Analysis of Upper Control Arm for finding optimized model using FEA and Experimentation

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Abstract: The present study simulates a practical system such as a vehicle upper control arm (UCM). The work deals into various application aspects and manufacturing aspects to formulate an idea of the system. The vehicle suspension system is always responsible for driving safety and comfort. The suspension unit carries the whole vehicle body and transmits all forces between body and road. Mostly Structure optimization techniques in static load conditions have been used in automotive industry for light weight and for performance improvement of modern new cars. This paper shows the study of practical example for static analysis and optimization of upper control arm. CAD model was prepared using CATIA R20 software and finite element analysis was done using ANSYS 15.0. Static analysis done, and low stressed region identified and material removed from that region in various iterations. Further for validations of the study, experimental analysis of finally selected iteration was done, and the results found are very close to FEA results.

Keywords: Upper control arm, optimization, FEA analysis, Structural analysis.

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. 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.

1.1 Control arm design:

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.

II. LITERATURE REVIEW

Dr. S. Balamurugan & M. Sridharan (2016).

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.

Y. Nadot, V. Denier- An experimental device have 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.

Jong-kyu Kim, SeungKyu Kim, Hwan-Jung Son, Kwon-Hee Lee, Young-Chul Park - In this research, the shape of upper control arm was determined by applying the optimization technology. This study considers the static requirement in the optimization process. In this study, the kriging interpolation method is adopted to obtain the minimum weight satisfying the static strength constraint. The real experiments on 1/4 car is conducted to validate the FEM analysis. At last, the correlation of each case about durability life is obtained. This study presents the design process of a control arm to reduce the weight satisfying the imposed requirements. The optimum design of static strength’s durability life has permanent life. Therefore, it is difficult to judge the durability of the control arm. To find the durability characteristic of the control arm, design values of optimum design is reduced, and fatigue analysis is performed.

Prof. A. M. Patil, Prof. A.S. Todkar, Prof. R. S . Mithari, Prof. V. V. Patil - The Wishbone control arm is a type of independent suspension used in motor vehicles. The general function of control arms is to keep the wheels of a motor vehicle from uncontrollably swerving when the road conditions are not smooth. The control arm suspension normally consists of upper and lower arms. The upper and lower control arms have different structures based on the model and purpose of the vehicle. By many accounts, the lower control arm is the better shock absorber than the upper arm because of its position and load bearing capacities. It has an “A” shape on the bottom known as wishbone shape which carries most of the load from the shock received. The lower control arm takes most of the impact that the road has on the wheels of the motor vehicle. It either stores that impact or sends it to the coils of the suspension depending on its shape. This study concludes under the static load conditions deflection and stresses of steel lower wishbone arm and composite lower wishbone arm are found with the great difference. Carbon fiber suspension control arms that meet the same static requirements of the steel ones they replace. Deflection of Composite lower wishbone arm is high as compared to steel lower wishbone arm with the same loading condition. The redesigned suspension arms achieve an average weight saving of 27% with respect to the baseline steel arms.

A. Rutci, 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 modelings were 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, 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 n 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.

V.V. Jagirdar, M.S. Dadar, and V.P. Sulakhe-
Wishbone structure for double wishbone front-independent Suspension for a military truck application is presented. At present, the vehicle is equipped with rigid axle with leaf springs. There are two aspects that dictate the design of wishbone structure, viz. the path of relative motion between the constituents of the suspension system and the forces transmitted between them. Also, enhancement of mobility was made possible by maintaining the live axle in the system. A double wishbone, double coil spring with twin damper configuration was employed for this application. MBD Analysis was carried out using MSC ADAMS.

B. Sai Rahul, D.Kondaiah and A.Purshotham,
This paper describes the analysis of upper arm of wishbone using software’s namely Catia and Hyper mesh. 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. In this paper the upper arm of a wishbone suspension system is analyzed for its fatigue life and transient behavior when a braking is initiated on the automobile. Altair hyper-mesh with CATIA modeling methods has been exhaustively used in obtaining the simulation results. Based on the simulation results, it is concluded that the arm of wish bone possess good fatigue life which is 1016 cycles and transient behavior with maximum peak stress value is 34MPa.

III. OBJECTIVES
- CAD modeling of existing upper control arm.
- Structural Analysis of UCM using FEA software.

IV. UPPER CONTROL ARM MODEL AND ANALYSIS

Fig. 4.1: Image of upper control arm

Fig. 4.2 3D cad model of upper control arm

4.1 Structural Analysis of link

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young’s Modulus, $E$</td>
<td>207 GPa</td>
</tr>
<tr>
<td>Poisson’s Ratio ,$\nu$</td>
<td>0.30</td>
</tr>
<tr>
<td>Density, $\rho$</td>
<td>7880 kg/m$^3$</td>
</tr>
<tr>
<td>Yield Stress, $\sigma_{yield}$</td>
<td>405 MPa</td>
</tr>
<tr>
<td>Ultimate Tensile Stress, $\sigma_{uts}$</td>
<td>550 MPa</td>
</tr>
</tbody>
</table>

Fig. 4.3: Boundary conditions to be applied
Like above analysis, steps are followed and various iterations are taken for optimization and readings are as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Stress (MPa)</th>
<th>Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>181</td>
<td>0.293</td>
</tr>
<tr>
<td>Iteration - 1</td>
<td>187</td>
<td>0.256</td>
</tr>
<tr>
<td>Iteration - 2</td>
<td>199</td>
<td>0.261</td>
</tr>
<tr>
<td>Iteration - 3</td>
<td>202</td>
<td>0.262</td>
</tr>
<tr>
<td>Iteration - 4</td>
<td>209</td>
<td>0.260</td>
</tr>
<tr>
<td>Iteration - 5</td>
<td>213.2</td>
<td>0.272</td>
</tr>
<tr>
<td>Iteration - 6</td>
<td>217.39</td>
<td>0.285</td>
</tr>
</tbody>
</table>

Experimental results of the finally selected parameters are tested on UTM under Room temperature and are as below:

<table>
<thead>
<tr>
<th>Component</th>
<th>Experimental – Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iteration 6 – Upper Control Arm</td>
<td>Reading 1</td>
</tr>
<tr>
<td></td>
<td>0.2820</td>
</tr>
</tbody>
</table>

V. Conclusion

- 3D CAD model is drawn based on drawing.
- Analysis results for existing UCM are 181 MPa stress, 0.293 mm deformation.
- Optimized UCM analysis results are 217.39 MPa stress 0.285 mm deformation.
- Optimized UCM experimental results are 0.2822 mm deformation.

References

9. Prof. A. M. Patil, Prof. A.S. Todkar, Prof. R. S .Mithari3, Prof. V. V. Patil, “Experimental & Finite Element Analysis of Left Side Lower
Wishbone Arm of Independent Suspension System", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)


