A Review on Vibration Analysis of Upper Control Arm of Light Motor Vehicle Suspension System

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Abstract- *All machines, vehicles and buildings are subjected to dynamic forces that cause vibration. Most practical noise and vibration problems are related to resonance phenomena where the operational forces excite one or more modes of vibration. Modes of vibration that lie within the frequency range of the operational dynamic forces always represent potential problems. Mode shapes are the dominant motion of a structure at each of its natural or resonant frequencies. Modes are an inherent property of a structure and do not depend on the forcesacting on it. On the other hand, operational deflection shapes do show the effects of forces or loads, and may contain contributions due to several modes of vibration. This project deals with optimization and modal analysis of the upper arm suspension of double wishbone suspension. Upper arm has been modeled using CATIAV5, meshing will be done in HYPERMESH12.0, and ANSYS will be used for post processing. Boundary forces will be calculated. Static analysis will be done which is needed to be done for optimization, low stressed region will be identified and material will be removed from that region. Re-analysis (modal) will be done on the modified model. Once we get desired results, model will be fabricated and tested with FFT analyzer to check for response of the arm.Suspension system of an automobile plays an important role in ensuring the stability of the automobile. Although it has been achieved to a considerable extent, another major aspect of suspension system is passenger car is luxury. A lot of research is going on in this direction, which led to the development of independent suspension system. Control arm plays major role in independent suspension system. It is generally made of forged steel which has considerable disadvantages such as weight, cost etc. The project involves the development of sheet metal control arm, which has many advantages over forged metal.*

Keywords- FEA, FFT Analyzer, LMV, Suspension system, Upper control arm

I. INTRODUCTION

The control arms allow up and down movement of the suspension while holding the knuckles, spindles, and axles firmly onto the car. They have been an integral part of suspension systems for nearly a century. Over this time, they have come in a variety of shapes, sizes, and materials but they have always served the same exact function - to hold everything together.

Control arm design changes as fast as automotive design and manufacturing technology does. Long ago, "double wishbone" suspension was the norm on the front of most cars. As you can imagine based on the name alone, the upper and lower control arms looked like wishbones. They were also called "A-Frames" or "A-Arms" depending on who you talked to (wishbones look like the letter "A" by the way, if you aren't familiar with poultry). This design is still common on many modern vehicles because it just plain works.

Fig 1: Control arm design [3]

When a vehicle has a Macpherson strut style front or rear suspension, lower control arms are the only type used. An upper control arm isn't needed because the strut takes its place. This also means one less ball joint, and a couple less rubber control arm bushings to worry about. For the rear of a vehicle with a solid axle, any style of control arms might be used to connect the rear axle to the frame or anybody. Most often, it is three or four control arms with rubber bushings on each end. These control arms are called "trailing arms" or "rear trailing arms". When a vehicle has independent rear suspension, it may have upper and lower A-Arms, trailing arms, or some other unique design that fits the shape of the vehicle.

A. Adjustable Control Arms:

Adjustable control arms are used to adjust wheel camber. Camber is the vertical alignment of the wheels. Negative camber means that the top of the wheel is tipped inward toward the center of the vehicle. Positive camber means that top of the wheel is tipped outward, away from the center of the vehicle. Adjusting camber is a huge factor when it comes to racing, stance, and the lowering or lifting a vehicle.

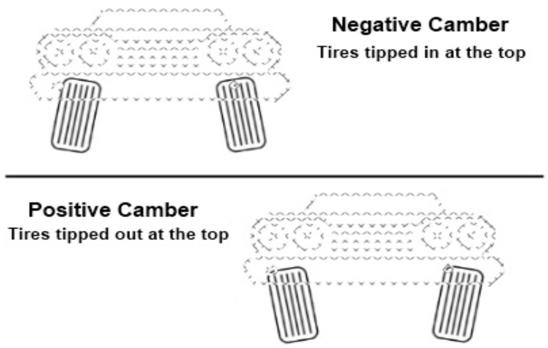

Fig 2 Camber angle[5]

When a lowering kit or a lift kit is installed on a car or truck, adjustable control arms are often needed to correct the negative or positive camber that goes along with them. If not corrected, the tires won't have the proper traction, and they will wear unevenly and prematurely. To set the camber properly with adjustable upper control arms, the vehicle needs to get an alignment by somebody that really understands what is going on. Some vehicles don't come with adjustable camber ability from the factory, so when a car like this arrives at an alignment shop and needs the camber corrected, panic can sometimes ensue.

B. Different control arms:

Stamped Steel Control Arms: The oldest versions of control arms were most commonly made from stamped steel because it was cheap, fast, and easy. This style of control arm often held coil springs in place on full framed cars, and was also an attachment point for shocks and sway bars. Their major weakness is rust. When stamped steel control arms live in a wet environment, they are nearly guaranteed to deteriorate from rust. Once the rust takes over, replacing the bushings and ball joints becomes quite a challenge, and sometimes impossible without damaging the control arm. Luckily, these control arms are usually the most inexpensive to replace.

Fig 3 Stamped Steel Control Arms[3]

ii) Cast Iron Control Arms: Over the years, many control arms have evolved from their humble stamped steel beginnings to elaborate cast aluminum pieces that are stronger and lighter than ever before. Being cast aluminum, they don't corrode quite like the steel control arms do, but since aluminum is a softer metal, they do bend and crack when things go wrong. This means that simple fender-benders or pot holes can potentially damage them, throwing the alignment way off.

Fig 4 Cast Iron Control Arm[3]

C. Types of Control Arms:

Control arms are found in two types: lateral and longitudinal control arms. Latitudinal control arms will connect to the chassis of the vehicle and point outward, while longitudinal control arms control up-and-down movements of the wheel. More than one control arm can be used in a multi-link suspension system.

The A-arm (called a Volvo control arm) attaches the suspension to the chassis of the vehicle. There may be as many as three or four control arms when coil springs are used in both the front and rear suspension systems. Upper control arms carry driving and braking torque, while the lower control arms pivot, providing up-and-down movement for wheels. A-arms can be used in different configurations and numbers. Two A-arms per wheel makes up a suspension system called a double wishbone suspension, or an independent suspension.
A Macpherson strut suspension utilizes one control arm at the bottom of the strut suspension and works in tandem with a spring and shock absorber. This type of system is used on many vehicles manufactured in today’s market. While the MacPherson strut suspension can be used as both front and rear suspensions, it is normally found in the front only, and provides steering in addition to support.

D. Function and Care of Control Arms

The control arms of a vehicle connect a vehicle’s steering rack to the wheels of the car, and they hold the wheels to the car's frame. Control arms allow the wheels to move and manage the motion of the wheels by pivoting. They assist in the wheels to response to varying road conditions by allowing the wheels to lift and descend as the wheels encounter bumps, dips, or other obstructions in the road. In addition to allowing for movement, control arms also assist the wheels in maintaining straight lines in relation to the road.

Control arms can sometimes be found on both front and rear suspensions and come in several different types. Some control arms keep the wheels from hopping and bouncing, while others assist in steering the car. Another type of control arm is found on anti-roll bars in some vehicles. Vehicles with front-wheel drive use control arms to counteract engine torque, making it possible to steer when power is applied to the wheels.

E. Why modal analysis: Modal analysis is an efficient tool for describing, understanding, and modeling structural dynamics. The dynamic behavior of a structure in a given frequency range can be modelled as a set of individual modes of vibration. The modal parameters that describe each mode are: natural frequency or resonance frequency, (modal) damping, and mode shape. The modal parameters of all the modes, within the frequency range of interest, represent a complete dynamic description of the structure. By using the modal parameters for the component, the model can subsequently be used to come up with possible solutions to individual problems.

Modal frequency response analysis is an alternative approach to determining the frequency response of a structure. Modal frequency response analysis uses the mode shapes of the structure to reduce the size, uncouple the equation of motion (when modal or no damping is used), and make the numerical solution more efficient. Due to the mode shapes are typically computed as part of characterization of the structure, modal frequency response analysis is a natural extension of a normal mode analysis

II .OPTIMIZATION

For related auto parts industry, modularization and weight reduction of chassis subassembly are one of the main goals in order to achieve fuel efficiency and lower production cost. Additionally, auto makers also require that the part manufacturers to provide a subassembly unit defined by modularization. Some parts are developed with their target weight predetermined in units of gram-force during proto design stage exemplifying the importance of lightweight design. In this study, a lightweight design of upper control arm is presented by applying optimization technique, considering static strength performances. Upper control arm is a structural component that pivots in two places. One end of control arm is attached to the body frame while the other end is attached to the steering knuckle. Upper control arm is a critical part of vehicle's suspension system since it plays an important role in riding comfort and handling performances. In this study, a forging part made of aluminum material is being investigated for the structural design. This study proposes the optimal structural design of an upper control arm, considering a static strength performance. The inertia relief method for FE analysis is utilized to simulate the static loading conditions One of the most important the assessment of automotive components is the durability criterion. Generally, for the suggested optimum design considering only static strength, the prediction of the fatigue life is needed to check the criterion. In this study, a 1/4 car module fornumerical analysis and a full car for experiment are conducted to examine the fatigue strength of the control arm. In case of 1/4 car module, both fatigue analysis and experiment are performed. In case of part model and full car, only fatigue analysis is performed. For the analysis of the full car model, VPG program is used. Comparing the results of the 1/4 car module and full car, the correlation about each case is found. Besides, the weak model is used in the experiment, since the experiment costs too much time.

III. LITERATURE RIVIEW

Literature review of dissertation work includes study of design and analysis of upper control arm. Also study the various optimization techniques. For the finite element based optimization purpose the study of suitable software for optimization of weight modal analysis will carry out by referring different books and earlier research works published in reputed journals.

Following is a list of researchers who has worked in this area of upper control arm and optimization. The combination with the following literature research on the use of upper control arm is expected to make the investigation as complete as possible.

A.A. Shinde, A.J. Chavan and Dr. K.P. Kolhe[1] were studied a tractor mounted hydraulic elevator A Tractor was tested for the mechanical harvesting by using digital load cell on stability study .This stability study was carried out by using strain gauge load cell .This experiment was fabricated using standard material specification of American society of testing material. In this study the main objective is that the static load acting on the elevator. This study is very useful for the study of the static loading of the elevator.

Pratik S. Awati and Prof. L. M. Judulkar [2] were studied complete FEM analysis of a suspension link for bending vibrations, pitching, bouncing and combined mode dynamic analysis for deformation and stresses. For this a 3-D solid parametric model of a suspension link is used for this. Multi body system approach is used to determine the loads acting on the suspension component and the body pickup point as inputs to finite element models of the component or vehicle structure. Vibration analysis is seen in both Hypermesh & Ansys software for validation of numerical method used for calculating the natural frequencies. The numerical method used here is BLOCK LANCZOS method. Then, the Pitching, Rolling, Breaking modes and combination of deformation is found out.

N. Vivekanandan , Abhilash Gunakiand Acharya [3] The main objective of the paper is to design and analyze the entire double wishbone suspension system for an All TerrainVehicle for improving the stability and handling of the vehicle. There has been tremendous development in the suspension system. The topic is focused on designing the above mentioned suspension systems considering the dynamics of the vehicle along with minimizing the unsprung mass. The suspension system of an All-Terrain Vehicle needs to be durable, light weight, efficient and less expensive. The vehicle must be able to withstand the harsh environment of off-road terrain. Stability of the vehicle and the ride comfort is given a prominent importance in this project.

Jagwinder Singh and Siddhartha Saha [4]In this, the static structural analysis was done to find out the stress, deformation and safety factor of component. The model was meshed using 10-noded tetrahedral elements. Result obtained from the analysis was studied to check whether the design is safe or not. In some cases the stresses becomes more than safe limit. In that case optimization approach is carried out to increase the structural strength of the component. In this case maximum von-misses stress is 211 MPa which is below the yield strength of the material. An experimental device has been developed to study fatigue phenomena for nodular cast iron automotive suspension arms. On the base of a detailed fracture analysis, it is shown that the major parameter influencing fatigue failure of casting components are casting defects: the High Cycle Fatigue behavior is controlled mainly by surface defects such as dross defects and oxides while the Low Cycle Fatigue is governed by multiple cracks initiated independently from casting defects. A methodology is proposed to define the maximum defect size allowable in a casting component. It correlates the empirical method proposed by Murakami to determine the evolution of the fatigue limit with defect size and a multi axial endurance criterion based on the Dang Van model. The junction between the two approaches gives a concurrent tool for the fatigue design of casting components. Validation of the proposed approach gives encouraging results for surface defects and constant amplitude proportional loading.Fatigue life of automotive lower suspension arm has been studied under variable amplitude loadings. In simulation, the geometry of a sedan car lower suspension arm has been used. To obtain the material monotonic properties, tensile test has been carried out and to specify the material mechanical properties of the used material, a fatigue test under constant amplitude loading has been carried out using the ASTM standard specimens. Then, the results used in the finite element software to predict fatigue life has been evaluated later to show the accuracy and efficiency of the numerical models which they are appreciated. A. Rutci [5]this paper describes the failure analysis of a lower wishbone (control arm) in a light commercial vehicle which had been involved in service loading. The wishbone was analyzed in two ways. In order to investigate reason of the failure, finite element modeling was conducted to evaluate stress distribution and reliability of wishbone. Moreover, the metallographic and hardness evaluation were made on weld seam of the failed part. From metallographic observations, the presence of porosity was found in weld seam. Hardness distributions from the parent material to weld region are measured in the expected range. The results of finite element analysis and metallographic examination showed that the fatigue failure was initiated from highly stressed region in weld seam, and the presence of porosity stimulated crack initiation as well as crack growth.

Gurunath Biradar, Dr. Maruthi B H, Dr. Channakeshavalu[6]In this thesis focus was on the modal analysis and statically analysis of upper arm, lower arm and steering knuckle. Fatigue analysis of existing double wishbone suspension system and modify the design using software's namely Unigraphics, Hypermesh, Optistruct and CODE.Based on initial analysis, the shape of upper arm of double wishbone was modified. Analysis results showed that displacement and stress in the upper arm reduced to 0.023 mm and 34.14 MPa respectively. Double wishbone damage control reduced to 0, stress reduced to 302.6 MPa and life improved to 10540 Hz. Design is safe since maximum stress 302.6 MPa was less than yield strength 350 MPa of structural steel.

B. Sai Rahul, D.Kondaiah and A.Purshotham [7] this paper describes the analysis of upper arm of wishbone using softwares namely Catia and Hypermesh. The objectives of this study are to characterize the dynamic behavior and to investigate the fatigue life of upper suspension arm. Control arm(Upper arm) is designed in 3d modeling Catia software and then imported in to Altair Hyper mesh for finite element modeling. The solutions of dynamic analysis obtained .The overall aim of the paper is to estimate the fatigue life of control arm. The results, thus obtained, can significantly reduce the cost and time to market; improve product reliability and customer confidence.

Lihui Zhao, Songlin Zheng, Jinzhi Feng, Qingquan Hong[8] Structure optimization techniques under static load conditions have been widely used in automotive industry for lightweight and performance improvement of modern cars. However, these static load conditions could not represent all the severe situations of automobile parts which subjected to complex loads varying with time, especially for lower control arm of front suspension. In this study, dynamic optimization of lower control arm was performed by combing traditional static load optimization techniques and multi-body dynamics by Equivalent Static Load (ESL). And the best draw-bead distribution of the stamped lower control arm was attained. Comparing the MBD analysis results of the new design derived from dynamic optimization and original structure, results show that the strength and stiffness was increased significantly while the mass was almost unchanged.

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