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TITLE: RECENT STUDY AND REVIEW ON FAILURE ANALYSIS OF KINGPIN AND ITS STRENGTH PERFORMANCE

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Abstract

Kingpin is the component of steering system used in vehicles to steer, control and used to provide stability to vehicle by means of axle and wheel spindle connector. It is designed in such a way that it should sustain major jerks, lodgings and sudden impact which directly transmit through the wheel. It is a rigid shaft which holds the load of vehicle comes on wheel. It is available in different shapes and sizes along with the different materials as per the type of vehicle.There are several research studies are available to understand the failure of kingpin. Major factors which leads the failure are the sudden jerks and unbalanced wheels which leads play in kingpin. If play accurse in kingpin joints, the wear takes place and kingpin get failed before its designed working period. In this paper several reasons of failure are studied and summarized to draw certain conclusion. For that purpose, several papers and research materials are taken into consideration.

Index Terms: *Kingpin failure, kingpin wear, steering system.*

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1. INTRODUCTION

A kingpin was processed by hot forging of a hot rolled 88,90mm round bar of SAE 4140 steel. The part was machined and thermal treated by quenching and tempering. The kingpin is assembled into a front wheel of an bus/ truck. Current-era automobile front suspension incorporates a physical kingpin, the axis defined by the steering knuckle pivot points acts a "virtual kingpin" about which the wheel turns. This virtual kingpin is inclined toward the centerline of the vehicle at an angle called the kingpin angle. Virtual or physical, the kingpin angle may also be referred to by its acronym KPA, kingpin inclination (KPI), or steering axis inclination (SAI), and remains a fundamental vehicle design parameter. On most modern designs, the kingpin angle is set relative to the vertical, as viewed from the front or back of the vehicle, and it is not adjustable, changing only if the wheel spindle or steering knuckles are bent.

The kingpin angle has an important effect on steering, making it tend to return to the straight ahead or centre position because the straight ahead position is where the suspended body of the vehicle is at its lowest point. Thus, the weight of the vehicle tends to rotate the wheel about the kingpin back to this position. The kingpin inclination also contributes to the scrub radius of the steered wheel, the distance between the centre of the tyre contact patch and where the kingpin axis intersects the ground.

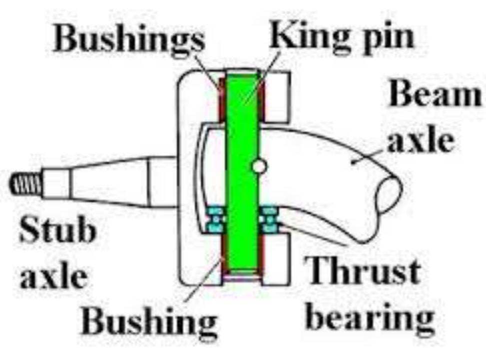

Fig. 1: Kingpin location on front axle.

2. LITERATURE REVIEWS

R. P. Rajvardhan1, S. R. Shankapal2, S. M. Vijaykumar3, "Effect Of Wheel Geometry Parameters on Vehicle Steering". The main intention of their study is to improve the steerability and handling of the vehicle by avoiding the steering pull and wheel wandering problems. As per the specification of their selected vehicle Honda CR-V, a multi-body model of the SUV was built in ADAMS/CAR software. The SUV model was validated by comparing simulation results with the standard graphs from literature. Using that model, manoeuvres for different values of wheel geometry parameters, were simulated. The steering effort, steering wheel returnability and the lateral forces produced by the tires were obtained in order to predict the behavior of the vehicle for different wheel geometry parameters.[1]

Dinesh Babu S.1, Farug H.2, Tanmay Mukherjee3, "Design & Analysis of Steering System for a Formula Student Car". They have design a simple yet effective steering system that reduces driver effort and also adapts to the track conditions offered such that the system does not fail causing harm to both the car and also the driver. A mathematical model is set up followed by geometrical validation and modelling of the entire steering system using CAD software SolidWorks and CATIA V5. Since like any other mechanical system stress is generated in the system, Static analysis is performed using ANSYS Workbench to check the static stress distribution. To ensure the dynamic response of the steering system Multi Body Dynamics (MBD) analysis is performed using Altair Hyperworks. [2]

Yung-Chang Chen, Hsing-Hui Huang, Ching-Hsu Hsieh and Jia-Bin Lin, "Determination of Kingpin Axis from Wheel Points Using Dual Quaternion Analysis". Authors have presented a dual quaternion analysis (DQA) method for calculating the kingpin axis geometry. The corresponding parameters include the caster angle, SAI angle, toe angle, caster trail and scrub radius. An ADAMS/Car simulation model for the strut-SLA suspension is employed to assess the efficiency of the proposed method. Two distinctive marker sets and the marker coordinates are extracted from the kinematic model. In addition, the finite screw axis (FSA) method is employed for purposes of comparison with the DQA method. The results reveal that the marker distribution has a significant effect on calculating the position of the screw axis. In contrast to the FSA method, the DQA analysis is immune to any singularities because it enables the simultaneous matrix of rotation and translation. Thus, their proposed method is suitable for determining the kingpin axis and its related parameters in a K&C test. [3]

Akash Sood1, Abhishek Pandey2, Savita Vyas3, "Analysis and Design of Steering and Suspension System by Mathematical and Computational Methodology". Their paper introduces a design and analysis of suspension and steering system of formula SAE vehicle by both mathematical and computational methodology for optimum performance. The design is according to the formula SAE rulebook. The deep understanding is established between logics and parameters of vehicle. The design parameters are decided either from logics or from worst condition of track and the simulation of parameters are conducted. [4]

Pravin R.Ahire1, Prof.K. H. Munde2, "Design and analysis of front axle for heavy commercial vehicle". Author have dealed with design and analysis of front axle. The same analysis with help of FE results were compared with analytical design. For which their study has been divided in to two steps. In the first step front axle was design by analytical method. For this vehicle specification – its gross weight, payload capacity, braking torque used for subject to matter to find the principle stresses & deflection in the beam has been used. In the second step front axle were modeled in CAD software & analysis in ANSYS software. [5]

Shpetim LAJQI, 2. Stanislav PEHAN, "Design of Independent Suspension Mechanism for a Terrain Vehicle with Four Wheels Drive and Four Wheels Steering". In their study, a terrain vehicle with four wheels drive and four wheels steer intended to use for recreational purpose. Authors have designed the suspension mechanism that fulfills requirements about stability, safety and maneuverability. Research is focused to do a comprehensive study of different available independent suspension system and hence forth develop a methodology to design the suspension system for a terrain vehicle. Few chosen suspension systems are analyzed into the very details in order to find out the optimal design of it. During development process of the suspension system should be considered design constraints and requirements provided in the check list. Afterwards the simulation results for kinematics analyses of suspension mechanism are performed in Working Model 2D and MATLAB environments. Achieved results are discussed in detail in order to find the best solution that will fulfill pretentious requirement from developed suspension system.[6]

Shijil P, Albin Vargheese, "Design and Analysis of Suspension System for an All Terrain Vehicle". Authors have studied the static and dynamic parameter of the suspension system of an ATV by determining and analyzing the dynamics of the vehicle when driving on an off road racetrack. Though, there are many parameters which affect the performance of the ATV, authors have focused only on to optimization, determination, design and analysis of suspension systems and to integrate them into whole vehicle systems for best results. The goals were to identify and optimize the parameters affecting the dynamic performance suspension systems within limitations of time, equipment and data from manufacturer. Lastly they also come across the following aspects.

a) Study the static and dynamic parameters of the chassis.
b) Workout the parameters by analysis, design, and optimization of suspension system.
c) Study of existing suspension systems and parameters affecting its performance.
d) Determination of design parameters for suspension system. [7]

Arun Singh, Abhishek Kumar, "Study of 4 Wheel Steering Systems to Reduce Turning Radius and Increase Stability". In their research, the performance of four wheels steered vehicle model is considered which is optimally controlled during a lane change maneuver in three type of condition which is low speed maneuver, medium speed maneuver and high speed maneuver. Four-Wheel Steering – Rear Wheels Control. For parking and low-speed maneuvers, the rear Wheel steer in the opposite direction of the front wheels, allowing much sharper turns. At higher speeds, the rest wheels steer in the same direction as the front wheels. The result is more stability and less body lean during fast lane changes and turns because the front wheels don't have to drag non-steering rear wheels onto the path. [8]

C.Radhakrishnan1, Azhagendran.K 2, "Design and Analysis of Automotive Shackle". Shackle as a part of suspension system, this help to enhance the leaf spring flexibility. The arrangement tends to tensile, bending, shear and proof loads. This will cause the failure of suspensions system. Finite element analysis (FEA) is carried out at static condition of the shackle, so that stress distribution can be observed for analysis of high stress zones. Solid works model is carried out in the analysis. The analysis is to compare the various loading condition and the overall stress distribution zones have been studied. [9]

J.B. Marcomini1*, C.A.R.P. Baptista2, "Failure Analysis of a Hot Forged SAE 4140 Steel Kingpin". The fifth wheel and kingpin connection system, a critical part of heavy vehicles, provides the link of tractor and trailer. The kingpin is usually manufactured by hot forging. A part manufactured by this process was assembled in a fifth wheel of an off-road truck and presented an early failure. The truck was used in a quarry until the kingpin failure, three months later. One process issue that can occur in hot forged products is a poor grain structure due to overheating, burning and cavitation. The Scanning Electron Microscopy (SEM) analysis of the failed part showed the presence of cavitation. However, the failure analysis results evinced that cavitation was not the main cause of the fracture, but a combination of wear, impact fatigue and overload. [10]

Yucheng Liu, "Recent Innovations in Vehicle Suspension Systems". Authors stated that suspension system is one of the most important systems in a modern vehicle. It significantly contributes to the vehicle's availability and safety; keeps vehicle occupants comfortable; also protects the vehicle from damage and wear. Due to its importance in the vehicle structure, a massive amount of effort has been spent on enhancing the performances of suspension system, such as stability, controllability, and other capabilities. Their study briefly reviews recent innovations and some representative patents (since 2000) in this area and outlines the features and advantages of these inventions. The future trends of research in the suspension system design are also discussed. [11]

J.P. Pascon, R.L. Teixeira, "Failure Analysis of a Hot Forged SAE 4140 Steel Kingpin". Authors have summarized some of the facts, the truck was used in a quarry under severe operation conditions, riding on an uneven ground, which caused overloads on the fifth wheel coupling. The overloads were transmitted to the kingpin causing the external surface deformation which lead to a clearance formation. The random nature of the applied loads and changes in loading point due to maneuvering justify the irregular deformation pattern observed in the kingpin cross section. This scenario was sufficient to allow the occurrence of contact-fatigue and impact-fatigue mechanisms. Moreover, the finite element analysis performed here corroborates the occurrence of plastic (or ductile) deformation at the lateral surface of the king pin in the case of those severe conditions. The cavitation observed in the kingpin material was not the main cause of the failure but just contributed for the fracture propagation. [12]

Andrew S.Ansara, Andrew M.William, "Optimization of Front Suspension and Steering Parameters of an Off-road Car using Adams/Car Simulation". The design of an off-road vehicle is very complicated as the car is subjected to very harsh conditions and it can fail easily causing a lot of damage if it isn't designed well. One of the most important parameters affecting the car's performance is the suspension and steering systems design as it affects the vehicle's performance in handling, during breaking and cornering, the tires contact with the ground, the forces acting on the vehicle's chassis and it also affects the driver's comfort during the ride. So given all that we need to pay a lot of attention to designing a set up where all the systems harmoniously work together to give the optimum performance that can allow to vehicle to operate with maximum safety, stability and reliability. [13]

Sagar Jambukara and Sujatha Cb, "Study of the Effects of Caster Offset and Kingpin Offset on Kinematics and Lateral Dynamics of Long Wheelbase Solid Axle Bus". Their study was to understand the effects of varying caster offset and kingpin offset on a long wheelbase bus and therefore an open loop study was conducted for the same. Handling response metrics were evaluated for three different manoeuvres, namely straight path driving, steady state circles and double lane change. The handling response metrics analysed include diameter of turn, tyre side-slip angles, body slip angle, yaw angle, yaw rate, chassis roll and forces at tyre road contact. A 2-variable (caster offset and kingpin offset) and 5-level design of experiments (DOE) was carried out using the full factorial matrix to determine the effects of the parameters on the above-mentioned handling metrics. The results show that both caster offset and kingpin offset have noteworthy influence on the kinematics and dynamics of the bus and hence their real-time control could be possibly considered for further improvement of handling performance. [14]

Marek Jaśkiewicz1, Jakub Lisiecki2, "Facility for performance testing of power transmission units". Their study describes the engineering design for a facility to test the performance of gearboxes and drive axles. Power transmission units are much more frequently tested on test rigs than in motor vehicles. The rig testing of such devices constitutes a very complex area because of the diversity of functions performed by individual components and their parts in the power transmission systems of motor vehicles and construction machinery. In the simulation tests carried out on simulation test rigs, the conditions of testing of individual units should match the expected conditions of operation for such units as much as possible. The test rigs used for this purpose are very complicated and expensive, but the results of rig tests are more reliable and accurate than they would be if other test methods were employed. The rig tests described here reflect the impact of anticipated service loads on the endurance of the unit under test. [15]

3. CONCLUSION

By studying all above research and papers following conclusions are drawn.

1. Very less study material is available on kingpin and its failure.
2. Authors have focused on entire steering and suspension system, whereas the separate attention is needed on kingpin.
3. Material change can also gives better results in case of kingpin failure.
4. It is observed that the vibrations are also responsible for failure, Hence large scope is available to study vibrations on kingpin.
5. Kingpin failure or brake accurse when sudden jerk or sudden impingement of load accurse and fails if play develops in kingpin joint.

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