DESIGN, MODELING, ANALYSIS & FABRICATION OF WHEEL HUB

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Abstract**—*****The paper represents the behavior of wheel hub subjected to different loads for different materials. It gives an insight to various options that can be used for wheel hubs and compare the different materials with each other. The wheel hub presently of cast iron is compared with three different materials viz. Al alloy, SS, Mg alloy. The effect of bump force, braking torque and cornering force are considered in the analysis. The outputstress for all the four materials are then utilized to calculate the fatigue life of wheel hub using the Goodman equation. After obtaining the endurance stress for each material hub, the life of wheel are calculated from SN curves for respective materials. The aim is to find a better material than cast iron which will have better life, better strength, less weight which will increase the entire vehicle efficiency and remove the failure of wheel hub occurring at the bolting locations due to crack initiation. A cyclic testing for wheel hub is conducted for 5000 cycles which ensures no failure of wheel hub of new fabricated material.***

Keywords- Wheel hub, C.I. ,Al Alloy, S.S., Mg Alloy, SN curve

I. INTRODUCTION

Wheel hub may be a very critical a part of the vehicle mechanical system which allows the steering arm to show the front wheels and support the vertical weight of the vehicle. Suspension systems in any vehicles uses different types of links, arms, and joint to let the wheels move freely , front suspensions also have to permit the front wheel to turn. Steering knuckle/spindle assembly, which have two separate or one complete parts attached together in one in all these links. Hub is that the part attached to upright, the purpose of a wheel hub is to attach a wheel to a motor shaft. Hubs also are wont to attach lifting arms, release doors and pulleys to motor shafts. Wheels are typically attached to hubs via the wheels face or its centre. The wheel is attached through fasteners to hub thanks to an honest strength and might be easily removed for storage or servicing. Hubs are typically attached to the motors by closely sliding over and locking into engagement with their shafts transferring torque from the motor, through the hub and to the wheel. Hub must be capable of rigidly supporting its share of the whole weight of a vehicle without failure during its expected generation. If the hub geometry and material selection are inadequate, it'll break assembly which cannot be repaired. In order to delve into the important subject of study of this project is important to introduce brief information about the operation and behavior of the wheel hub. The hubs or axes support machine elements at rest or rotating, as in our case the wheels. Also the hubs or axes withstand axial forces, cutting forces, bending's and torsional moments. the choice bending of the rotary axes brings the danger of fatigue failure in every transition section, every change of section, every groove, holes, etc. the strain spikes will be eliminated by taking various precautions during design. Finally, it's possible to stop axial displacement centers or axes with lateral stop on the bearing, snap rings or circlips. The wheel hub assembly make is feasible for you to possess a smooth and hassle-free driving experience. The hub is directly connected to the wheel, and is connected to the upright. The upright is to stay stationary relative to the chassis while the hub is to rotate with the wheel. this is often done by placing an effect between the hub and upright. Typically a spindle is pressed into the upright and doesn't rotate and an impression is pressed into the hub, and therefore the spindle is pressed into the bearings allowing the hub to rotate about the spindle. Unsprung mass is that the mass of the wheel, hub, rotor, caliper, uprights, spindle, and restraint. it's important to scale back unsprung mass so as to extend acceleration. The greater the unsprung mass, the slower the acceleration.

II. LITERATURE REVIEW

A. Wheel Hub Fatigue Performance under Non-constant Rotational Loading and Comparison to Eurocycle Test .[1]

Wheel Eurocycle (EC) loading condition may be adapted to hub as a results of comparable loading characteristics on vehicle. A correlation is constructed between road load data (RLD) for specified vehicles and EC test spectrum. to provide correlation between EC and RLD, test speed, axial and lateral loads at EC are converted to cyclic loading condition and relevant loading scenarios are generated. Rotational effect is taken into consideration. Pseudo-damage results of RLD and EC spectra are compared and expected fatigue lifetime for hub is presented.

B. Fracture Analysis Of Wheel Hub Fabricated From

PressureDie Cast Aluminum Alloy.[2]

A catastrophic failure of wheel hub occurred during service. the character of failure was a corner crack emanating from a spoke hole. An analytical investigation was administrated using the tool of Linear Elastic Fracture Mechanics to determine the reason for failure. The nonlinear behavior is because of the presence of fabric in homogeneities and micro-discontinuities. Plastic zone correction is created. The presence of fabric in homogeneities and micro-discontinuities tend to change the conditions near the crack tip.An analytical estimation was distributed so as to calculate the minimum number of cycles covered by the wheel hub in commission. The initiation of crack growth is complex due to heterogeneity and morphology of the fracture surface. Fractographic and metallographic studies are allotted to help the understanding of the comer cracking problem.

C. *New methodology for accelerating the four-post testing of tractors using wheel hub displacements.*[3]

Durability tests of tractor prototypes need substantial financial and time commitments. The duration and value of tests may well be reduced using accelerated tests ready to reproduce on the structural a part of the tractor, the identical damage produced on the tractor during its world but over a reduced fundamental measure. it's been recently demonstrated how it's possible to hurry up the tests using automotive proving grounds. However an entire prototype with all its components is important to perform tests on proving grounds, but to check only the structural durability is feasible the employment of a 4-post bench. A 4-post bench is in a position to breed a selected vehicle response, with the likelihood of applying fatigue editing techniques to get rid of the non-damaging portions of the load signals. These techniques are usually applied to load signals measured with strain gauges during tests on proving grounds. However, strain gage installations and data validation of the acquired signals are time-consuming. Here a brand new method, able to calculate the displacements on the wheel hub.

D. *Finite element analysis model of rotary forging for assembling wheel hub bearing assembly.* [5]

In this paper, computationally efficient finite element analysis model of the rotary forging process for assembling a wheel hub bearing assembly is presented. The analysis model consists of part of fabric defined by two artificial planes of symmetry, which is to cut back computational time taken in simulating the holistic process. Three cases of 30°, 60° and 90° analysis models for simulating rotary forging processes are studied to validate the current finite element analysis model. The predictions at their planes of symmetry and mid-planes are investigated and compared with the experiments, revealing that the predictions at the mid-planes are in good agreement with the experiments for all the cases while those at the planes of symmetry are to the contrary. Thus, the 60° analysis model is usually recommended for both computational efficiency and solution reliability. With this finite element analysis model, one hour of computational time with PC are often sufficient enough to get valuable information about such rotary forging processes because the wheel hub bearing assembly making process..

III. THE PROPOSED METHOD

In a traditional method car utilized wheel hub fabricated from forged iron. forged iron provided strength to hub against bending during cornering and bump situations and resisting against torsion during braking. Although the previous design has worked alright in terms of strength but it had major issues like the wheels hubs were heavy, Cracks initiated in wheel hubs resulting in failure. In traditional method main variables that affect the damage results are the vehicle loading condition (vehicle types), suspension types and work. it's noted that front hub designs has far more damage than rear, because it's more conservative than front hub. The failure of wheel hub showed relatively lower mechanical properties than specification.

The crack initiation depends on microstructure moreover of fabric. The analysis considers the plastic deformation is focused on relatively small area. FFT is additionally a way useful method for detecting the faulty hub bearings. the assorted forces functioning on wheel hub which form the premise of design for wheel hub are bump force, braking torque, force. during this project we would like to style the wheel hub of for material optimization. That the project to seek out the optimal design for hubs.

IV. FINITE ELEMENT ANALYSIS

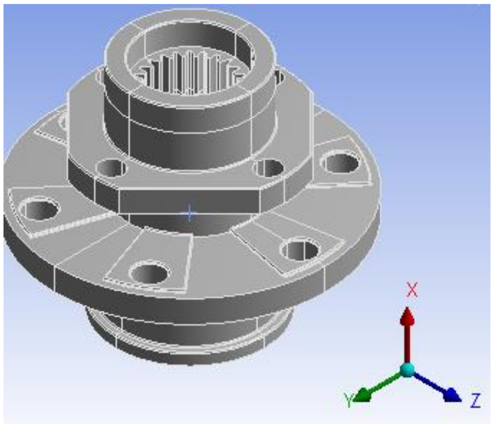


Fig. 4.1 Geometry of wheel Hub

Calculations:

- Braking Torque:

Brake pedal force:

1. The Brake applied on the pedal is assumed to be 300 N (30.6 kgf)
2. Pedal ratio of every 4 wheeler is 6:1
3. fmax = force × pedal ratio

   = 300 × 6

   = 1800 N

Where,

f max = force applied onto the master cylinder

Hence, P = $\frac{f\,max}{\left(\frac{\pi}{4}\right)\times d^2}$

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

Fmax = P × $\frac{\pi}{4}$ ×D2 [by Pascal's Law]

(Fmax = force acting on each Cylinder, D = diameter of the piston Cylinder in the caliper)

By Solving,

Fmax = fmax × ($\frac{D}{d}$)2

= (1800) × (0.03 / .019)2

= 4487.53 N

Torque acting on the disc:

T = Fmax × μ × Re × number of pistons per caliper

= 4487.5346 ×0.3 × 0.097 ×3

= 391.76N-m

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

Re = Radius of the disc.

- Bump Force:

Max velocity of Vehicle = 156 kmph.

Mass of the vehicle= 2225kg

- From Newton's second law of motion:

$$F = m \times 3 \times g$$
$$= 2225 \times 3 \times 9.81$$
$$= 65481 \text{ N}$$

Force Applied on each Wheel $= \frac{F}{4}$

$$= \frac{65481}{4}$$

F ≈16000 N

- Cornering Force:

The cornering force is due to the vehicle taking a turn and the centripetal force acting on the vehicle, it is calculated as follows:

$$F_{cr} = \frac{mv^2}{r}$$

$$F_{cr} = \frac{2225 \times 11.11^2}{10}$$
$$= 27466.38N$$

Now, the cornering force acting on one wheel hub is calculated as,

$$F_{cr} = \frac{27466.38}{4}$$
$$= 65481 \text{ N}$$

BOUNDARY CONDITIONS:-.

Following are the boundary conditions applied for finite element analysis shown in Fig. 4.2:

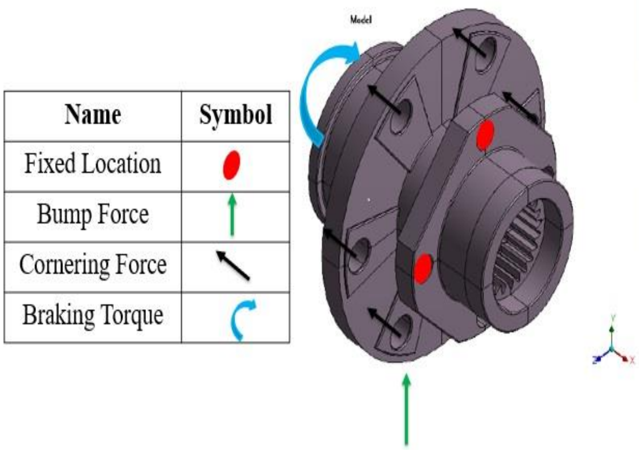


Fig. 4.2 Boundary Conditions

V. RESULTS

i. Cast Iron

Based on FE Analysis for cast iron the stress observed is shown in Fig 5.1 Cast iron Stress plot:

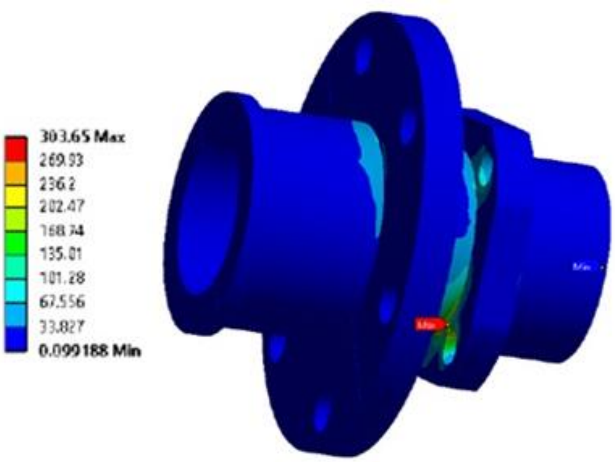


Fig. 5.1 Cast Iron Stress Plot

- Mean Equivalent stress – 151.82 MPa
- Alternating Equivalent stress – 151.82 MPa
- Weight= 1.67 kg

Based on Goodman Equation, we get the endurance stress as follows,

$$\frac{\sigma a}{\sigma e} + \frac{\sigma m}{\sigma ut} = 1$$

$$\frac{151.82}{\sigma e} + \frac{151.82}{460} = 1$$

$\sigma e = 226.6$ MPa

The endurance stress for C.I. wheel hub is 226.6 MPa.

Based, on the value we will find the life of hub from SN curve of CI below Fig. 4.4 SN curve of cast iron

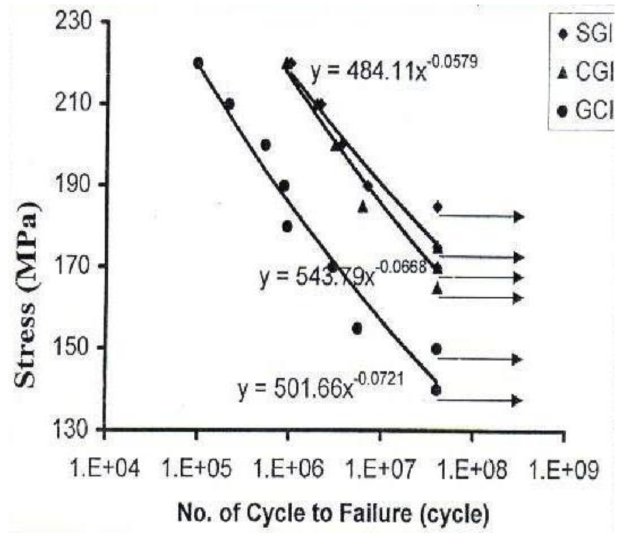


Fig. 5.2 SN curve of cast iron

The fatigue life of wheel hub for cast iron material from SN curve is more than 200000 cycles. This life cycle is below 1000000 cycles to be considered for infinite life consideration.

ii. Stainless Steel

Based on FE Analysis the stress observed is shown in Fig 5.3 S.S. stress plot:

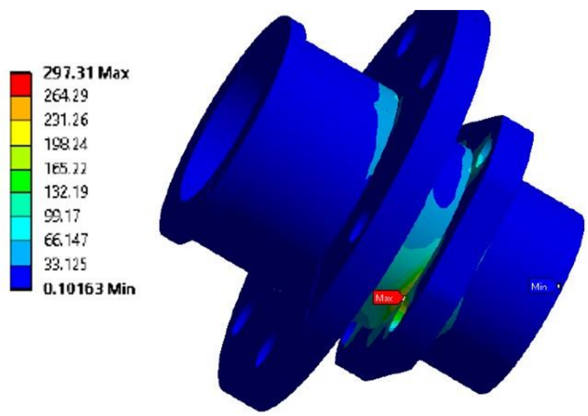


Fig. 5.3 S.S. Stress Plot

- Mean Equivalent stress – 148.65 MPa
- Alternating Equivalent stress – 148.65 MPa
- Weight= 1.8 kg

Based on Goodman Equation, we get the endurance stress as follows,

$$\frac{\sigma a}{\sigma e} + \frac{\sigma m}{\sigma ut} = 1$$

$$\frac{148.65}{\sigma e} + \frac{148.65}{505} = 1$$

$\sigma_e = 210.6$ MPa

The endurance stress for S.S.. wheel hub is 226.6 MPa. Based, on the value we will find the life of hub from SN curve of S.S. below Fig. 5.4 SN curve of S.S:

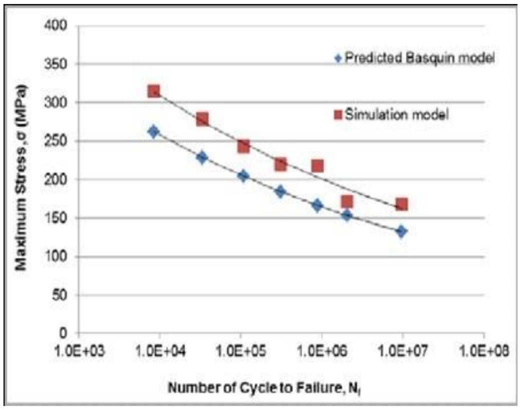


Fig. 5.4 SN curve of S.S.

The fatigue life of wheel hub for stainless steel material from SN curve is 100000 cycles.

iii. Aluminium Alloy:

Based on FE Analysis the stress observed is shown in Fig.5.5 Al Alloy Stress Plot:

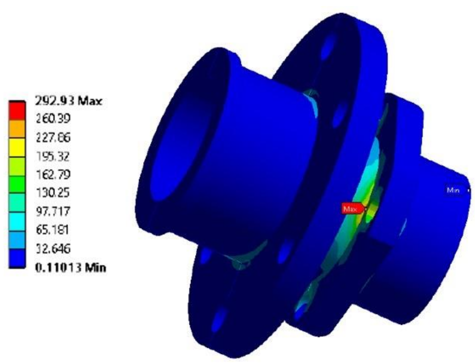


Fig.5.5 Al Alloy Stress Plot

- Mean Equivalent stress – 146.46 MPa
- Alternating Equivalent stress – 146.46 MPa
- Weight: 0.64511 kg

Based on Goodman Equation, we get the endurance stress as follows,

$$\frac{\sigma a}{\sigma e} + \frac{\sigma m}{\sigma ut} = 1$$

$$\frac{148.65}{\sigma e} + \frac{148.65}{505} = 1$$

$\sigma_e = 196$ MPa

The endurance stress for aluminium alloy wheel hub is 196 MPa. Based, on the value we will find the life of hub from SN curve of Al alloy below Fig. 5.6 SN curve of Aluminium alloy:

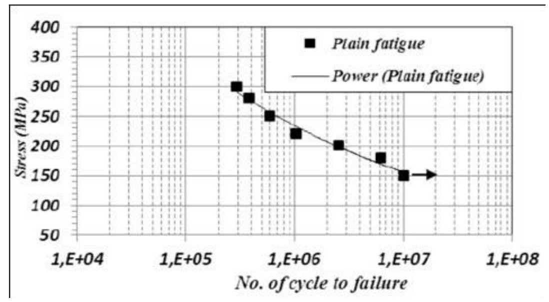


Fig. 5.6 SN curve of Aluminium alloy

The fatigue life of wheel hub for Al alloy material from SN curve is more than 3000000 cycles. This shows the design of wheel hub with aluminum alloy as material of hub for infinite life cycle as it crosses the mark of 10^6 cycles.

iv. Magnesium Alloy

Based on FE Analysis the stress observed is shown in Fig.5.7 Mg Alloy Stress Plot:

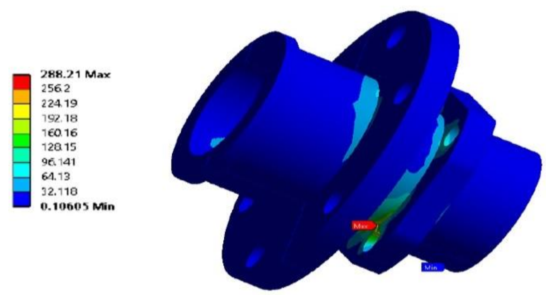


Fig.5.7 Mg Alloy Stress Plot

- Mean Equivalent stress – 144.1 MPa
- Alternating Equivalent stress – 144.1 MPa
- Weight: 0.4192 kg

Based on Goodman Equation, we get the endurance stress as follows,

$$\frac{\sigma a}{\sigma e} + \frac{\sigma m}{\sigma ut} = 1$$

$$\frac{144.1}{\sigma e} + \frac{144.1}{250} = 1$$

$\sigma_e = 340$ MPa

The endurance stress for magnesium alloy wheel hub is 340 MPa. Based, on the value we will find the life of hub from SN curve of Mg alloy below Fig. 5.8 SN curve of Mg alloy:

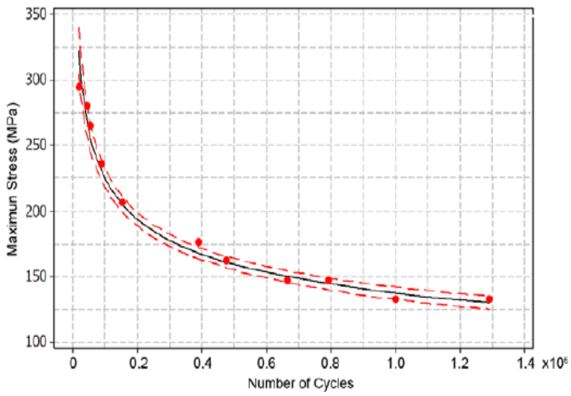


Fig. 5.8 SN curve of Mg alloy

The fatigue life of wheel hub for Mg alloy material from SN curve is less than 50000 cycles. This shows the design of wheel hub with magnesium alloy as material of hub cannot be used as it does not cross the mark of 10^6 cycles. From finite element analysis it is observed that aluminium alloy is a better option for wheel hub giving a good life cycle than cast iron hub and in turn reducing the weight of hub. We will be proceeding for fabrication of hub for aluminium as its material. Table 5.1 Summary of results gives us the finite element analysis outputs.

Table 5.1 Summary of results

Name	Weight (Kg)	Stress (MPa)	Design Life
Cast Iron	1.67	303	200000
Stainless Steel	1.8	297.31	+100000
Aluminium Alloy	0.645	292.3	+3000000
Magnesium Alloy	0.419	288.21	50000

VI. FABRICATION OF WHEEL HUB

As per FEA result it is observed that aluminium alloy will give us good life and reduced weight. The manufacturing of hub is carried out and the cyclic loading testing for hub standard will be done for FEA correlation for 4000 cycles of loading and unloading. The wheel hub was fabricated on three machines such as lathe, drilling and milling machine. The Operation steps show us the process sheet operation that is carried out on the three respective machines for the wheel hub fabrication.

Fig. 6.1 Manufacturing images of wheel hub

- **EXPERIMENTAL TESTING & VALIDATION**

The wheel hub mounted on UTM for cyclic loading.The fixture of wheel hub on UTM is as shown in Fig 5.1.Wheel hub fixture on UTM. The test was carried out for total 5000 cycles.

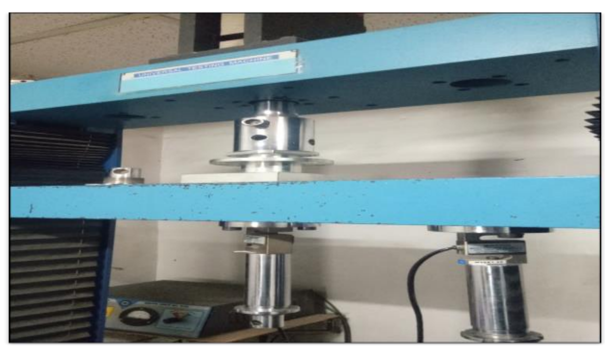
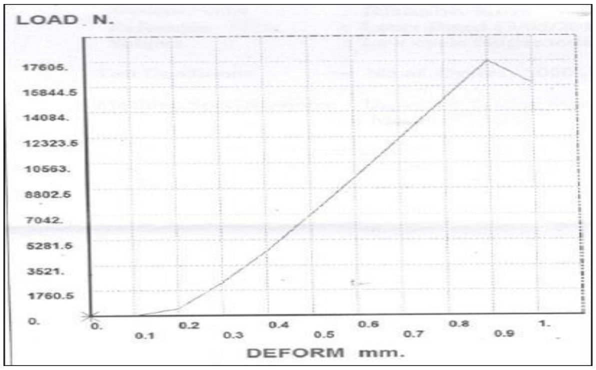
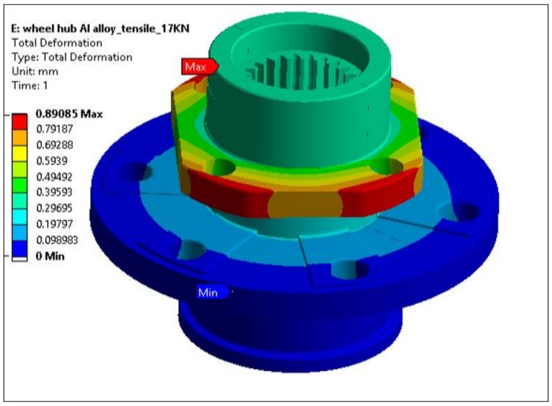


Fig. 5.1 Wheel hub fixture on UTM

Cyclic testing for 5000 cycles was carried on aluminium alloy wheel hub. The wheel hub was subjected to 17kN load for 1000 cycles and further 4000 cycles for 7kN.



a)



b)

Fig. 5.2 a) Experimental testing and b) FEA result of wheel hub

The output of load Vs displacement is plotted and it is in agreement with the finite element analysis. The Deflection of wheel hub subjected to 17kN in FEA is 0.89mm as shown below in Fig. 5.2

VII. RESULT AND DISCUSSION

From the analysis of wheel hub for different materials, we considered the worst case loading condition that the hub will be subjected to bump force, cornering force as well as braking torque at the same time while the car is taking a turn and evaluate the stress and life for one wheel hub in which we observed aluminium alloy gives us better result in terms of fatigue life of over 10^6 cycles compared to remaining three materials as mentioned in Table 6.1. This analysis ensures worst case condition for solving in which the wheel hub gives good life prediction ensuring more life when the wheel is subjected to any two combinations of applied boundary conditions in real life condition.

Table 6.1 Predicted Life of wheel hub

Name	Weight (Kg)	Design Life in cycles
Cast Iron	1.67	200000
Stainless Steel	1.8	+100000
Aluminium Alloy	0.645	+3000000
Magnesium Alloy	0.419	50000

Table 6.2 Validation of Experimental Testing and FEA

Aluminium Alloy Wheel Hub	Deformation in mm
FEA	0.89
Physical Testing	0.9

VIII. CONCLUSION

The finite element analysis and testing results performed on wheel hub for different materials give us the following output. The fatigue life of wheel hub is checked with four materials cast iron, stainless steel, aluminum alloy and magnesium alloy with different physical properties of each subjected to same boundary conditions and it is observed that weight of wheel hub in ascending order of materials is magnesium alloy, aluminium alloy, cast iron and stainless steel. The inertia effect is reduced with low weight wheel hubs compared to baseline cast iron.

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