Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Structural Analysis of a ATV Wheel Hub

Mr. U. Yashvanth
Asst. Prof., Department of Automobile Engineering
Hindustan Institute of Technology & Science
Chennai, India 603103

Mr. Mohammad Raffi
Department of Automobile Engineering
Hindustan Institute of Technology & Science
Chennai, India 603103

Mr. Ganapa Raghu Vamsi Reddy
Department of Automobile Engineering
Hindustan Institute of Technology & Science
Chennai, India 603103

***Abstract*— Through the concept of automotive product design and analysis, designing and optimizing the wheel hub of a commercial ATV without affecting the strength of the wheel hub. The ATV wheel hub is been analyzed to meet the minimum factor of safety and to contribute more towards vehicle ride handling characteristics. The wheel hub is been optimized in order to reduce the scrub radius of the tire which is in contact with the road and to reduce the unsprang weight of the vehicle. This particular is been achieved without affecting strength and durability of the part. The strength and durability of the part is maintained same with usage of lightweight aero graded Aluminium 7075 T6 material rather than Cast Iron or Mild Steel which reduces nearly thirty six percentage of the wheel hub weight. The design is been optimized in such a way that it contributes more towards the ease of manufacturing and supports change in order of manufacturing.**

Keywords*— *Wheel Hub, All Terain Vehicle, Aluminium 7075 T6, Design optimization, Structural Analysis

I. INTRODUCTION

A wheel hub acts as an interference between the wheel and steering knuckle, which is also been called as uprights. The wheel of the vehicle is been fastened to the wheel hub, where the wheel hub have tendency to rotate freely inside the floating axle of the upright or the stub axle of the upright. The wheel hub may have either six or four wheel bolts to fasten wheel with the hub, which completely depends on the different design and manufacturers.

It is very crucial to design the wheel hub according to the pitch circle diameter of the wheel rim and to accommodate the disc brake rotor. The wheel hub even plays a vital role over the vehicle ride handling characteristics, which also have a major interference over the scrub radius of the tire. The thickness of the wheel hub may even alter the scrub radius of the tire without any change in the kingpin axis of the upright and offset of the wheel rim. In addition, it is very vital to have a wheel hub with strong wheel supporting points, which can take both linear and axial load acting on the wheel of the vehicle during dynamic condition. Hence, a proper analysis of the wheel hub to has carried out which have a tendency to withstand and adapt to all the road conditions and impact loads acting on the tire.

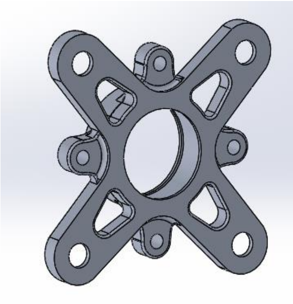


Fig 1: Front Isometric view Of Whee Hub.

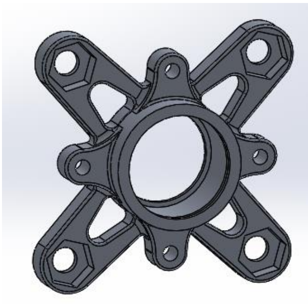


Fig 2: Rear Isometric View Of Wheel Hub.

The wheel hub is to be made to ensure that it have good resistivity to fatigue and shear stress application during the course of application of braking torque and the sudden impact of bump force over it at the same time.

II. MATERIAL SELECTION

The wheel hub is to be manufacture to take high axial, longitudinal and lateral loads from road surface. This above conditions can only be satisfied if the wheel hub material have high ultimate tensile strength and ultimate yield strength. Commercially the wheel hubs are manufactured using common available materials like Cast Iron, Wrought Iron and Mild Steel. Iron and Steel have required strength and other physical properties. The only concern using this material are the density of the material, which have higher contribution over the weight of the material. Manufacturing wheel hubs through the above-mentioned material increases the unsprang mass of the vehicle that may compromise the ride characteristics and can decrease the fuel efficiency of the vehicle.

In order to overcome this problem, aero graded Aluminium 7075 T6 material is been used to manufacture the wheel hub. The Al 7075 T6 have lower density compared to Iron and Steel are also lighter in weight. They even carry similar physical properties with uncompromised ultimate tensile and yield strength. Similarly, Aluminium have same machinability percentage to Iron and Steel. The difference in physical and mechanical properties of the material mentioned below in the table.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

A. Mild Steel

TABLE I: PHYSICAL AND MECHANICAL PROPERTIES OF MILD STEEL

PHYSICAL PROPERTIES		
QUANTITY	***VALUE***	***UNIT***
Density	7.87	g/cm^3
MECHANICAL PROPERTIES		
QUANTITY	***VALUE***	***UNIT***
Tensile strength, Ultimate	440	MPa
Tensile Strength, yield	370	MPa
Young's Modulus	205	GPa
Poisson Ratio	0.290	—

B. Cast Iron

TABLE II: PHYSICAL AND MECHANICAL PROPERTIES OF CAST IRON

PHYSICAL PROPERTIES		
QUANTITY	***VALUE***	***UNIT***
Density	7.87	g/cm^3
MECHANICAL PROPERTIES		
QUANTITY	***VALUE***	***UNIT***
Tensile strength, Ultimate	520-570	MPa
Tensile Strength, yield	540	MPa
Young's Modulus	200	GPa
Poisson Ratio	0.291	—

C. Aluminium 7075 T6 (Aero-Grade)

TABLE III: PHYSICAL AND MECHANICAL PROPERTIES OF AL 7075 T6

PHYSICAL PROPERTIES		
QUANTITY	***VALUE***	***UNIT***
Density	2.81	g/cm^3
MECHANICAL PROPERTIES		
QUANTITY	***VALUE***	***UNIT***
Tensile strength, Ultimate	572	MPa
Tensile Strength, yield	503	MPa
Young's Modulus	7.71	GPa
Poisson Ratio	0.33	—

TABLE III: CHEMICAL PROPERTIES OF AL 7075 T6

ELEMENT	***% WIEGHT***
Copper, Cu	1.2-2
Manganese, Mn	MAX 0.3
Silicon, Si	0.4 Max
Chromium, Cr	0.18 – 0.28
Magnesium, Mg	2.1-2.9
Titanium, Ti	0.2 Max
Zinc, Zn	5.1-6.1
Aluminum, Al	87.1-91.4

III. FORCES ACTING ON WHEEL HUB

There are four different types of forces acts on wheel hub during dynamic motion, which is been mentioned below in the following.

- Lateral Forces
- Bump Forces
- Braking Torque
- Driving Torque

The force acting on the wheel hub during the course of vehicle cornering exerts opposite cornering force on the wheel, which called as lateral force, exerted axially on the wheel. Similarly, the force exerted of the vehicle wheel during the course of jounce (Bump) known as bump force, exerted longitudinally on the wheel. The torque generated during the application of braking force over the disc rotor called as braking torque and the torque exerted on the wheel by the powertrain for the motion of the vehicle called as driving torque.

A diagrammatical representation of forces acting on the wheel hub is shown in the below figure,

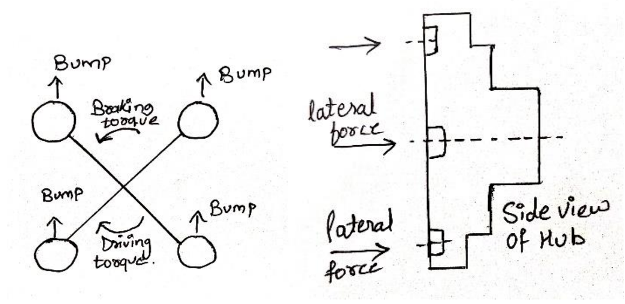


Fig 2: Free Body Diagram of Direction of Force Application on Wheel Hub

IV. CALCULATION

Note: *The following wheel hub is been designed for vehicle of maximum gross weight 300kgs and with maximum speed up to 60kmph*

A. Brake Torque

<u>Considerations:</u>

Diameter of Disc Rotor: 0.175m

Coefficient of Friction: 0.5

Piston Force: 1,970N

$$T = r * c * f$$

'T'= Braking Torque in newton meter **Nm**

'r'= Radius of rotor in meter **m**

'c'= Coefficient of friction between rotor and brake pad

'f'=Piston force on rotor in newton **N**

$$T = 172.37\text{Nm} \quad (1)$$

B. Lateral Force

<u>Considerations:</u>

Sprung Mass at Front: 150kgs

Velocity of Vehicle: 10.5m/s^2

Turning Radius: 2.5m

$$F = \frac{\text{sprung mass at front or Rear} * (\text{Vehicle Velocity})^2}{\text{Turning Radius of Vehicle}}$$

$$= \frac{150 * 10.5^2}{2.5} = 6{,}615\text{N} \quad (2)$$

C. Bump Force

The value of bump force is been considered from Suspension Analysis Parallel Wheel Travel of Quarter Car Model simulated in ADAMS Car 2017. Where all the weight of the suspension system, steering system, sprung mass and unsprang mass have been gave as input in the simulation, and simulated over a bump of 6 inch height. The graph displaying the force excreted on the wheel hub is been plotted and the same value is considered for wheel hub analysis.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

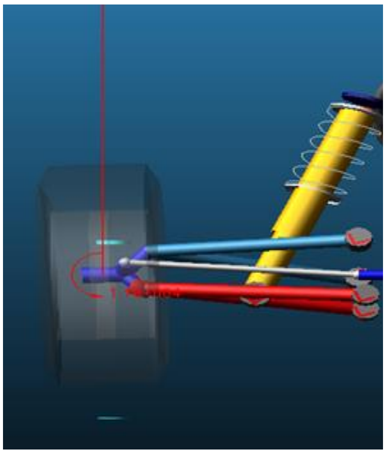


Fig 3: Suspension Parallel Wheel Travel Quarter car Model

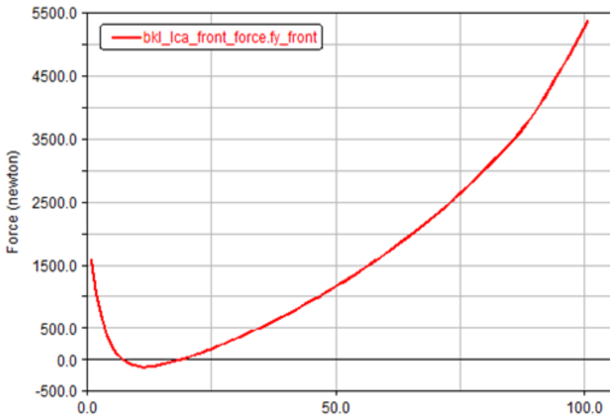


Fig 4: Bump Force Graph on Wheel Hub

The Bump Force Plotted is 5,550N (3)

V. CAD MODELLING

The wheel hub was designed in 3D modeling software namely Dassult's Solidworks 2018. The wheel hub is been designed for wheel rim pitch circle diameter of 110mm and disc rotor pitch circle diameter of 36mm. The hub is been designed for stub axle type wheel assembly. The total weight of the hub been measured as 140 grams. The hub can accumulate a single angular contact bearing of width 19mm and diameter 42mm.

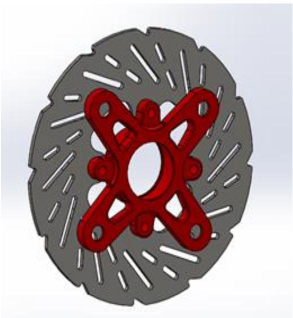


Fig 5: CAD Model Front View

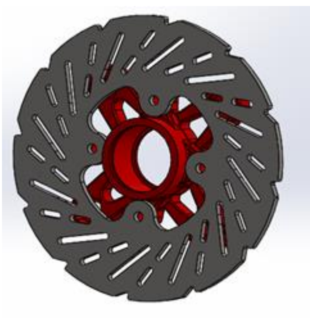


Fig 6: CAD Model Rear View

VI. ANALYSIS

The analysis of the above given CADD model is been carried out in ANSYS Workbench 2019. The main aim of the analysis is to find the stress formation on the hub during the action of load in all condition. The major conditions that been considered are Bump Force, Braking Torque and Lateral Force as calculated above. Depending on this loads the stress developed inside the hub measured with the amount of deformation and the maximum stress taking points predicted. Further, the stress taking points analyzed in order to check the factor of safety of the hub. The minimum factor of safety of the hub considered as 1.5. The hub should undergo minimum amount of deformation, which should be under the elastic limit of the hub material. In addition, the fatigue tool used to determine the life of the hub. The mesh considered and hub setup shown below.

A. Mesh Setup

Fig 6: Meshing of Hub

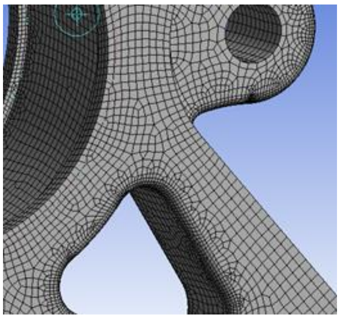


Fig 7: Mesh Preview on Hub

TABLE V: ANALYSIS PARAMETER SETUP

Parameters	***Values***
Analysis Type	Structural Analysis
Meshing Method	Beam Method
Element Type	Hex Dominant
Element Size	1mm
Mesh Type	3D
Number Of Elements	415514
Solver	Sparse Direct

B. Load Conditions and Analysis

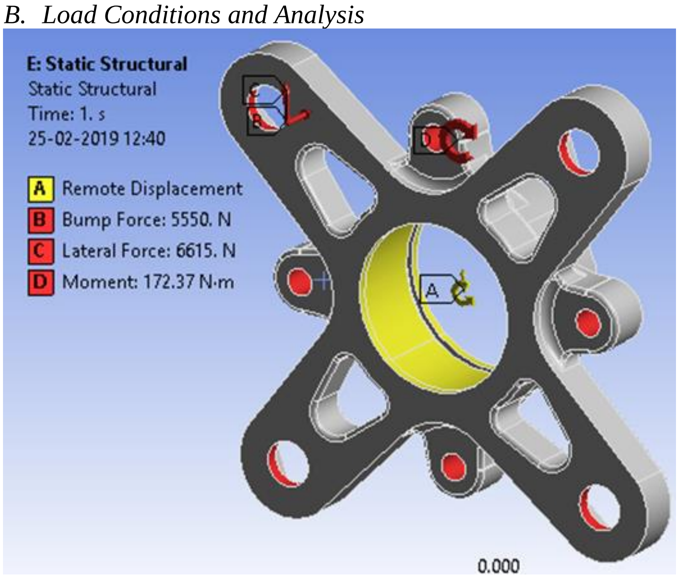


Fig 8: Analysis Setup Preview with All the Force Acting On the Wheel Hub

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 03, March-2019

Form the above figure 8, the bump force is represented as 'B' which is acting towards the y-axis of the hub and similarly the lateral force 'C' is acting towards z-axis of the wheel hub. The wheel hub displaced up to 154.2mm towards y-axis as a representation of hub traveling over a bump, and anti-clock wise rotation of 360° given representing the rotation of the hub. Braking torque 'D' given in clock-wise direction, which acts opposite to the direction of the rotation of the wheel hub.

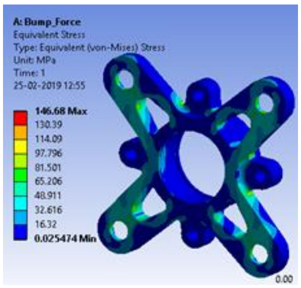


Fig 9: Stress Analysis Over Bump Force

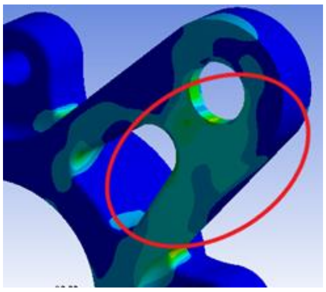


Fig 10: Stress Formation Area (Max Stress: 148Mpa)

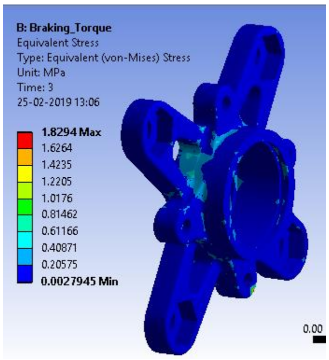


Fig 11: Stress Analysis Over Application of Brakes

Fig 12: Stress Taking Area (Max Stress: 1.8Mpa)

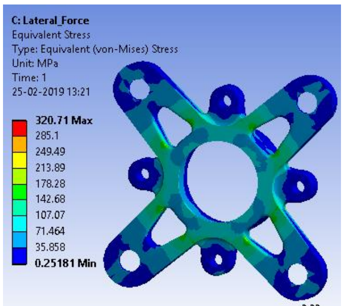


Fig 13: Stress Analysis over Application of Lateral Force

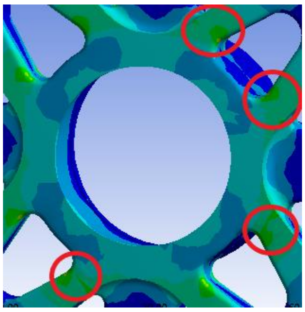


Fig 14: Stress Taking Area (Max Stress: 326Mpa)

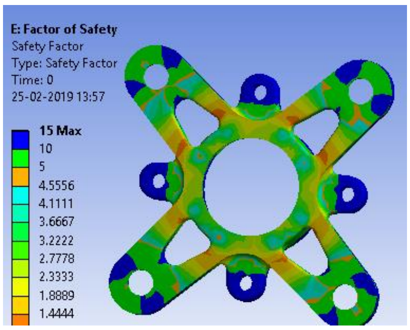
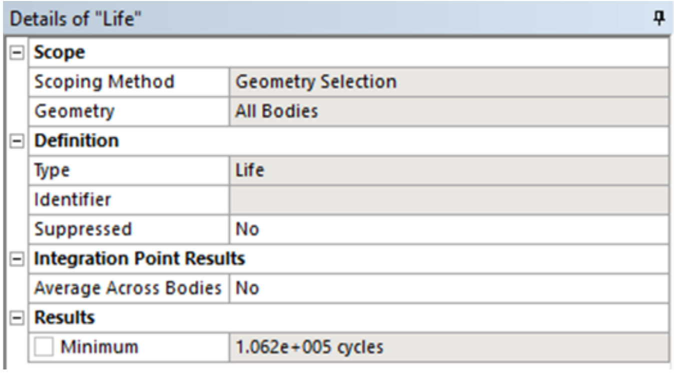


Fig 15: Safety Factor of Wheel Hub (Min: 2.33 & Max: 15)

The safety factor of the wheel hub was derived using Fatigue Tool option when all the forces where applied on the wheel hub. The life span of the hub have been predicted similarly using Fatigue Tool, where the same stress was continuously applied over the period of cycle till the wheel hub fails in functioning, as shown below in figure 15.



Details of "Life"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Life
Identifier	
Suppressed	No
Integration Point Results	
Average Across Bodies	No
Results	
Minimum	1.062e+005 cycles

Fig 16: Life Period of Wheel Hub using Fatigue Tool

VII. CONCLUSION

The wheel hub is been designed and analyzed under all off-roading conditions and plotted the safety factor with minimum and maximum deformation. The minimum life cycle of the part was predicted using stress analysis. The hub designed, in order to accumulate the disc brake rotor and the wheel rim. The hub satisfied the optimization in weight with uncompromised strength. Similarly contributes more towards optimum scrub radius, fuel economy and vehicle ride-handling characteristics. The results obtained through the analysis listed below in the table.

TABLE VI: RESULT

RESULTS	***MINIMUM***	***MAXIMUM***
Factor of Safety	2.33	15
Deformation (mm)	0.34	0.68
Von Mises Stress (Mpa)	0.625	326

REFERENCES

[1] Gillespie, Thomas d; "Fundamentals of vehicle dynamics", Warren dale, pa: society of automotive engineers Inc., year 1999
[2] Milliken, William f & Milliken, Douglas l; "Race car vehicle dynamics", warren dale, pa: society of automotive engineers Inc., year 1995
[3] Smith, Carroll; "Tune to win", Fallbrook, ca: aero publisher's Inc., year 1978
[4] Finite element analysis of Chevrolet front hub with the help of inventor – vol.02, issue-02, (February 2014) ISSN: 2321-1776.