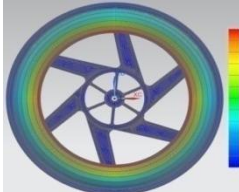
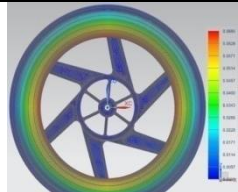

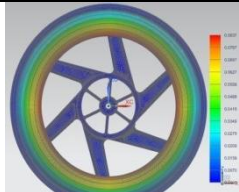

4.1 Analysis Data of Aluminium Alloy:

Table 2 Mechanical Properties of Aluminium Alloy

Mechanical Properties	Value	Units
Density (ρ)	2770	Kg m ⁻³
Coefficient of Thermal Expansion	0.000023	C ⁻¹
Specific Heat	875	Jkg ⁻¹ C ⁻¹
Compressive Yield Strength	2800*10 ⁵	Pa
Tensile Ultimate Strength	3100	Pa
Reference Temperature	22	C
Young's Modulus (E)	7.1*10 ¹⁰	Pa
Shear Modulus (G)	2.6692*10 ¹⁰	Pa
Poisson's ratio (ν)	0.33	
Bulk Modulus	6.9608*10 ¹⁰	Pa

4.2 Analysis Results of Aluminium Alloy:

Table 3 Analysis Results of Aluminium Alloy

Load/Pressure	Displacement (mm)	Equivalent stress (Mpa)	Load/Pressure	Displacement (mm)	Equivalent Stress (Mpa)
Load 0 and Pressure 0			Load 1 and Pressure 1		
Load 2 and Pressure 2			Load 3 and Pressure 3		

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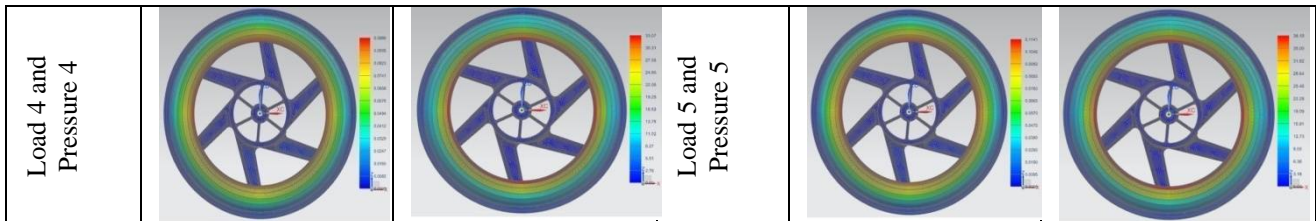


Table 4 Maximum Values From the Analysis Results

Load/ Pressure	Max. Displacement (mm)	Equivalent stress (Mpa)	Load/ Pressure	Max. Displacement (mm)	Equivalent Stress (Mpa)
At 0	0.0381	12.77	At 1	0.0532	17.83
At 2	0.0685	22.94	At 3	0.0837	28.01
At 4	0.0988	33.07	At 5	0.1141	38.19

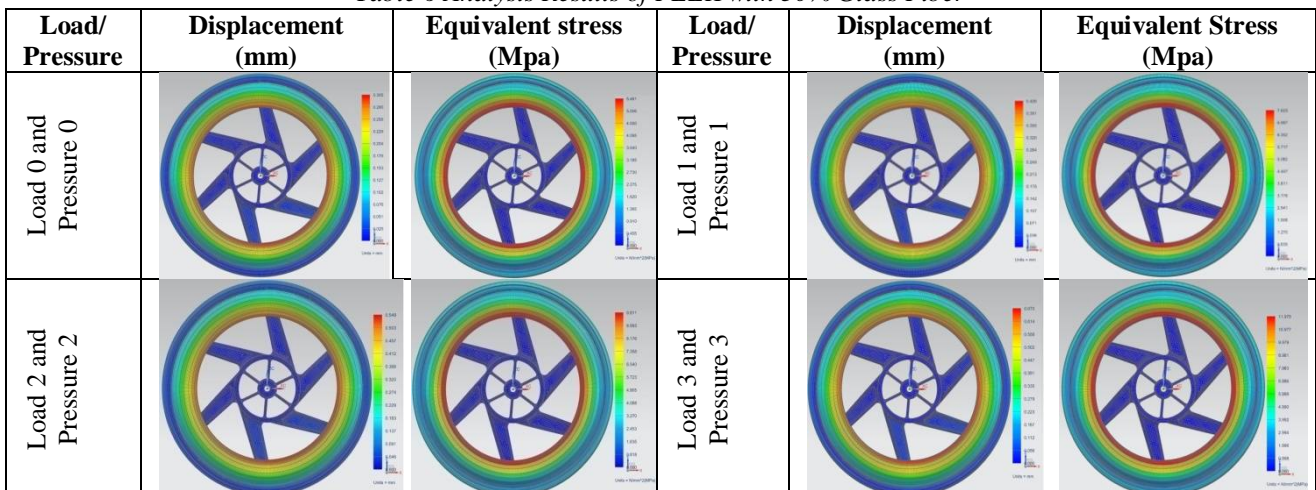
4.3 Analysis Data of PEEK with 30% Glass Fiber:

Table 5 Mechanical Properties of PEEK with 30% Glass Fiber

Mechanical Properties	Value	Units
Density	1320	Kg m ⁻³
Coefficient of Thermal Expansion	46.8*10 ⁻⁶	C ⁻¹
Specific Heat	1470*10 ⁶	Jkg ⁻¹ C ⁻¹
Compressive Yield Strength	118*10 ⁶	Pa
Tensile Ultimate Strength	100*10 ⁶	Pa
Reference Temperature	22	C
Young's Modulus	3.6*10 ⁹	Pa
Shear Modulus	1.4*10 ⁹	Pa
Poisson's ratio	0.39	
Bulk Modulus	6.9608*10 ¹⁰	Pa

4.4 Analysis Results of PEEK with 30% Glass Fiber:

Table 6 Analysis Results of PEEK with 30% Glass Fiber



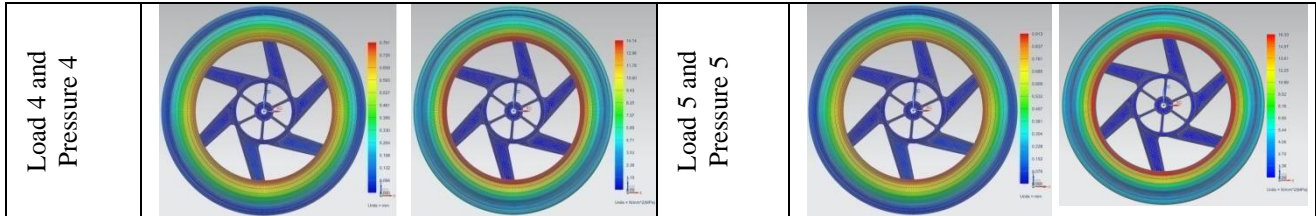


Table 7 Maximum Values From the Analysis Results

Load/ Pressure	Max. Displacement (mm)	Equivalent stress (Mpa)	Load/ Pressure	Max. Displacement (mm)	Equivalent Stress (Mpa)
At 0	0.305	5.461	At 1	0.426	7.623
At 2	0.549	9.811	At 3	0.670	11.975
At 4	0.791	14.14	At 5	0.913	16.33

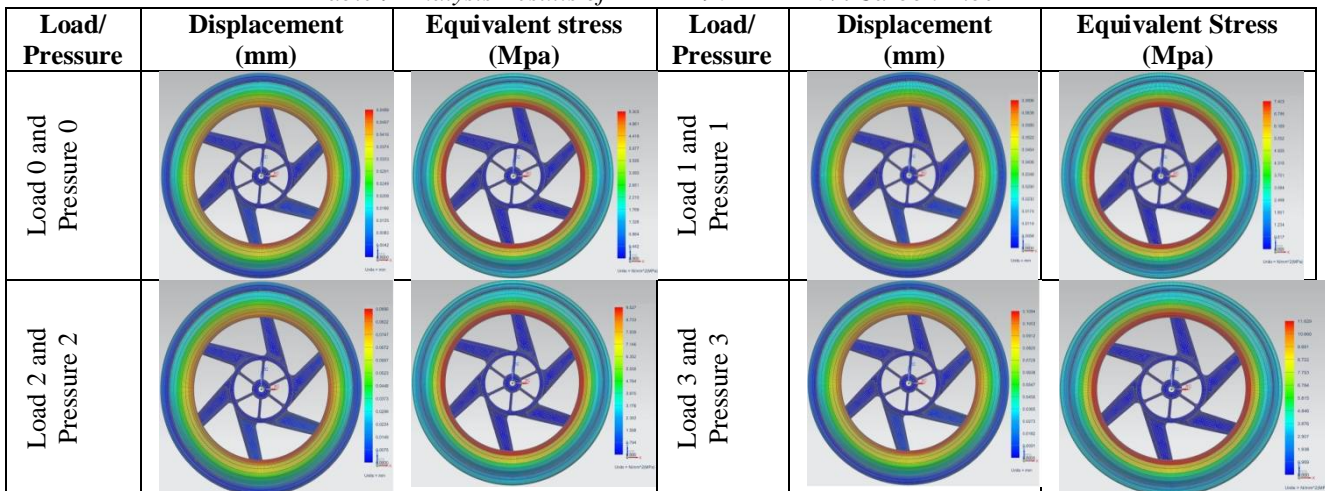
4.5 Analysis Data of PEEK – 90 HMF 20% Carbon Fiber:

Table 8 Mechanical Properties of PEEK - 90 HMF 20% Carbon Fiber

Mechanical Properties	Value	Units
Density	1370	Kg m ⁻³
Tensile Yield Strength	2.8*10 ⁸	Pa
Compressive Yield Strength	2.7*10 ⁸	Pa
Tensile Ultimate Strength	1*10 ⁸	Pa
Young's Modulus	2.2*10 ¹⁰	Pa
Shear Modulus	7.557*10 ⁹	Pa
Poisson's ratio	0.4556	
Bulk Modulus	8.2583*10 ¹⁰	Pa

4.6 Analysis Results of PEEK – 90 HMF 20% Carbon Fiber:

Table 9 Analysis Results of PEEK - 90 HMF 20% Carbon Fiber



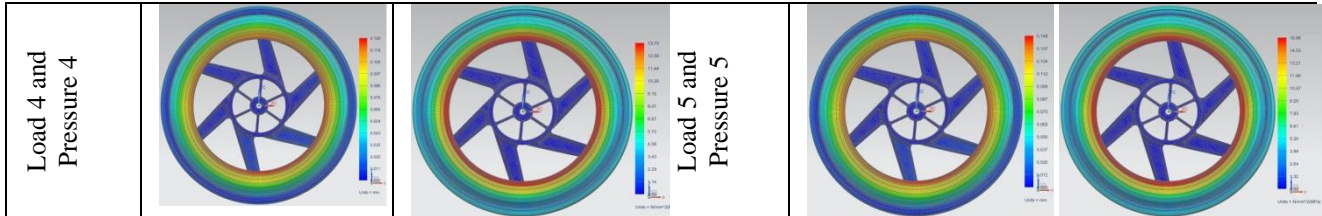


Table 10 Maximum Values From the Analysis Results

Load/ Pressure	Max. Displacement (mm)	Equivalent stress (Mpa)	Load/ Pressure	Max. Displacement (mm)	Equivalent Stress (Mpa)
At 0	0.0499	5.303	At 1	0.0696	7.403
At 2	0.0896	9.527	At 3	0.1094	11.629
At 4	0.129	13.73	At 5	0.149	15.86

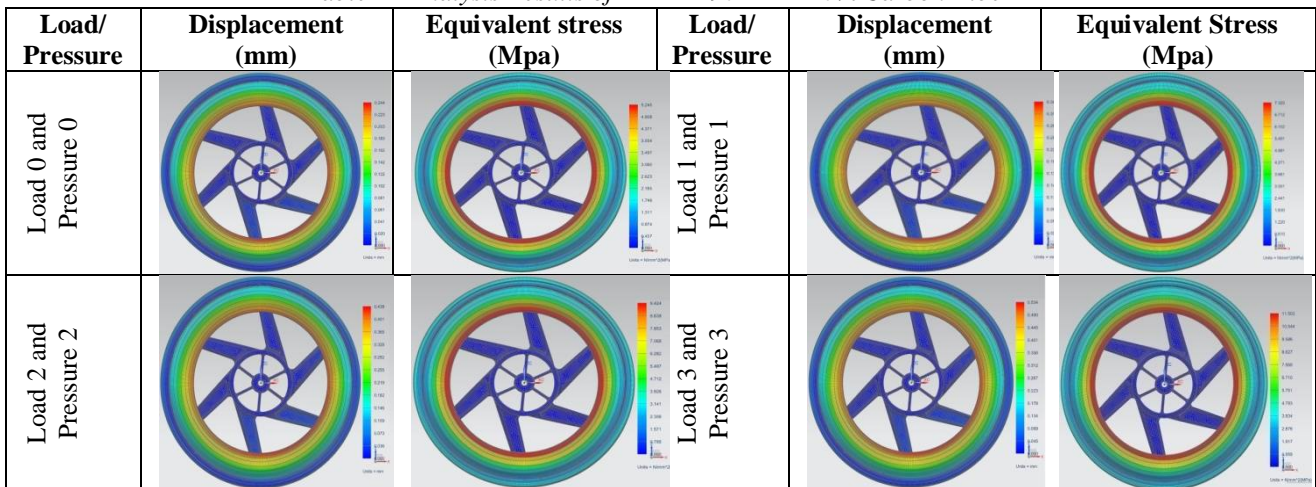
4.7 Analysis Data of PEEK – 90 HMF 40% Carbon Fiber:

Table 11 Mechanical Properties of PEEK - 90 HMF 40% Carbon Fiber

Mechanical Properties	Value	Units
Density	1450	Kg m ⁻³
Tensile Yield Strength	3.3*10 ⁹	Pa
Compressive Yield Strength	3.1*10 ⁸	Pa
Tensile Ultimate Strength	1*10 ⁸	Pa
Young's Modulus	4.5*10 ⁹	Pa
Shear Modulus	1.5203*10 ⁹	Pa
Poisson's ratio	0.48	
Bulk Modulus	3.75*10 ¹⁰	Pa

4.8 Analysis Results of PEEK – 90 HMF 40% Carbon Fiber:

Table 12 Analysis Results of PEEK - 90 HMF 40% Carbon Fiber



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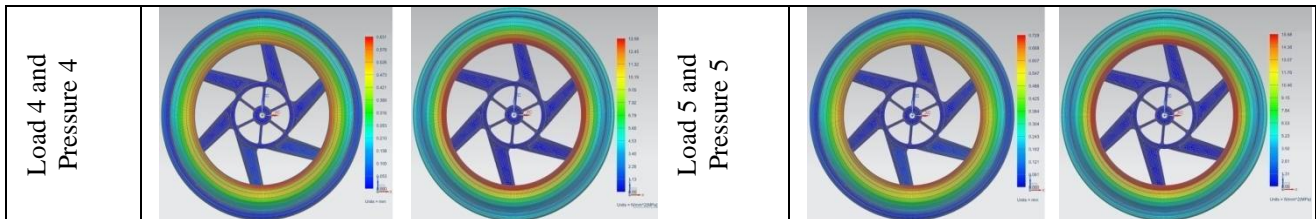


Table 13 Maximum Values From the Analysis Results

Load/ Pressure	Max. Displacement (mm)	Equivalent stress (Mpa)	Load/ Pressure	Max. Displacement (mm)	Equivalent Stress (Mpa)
At 0	0.244	5.245	At 1	0.340	7.322
At 2	0.438	9.424	At 3	0.534	11.503
At 4	0.631	13.58	At 5	0.729	15.68

V. RESULTS AND COMPARISON

Table 14 Comparison of Max. Displacement Results

Load/ Pressure	Aluminium Alloy (mm)	PEEK 30% C.F. (mm)	PEEK 90-HMF 20% G.F (mm)	PEEK 90-HMF 40% G.F (mm)
At 0	0.0381	0.305	0.0499	0.244
At 1	0.0532	0.426	0.0696	0.340
At 2	0.0685	0.549	0.0896	0.438
At 3	0.0837	0.670	0.1094	0.534
At 4	0.0988	0.791	0.129	0.631
At 5	0.1141	0.913	0.149	0.729

Table 15 Comparison of Max. Equivalent Stress Results

Load/ Pressure	Aluminium Alloy (N/mm ²)	PEEK 30% C.F. (N/mm ²)	PEEK 90-HMF 20% G.F (N/mm ²)	PEEK 90-HMF 40% G.F (N/mm ²)
At 0	12.77	5.461	5.303	5.245
At 1	17.83	7.623	7.403	7.322
At 2	22.94	9.811	9.527	9.424
At 3	28.01	11.975	11.629	11.503
At 4	33.07	14.14	13.73	13.58
At 5	38.19	16.33	15.86	15.68

VI. CONCLUSION

We have presented the original design of the Wheel rim of a commercial vehicle HONDA CB SHINE. The maximum values of stresses and displacements of aluminium alloy and different types of composite materials for various types of loads and pressures were analyzed and tabulated. While comparing the results we concluded that **aluminium alloy** is the suitable material for this commercial vehicle for the respective design. The proposed design is modeled using 3D parametric software Pro/Engineer, CREO 2.0 and analyzed using NX NASTRAN 8.5.

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VII. FUTURE SCOPE

In future we will analyze the performance of this two wheeler rim by varying the material or modifying the current design of wheel rim includes reducing the number of spokes, modifying the fillet radius at the intersection of the spoke and the hub in the present design and that modified design will be analyzed and compared under the same loading conditions. We believe this proposed design would anticipate further advances in future.

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