A Review on Weight Optimization of Tie Rod

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***Abstract*— For analysing various dynamic parameters like natural frequency, maximum stress analysis and deformation of a tie rod, the FEA analysis of a typical tie rod is carried out. Different causes of tie rod failure are the fluctuating forces during steering and bumping of the vehicle. When vehicle is in static condition, steering forces are also considered for analysis. Two major types of tie rod failure are vibration and fatigue failure if the resulting vibrations are severe and greater than previously estimated.In this paper, a systematic study is carried out to understand the structural characteristics and its dynamic behaviour. This study mainly focuses on FEA analysis of a typical tie rod and determining its natural frequency by changing materials. And using this analysis for selecting a specific material which optimizes the weight of the tie rod without compromising its functional parameters.**

***Keywords*— Tie rod, Weight optimization, Ball joint, Coil spring, CATIA, Ansys, Knuckle.**

I. INTRODUCTION

Tie rod is the most vital part of the vehicles steering system which connects steering rack to the steering arm of the vehicle. In conventional steering system tie rods are used for transferring the forces to turn the wheel. Tie rod is a cylindrical rod with a threaded portion in the middle, for changing direction of car, the steering wheel is turned in that direction. Then the wheel shaft transfers this movement and connecting to the track rod enabling motion of tie rod. The possible causes of tie rod failure are improper material selection poor design, fatigue load and wear and tear of tie rod. Tie rod is subjected to compressive and tensile loads though maximum percentage weight of vehicle is carried by the suspension system varying forces and vibrations due to bumping of vehicle transmits to tie rod which may lead to the failure of tie rod. Passenger bus in static condition requires more force than the one in moving bus. Tie rod contains geometric imperfections and modified boundary conditions from a perfect cylindrical tie rod since a tie rod consists of outer and inner ends threaded into a middle rod body with changing end conditions. So, it is important to accurately find out the buckling loads of tie rods.

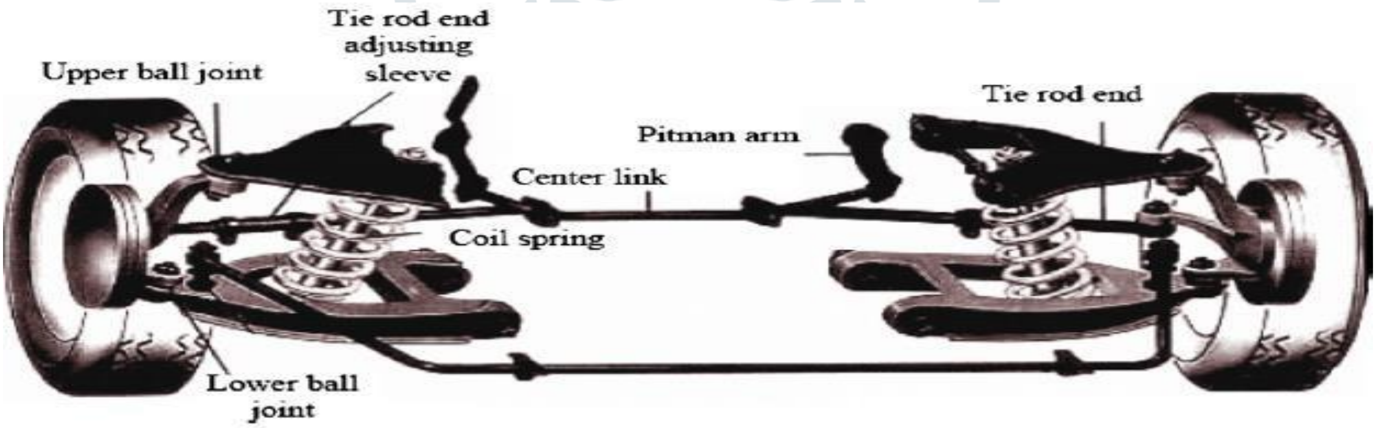

Fig. 1.1: Conventional Suspension

II. LITERATURE REVIEW

A. H. Falah, et al. conducted a study on failed tie rod end of a special utility vehicle. Hardness measurements and spectrum analysis showed that the failed part was AISI 8620 steel. The hardness and composition of the material didn't match with specified standard. Subsequent study revealed that fatigue was main cause of the failure of tie rod end. The region where crack initiated and beach marks could be clearly identified on the fractured surface of tie rod end. Analysis showed that fatigue crack originated from destructive areas in the vicinity of the throat and propagated from there. Following studies indicated that the primary cause of the failure of the tie rod was likely material deficiency. This hypothesis was supported by the observations that formation of the crack initiation and propagation together with a final rupture within the fractured area. So, in a nutshell, the accident took place as a result of incompatible tie rod.[5]

Ikpe Aniekan, et al. have studied the possible ways under which the tie rod may fail due to varying forces. A vehicle exposed to rough terrains, potholes, speed bumps or minor accident is subjected to horizontal, vertical and lateral loading conditions acting on the suspension system and distributed to other linkages including the tie rod. Under such condition, a vehicle tie rod can under compressive or tensile force characterised by buckling. Consequently, tie rod ends may wear out, causing misalignment of the vehicle wheels and endangering the lives of passengers. Various causes of failure of tie rod and factors affecting tie rod performance are investigated in this paper. To determine the compressive and tensile stresses acting on vehicle suspension system, McPherson suspension model was simulated in ADAMS software and the results showed a maximum compressive load of 18563N and maximum tensile load of -13340N.In some cases, the compressive load which often results in buckling failure of the tie rod may not need to be as high as 18563N.Before the tie rod fails, as other several factors considered in this paper were found to operate in sequence with compressive and tensile loads transferred to tie rod from the suspension system until failure occurs. Hence, vehicle tie rod is the life line of the steering wheel and should be considered seriously during manufacturing and inspected frequently while in operating condition to avoid abrupt failures.The weight of car in static condition is very low compared to weights acting on tie rod during working condition. In this paper, reverse braking and bumping scenario for compressive load and cornering and bump scenario for tensile load were found to have the most severe impacts on the tie rod during its service life, coupled with other factors such as Fatigue, Corrosion, poor manufacturing route, misalignment, service loading though not too severe as the tensile and compressive forces. Furthermore, longitudinal and lateral forces were obtained during the ADAMS simulation. These forces can result in bending of tie rod, but these effects on the tie rod were not taken into consideration because of the small values obtained when compared to compressive and tensile loads in z-direction.Therefore, companies manufacturing tie rods must pay attention to these factors as well as the material properties during design, since it is one of the ways to make the tie rod less susceptible to buckling and fracture failure.[1]

Soohyun Nam, et al. have developed light weight carbon composite tie bar which replaces the conventional steel tie bar. The main advantage of using carbon composite for making the tie rod is that it accomplishes high elastic strain and provide constant compaction pressure to the stack when used for long period of time. Authors have discussed various materials for developing thread and rod parts so that tensile strength of the tie rod cannot be compromised. Because of high drapability carbon fibre mat was used for thread part instead of unidirectional (UD) or fabric type carbon fibre. Due to high strength and elongation, the UD and fabric were used for rod part. Based on these specifications the tie bar specimen was fabricated and the optimum configuration of tie rod was suggested by the author.[2]

Sergio Lagomarsino, et al. have studied tie rods in masonry arches and vaults for tensile axial forces. The procedure for identification uses first three modal frequencies of the tie rod, measured by means of dynamic test. The structural system contains a beam with uniform section subjected to an axial tensile force and spring which is hinged at both ends. Beside the axial tensile force, the unknown variables are the bending stiffness of the section and the stiffness of the rotational springs. Since the equation of structural system doesn't allow analytical solution, the paper proposes the numerical solution.[6]

Wei Duan, et al. have studied threaded regions of tie rod. Tie rod is an important load carrying component of a car, the bearing capacity of a tie rod is not just determined by a strength of a rod but also by the strength of a threaded region. This paper reports the result of analysis of a threaded region and finding the minimum number of teeth to be required for avoiding the tie rod from failure. The research is done on two categories of largely used tie rods (i) LG75-00 with triangular thread and (ii) LG100-00 with trapezoidal thread. The results advice the minimal number of threads to be engaged together for avoiding a tie rod from failing by practical bending and shear application.

(i) Test on LG75-00 steel tie rod: When eight number of teeth was engaged with a mean pulling force of 3498 KN. Plastic deformation occurred followed by neck formation and further splitting the cross section of the unengaged region of the threaded part. The thread engaged were in good condition and no harm was taken place on threads. Which suggest that the strength of threaded connection was stronger than steel tie rod body itself. When 2,4,5 threaded connection was taken the threaded region was damaged and if threaded connection above 7 were taken the tie rod itself was damaged.

(ii) The same test was conducted on a LG100-00 steel tie rod and result was concluded as eight number of thread connection was safe above which the tie rod itself was damaged and below 8 threaded connection the threads were harmed, therefore for safe threaded connection eight number of teeth should be engaged.[3]

M. Amabili, et al. have done work on evaluation on tensile force in tie rods using frequency-based identification method. The benefits of this method are that it reduces measurement errors and easy to execute. The first natural frequency of tie-rods is experimentally analysed by measuring frequency response function (FRF). A numerical model on Rayleigh-Ritz method is grown for an axially loaded tie rod with the help of Timoshenko beam theory retaining shear deformation and rotary inertia.[4]

III. Conclusions

This paper presented a literature review on studies related to optimization of tie rod. Researcher doing their work in design and analysis of tie rod and testing it for various conditions. Review found that especially in the area of displacement, stress, strain, fatigue load, fatigue life, boundary conditions,etc. It is a significant study which require in depth investigation to understand structural characteristics and dynamic behaviour. From the above literature review it is found that various softwares or tools like CATIA, ANSYS, Hypermesh, Creo, Nastran, etc. are used to design and analyse the tie rod.

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