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Design and Optimization of Hub and Knuckle Assembly for Off Road Vehicles: A Review

Ravi G. Kaithwas[1], Diksha U. Kamble [2], Nilesh B. Dakhore [3], S. S. Bhansali [4]

[1]Undergraduate Student, Department of Mechanical Engineering, Jawaharlal Darda Institute of Engineering & Technology, Yavatmal, Maharashtra, India, ***ctravindra@gmail.com***

[2] Undergraduate Student, Department of Mechanical Engineering, Jawaharlal Darda Institute of Engineering & Technology, Yavatmal, Maharashtra, India, ***dikshaukamble1995@gmail.com***

[3] Undergraduate Student, Department of Mechanical Engineering, Jawaharlal Darda Institute of Engineering & Technology, Yavatmal, Maharashtra, India, ***nileshdakhore088@gmail.com***

[4]Assistant Professor, Department of Mechanical Engineering, Jawaharlal Darda Institute of Engineering & Technology, Yavatmal, Maharashtra, India, ***sushant2511@yahoo.co.in***

Abstract

The knuckle and Hub Assembly utilized in many vehicles like cars to trucks, to avoid the damage to the chassis of vehicles from different road conditions. The suspension system is connected to the knuckle according to the requirement of the various vehicles, for off road vehicles like BAJA ATV's and others, where the performance is much more important. This paper gives an introduction to the various methods of optimized by the various authors to increase their performance for off road vehicles. This paper also focus over other benefits of the weight optimization using computer aided platforms in automotive sectors specially the special purpose design vehicles like ATV's which are designed for certain duration or events.

Index Terms: *Hub, Knuckle, Weight optimization, CAD, CAE, FEA*

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1. INTRODUCTION

In automotive sector power to weight ratio is important when it comes to the efficiency of a vehicle. From last few decades various development is done in improvement of break power and design of vehicles. The optimisation of vehicle weight can be better aspect when it comes the increasing performance of the vehicle as there are tremendous developments already done in the sector of IC engine in field of its design, structure, weight optimisation, path of flame propagation and materials and we almost reach to the peak of IC engine development.
Now weight and design optimization of vehicle components are going to play vital role in increasing of specific power **[3][8]**.

Fig-1: Exploded view of assembly [2]

Now a days the weight and design optimization is performed using Computer Aided Design (CAD) and Computer Aided Engineering (CAE) software. Which helps in cost cutting, time saving and perform various tests related to design, loading, structure and thermal stresses without preparing its prototype or physical model **[1][2][3]**.

The weight, shape and design can be optimized using CAE software like ANSYS. The structure wise details about the failing model is shown diagrammatically using software hence we get scope for further development without performing destructive test over the model**[4][5][6][8]**.

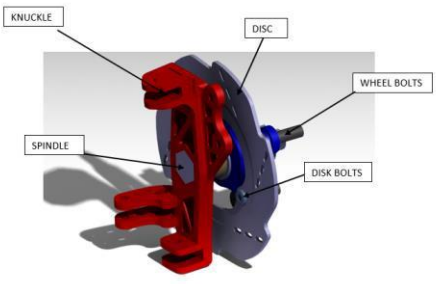

Fig-2: Wheel Assembly View-1 [3]

The hub and knuckle assembly is an integral part of wheel assembly of the vehicle. A wheel hub is axle and bearing mechanism around which the wheel revolves. It is the mounting assembly for a wheel of car or vehicle. A steering knuckle is that part which contain the wheel hubs and spindle, it is also attached to the suspension and steering component. The knuckle also known as upright **[6]**.

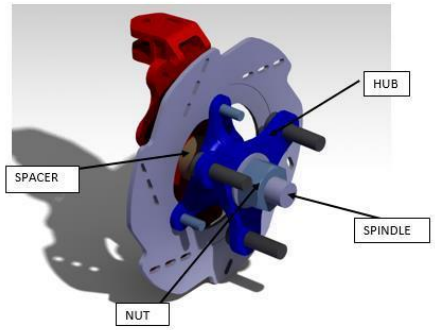

Fig-3: Wheel Assembly View-2 [3]

2. BRIEF DESCRIPTION TO HUB AND KNUCKLE

2.1 Wheel Hub

Wheel hub is a part where the wheel rim is mounted over it. The hub is rotating inside the knuckle. The purpose of wheel hub is to attach a wheel to the engine shaft. The steering hub is placed inside the knuckle where it can rotate freely, the hub bearing mounted between the hub and knuckle which provide stability to the hub and hence to the wheel of vehicles. Wheels are typically to hub via the face of the wheel or rim or it's centre. Fasteners are utilized to for rim to the hub as it's most suitable method and it can be easily removed for servicing or storage. Also, the fasteners provides good stability n strength. The hub transmitting the break power through transmitting shaft to the wheel. Following are the most common methods for torque transmission:

- Press fits
- Set screws
- Keywords or Pin joints
- Splines

Fig-4: wheel hub model [5]

The hub must be capable of rigidly supporting wheel and sustain the weight of vehicle also, the torque transmitting through it without failure during it's expected life span. If the hub geometry and material selection are inadequate, the hub can break completely or bend so much that it cannot transmit the torque to the wheel for drive **[4][6][7][9][10]**.

Fig-5: Wheel hub [4]

2.2 Steering Knuckle

The Steering Knuckle is automobile component which is associated with the suspension geometry of the vehicle. it is used in the front where the steering is to be achieved. In automotive suspension, a steering knuckle contains the wheel hub or spindle, and attached to the suspension and steering components. It is generally called a steering knuckle, spindle, upright or hub. The steering arm attached to the Steering Knuckle on which the tie rod is located, to achieve the steering phenomenon. The tie rod ends of the track rod transfer motion to the wheels by Steering knuckle on the wheel hub.

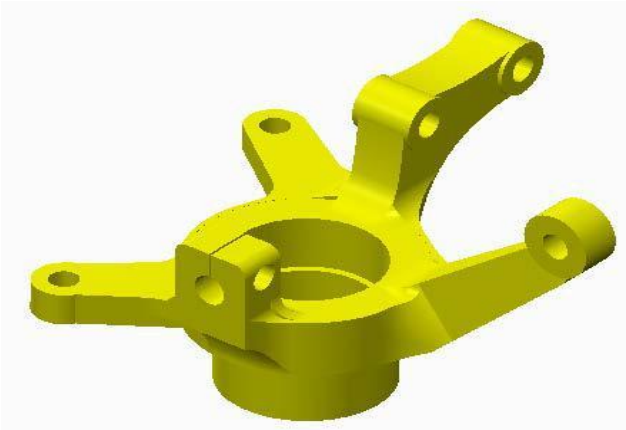

Fig-6: Steering Knuckle Joint Model [1]

The wheel and wheel assembly attach to the hub or spindle of the knuckle where the wheel rotates while being held in a stable plane of motion by the suspension assembly/knuckle. Tie rod ends and the track rod are two links of the steering system of the vehicle, which are designed according to an individual steering geometry. When the steering knuckle moves right or left, the wheels rotate about its axis. There are various designs available of a wheel hub. The purpose of the steering knuckle is to facilitate the steering of the vehicle by transferring the motion the rack (transferred from the rotation of the pinion due to the rotation of steering wheel) to the wheels. The double-wishbone suspension is attached to the upper control arm at the top and the lower control arm at the bottom of the knuckle. The wheel assembly is attached at its

centre point of the knuckle. The limb of the knuckle that sticks out, to which the steering mechanism connected to turn the knuckle and wheel assembly. Double wishbone can be divided into two main types, one comes with a hub and another comes with a spindle. In a non-drive suspension the knuckle usually has a spindle onto which the brake drum or brake rotor attaches. The wheel/tire assembly then attaches to the supplied lug studs, and the whole assembly rotates freely on the shaft of the spindle.

Fig-7: knuckle

In a drive suspension the knuckle has no spindle, but it has a hub into which is fixed the bearings and shaft of the drive mechanism. The end of the drive mechanism would then have the necessary mounting studs for the wheel/tire and/or brake assembly. Therefore, the wheel assembly would rotate as the drive shaft (or half-shaft) dictates. It would not turn liberally by itself, but only if the shaft was disconnected from the transaxle or differential. A driven suspension as defined may also be steerable. This is often called a drive/steer arrangement.

This knuckle does the job of either providing the rest place of hub with the bearing (Also known as the dead-shaft assembly of Knuckle and Hub) or the knuckle rests on the hub (Also known as Live-Shaft assembly) Steering knuckle has mounting points of wishbones, if any or any else necessities as the suspension links demands. It also has the calliper mounting points to mount the braking system if Disc brakes are to be integrated. The factor of severity of a knuckle is on the peak scale, as if the knuckle fails, whole of the geometry breakdowns and the auto is no more in functioning condition **[1][2][3][5][8][10]**.

3. LITERATURE REVIEW

Pilla. Anitha and V. Hari Shankar [1] concluded to reduce the weight of steering knuckle joint the optimization of knuckle targeting reducing the weight as the objective function with required strength, frequency and stiffness. The composite materials have more elastic strain energy storage capacity and high strength to weight. Composite materials offer opportunity for substantial weight saving. In the knuckle joint less stress value, less weight and the model is analysed cast iron is optimised different case of material reduction.

Sameer Santosh Mahadik [2] focused on essentialness to produce the light weight assembly in order to increase the vehicle performance. Author has focused over the unsprang mass of wheel. Using FEA method he minimise the unsprang mass of hub and wheel assembly which can provide proper drive and stability to the vehicle.

Joijode Vrushabh Umesh and Yadav Abhishek [3] focused the optimization of wheel assembly, knuckle and hub assembly he concluded following point about designing of components. For avoiding fatigue failure in knuckle and other components the analyse must be carried out in order to obtain actual stresses induced in the components also the stated that for accurate results of analysis, mesh quality must be high and failing element must be less than 3%.

Basavaraj Sajjan et al. [4] focus over the design of wheel hub which reduces rotational mass using light weight material Aluminium 6061 T6. It's approximate 35% less weight than the EN8 Mild Steel and using Finite Element Analysis. The optimised hub design having equal strength to EN8 Mild Steel hub and this optimization result in weight saving of the wheel hub without affecting it's functional requirements.

Rahul Sharma and Raman Nain [5] focus over the design of front and rear hub using Finite Element Analysis (FEA) and the result shows that the stress induced in the various design component is less than the yield strength with a suitable factor of safety and hence the design and components are safe and can be utilised further in vehicle of BAJA.

Gaurav Saxena et al. [6] reviewed that maximum available research o hub and upright assembly conducted is purely simulation based on Finite Element Method (FEM). The FEA is providing the accurate results to access strength and fatigue, life and shape optimisation of the hub and upright. The applied boundary conditions are calculated analytically.

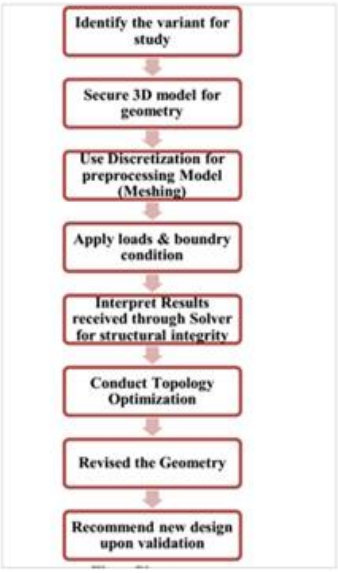

Fig-8: Design Optimization Flowchart [6]

Aditya Pratap Singh et al. [7] reviewed calculation helped to achieve better under-steer All-Terrain Vehicle (ATV) which is able to handle tough conditions. The static load on wheel hub is needed to calculate analytically for elucidating the characteristics. This paper focus over the optimization of under-steer geometry for better handling and security according to conditions.

Gondi PrabhuCharan Teja et al. [8] get the results using shape optimisation method is utilized to reducing the mass of knuckle by 60% approximately and factor of safety 4 is maintained. Maximum stress and displacement are within control. The optimisation process gives a small change into the displacement hence change in volume and shape. But, it does not influence significantly to the stiffness of the structure.

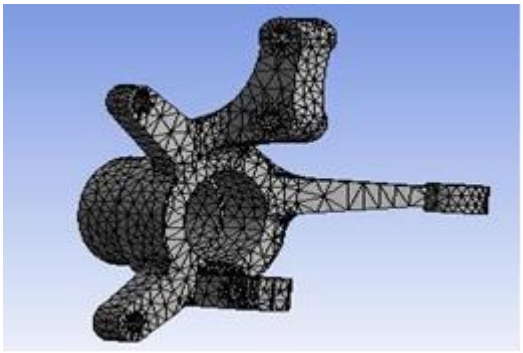

Fig-9: Meshing applied to model [8]

Kushal Choudhari et al. [9] provide the design and manufacturing the upright assemblies for the car. They also provide an in depth process study to reach final design. The hub assembly for wheel is designed and analysed which provide safe model to fabrication.

Vivek Dhameliya and Nishant Sheta [10] reviled that the 3D CAD modelling can be utilized to produce adequate design with high strength, rigidity, and light weight with higher factor of safety. The CAE analysis provide the details about the weak section of design also, the Finite Element Analysis (FEA) helps to optimize over safe region by removing it from design. Using CAD and CAE we can also know about the weight of the designed part, modification if faster, time and cost saving process. Using FEA we don't need to perform destructive test again and again using various load condition and it's time saving analysis process over conventional process.

4. CONCLUSION

From the above reviews we can conclude that the destructive test analysis is an outdated method for testing of components. The simulation and computer aided platform provide better results even without performing the destructive test. The computer generated results are time saving and accurate, also they helps in cost saving, weight, shape and life optimization of knuckle and hub using Finite Element Analysis (FEA).

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