Review on Structural Analysis of Knuckle Joint

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Abstract— Steering Knuckle plays major role in many direction controls of the vehicle it is also linked with other linkages and supports the vertical weight of the car. The current work studies the various researches conducted in optimizing design and material of knuckle joint using numerical and experimental techniques. The study also includes manufacturing process involved, contact stresses and application of FEA software in analysis of structural behaviour of bevel gears. The topological optimization conducted by scholars throws light on possible mass reduction and its effect on strength of knuckle joint.

Keywords: Knuckle Joint, Structural Analysis, Design Optimization

I. INTRODUCTION

A knuckle joint is used to connect two rods which are under the action of tensile loads whereas, if the joint is guided, compressive load may be supported by rods. A knuckle joint can be easily disconnected when required. Its uses are link of a cycle chain, tie road joint for roof truss, valve rod joint with eccentric rod, pump rod joint, tension link in bridge structure and lever and rod connection of various types. In knuckle join, one end of one of the rods is made into an eye and the end of the other rod is formed into a fork with an eye in each of the fork leg. The knuckle pin passes through both the eye hole and the fork holes and may be secured by means of a collar and taper pin or spilt pin. The knuckle pin may be prevented from rotating in the fork by means of a small stop, pin, peg, or snug. In order to get a better quality of joint, the sides of the fork and eye are machined, the hole is accurately drilled and pin turned. The material used for the joint may be steel or wrought iron. Knuckle joints may be cast or fabricated or forged. In the knuckle joint illustrated, the rods are integral with the eye and fork. In fig 1 A knuckle joint is a pin joint used to fasten two circular rods. In this joint, one end of the rod is formed into an eye and the other into a fork. For making the joint, the eye end of the rod is aligned into the fork end of the other and held in position by means of a collar and a taper pin. Once the joint is made, the rods are free to swivel about the cylindrical pin. Knuckle joints are used in suspension links, air brake arrangement of locomotives, etc.

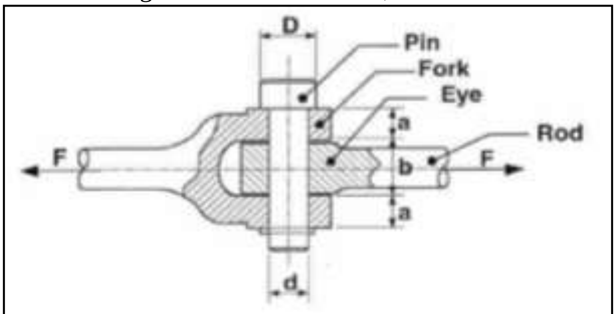

Fig. 1: Knuckle joint

Knuckle joints are made up of cast iron and stainless steel. With the advancements in the field of polymers, Teflon can be used for knuckle joints also. The results obtained from simulation proves that for same loads, total deformation, stress and strain are much less in comparison to cast iron. The knuckle joint assembly consists of following major components.

1) Single eye
2) Double eye or fork
3) Knuckle pin
4) Collar
5) Tapper pin.

The end of one of the rods is forged in the form of a fork while the end of the other rod has an eye, which can be inserted in the jaws of the fork. A cylindrical pin is passed through the holes in the forks and the eye. The pin is secured in position by a taper pin, split pin or a thin nut screwed up to shoulder on the end of the pin. The ends of the rods are made octagonal for good hard grip. A knuckle joint is used to connect the two rods which are under the tensile load, when there is requirement of small amount of flexibility or angular moment is necessary. There is always axial or linear line of action of load.

Fig. 2: Single Eye

Fig. 2: Double Eye

Fig. 3: Knuckle Pin

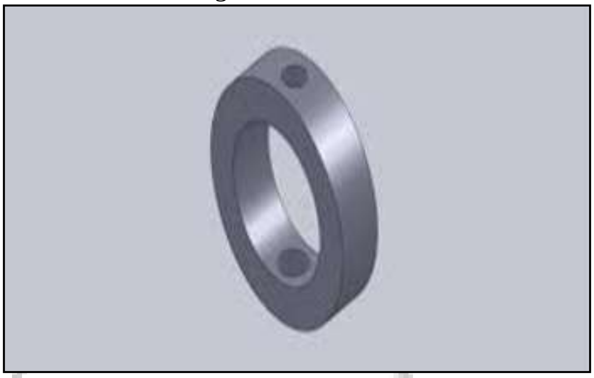

Fig. 4: Collar

Fig. 5: Tapper Pin

At one end of the rod the single eye is formed and double eye is formed at the other end of the rod. Both, single and double eye are connected by a pin inserted through eye. The pin has a head at one end and at another end there is a taper pin or split pin. For gripping purpose, the ends of the rod are of octagonal forms. Now, when the two eyes are pulled apart, the pin holds them together. The solid rod portion of the joint in this case is much stronger than the portion through which the pin passes. The knuckle joint is used in many applications such as wiper, tie rod joint of roof truss, tension link in bridge structure, link of roller chain, in tractor, elevators chains, valve rods, wire line tool-string etc.

II. Literature Review

Sangamesh et al. [1] studied the stresses in Knuckle joint using analytical method. Further study in this direction can made by using various directions of the pin and the capacity to withstand load. The present work is concentrating on which type of meshing is preferable for components.

Sanjay Yadav et al [2] has done static analysis of steering knuckle component. The design of Steering Knuckle component is done with the help of Computer Aided Engineering (CAE). [2]

Mahesh P. Sharma et al. [3] has done static analysis of steering knuckle. We have design a knuckle which accommodates dual calliper mountings for increasing braking efficiency & reducing a stopping distance of a vehicle. CAD modal of knuckle was prepared in CREO2.0. Static analysis was done in ANSYS WORKBENCH by constraining the knuckle, applying loads of braking torque on caliper mounting, longitudinal reaction due to traction, vertical reaction due to vehicle weight and steering reaction. [3]

Adiya Chavan et al [4] has redesign the steering knuckle in order to reduce the un sprung weight of a single seat All-Terrain Vehicle (ATV) while retaining a satisfactory safety factor for better performance of the vehicle. A twostep process has been used for the same. First step is modelling the knuckle as per the structural considerations and design constraints set by suspension, steering and brake assemblies & determination of loads acting on the knuckle.

Purushottam Dumbre et al.[5] has reduced weight of the vehicle by increasing additional luxurious and safety features. The increasing weight of the vehicle affects the fuel efficiency and overall performance of the vehicle.

Atul Yadav et al [6] The aim of their research is to scale down the mass of an existing steering knuckle component of a local car model, using Creo 2.0, and performing its shape optimization, using Hyper works as pre and post processor and Nastran as a solver, in order to meet the required strength attributes at the cost of minimum weight.

Nilesha Patil et al.[7] has studied and calculated the stresses in Knuckle joint using analytical method. A knuckle joint is used to connect two rods under tensile load. These joints are used for different types of connections e.g. tie rods, tension links in bridge structure.

S V Dusane et al [8] has studied about steering and suspension system, which allows the front wheels to turn and also allow the movement of suspension arms motion. The light weight and high strength component is always in demanding for race car application.

M. Prabhu et al [9] has explored performance opportunities, in the design and production of a steering knuckle. This can be achieved by performing a detailed load analysis. Therefore, this study has been dealt with two steps. First part of the study involves modeling of the steering knuckle with the design parameters using the latest modelling software, and also it includes the determination of loads acting on the steering knuckle as a function of time. [9]

Yasoda Sreeram et al [10] has optimized the steering knuckle targeting reducing weight as objective function with required strength and stiffness. In automotive suspension, a steering knuckle is that part which contains the wheel hub or spindle, and attaches to the suspension components.

R. C. Juvinall et al. [11] stated in static failure theory that whatever is responsible for failure in standard tensile test will also be responsible for failure under all other conditions of static loading.

Fuganti et al. [12] described the development of a suspension steering knuckle through application of thixo forming technology of an aluminum alloy and described the methodology which was used for material/technology choice and component optimization. A component weight saving of about 30% was obtained, compared to the solution made of cast iron.

K. S. Chang et al. [13] discussed an integrated design and manufacturing approach that supports the shape optimization. The main contribution of the work is incorporating manufacturing in the design process, where manufacturing cost is considered for design. The design problem must be formulated more realistically by incorporating the manufacturing cost as either the objective function or constrain function.

R. Roy et al. [14] focused on recent approaches to automating the manual optimization process and the challenges that it presents to the engineering community. The study identifies scalability as the major challenge for design optimization techniques. GAs is the most popular algorithmic optimization approach. Large-scale optimization will require more research in topology design, computational power and efficient optimization algorithms.

R. L. Jhala et al. [15] assessed fatigue life and compares fatigue performance of steering knuckles made from three materials of different manufacturing processes. These include forged steel, cast aluminum, and cast iron knuckles. Finite element models of the steering knuckles were also analyzed to obtain stress distributions in each component. Based on the results of component testing and finite element analysis, fatigue behaviors of the three materials and manufacturing processes are then compared. They conclude with that forged steel knuckle exhibits superior fatigue behavior, compared to the cast iron and cast aluminum knuckles.

Muhammad et al. [16] achieved mass or weight reduction of steering knuckle of 8.4% that of existing, subjected to various loads at different conditions using finite element analysis software.

M. A. M. Nora et al. [17] used finite element method to analyze the frame of a low loader structure consisting of I-beams design application of 35 tons trailer designed in-house by Sumai Engineering Sdn. Bhd, (SESB). The material of structure is Low Alloy Steel A 710 C (Class 3) with 552 MPa of yield strength and 620 MPa of tensile strength. The scope of this study concern on structural design of the I-beams for info and data gathering, which will be used for further design improvement. Finite element modeling (FEM), simulations and analysis are performed using a modeling software i.e. CATIA V5R18.Firstly, a 3-D model of low loader based on design from SESB is created by using CATIA. Stress and displacement contour are later constructed and the maximum deflection and stress are determined by performing stress analysis. Computed results are then compared to analytical calculation, where it is found that the location of maximum deflection agrees well with theoretical approximation but varies on the magnitude aspect. Safety factor for the low loader structure has also been calculated. In the end, the current study is important for further improvement of the current low loader chassis design.

A workshop report [18] published by an agency of the United States government (Feb2013) focused on the development of light duty vehicle. The goals for reduction of weight of vehicle are set for the period of 2020 to 2050. The target for reduction of weight of LDV chassis and suspension system is 25% by the year 2020.

S. Vijayarangan et al. [19] used the different materials than regular material for optimization of steering knuckle. They use Metal Matrix Composites (MMCs) as it have potential to meet demanded design requirements of the automotive industry, compared with conventional materials. Structural analysis of steering knuckle made of alternate material Al-10 wt. % Tic was performed using commercial code ANSYS. It is found from the analysis; the knuckle strut region has maximum stress and deflection during its life time. The results obtained from numerical analysis and experimental testing using particulate reinforced MMCs for steering knuckle with a weight saving about 55% when compare with currently used SG iron.

Nipun Kumar,Gian bhushan, Pankaj chandna [20] studied the analysis of knuckle joint of various materials using CAE tools. Knuckle joint of various materials like aluminum, stainless steel, structural steel, magnesium and gray cast iron has been studied and it was found that knuckle joint made of aluminum has highest factor of safety for 50 KN loading condition. Hence knuckle joint made of aluminum best suited for 50 KN loading condition.

P. Nirala et al. [21] carried out the topology optimization of clamp cylinder t using CAE tools to reduce weight with the constraints of standard operating condition. The new optimized design of configuration is proposed. FEA of optimized cylinder is also carried out and compared with acceptance criterion. The optimized model is equally strong and light in weight compared to existing model. The topology optimization of the component is carried out and substantial reduction in weight about 70 kg is obtained and also obtained stress and deformation within acceptance criteria.

III. CONCLUSION

The optimized design of knuckle is analyzed using techniques of FEA and findings are encouraging. The optimized design has shown that nearly 10% weight reduction is possible without much compromise in strength of knuckle. The newer optimization techniques like topological optimization predicts appropriate mass reduction density in various regions of knuckle joint. This enables designers to focus on these regions for reduction of geometry.

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