Product Design and Development of Wheel Hub for an All-Terrain Vehicle (ATV)

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***Abstract* - Utilizing the Concept of Product Design and Development in order to Design, analyse, manufacture and test a wheel hub for an All Terrain Vehicle (ATV). Using Finite Element Analysis as a method for reduction of cost in terms of material and manufacturing, we compared the results of different designs with different materials and selected the optimum combination for manufacturing. Commercial vehicle industry is focusing on bringing quality products at competitive costs. While product weight has got a direct impact on the cost of the component, it also has an impact in the operating profits in case of a commercial vehicle. This project explains the use of the design and development of hub, the result of this project is that proposed hub which uses aluminium 6061 T6 as the material is approximately 35% less weight than the EN8 Mild Steel hub. The designed hub was effectively used in our Electric ATV which was subsequently approved by the panel judges of the SAE BAJA 2015. Based on the outputs obtained from the previous design, new practical designs were generated and FE analysis was carried out for the optimized design to verify the strength of the hub. This optimized material resulted in weight saving of the wheel hub without affecting the functional requirement.**

Keywords— Wheel hub; EN8 mild steel; style;Al6061 T6

I. INTRODUCTION

Product design is conceptualization of an idea about a product and transformation of the idea into a reality. To transform the idea into reality a specification about the product is prepared. This specification is prepared by considering different constraints such as production process, customer expectation, etc. In product design stage every aspects of the product are analyzed. Also, the final decision regarding the product is taken on the basis of the analysis. This decision can be any aspect related to the product, e.g. dimension and tolerances, type of material for every components etc.

This work is based on the design and analysis of front hub for weight reduction and increase the strength of hub by the help of Nastran / Patran. The weight and dimension of the hub must be as small as possible because of the un sprung weight which further reduce the rotational mass. Engineering component with optimum use of material and easy manufacturability is a direction where prior simulation through finite element method is found to be very useful. Wheel hub of car is one of the major and very important components and needs very good material and design in low cost and avoids failure. The three basic elements of a wheel are the hub, the spokes and the rim. Sometimes these components will be one piece, sometimes two or three. The hub is the center portion of the wheel and is the part where the wheel is attached to the suspension through the wheel carrier (or knuckle). The spokes radiate out from the hub and attach to the rim. The rim is the outer part of the wheel that holds the tyre. A hub assembly contains the wheel bearing and hub to mount the wheel to vehicle. It is located between the brake rotor and axle.

II. METHODOLOGY OF PRODUCT DESIGN

Product design is one of the most important and sensitive factor for an organization. Success or failure of the product decides company’s business, market share and reputation. So during design stage various factors related to the product needs to be addressed.

- Synthesis: Try to develop different alternatives
- Conceptualization: Draw sketches in exact scale for different alternatives
- Analysis: Analysis different alternatives with respect to operability, maintainability, inspection, assembling and dismantling issues, cost parameters, production methods, etc.
- Selection: Select the best alternative
- Basic engineering: Prepare layout in exact scale, calculate strength of components and select proper cost effective material.
- Detail design: Prepare detail engineering drawing for each component
- Prototype: If option is there, then prepare prototype and test it
- Manufacturing: If prototype is not made, then follow manufacturing steps and solve manufacturing problems and assembly problems, if any.
- Operation: collect feedback during actual operation of the new product. If any problem exists, try to provide design based solution. Also, implement lessons in the future design.
- Product development: If any modification can be done, implement the same in the next generation product.

III. DESIGN CONSIDERATION

- The bolt pattern, determined the by the type of rim.
- Size of the rim should be considered.
- Selection of material must be strong enough to take the weight of the car.
- Wheel bearing in the hub depends on ID and OD of spindle coming out of hub.
- The Type of lug nuts or bolts should be decided.

Wheel hub is highly street safety component which must not fail under the applied loading condition. The main parameters for design of wheel hub assembly are:

- Loading condition
- Manufacturing process
- Material behaviour

The influence of these parameters are interactive so material fatigue behaviour will be change depending upon the wheel hub design and loading condition:

Selection of material

Any engineering component has one or more functions (to support a load, to contain a pressure, to transmit heat, etc.).

- The designer must have an objective (to make it as cheap as possible, or as light as possible, or as safe as possible or some combination of these)
- Should know the environment in which the product is being used.
- The component must carry the given load without failure.
- It should function in a certain temperature range.
- The objective must be achieved subject to constraints.

A. *Material Property*

The two materials considered for the wheel hub are Aluminium 6061 T6 and EN8 Mild Steel. The properties of the materials are mentioned below:

Aluminium 6061 T6

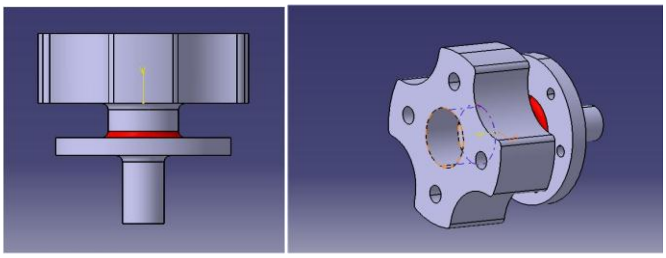
- Density: 2.7 g/cm3
- Brinell Hardness number: 95 BHN
- Rockwell Hardness number: 40 Ra
- Ultimate Tensile Strength: 310 MPa
- Tensile Yield Strength: 276 MPa
- Modulus of Elasticity : 68.9 GPa
- Poisson's ratio: 0.33
- Fatigue Strength: 96.5 MPa
- Melting Point: 582 - 652°C
- Specific Heat Capacity: 0.896 J/g-°C)

EN8 Mild Steel

- Density: 7.85 g/cm3
- Brinell Hardness number: 201 BHN
- Rockwell Hardness number: 93 Ra
- Ultimate Tensile Strength: 620 -740MPa
- Tensile Yield Strength: 415MPa
- Modulus of Elasticity : 190-210 GPa
- Poisson's ratio: 0.27-0.30
- Melting Point: approx. 1500°C
- Thermal conductivity: 50.7 W/mK

IV. DESIGNING A CAD MODEL

CATIA delivers the unique ability not only to model any product, but to do so in the context of its real-life behaviour. Design in the age of experience. Systems architects, engineers, designers and all contributors can define, imagine and shape the connected world. CAD model of Wheel Hub was developed in 3D modelling software CATIA V5 R20.Hub design mainly depends on Rim size, Bolt pattern and Weight of the Car. CAD model of Wheel Hub was developed in 3D modelling software CATIA V5 R20.Hub design Mainly Depends on Rim Size, Bolt Pattern and Weight of the Car.



V. ANALYSIS

Analysis was carried out using PATRAN as pre and postprocessor and NASTRAN as solver.

Patran is the world's most widely used pre/post-processing software for Finite Element Analysis (FEA), providing solid modelling, meshing, analysis setup and post-processing for multiple solvers including MSC Nastran, Marc, Abaqus, LS-DYNA, ANSYS, and Pam-Crash. Patran provides a rich set of tools that streamline the creation of analysis ready models for linear, nonlinear, explicit dynamics, thermal, and other finite element solutions. From geometry cleanup tools that make it easy for engineers to deal with gaps and slivers in CAD, to solid modeling tools that enable creation of models from scratch, Patran makes it easy for anyone to create FE models. Meshes are easily created on surfaces and solids alike using fully automated meshing routines, manual methods that provide more control, or combinations of both. Finally, loads, boundary conditions, and analysis setup for most popular FE solvers is built in, minimizing the need to edit input decks. MSC Nastran is a multidisciplinary structural analysis application used by engineers to perform static, dynamic, and thermal analysis across the linear and nonlinear domains, complemented with automated structural optimization and embedded fatigue analysis technologies, all enabled by high performance computing. MSC Nastran may be used to:

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- Virtually prototype early in the design process, saving costs traditionally associated with physical prototyping.
- Remedy structural issues that may occur during a product's service, reducing downtime and costs.
- Optimize the performance of existing designs or develop unique product differentiators, leading to industry advantages over competitors.

A. Static Analysis

To observe maximum stress produce in Hubs, model is subjected to extreme conditions and static analysis is carried out in Nastran/Patran. Hub has constraint at Rim mountings. Braking Torque and Bump Force was analytically calculated and applied to Hub. A combined load of 3090N braking Torque and 3g Bump Force were applied to the model considering the longitudinal load transfer during braking

LOADING CONDITIONS

Breaking Torque	473.33N-m
Bump Force	3g = 3090N

Calculations

- Braking Torque:

Brake pedal force:

1. The force applied on the pedal is assumed to be 294.3 N (30kgf)

2. Pedal ratio = 6:1

3. fmax= force* pedal ratio

= 294.3 * 6

= 1765.8 N

(fmax= force applied onto the master cylinder)

Hence, P = fmax/ (π/4) * d2

(P =hydrostatic pressure, d = diameter of master cylinder's piston)

Fmax = P * π/4) * D2 [by Pascal's Law]

(Fmax = force acting on each piston of the caliper,

D = diameter of the piston in the caliper)

By solving,

4. Fmax = fmax * (D / d)2

= (1912.95)*(.029 / .019)2

= 4074.98 N

Torque acting on the disc:

T = Fmax * μ * Re * number of pistons per calliper

= 4074.8 * 0.3 * 0.097 * 4

= 474.33 N-m

Where,

μ = Coefficient of friction between brake pad and disc (0.3)

Re = effective radius of the disc (97mm).

- Bump Force

Max velocity of Vehicle = 60kmph.

Mass of the vehicle=420kg

From Newton's second law of motion:

F=ma

F=420*3*g

F=420*3*9.81

F=12,360.6N

i.e., Force applied on each wheel is

(12,360.6/4) + (474.33/0.25) =5000N.

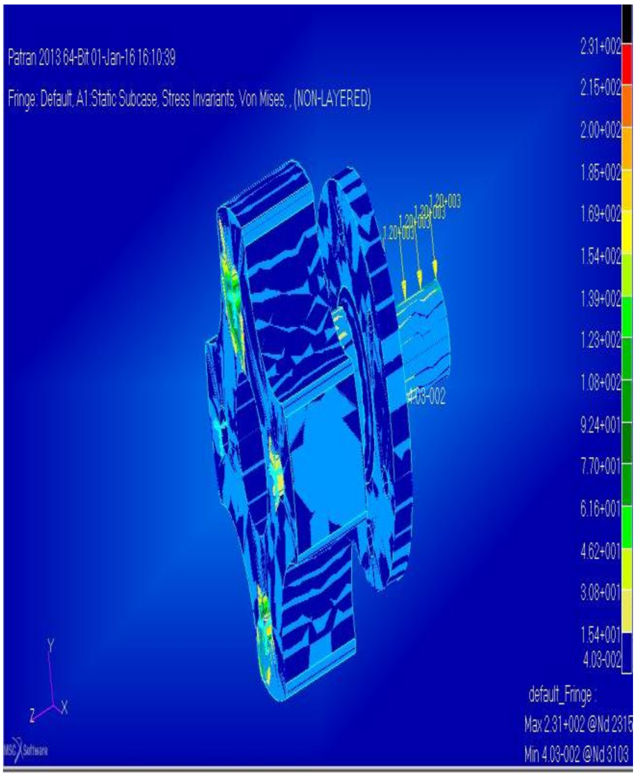
RESULTS

PARTICULARS	ALUMINIUM	EN 8 MILD STEEL
LOAD APPLIED (N)	5000	5000
MAX STRESS(N/mm2)	231	237
YEILD STRENGTH(N/mm2)	276	415
FOS	1.2	1.75
WEIGHT(kg)	2.3	6.667

A. Stress Induced: Material- Aluminum 6061 T6

Insert picture

B. Stress Produced: Material – EN8 Mild Steel



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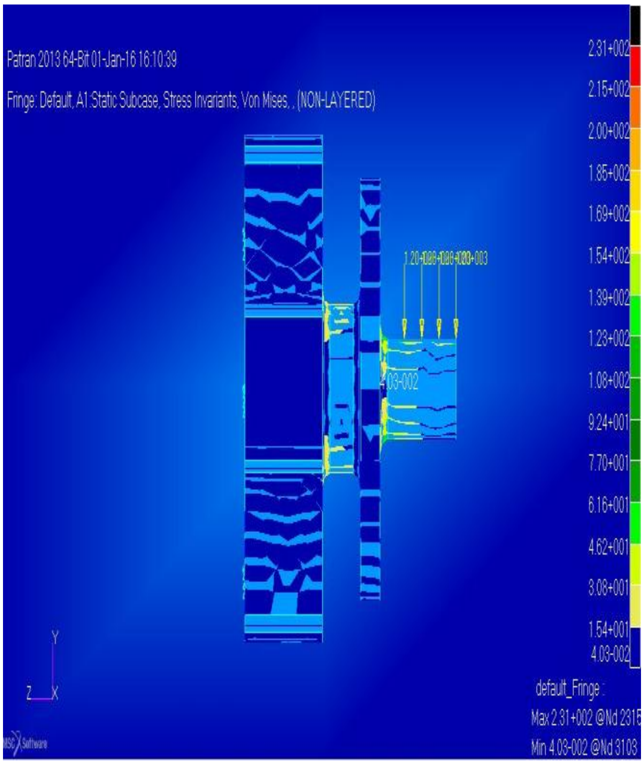
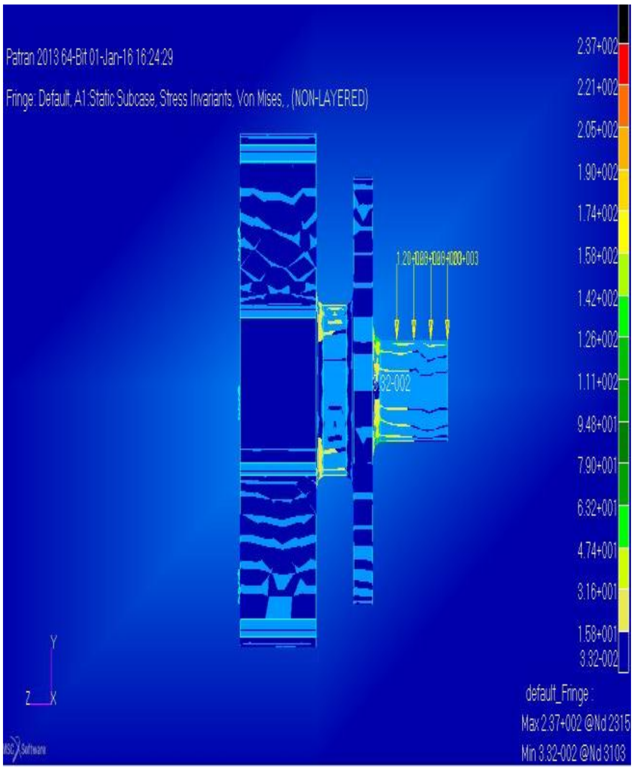
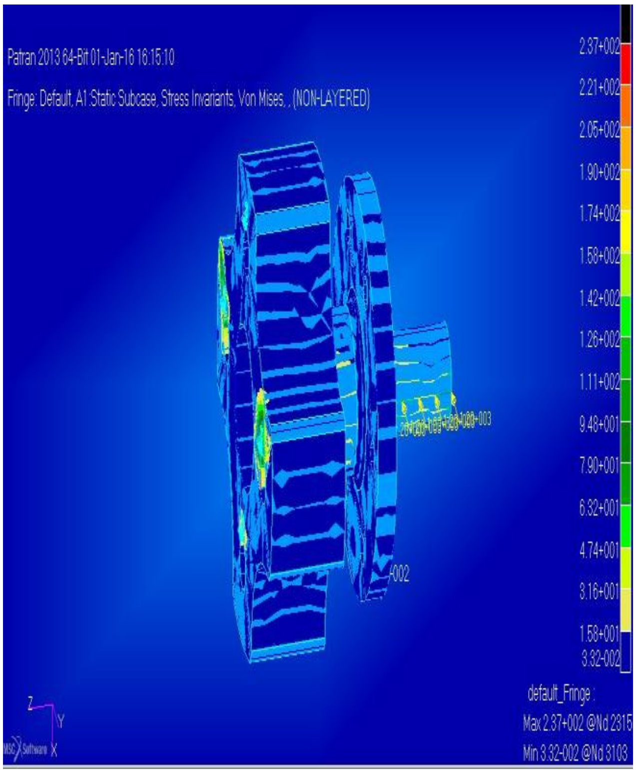


. STRESS DEVELOPED IN ALUMINIUM





STRESS DEVELOPED IN EN 8 MILD STEEL

VI. MANUFACTURING PROCESS

Raw Material: Aluminium 6061

6061 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S," it was developed in 1935. It has good mechanical properties and exhibits good weld ability. It is one of the most common alloys of aluminium for general purpose use.

It is commonly available in pre-tempered grades such as 6061O (annealed) and tempered grades such as 6061T6 (solutionized and artificially aged) and 6061T651 (solutionized, stress relieved stretched and artificially aged).

A. Chemical Composition

Chemical composition	Minimum(by weight)	Maximum(by weight)
Silicon	0.4%	0.8%
Iron	-	0.7%
Copper	0.15%	0.4%
Manganese	-	0.15%
Magnesium	0.8%	1.2%
Chromium	0.04%	0.35%
Zinc	-	0.25%
Titanium	-	0.25%
Other elements	not more than 0.05% each	0.15%
Aluminium	95.85%	98.56%

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B. Mechanical Properties

T6 temper 6061 has an ultimate tensile strength of at least 42,000 psi (300 MPa) and yield strength of at least 35,000 psi (241 MPa). More typical values are 45,000 psi (310 MPa) and 40,000 psi (275 MPa), respectively. In thicknesses of 0.250 inch (6.35 mm) or less, it has elongation of 8% or more; In thicker sections, it has elongation of 10%. T651 temper has similar mechanical properties.

The typical value for thermal conductivity for 6061T6 at 77°F is around 152 W/m K. A material data sheet defines the fatigue limit under cyclic load as 14,000 psi (100 MPa) for 500,000,000 completely reversed cycles using a standard RR Moore test machine and specimen. Note that aluminium does not exhibit a well-defined "knee" on its S-N graph, so there is some debate as to how many cycles equates to "infinite life". Also note the actual value of fatigue limit for an application can be dramatically affected by the conventional derating factors of loading, gradient, and surface finish.

Uses

- Bicycle frames and components.
- Many fly fishing reels
- The famous Pioneer plaque was made of this particular alloy.
- The secondary chambers and baffle systems in firearm sound suppressors (primarily pistol suppressors for reduced weight and improved mechanical functionality), while the primary expansion chambers usually require 174PH or 303 stainless steel or titanium.
- The upper and lower receivers of many AR15 rifle variants.
- Many aluminium docks and gangways are constructed with 6061T6 extrusions, and welded into place.
- Material used in some ultra-high vacuum (UHV) chambers.
- Many parts for remote controlled model aircraft, notably helicopter rotor components.

C. Process Involved in the Manufacturing

- Turning Operation
  - ➢ Turning
  - ➢ Facing
- Milling Operation
- Drilling on Milling Machine
- Milling for weight reduction

VII. MANUFACTURED WHEEL HUB

WHEEL HUB

VIII. PRODUCT TESTING & VALIDATION

Acceleration Test

Acceleration is measured as the time to complete a 30.48 m (100 ft.) or 45.72 m (150 ft.) flat, straight course from a standing start. The course surface may vary from pavement to loose dirt. The acceleration and the timing is determined with the help of a device known as the Transponder which mounted to the front right side of the vehicle.

Hill climb or Traction Test

This event tests the vehicle's relative ability to climb an incline from a standing start or pull a designated object, e.g. “eliminator skid”, vehicle, or chain, along a flat surface. The organizer will determine the hill height steepness and surface or object to be pulled.

Brake Test

This test is mainly done to check the functionality of the brakes. The organizer will determine if all the wheels lock at a time within the given Stopping Distance. Even if one of the wheels do not lock, the vehicle will not qualify for the final Endurance event.

Inspection Result

IX. DFMEA FOR WHEEL HUB

Design Failure Mode and Effects Analysis (DFMEA) is used to uncover design risk, which includes possible failure, degradation of performance and potential hazards. The DFMEA is typically the first FMEA tool used in product development. When performed properly, there are many benefits of DFMEA.

POTENTIAL FAILURE MODES	POTENTIAL EFFECTS OF FAILURE	S	POTENTIAL CAUSES OF FAILURE	O	D	RPN	RECOMMENDED ACTIONS
1. Improper installation of axle nut	A hub that is fixed loosely will cause the hub and wheel assembly to oscillate laterally sidewise).		Over-tightening or loosely fixing the axle nut will result in problems as mentioned in the effects column	5	2	80	Use torque wrench while tightening the axle nut to prevent it from being under-torqued or over-torqued.
2.Overloading the vehicle	Overloading a hub creates similar conditions as over-tightenig the hub. Due to the excessive weight, localized heating of the lubricant takes place {between the bearing rollers and bearing races} .it causes the bearings to fail or fatigue.		Overloading a vehicle i.e., putting extra load on each wheel than it can tolerate or manage.	7	3	147	Don't overload the vehicle or the wheels beyond Its capacity.

X. CONCLUSION

- Wheel Hub has been designed for an ATV of mass 440Kg and the maximum speed of 60kmph.
- The Designed Hub gives stability during rotation of the wheels.
- The Weight and Dimension of the Hub is such that it reduces the rotational mass.

XI. ACKNOWLEDGMENT

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