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Finite Element and Experimental Analysis of Automobile Lower Control Arm

Shrikant P Katakdhond[1] and Nilesh.G.Jawarkar[2]
PG Student, Department of Mechanical Engineering[1]
Associate Professor, Department of Mechanical Engineering[2]
JSPM's Rajarshi Shahu College of Engineering Tathawade Pune, India
[1]katakdhond105@gmail.com, [2]njawarkar1@gmail.com

Abstract: *In automotive suspension, a control arm is a hinged suspension link between the chassis and the suspension or hub that carries the wheel. The lower control arm is a unique type of independent suspense used in machine vehicles. The lower control arm is subjected to many loads due to variation in gross weight and impacts due to fluctuation of road surface and additional forces. The experimental findings are validated using Finite Element Analysis (FEA) Performed in Ansys workbench to analyze stress distribution and deformation behaviour Experimental testing is performed. New design of Automobile lower control arm is manufactured Future Research directions are also outlined to enhance the reliability of lower control arm. In this paper we have taken the literature review of previous papers based on that taken conclusion.*

Keywords: Cast Iron, Aluminium Alloy, Finite Element Analysis(FEA), Ansys, Stress Concentration, suspension system

I. INTRODUCTION

The lower control arm (LCA) is a critical component of an automobiles suspension system, responsible for connecting the chasis to the wheel assembly while allowing for controlled motion and stability. given its role in handling dynamic loads. ensuring the structural integrity and performance of the LCA is essential for vehicle safety and ride comfort. in recent years both Finite Element Analysis (FEA) and experimental methods have emerged as powerful tools for evaluating and optimizing the design of LCAs under various operating conditions.

A control arm, also known as an A-arm, is **a hinged suspension link between the chassis and the suspension upright or hub** that carries the wheel.The lower control arm is a type of independent suspension used in vehicles. During the actual working condition, the maximum load is transferred from upper arm to the lower arm which creates possibility of failure in the arm.

The lower control arm playing a critical role in maintaining stability, handling, and comfort..it is equipped with bushings and a ball joint that allows smooth pivoting motion and helps absorb road shocks and vibration. it works with other suspension component like shocks, struts ensuring that the tires maintain contact with the road under various driving condition..

Control arms connect a vehicles suspension to its frame, typically using bushing and a ball joint. Most modern cars have single lower control arm as per wheel (Mac person strut) while others use upper and lower arms(double wishbone) shapes vary A,l, or straight shaft..Materials include stamped steel, cast iron, they reduce friction and absorb road shocks.

The lower control arm must with stand Various dynamic forces, including, braking, cornering and road surface impacts.the design and analysis of the LCA are crucial to ensure structural integrity, safety, and longevity.

Function of lower control arm

1) Connects the chassis to the wheel hub
2) Allows for controlled wheel movement
3) Absorb forces

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4) Maintain wheel alignment
5) Connects via bushings and ball joints to reduce noise and absorb vibration.
Lower control arms are typically found in the front suspension system, with one on each side.
Lower control arms are essential for good vehicle handling, stability, and overall performance

II. LITERATURE REVIEW

M. Sadiq A. Pachapuri et. al. (1) Control arms are depended suspense links between the lattice and the mecca that carry the wheel. They control the tyre end position in a single degree of freedom, maintaining radial distance from the lattice mount. Wishbones, triangular with two extensively spaced lattice comportments, control two degrees of freedom without taking fresh links. Utmost control arms form the lower link of a suspense, with many designs using them as the upper link. The lower arm should be sturdy to help fluttering noise over the humps. This paper calculates forces acting on the lower arm of a four- wheeler under critical lading conditions using Finite Element Analysis for the McPherson type suspense system. Other analyses include static analysis, free-free and constrained modal analysis, fatigue analysis, and topological optimization, performing in reduced weight.

Prashant Gunjan et.al (2) The analysis of the automobile lower control arm involves finite element analysis (FEA) using ANSYS software to assess stress, deformation, and optimize design through topology optimization, ultimately reducing mass and production costs while improving material quality and performance.(1)

K Sookchanchai et.al. (3) Global environmental regulations have led auto manufacturers to borrow featherlight technologies, including advanced accoutrements and manufacturing processes, to meet these restrictions. This study focuses on optimizing the shapes of structural factors to meet functional conditions and manufacturing processes. Topology optimization (TO) be used to reduce weight and ameliorate performance of a lower control arm (LCA) of vehicle suspense. FE simulations were conducted under colorful cargo cases, and stress distribution and overall stiffness were collected as nascence. The TO procedure classified critical cargo carrying regions and applied member-size constraints to enable a LCA layout probably produced by essence forming. This optimization system can guide featherlight design of other automotive stamping corridor

Rahul Sindhwania et. al. (4) this paper discusses the design and optimization of suspense accoutrements for perpetuity Motorsport's Formula Society of Automotive Engineers (FSAE) vehicle. The design process involved considering factors like formula auto dynamics, element packaging, and product and performance. The plan was divided into product, trial, and blessing of the 2019 formula auto, and analysis, design, manufacturing, and trial and blessing of the 2020 formula suspense system. The 2019 formula auto was tested to gather information on design presuppositions and determinations. The analysis stage used multiple programs to estimate stresses and fatigue, proving trust ability isn't a factor in race buses. The trial and analysis stage used the same procedures but with advanced procedures for the 2020 auto. This paper aims to help masterminds in designing and optimizing suspense accoutrements for the FSAE vehicle

M. Sadiq Li et. al. (5) Control arms are hinged suspension links between the chassis and the hub that carry the wheel. They control the tyre end position in a single degree of freedom, maintaining radial distance from the chassis mount. Wishbones, triangular with two widely spaced chassis bearings, control two degrees of freedom without requiring additional links. Most control arms form the lower link of a suspension, with few designs using them as the upper link. The lower arm should be sturdy to prevent fluttering noise over the humps. This paper calculates forces acting on the lower arm of a four-wheeler under critical loading conditions using Finite Element Analysis for the McPherson type suspension system. Other analyses include static analysis, free-free and constrained modal analysis, fatigue analysis, and topological optimization, resulting in reduced weight

Jitendra G.Shinde et.al.(6) Lower Control arm in automotive vehicle acts as a linkage between sprung and unsprang mass of vehicle. TheOne of the primary concerns for vehicle components is weight reduction, and the lower control arm is no exception. However, the lower control arm is susceptible to bending and failure due to the various loads it experiences.This project focuses on utilizing finite element analysis to examine and enhance the lower control arm. CATIA software was utilized to design the model for the lower control arm, and a static analysis is conducted using specialized analysis software. The project addresses several physical properties of the lower control arm, such as strength, yield strength, and weld ability, by altering the material used. By transitioning from EN-18 steel to Extra Deep

Drawn steel, we have achieved significant improvements in the performance of the control arm The initial stress and fatigue analysis of the previous lower control arm design revealed that the stress limit was exceeded and the component did not have a safe fatigue life. To address these issues, modifications were made to the design to remove stress raisers and improve overall reliability. The modified design was then subjected to stress analysis, which showed that the stress values were within safety limits and the component had a considerably improved life. As a result, the design of the lower control arm was successfully modified to enhance its safety and durability.

Miss P.B.Patil et.al (7) In this paper, lower control arm of Indica Vista car is used for analysis. Modal analysis is done on control arm to find its natural frequency. Modes of vibration that lie within the frequency range of the operational forces always represent potential problems. Mode shapes are the dominant motion of a structure at every of its natural or resonant frequencies. Modes are an inherent property of a structure and do not depend upon the forces that act on it. Existing model is taken and optimized by removing material from high stressed region. Modal analysis is carried out in Ansys. This optimized model is fabricated and tested on FFT analyzer for validation.

In this particular research work we carried out FEA analysis of existing lower control arm. According to this work we found that there is a scope for optimization. Lower control arm is meshed in Hypermesh and solver deck for modal analysis is prepared. Then this total data was incorporated into Ansys software which gives the natural frequencies of exciting lower control arm. By using the topology optimization technique, lower control arm is optimized & natural frequencies are extracted. After that the comparative study of existing and optimized lower control arm is undergone. Then optimized lower control arm is fabricated and tested using FFT analyzer

Dattatray Kothawale et al (8) - This paper deals with finite element analysis for MacPherson type suspension system lower control arm (LCA) of 4W suspension system. The main function of the lower control arm is to manage the motion of the wheels & keep it relative to the body of the vehicle. The control arms hold the wheels to go up and down when hitting bumps. In this project we have prepared CAD Model using PRO-E Software & finite element analysis using Ansys software. We have studied to calculate various dynamic loads like road bump, kerb strike, braking, cornering & acceleration load case. By applying all this forces in X, Y and Z directions perform non-linear static analysis using Ansys software. The main significance of the analysis is to check the structural strength of LCA using dynamic forces. It will going to save the testing as well as validation cost. Also, validating final finite element analysis results through the physical testing of the component. The aim behind this project analysis is to show the how finite element analysis is helping in complete product development cycle. Because it going to saves lot of cost, as every vehicle having generally 3-4 stages in complete product development cycle, stages are Proto-I, Aplha-II, Gamma-III & Beta-IV. By believing on the results of finite element analysis company / organization can skip one or two stages in between proto & final product. This paper will show the validation of finite element analysis results with actual physical sample testing**.**

Ranshing Aishwarya Sanjeev et al (9)- This Paper presents a systematic approach towards the optimization of the lower control arm design, aiming to enhance its performance and reliability while considering factors such as weight reduction, material selection, and structural integrity. The optimization process begins with a comprehensive review of existing lower control arm designs, identifying their strengths and limitations. Next, various design parameters are identified and evaluated, including geometric dimensions, material properties, and attachment points. Utilizing advanced computer-aided design (CAD) software and simulation tools, a virtual model of the lower control arm is created to assess its structural behavior under different loading scenarios**.**

The existing and optimized models of the lower control arm were subjected to static structural analysis in ANSYS Workbench, evaluating their stress and deformation under given boundary conditions. The deflection and stress levels observed in the optimized model were found to be within acceptable ranges, indicating that the modified design is safe for use. Furthermore, the weight of the final optimized model was measured to be 1.03 kg.

M.Sridharan et al (10)- The main objective of this paper is to model and to perform structural analysis of a LOWER CONTROL ARM (LCA) used in the front suspension system, which is a sheet metal component. LCA is modeled in Pro-E software for the given specification. To analyze the LCA, CAE software is used. The load acting on the control arm are dynamic in nature, buckling load analysis is essential. First finite element analysis is performed to calculate the buckling strength, of a control arm. The FEA is carried out using Solid works stimulation package. The design modification has been done and FEA results are compared. The influencing parameters which are affecting the response are identified. After getting the final result of finite element analysis optimization has been done using design of experiment method. Taguchi's design of experiments has been used to optimize the number of experiments. By reducing thickness of the sheet metal and by suggesting the suitable material the production cost of lower control arm is reduced. This leads to cost saving and improved material quality of the product.

M.H.A.Rahman et al (11) The paper investigates the design optimization and fabrication of an aluminum cast lower control arm, The aluminum lightweight front lower control arm will be developed using casting processing route and its performance will be investigated to determine the mechanical properties of the parts. In this work, the new concept design of cast lower arm are employed. employing topology optimization for a 20% weight reduction, followed by structural strength analysis to evaluate performance, ensuring lightweight, high strength, and corrosion resistance and suitable for current vehicle

Performance

III. CONCLUSIONS

Finite element analysis of the lower control arm provided crtical insights into its structural performance under various load condition. the results revealed stress distribution deformation pattern this analysis confirms that finite element methods are essential for ensuring durability safety and optimal material usage in suspension

As automotive technology advances, improvements in control arm design and materials continue to enhance durability and functionality, making them more reliable and efficient for modern vehicles.

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