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Review Article

Tie Rod Design and Analysis: A Review

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Abstract

The FEA analysis of Tie rod is carried out to check its fatigue life, & improve the fatigue life. The most percentage weight of vehicle is taken by suspension system; however tie rod may get fail due to fluctuating forces during steering and bumping of vehicle .The forces from the steering is also considered during the static condition of car. Vibration and fatigue of Tie rod has been continuously a concern which may lead to structural failure if the resulting vibration and stresses are severe and excessive. It is a significant study which requires in-depth investigation to understand the structural characteristics and it dynamic behavior. This paper presents and focuses on some Finite Element Analysis (FEA) of a typical tie rod of a car will be carried out and fatigue life will be determined.

Keywords: *Tie rod, optimization, fatigue life, buckling load, steering link, improvement of fatigue life, FEA.*

1. Introduction

Tie rods connect the center link to the steering knuckle on automobiles with conventional suspension systems and recirculating ball steering gears, Fig. 1. On automobiles with MacPherson strut suspension and rack and-pinion steering gears, tie rods connect the end of the rack to the steering knuckle, Fig. 2. A tie rod consists of an inner and an outer end as shown in both previous figures. Tie rods transmit force from the steering center link or the rack gear to the steering knuckle, causing the wheels to turn. The outer tie rod end connects with an adjusting sleeve, which allows the length of the tie rod to be adjustable. This adjustment is used to set a vehicle's toes, a critical alignment angle, sometimes referred to as the caster and camber angles (A. H. Falah, *et al*. 2007, Manik A. Patil, *et al*. 2013).

Tie rods may fail in many different ways, and except for a slight increase in noise level and vibration, there is often no indication of difficulty until total failure occurs. Several causes of tie rod end failure have been identified. These include poor design, incorrect assembly, overloads, inadvertent stress raisers or subsurface defects in critical areas, use of incorrect materials and/or manufacture process, and improper heat treatment (H.R. Kim, *et al*. 2002).

Failure of tie rod may cause instability of vehicle and can cause an accident. So it's important to check the strength of tie rod.

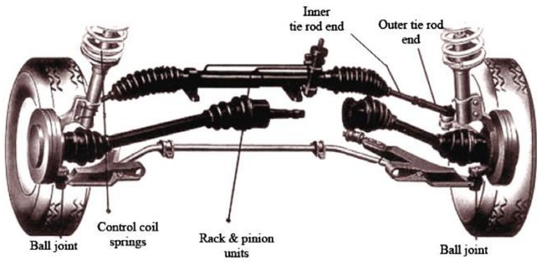

Fig. 1 McPherson Suspension System

Fig. 2 Tie Rod End

Fig. 3 Tie Rod

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The load coming on tie rod is mostly compressive. The efforts required where car is moving are comparatively less with stationary car. The working strength of the tie rod is that of the product of the allowable working stress and the minimum cross-sectional area (Seung K. Koh 2009). Vibration and buckling of Tie rod has been continuously a concern which may lead to structural failure if the resulting vibration and stresses are undesirable and excessive (Pradeep Mahadevappa Chavan, *et al*. 2014).

It is found that tie rod is primarily encounter under compressive loads and hence fails in buckling. Moreover due to suspension components fluctuating loads are also coming on tie rod due to random loads coming on suspension of vehicle (Shripad Mungi, *et al*. 2015). From various theoretical studies and practical observations, it is observed that tie rod is under compressive loading condition and hence fails in buckling. Apart from this because of suspension force components fluctuating loads are also coming on the tie rod, due to random loads on a suspension of a vehicle (Satish U.Wayal, *et al*. 2016).

2. Literature review

Following is the literature review of some papers giving more information about their contribution in design and analysis of tie rod.

Some of the researchers doing their work in Design and analysis of tie rod.

A. H. Falah, *et al*. (2007) carry out study on a failure analysis of a tie rod end of a sports utility vehicle (SUV) steering mechanism. In that paper he conduct Visual examination, photo documentation, chemical analysis, hardness measurement, and metallographic examination. The failure surface was examined with the help of a scanning electron microscope (SEM) equipped with EDAX facility that determines chemical composition at desired locations within the part. Author found that the tie rod end had failed by fatigue with a crack initiation at the throat (minimum) area of the threaded part due to material deficiency and improper heat treatment. Fractographic features indicated that fatigue was the main cause of failure of the tie rod end. Failure analysis results indicate that the primary cause of failure of the tie rod was likely material deficiency.

Seung K.Koh (2009) works on fatigue analysis to prevent fatigue failures and estimate the fatigue life of an automotive steering link. Finite element method was employed to determine local stress and strain distributions of the link. The experimental strains at the critical locations were measured by using strain-gages in order to verify the accuracy of the finite element analysis results. A carbon tube steel of STKM12C for the steering link exhibited cyclic softening behavior. As expected by the during finite element stress analysis, cracking occurred at the curved region of the tubular steering link rod and propagated circumferentially to the opposite side of the link rod, resulting in the final fracture.

H.R. Kim, *et al*. (2002) In this paper author carried out experiment which were of effects of additives, Ti +B, Zr, Sr, and Mg, on the mechanical properties and the microstructure of a preform cast were investigated. A finite element analysis was performed to determine an optimal configuration of the cast preform. Lastly, a forging experiment was carried out to make the final product of an aluminium tie-rod end by using the cast preform. The highest hardness was obtained when 0.2% Mg was added. Author conclude It is possible to propose the preform for the forging of a aluminium tie-rod end for the steering system of automobiles using the 3D FE analysis and the results of the analysis are similar to the results of the forging experiment.

Suraj Joshi, *et al*. (2011) in that paper author works on analysis of the strength of the threaded connection and determining the optimal number of turns of thread engagement. This paper reports the results of full-scale tensile rupture experiments on two categories of large-scale steel tie rods provided by China JULI Corporation: (i) LG75-00 steel tie rods with triangle threaded connection, and (ii) LG100-00 steel tie rods with trapezoidal threaded connection. The full-scale tensile rupture experiments were carried out to test the maximum allowable axial working load under different numbers of turns of engaged threads. The results of these experiments suggest minimum number of turns of thread engagement for preventing the failure of thread teeth of steel tie rods in practical shear and bending applications. author conclude that In order to minimize the probability of shear and bending failure occurring in the engaged thread teeth on a steel tie rod in service, the number of engaged thread turns should be kept as low as possible. The trapezoidal threaded connection is strongly recommended in where the nominal diameter of the connection is greater than 80 mm. When the number of engaged turns is exactly eight, failure occurs at the middle part of unengaged thread. the resistance to shear and the resistance to bending of the threaded connection are both greater than the tensile strength of the tie rod body with unengaged threads. It is recommended that the minimum number of turns of threaded engagement should be at least eight in any practical engineering applications of steel tie rods.

Soohyun Nam, *et al*. (2015) conducted study, a light weight carbon composite tie bar having threads at the ends with higher failure strain and specific strength compared to the conventional steel bolt tie bar was developed. The tie bar was composed of a thread part and a rod part. a ply of fabric was adopted to increase the tensile properties of the carbon composite tie bar by impeding the crack propagation.

Sergio Lagomarsino, *et al*. (2005) studied the tensile axial force of metallic tie-rods in masonry arches and vaults. The identification procedure uses the first three modal frequencies of the tie-rod, measured by means of a dynamic test. The reference structural system consists of a beam with uniform section, subjected to an axial tensile force and spring-hinged at both ends. Besides the axial tensile force, the unknown variables are the bending stiffness of the section and the stiffness of the rotational springs. Since the characteristic equation of this structural system does not allow analytical solutions, the paper proposes an approximate numerical solution, based on a minimization procedure of a suitable error function. The robustness of the method is tested by identifying a number of ideal tie-rods, modeled by means of a FEM code.

T. P. Smith (1971) completely automatic machine designed for eddy current inspection of critical areas on automobile steering tie-rods is described. The machine allows a uniform standard of inspection and can test components at four times the rate of an operator using manual methods.

Patrick O. Ebunilo, *et al*. (2016) investigated the theory of durability and reliability on vehicle tie rods and it was found out that buckling is the major failure mode that hampers its longevity during braking, cornering and both compressive and tensile load acting on the vehicle while going through speed bumps. Using CATIA software, both ends of the tie rods (inner and outer) were subjected to different load case scenarios obtained from ADAMS software. The load cases were analyzed to find the maximum loads in both directions, capable of causing the tie rod to buckle. CATIA software was used to model several designs and analyze possible areas of stress concentrations on the tie rod.

Nitin S. Duryodhan, *et al*. (2015) conducted their work that modeling of steering shaft is done by using Creo software and for the analysis ansys software is used. In this paper literature survey is made and it is found that there is lot of scope to improve the intermediate steering shaft and to improve its strength and rigidity by optimizing the design of the intermediate steering shaft by reducing the cost of the material and by saving the material.

Pradeep Mahadevappa Chavan, *et al*. (2014) works on buckling strength and compare buckling performance of Tie rod for different materials. Finite element models of the Tie rod also analysed to obtain stiffness and stress distributions in each component. Based on the experimental test results, theoretical calculation results and finite element analysis with NASTRAN results, stiffness values are validated. The mode shape and natural frequency results for different materials obtained in the normal modal analysis are compared. Author concluded Meshed model of Tie rod satisfied all quality criteria and hence the FEA results are accurate. The 1^{st} Mode natural frequency of carbon steel tie rod component is greater than the cast iron and aluminium tie rod component, so carbon steel tie rod is more suitable material for design of car tie rod.

Owunna Ikechukwu, *et al*. (2016) investigated the tie rod failure and factors affecting the tie rod performance. to determine the severity of tensile and compressive forces acting on a vehicle suspension system, McPherson suspension model was simulated in ADAMS software and the result showed a maximum tensile load and a maximum compressive load. In this paper, Reverse Brake and Bump 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 compressive and tensile forces.

Arif Senol Sener (2016) conducted their work that, Turkish customer automobile usage was determined by a questionnaire in order to form the Turkish Mission profile for a LCV (light commercial vehicle). A comparison between Turkish customer usage and a of the European County's mission profile was done. Referencing sale percentage of this vehicle and the region of the failures come out on other model vehicles were produced before and also Turkey's geographic and climate condition, a new test road was formed for this kind of vehicle. İn order to determine Turkey's rods fatigue characteristics a road test executed. About 50 road routes and some rough road's fatigue characteristics were acquitted with a LCV (Light Commercial vehicle) equipped with sensors. Collected data were elaborated with a software program such as; spike analysis, frequency analysis, arithmetic manipulation etc.. After that the general load spectrum of Turkey's roads belong to the steering wheel tie rod is formed. Rain-flow statistical counting method was applied steering wheel tie rod's signals in order to make fatigue comparisons meaningfully and other application. Then Fatigue analysis of the steering wheel tie rod according to MP (Turkish mission profiles) were calculated by using FEA (Finite Element Analysis) and verified by the Palsmgren-Miner rule.

Anne-Sophie Beranger, *et al*. In the automotive industry, most of the components are subjected in service to fatigue loading which may result in failures. In order to reduce design lead times and to assure a high reliability level of the parts, general procedures for durability assessment are developed. In this framework, this paper aims to present a fatigue life assessment methodology. Various factors are involved in the analysis: material fatigue data, multiaxial fatigue criteria, finite element method (FEM) calculations. A validation of this procedure was conducted via data generated from tests on a real current production component, namely a RENAULT Safrane suspension arm which was die cast from spheroidal graphite (SG) cast iron.

Amol Shende, *et al*. (2016) author work on vibration, buckling strength of the existing tie. The FE models of the tie rod also analysed to get the stiffness and stress distributions in each component. In modal analysis author obtained natural frequencies and mode shapes. Displacement stresses and strains obtained by performing static analysis of existing model. For existing model stresses were in safe limit further we had to check problem for transient dynamic response. By performing transient analysis we obtained 140Mpa stresses at both ends, under repeated loading structure will fail at this stress so there was a scope for modification.

Manik A. Patil, *et al*. (2013) conducted their work that The FEA analysis of tie rod is carried out to check its natural frequency, maximum stress analysis and deformation. The most percentage weight of vehicle is taken by suspension system; however tie rod may get fail due to fluctuating forces during steering and bumping of vehicle .The forces from the steering is also considered during the static condition of car. Vibration and fatigue of Tie rod has been continuously a concern which may lead to structural failure if the resulting vibration and stresses are severe and excessive.

Madhuri B. Thombare, *et al*. (2017) carry out study on weight reduction will reduce fuel efficiency, efforts to reduce emission & therefore save environment. In order to achieve these targets optimize parameters that affect the structural performance of tie rod. Results obtaining from the FEA are validated by using the experimental results. In case of buckling analysis, the buckling load factor obtained for optimized tie rod from buckling mode and critical buckling load is calculated. Results obtaining from the Finite element analysis are validated by using the theoretical results.

Prashant R. Vithalkar, *et al*. (2015) this paper focuses on the study of buckling load on the tie rod of steering system that undergoes an axial compression. They had analyze tie rod for to improve the mass and buckling load of tie rod and to find out maximum deformation and stress. Present research is divided in two parts. First, to conduct survey amongst the buses, examine the causes of failure and second is to design and analysis to recommend best possible alternatives of Tie Rod with the aid of advanced design tools like CAD. Tie Rod failure is one of the major problems facing for MSRTC workshop supervisor.

Malge Sangeeta Ganesh, *et al*. (2014) in this Paper Various Structural analyses such as Static-Structural, Modal Analysis of a steering rod are done. Static-structural analysis is capable to find out deformation in body in which Von-misses stress are calculated and this state that up to what extent the deformation in the rod occurs. While modal analysis is important in vibration point of view. i.e. Vibrations in body can be calculated up to what frequency the steering rod can sustain the load or Harmonic frequency of the body From above Optimisation of steering rod can be done. In This Paper structural analysis of ford fiesta classic car steering rod is done to optimise the Steering rod with better results than existing one.

Raghavendra K, *et al*. (2014) work done on analyze tie rod for active to improve the mass and buckling load of tie rod. The objectives of this study are to carry out the theoretical, experimental and modal analysis of tractor Tie rod to find different modes shapes by analysis FE software.

Ganesh B. Baraskar, *et al*. (2016) in this paper is work done on assess buckling strength and compare buckling performance of Tie rod for different proposed dimension of Tie rod with constant length and same material. Finite element models of the Tie rod also analyzed to obtain stiffness and stress distributions in it. The mode shape and natural frequency results for different proposed dimensions of tie rod obtained in the normal modal analysis and in buckling analysis, the buckling load factor obtained for that tie rod are compared and critical buckling load is calculated. Results getting from the Finite element analysis are validated by using the theoretical results.

Shripad Mungi, *et al*. (2015) objective of his research is a weight optimization. where they are proposed the optimized design of Tie rod that has a minimum weight and maximum critical buckling load carrying capacity. From results of normal mode analysis, it is seen that the natural frequency of existing design is 626 Hz and proposed design is 736 Hz. So there is ~ 18% rise in natural frequency of proposed design. The weight of existing tie rod is ~ 0.498 Kg and proposed design is ~ 0.421Kg. So there is approximately around 14% weight reduction is achieved.

Bharath S Gowda, *et al*. (2016) this paper presents and focuses on some Finite Element (FE) analysis of a typical tie rod of a car will be carried out and natural frequency will be determined. In the structural design optimization it is seen that pentagonal and hexagonal structure gives better results than the circular cross section. Among them the pentagonal structure has better results so that pentagonal structure is proposed for the Tie rods. From the material analysis and optimization the Grey cast iron gives lesser deformation and high damping capacity than the other material composition.

Satish U.Wayal, *et al*. (2016) the work was focused on functioning of the tie rod, the methods of its performance evaluation its optimization. The tie rod end job is to ensure the wheels are well aligned. It provides the adjustment of wheel alignment that keeps the inner and outer edges of the tires from wearing out. Hence, the tie rod functioning is crucial for steering as well as suspension performance of vehicle. Hollow Tie rod with 11.0mm ID is select after analysis, and further material analysis is done using 11.0 mm as ID. It gives 13.80% less weight than solid tie rod, without failure. Aluminum is suggested as applicable material after analysis.

3. Result and Discussion

From above literature review, it is observed that the tie rod failure occurs due to various loads like tensile, compressive, share and fatigue, etc. The above literature review showed that there is a necessity to analysis of tie rod with various parameters such as geometrical parameters and material parameters. Static analysis is performed to know the maximum stress developed on the tie rod and also the displacement and reaction forces at the contact location.

From above literature review observed that the critical buckling load calculated from the theoretical method is comparatively lower than the liner and non-linear buckling analysis. The objectives most of the work carried by various authors was to displacement, stress, strain, buckling, eigen value, mode shape and natural frequency, fatigue load, fatigue life, boundary conditions, mass of the model.

Conclusion

The paper presented a literature review concerning the studies on optimization of tie rod. The researchers doing their work in Design and analysis of tie rod. Review found that especially in the area of displacement, stress, strain, buckling, eigen value, mode shape and natural frequency, fatigue load, fatigue life, boundary conditions, mass of the model. It is a significant study which requires in-depth investigation to understand the structural characteristics and it dynamic behaviour.

From the above literature review, it is observed that various tools such as CATIA, Nastran , creo, Ansys & Hyper mesh are used to design and analysis of tie rod respectively.

References

A.H. Falah *et al.* (2006), Failure investigation of a tie rod end of an automobile steering system, *Engineering Failure Analysis*, Vol. 14, pp. 895-902.

Amol Shende, Vivek Padole, (2016) Failure Analysis and Fatigue Life Improvement of Existing Steering Mechanism (Tie-Rod) of Heavy Commercial Vehicles using FEA, *International Journal for Scientific Research & Development,* Vol.4, Issue. 07, pp. 880-882.

Arif Senol Sener (2016) Steering Wheel Tie Rod Fatigue Life Determination According to Turkish Mission Profiles, *International Journal of Engineering Technology,* Vol. 02, No. 02, pp. 56-62.

Bharath S Gowda *et al*. (2016) Analysis And Optimization Of Tie Rod For Steering Mechanism Of A Car at *International Journal of Innovative Research in Technology* Vol. 03, Issue. 03, pp.61-64.

Ganesh.B.Baraskar, Dr.V.S.Joshi (2016)performance evolution of tie rods in suspension system of car using FEA at *International Journal for Scientific Research and Development,* Vol. 03, Issue 11, pp. 197- 200.

H.R. Kim *et al*. (2002) A study of the manufacturing of tie-rod ends with casting/forging process, *Journal of Materials Processing Technology*, pp. 471-476.

Ikpe Aniekan Essienubong *et al*. (2016) Design of a Low Alloy Steel Vehicle Tie Rod to Determine the Maximum Load That Can Resist Failure *Journal of Robotics, Computer Vision and Graphics,* Vol. 01, No.01, pp.1-11.

Madhuri B. Thombare, Prof P. S. Talmale, (2017) Optimization Analysis of Automobile Tie Rod using FEA and xperimental Approach at IJESC Vol. 07, Issue No.8.

Malge Sangeeta (2014) Performance of the Structural Analysis of Ford Car Steering Rod at *International Journal of Research in Advent Technology,* Volume 2, Issue 2, pp. 01-05.

Manik A. Patil *et al*.(2013) FEA of Tie Rod of Steering System of Car International Journal of Application or Innovation in Engineering and Management, Vol. 02, Issue. 05, pp. 222-227.

Nitin S. Duryodhan , R. R. Gawande (2015) Modelling of Intermediate Steering Shaft of Fiesta Car and Its Static Structural Analysis, *International Journal of Computer Applications*, pp. 01-04.

P. R. Vithalkar *et al*. (2015) Study of analysis of bus passenger tie rod *International Journal of Research in Engineering & Technology,* Vol. 04, Issue 11, pp. 239-242.

Pradeep Mahadevappa Chavan, M M M Patnaik (2014) performance evaluation of passenger car tie rod using numerical and theoretical approach with different materials, *International Journal of Research in Engineering & Technology,* Vol. 03, Issue 08, pp. 92-100.

Raghvendra K, Ravi K Buckling analysis of tractor tie rod subjected to compressive load, *International Journal of Mechanical of Industrial Technology (IJMIT)*, Vol. 02, Issue 01, pp.125-129.

Satish U.Wayal and Prof. Tushar katratwar (2016) Transient Dynamic Analysis for Optimization of Tie Rod Using FEM *International Journal of Scientific and Research Publications*, Vol. 06, Issue 09. Pp. 263-267.

Sergio Lagomarsino ,Chiara Calderini, (2005)The dynamical identification of the tensile force in ancient tie-rods, *Engineering Structures, Vol.* 27, pp. 846–856.

Seung K. Koh (2009) Fatigue analysis of an automotive steering link, *engineering failure analysis,* Vol. 16, pp. 914-922.

Shripad Mungi (2015), Performance Optimization of Tie rod using FEAIJERD, *International Journal of Engineering Research and Development,* Vol. 11, Issue 03, pp.27-33.

Soohyun nam. *et al*. (2015) Development of the light weight carbon composite tie bar, *Composite Structures,* Vol. 134, pp. 124-131.

T. P. Smith (1971), Automatic crack detection system for automobile steering tie rods.

Wei Duan a, Suraj Joshi, (2011) Failure analysis of threaded connections in large-scale steel tie rods, *Engineering Failure Analysis*, Vol. 18, pp. 2008-2018.