An overview on front axle analysis of an automobile

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Abstract- **Front axle is the most important part especially in a load carrying vehicle. The failure of front axle is a serious concern in commercial vehicles. So, it is necessary to analyze the front axle that able to withstand at severe load conditions before its manufacturing. To this kingpin stub axle plays a major role in direction control of a vehicle. This is to analyze the front axle at different loads. Kingpin stub axle linked with other linkages and supports vertical weight of the vehicle. This mainly deals about the improvement of strength of front axle, material selection. For finding the stresses on the beam using various software which are available for the static analysis and finding the loads at which axle is going to be deformed. The analysis is carried out to the vertical loads where total weight is carried out by the vehicle. As using the kingpin stub axle assembly for front axle the cornering load is more for kingpin. As the vertical loads are applied on the PAD spring which gives major support for front axle. Further the objective of analysis is to improve product quality, developing time, material and manufacturing costs and maintaining stress levels. This can be achieved by performing detailed load analysis.**

Index terms- Front axle, Stub axle, Static analysis, Material selection, Weight reduction

I. INTRODUCTION

An axle is a centre shaft for a rotating wheel or gear. On wheeled vehicles, the axle may be fixed with the wheels, rotating with them or fixed to the vehicle with the wheels rotating around the axle. The 30-40% of vehicle weight is carried by the front axle. Bearings or bushings are provided at the mounting points where the axle is supported. Conventionally the front axle (FA) is designed and analyzed using various softwares like Solid works, hyper works capabilities, ANSYS analysis software. It is further optimized for reduction in mass. Generally the static analysis of FA is carried out to withstand all the forces coming in the working conditions of the vehicles. While the off road conditions like as uneven surfaces and bumpy roads on which the vehicle has to operate. These ground irregularities leads to unexpected loads coming on to the body parts. Ackerman geometry plays an important role in turning radius. Kingpin stub axle assembly is main load carrying member for front wheels and helps in steering of the vehicle. Stub axle takes the load coming from the front wheels and transfers it into supports. Front axle is like a simply supported beam. Under dynamic conditions, vertical bending moment is increased due to road roughness. Thus it is very difficult to find the crack propagation in short time. During the operation of the vehicle, road surface irregularity causes cyclic fluctuations of stresses on the axle, which is the main load carrying member. Front portion of the automobile is carried out by a beam. So, in the front axle there are two types (i) Dead axle (ii) Line axle. Dead axles are those which do not rotate. These axles have sufficient rigidity and strength to take the weight. The ends are suitably designed to accommodate stub axles. Line axles are used to transmit power from gear box to front wheels. Kingpin on one end is connected to stub axle and other end is connected to front axle via stud and bushes. At static condition the axle may be considered as beam supported vertical upwards at the ends i.e. at the centre of the wheels and loaded vertically downwards at the centre of the spring pads. The vertical bending moment thus caused is zero at point of support and rises linearly to maximum at the point of loading remains constant. On wheeled vehicles, the axles could be mounted to the wheels, also can maintain the position of the wheels relative to each other and to the vehicle body. The front axle beam along with hub which we seen in commercial vehicles which are heavy weight. To optimize such solution to design a new shape of front axle support this reduces the weight by changing material of the axle and to increase the performance of the vehicle.
FA analysis is carried out to find out factor of safety for critically stressed region due to vertical load,

brake load and cornering load under running conditions.

II. ASSEMBLY OF FRONT AXLE

An axle is a central shaft used for rotating wheel. On wheeled vehicles, the axle could be mounted to the wheels, rotating with them, or located to its surroundings, with the wheels rotating around the axle. The axles achieve to transmit driving torque to the wheel. Also it can maintain the position of the wheels relative with each other and to the vehicle body. The axles must additionally bear the weight of the vehicle plus any cargo. The front axle beam is one of the main parts of vehicle suspension system shown in Fig. 1. It houses the steering assembly as well. About thirty 30-40 percentage of the total vehicle weight is taken up by front axle. Front axle is made of I-section in the middle portion and circular or elliptical section at the ends. The special x-section of the axle makes it able to withstand bending loads due to weight of the vehicle and torque applied due to braking. It consists of main beam, stub axle, and swivel pin, etc. The wheels are mounted on stub axles. The front axles are generally dead axles, but are live axles in small cars of compact designs and also in case of four-wheel drive.

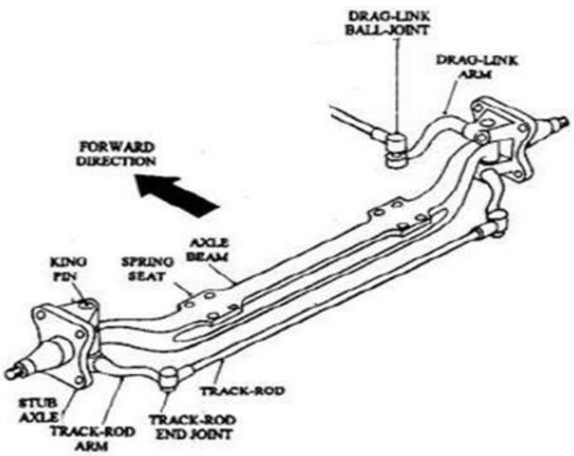

Fig. 1. Front axle assembly

The front axle is generally a forged component for which a higher strength to weight ratio is desirable. The “I” cross section has lower section modulus and hence gives better performance with lower weight. This type of construction produces an axle that is lightweight and yet has great strength. The I-beam axle is shaped so that the centre part is several inches below the ends. This permits the body of the vehicle to be mounted lower than it could be if the axle were straight. A vehicle body that is closer to the road has a lower centre of gravity and holds the road better. On the top of the axle, the springs are mounted on flat, smooth surfaces or pads. The mounting surfaces are called spring seats and usually have five holes. The four holes on the outer edge of the mounting surface are for the U-bolts which hold the spring and axle together. The centre hole provides an anchor point for the centre bolt of the spring. The head of the centre bolt, seated in the centre hole in the mounting surface, ensures proper alignment of the axle with the vehicle frame.

The kingpin acts like the pin of a door hinge as it connects the steering knuckles to the ends of the axle I-beam. The kingpin passes through the upper arm of the knuckle yoke, through the end of the I-beam and a thrust bearing, and then through the lower arm of the knuckle yoke. The kingpin retaining bolt locks the pin in position. The ball-type thrust bearing is installed between the I-beam and lower arm of the knuckle yoke so that the end of the I-beam rests upon the bearing. This provides a ball bearing for the knuckle to pivot on as it supports the vehicle's weight. When the vehicle is not in motion, the only job that the axle has to do is hold the wheels in proper alignment and support part of the weight. When the vehicle goes into motion, the axle receives the twisting stresses of driving and braking. When the vehicle operator applies the brakes, the brake shoes are pressed against the moving wheel drum. When the brakes are applied suddenly, the axle twists against the springs and actually twists out of its normal upright position. In addition to twisting during braking, the front axle also moves up and down as the wheels move over rough surfaces. Steering controls and linkages provide the means of turning the steering knuckles to steer the vehicle. As the vehicle makes a turn while moving, a side thrust is received at the wheels and transferred to the axle and springs. These forces act on the axle from many different directions. Therefore, that the axle has to be quite rugged to keep all parts in proper alignment. The outer end of the spindle is threaded. These threads are used for installing a nut to secure the wheel bearings in position. A flange is located between the spindle and yoke. It has drilled holes around its outer edge. This flange provides a mounting surface for the brake drum backing plate and brake components. The kingpin acts like the pin of a door hinge as it connects the steering knuckles to the ends of the axle I-beam. The kingpin passes through the upper arm of the knuckle yoke, through the end of the I-beam and a thrust bearing, and then through the lower arm of the knuckle yoke. The kingpin retaining bolt locks the pin in position. The ball-type thrust bearing is installed between the I-beam and lower arm of the knuckle yoke so that the end of the I-beam rests upon the bearing. This provides a ball bearing for the knuckle to pivot on as it supports the vehicle's weight. When the vehicle is not in motion, the only job that the axle has to do is hold the wheels in proper alignment and support part of the weight. When the vehicle goes into motion, the axle receives the twisting stresses of driving and braking. When the vehicle operator applies the brakes, the brake shoes are pressed against the moving wheel drum. When the brakes are applied suddenly, the axle twists against the springs and actually twists out of its normal upright position. In addition to twisting during braking, the front axle also moves up and down as the wheels move over rough surfaces. Steering controls and linkages provide the means of turning the steering knuckles to steer the vehicle. As the vehicle makes a turn while moving, a side thrust is received at the wheels and transferred to the axle and springs. These forces act on the axle from many different directions. Therefore, that the axle has to be quite rugged to keep all parts in proper alignment.

III. SURVEY OF IMPORTANT LITURATURE

Much research work has been done in the field of analysis of front axle. The literature review of some papers gives more information about their contribution in design and analysis, optimization of front axle. Min Jhang, Lijun Li (2016) analyzed stress and fatigue life of front axle beam by finite element analysis and experimental method. Also, investigate the effect of crack parameters like length and depth on fatigue life [1]. M.M. Topac (2008) evaluated the fatigue failure prediction and fatigue life of a rear axle housing prototype by using Finite element analysis of heavy duty truck. The expected load cycles required to fail during the vertical fatigue tests of a rear axle housing prototype is studied and mechanical properties were determined of housing material [2]. N. León , O. Martínez, P. Orta C., P. Adaya (2000) performed Various experiments and numerical methods were adopted to obtain the stress analysis of a frontal truck axle beam and improved the quality of product by reducing the development time has given the case studies on front axle beam where he explains the complete procedure of analysis of front axle beam. Also explains how he reduced the weight of front axle beam by parametric optimization [3]. Raed EL-Khalil, works on discrete simulation and computer modeling serve as an effective means for the analysis and optimization of manufacturing systems. Simulation and computer modeling tools provide a quantitative means for the analysis of a current manufacturing process as well as evaluating alternative designs and/or systems. This paper will present an analysis and optimization of a new manufacturing system for front suspension axle assembly process utilizing computer modeling and simulation. This paper is sponsored by one of the original equipment manufacturers axle assembly plant in North America. The main objective of this paper is to determine the optimal offline buffer locations for a front axle assembly line to achieve maximum throughput within budget limitations [4]. Siddarth Dey, P.R.V.V.V Sri Rama Chandra Murthy. D, P.Baskar done Structural Analysis of Front axle beam of a Light Commercial Vehicle (LCV)-(2014) to determine the load capacity of the front rigid axle of a LCV and determine its behavior at static and dynamic conditions. This work analyses the static, transient and modal analysis of the front axle beam. The geometry of axle is created in Pro-E WildFire5.0 software which is imported to ANSYS14.5. A fine congregate finite element model (meshed) is generated using the software to assess the strength and capability of the product to survive against all forces and vibrations [5]. Prathapa.A.P , N. G.S. Udupa done Structural Analysis of Front axle apart from above loads is critically subjected to cyclic and shock loads. In case of four wheelers, Six wheelers and multi axle vehicles role of frontal axle is most important since it drives the rear axle .A robust design of frontal axle involves load calculations and load considerations for four wheeler and six wheeler, Followed by preliminary and detailed design considerations . In the light, of the above an automobile truck frontal axle is considered for the topic of research to understand its behavior to the loads during service conditions and also at off design conditions for four wheeler and also for six wheeler. The study involves load calculations for various conditions namely four wheeler, six wheeler ,gyroscopic couple ,Fatigue, dead weight This work is focused on structural evaluation of front axle using FEA approach with preliminary detailed design considerations which, includes Gross weight of the vehicle ,Inertial loads, dynamic loads and Rolling resistance. Commercial FE software (ANSYS) is used to determine the structural integrity of Frontal axle [6].

Ru-xiongLi ,Song-huaJiao , Jin-lvWang ,In this paper automobile front axle taken for both process of exact roll forging billet and die design are studies as the result blank making roll forging die of front axle , pre molding roll forging die and final forming roll forging die are design seperatoly [7]. Hemant L. Aghav1, M.V.Walame ,presents Front axle of heavy duty truck is the important component of vehicle and needs good design under the various loading conditions of the complete vehicle. Aim of the work is to stress analysis and predict the life of front axle for vertical, and vertical and braking loading case. The fatigue life of front axle is generally estimated by stress life approach and strain life approach method. Front axle beam assembly was modeled in the NX cad software. Meshing and Stress analysis is performed by ANSYS workbench and fatigue analysis is performed by NCODE design life ANSYS tool under different loading cases. Fatigue life of axle obtained by FEA method is more than 2 x 105 cycles, which is considered as safe for vertical loading case. Similarly, Fatigue life of axle obtained is more than 4 x 103 cycles, which is considered as safe for vertical and braking loading case. The max stress region is below spring pad of axle for vertical loading and in the goose neck of axle for vertical and braking loading case [8].

Nagendra Reddy H R , Altaf Bhandari, Manjunath S L, Madhu M S,Siddesh , Present study to focus on mechanical integrity and life evolution of front axle using FEA approach, blending the classical approach for preliminary design considerations and loading conditions, including Gross weight of the vehicle, Inertial loads Gradient resistance and rolling resistance. Consider the selected front axle is proved to be beam of uniform strength. And Customized methodology of analysis through sub modelling technique, dynamic characteristics subjected to cyclic loading good man dia-gram are utilised to find life evaluation [9]. Sumit P.Raut, Laukik P.Raut in a review of various techniques used for shaft failure analysis .The various methodology used for failure analysis of the shaft used in different application by various authors are reviewed in this paper. This paper presents the comparison of the different methodology used, their application and limitation by various authors. The objective of present work is to study the various methodologies used for the shaft failure analysis and to choosiest methodology suitable for the failure analysis of shaft used in gear box which is mounted on the overhead crane to prevent repetitive failure. Shaft failure leads to heavy loss due to stoppage and repairing cost associate with the breakdown [10].

Ketan Vijay Dhande1, Prashant Ulhe, On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to its surroundings, with the wheels rotating around the axle. The axles serve to transmit driving torque to the wheel, as well as to maintain the position of the wheels relative to each other and to the vehicle body. The axles in a system must also bear the weight of the vehicle plus any cargo. The front axle beam is one of the major parts of vehicle suspension system.. In present research work design of the front axle for Ashok Leyland 1612 Comet heavy commercial vehicle were done. The approach in this work has been divided into two steps. In the first step front axle was design by analytical method. For this, the vehicle specifications, its gross weight and payload capacity in order to find the stresses and deflection in the beam has been used. In the second step front axle were modeled in NX-CAD and meshed in HYPERMESH software module. The meshed model was solved in ANSYS software. The FE results were compared with analytical design [11].

Leon et al. (2000) used experimental and numerical methods, for the stress analysis of a frontal truck axle beam. The results obtained by finite element method were verified experimentally using photo stress. Mahanty et al. (2001) performed an experimental and numerical analysis of a tractor's front axle. Based on finite element analysis results redesign was carried out for the front axle for weight optimization and easy manufacturability. Five different models were proposed based on ease of manufacture and weight reduction. The results obtained by finite element method were analyzed by thirteen different certification test load conditions. Maly and Bazzaz (2003) used experimental and numerical methods, for design change from casting to welding for an axle casing [12].

Review of literature suggested that many authors have reported determination of stress, deflection and analysis of the automobile axel for different boundary conditions and some researchers have worked on the calculation of critical points in the automobile axel , still there exists to redesign and modify the geometry of the automobile axel to optimize the weight of the automobile axel and check the physical properties under given condition for safer work as shown in the following Table 1 [13] the comparison between analytical and FEA results for the different materials. Deflection from FEA results are in good relation with Analytical results.

Table 1. Comparison of analytical calculation and FES results

Materials	Parameters	Analytical results	FEA results
SAE1018	γ_{max} (mm)	4.84	4.16
	σ (N/mm^2)	21.46	37.78
AISI1020	γ_{max} (mm)	5.085	4.17
	σ (N/mm^2)	21.46	37.79
Cast iron	γ_{max} (mm)	9.24	4.29
	σ (N/mm^2)	21.46	37.12
SAE4130	γ_{max} (mm)	5.35	4.17
	σ (N/mm^2)	21.46	37.71

IV. METHODOLOGY

During the front axle modeling process, according to the front axle structural characteristics and the subsequent mesh divide ease, it guarantees the front axle’s structure characteristic as well as convenience following finite element analysis, and carries on the partial simplification to the front axle structure, thus establishes front axle’s finite element computation shell model. Based on the front axle structural characteristics and bear loading conditions to make appropriate assumption, simplify the front axle entity model into reasonable mechanical model, and choice three static analysis conditions, namely the front axle static full load, Impact load, Emergency braking make loading analysis, and set the loading analysis results as finite element modal’s loaded load, and come within the linear elastic to calculate respectively the front axle’s tensile strength and yield strength in these three conditions. a axle redesign for the three condition, then check the actual deflection occurred in those design, select the best design according to condition. During the optimization process the evaluation of the different alternative combination of product design parameter is carried out to achieve one or several objective functions. Generally the design parameters are subject to restrictions and boundary conditions that has to be previously described and defined. Furthermore a search strategy has to be defined to find the combination of design parameters that fulfills the objective functions. Commonly, during product development existing limitations affect product performance, for example: natural physic laws, material properties, customer specifications, existing standards etc. These limits constraint the product design specifications, in achieving the desired objective functions. One important constraint are permissible stress and strain levels. The optimization process involves following activities: - Selection of variables that describe the design alternatives - Selection of objective functions to be minimized or maximized. - Establishment of restrictions, expressed in terms of design variables, which must be satisfied by any acceptable design [14].

V. CONCLUSIONS

Weight reduction plays an important role in selection of an automobile component. When the weight of the vehicle is reduced then the fuel consumption of the particular vehicle will be decreased. If the fuel consumption rate is increased then the emission rate also increases. The factors that mostly affects the emission from the engine includes vehicle class, weight, driving cycle, vehicle vocation, fuel type and vehicle age. Due to this the researchers have given more importance for produce light weight components. The present review is an attempt to reduce the weight of the front axle of a heavy duty vehicle. The weight is reduced by changing the front axle design slightly without sacrificing its strength. By minimizing the weight of the component the fuel consumption rate is reduced by 5-10%.

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