Review of Suspension System for a Race Car

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Abstract - *Suspension is a complicated system having many parameters to consider while designing especially for race cars. The paper reviews on 'Suspension System for a Race car' which are previously published by the researchers. The main objective for review is to find the suspensions ideally used in race car applications and find the flow to design one such system. The paper shows the steps which begins with kinematic design and MBD analysis to obtain the proper behaviour of the system. The force extraction is shown through the software or is derived through the conventional hand calculations. The paper also shows how components are designed, analysed and optimized to keep the unsprung weight minimum.*

Key Words: Suspension System for Race car, FSAE Suspension system, Double Wishbone for FSAE etc.

INTRODUCTION

The suspension system is one of the most important system of an automobile to be considered while designing a car. All of the forces such as accelerative, lateral and longitudinal are forced on the ground through the tires which are required to be held in ground contact patch by the help of good suspension system. Therefore the purpose of suspension system is to keep the largest possible tire contact patch in every condition. If the suspension system failed to do so then the car would not be able to perform at its full potential. A good suspension system is therefore a combination of good kinematic design to achieve maximum contact patch with the pavement as possible, optimal damping in worst condition, good spring rate selection to keep the tire on ground at all times and finally a well optimized suspension components that are not deflected under various loading condition which will be induced upon them.

Y. Kami, et al. [1] discussed about the double wishbone suspension system that are used on low hood line and wide track vehicles. They also stated that due to camber change characteristics, desired under steer qualities are maintained under high lateral acceleration which was the goal for this car. Authors also said that double wishbone suspension system is more costly as compared to Macpherson strut type suspension but double wishbone suspension system is best suited for race car application.

Andrew Deakin, et al. [2] suggested that the suspension performance is improved by validation and correlation between simulations. Later on they validated vehicle dynamics and kinematic analysis which have been validated through the use of objective testing and kinematics rig testing. From their experiments performed, we can conclude that vehicle dynamic analysis has been used as development tool.

David E. Woods, et al. [3] calculated ride and roll rates on each axle also they pointed out various frequencies for different cars (e.g. 0.8-1.5Hz for sedan & sports cars, up to 2Hz for non-aero cars and 5-7Hz for aero cars). They highlighted that rear axle frequency should be slightly higher to isolate any road surface discontinuity. They mentioned optimum road holding ability is increased through maintaining constant wheel loads as well as highlighted the kinematic goals are to minimize the effects due to bump & roll, to keep the wheels in upright position at all times.

Badih A. Jawad, et al. [4] performed various force analysis on different types of suspension components. They calculated braking torques at brake calliper mount on upright. They performed, cornering force is applied on bottom lug bolt & on top lug bolt in opposite direction while fixing the centre hub. The authors also said that rocker arm should have MR of 1 to accomplish wheel displacement equal to spring displacement. Their experiments highlighted that braking, cornering & combination of both the forces is applied at A-arms, upright, hub, spindle, and rocker.

M. Raghavan, et al. [5] study pointed out, how to find exact tie rod attachment point location with the help of an algorithm to achieve linear toe curve. The use of the algorithm showed a significant results in getting the location of tie rod attachment which can be tedious if done in unconventional way. Finally their results showed that using algorithm the computing process time decreased.

M. Raghavan et al. [6] study showed an algorithm which is used to find the prescribe height of roll centre and the algorithm is in mathematically form and can be used to find out the relative lengths of control arms. Their results shows how to fix roll centre with respect to ground and sprung mass. The algorithm helps us to avoid the iterative tedious process.

Zhen Zhang, et al [7] highlighted that, their studies showed that geometry of steering and suspensions main parts were optimized by math based software. Once the parts were optimized by software, their goal was to achieve minimum mass of suspension components as well as to maintain sufficient structural strengths in order to achieve the less braking distance and good fuel economy.

Dennis Robertson, et al. [8] highlighted and described all about fundamental terminologies required as well as told about the suspension geometry. Once the geometry is selected the next process is finding wheel rate, frequencies (frequency should be in the range of 1.5-2.0 Hz) & roll gradient. They pointed out after getting the forces required from MBD software then bearing selection will be done between large roller bearings and small roller bearings.

Alam, et al. [9] performed the variable iterations on coefficient of damping of damper by deciding various graphs (spring mass amplitude vs time, unsprung mass amplitude vs time, frequency response vs magnitude). Now the authors validated the damping coefficient of damper by using half car model during rolling by the use of sprung mass amplitude vs time as well as unsprung mass amplitude vs time graph for both front and rear dampers.

The Conor Riordan, et al. [10] highlighted how optimization is done by topology in overall design by Altair Optistrut software. They used upright to demonstrate the optimization where forces and braking torque were applied on the calliper mount points. The use of topology to find out the areas of stressed and non-stresses areas can be completely eliminated to save weight and inertia forces. Their results showed overall decrease in component weight of 15 percent when such topology optimization was used.

Mohammadjavad Zeinali, et al. [11] considered front double wishbone suspension parameters are related as multi body model. This means that the bodies or links are connected to each other by joints that restricts their relative motion. Further they took model of front suspension and steering design based on steering and suspension key points; the KPI, cater & camber angle were analysed in positive and negative displacement of wheel travel.

Chen Qiu, et al. [12] showed how the parallel mechanism were used at the rear end of the vehicles suspension system. The authors denoted that the 5 DOF are required to constraint the system as well as to transfer the shocks from the road to strut in easy manner, so as to reduce the resultant maximum stress.

Silva, et al. [13] reported that after the hard point's selection in kinematic software, the length of the upper control arm as well as the lower control arm is found out by distance formula. Then the authors also found out the toe angle, caster angle and camber angle by trigonometric relation.

Saurabhy, et al. [14] performed out the kinematic analysis of the line diagram for obtaining the required camber gain, change in caster & toe angle during bump and droop. After the kinematic analysis, the spring stiffness & calculation of lateral, vertical and longitudinal forces is carried out by them. They carried out next step of quarter car model analysis which was used to obtain damping coefficient of the damper. Then finally the authors validated the parameters during cornering.

Akshay Bhoraskar, et al. [15] study mainly focused on the static structural analysis of vehicle and wheel. The observation of authors depicts that the double wishbone arms experiences minimum stress and hence can be used in heavy loads [Due to presence of spring and damper system]. They also reported that maximum deformation and maximum stress are generated along the spring which absorbs most of the force while frameworks were subjected to minimum deformation which was the main goal of their suspension.

Lei Yang, et al. [16] showed, how loads are extracted from Multi Body Dynamics Analysis and the types of loads were noted. The forces and torques of the mechanical joints between frame and suspensions have been calculated by them. They also showed force distribution from wheel to the chassis from the suspension components for e.g. Road-wheel, upright-control arms, upright-push rod.

Subodh Subedi, et al. [17] studies highlighted an overview of suspension design starting with quarter car model that have been used for kinematic analysis. Then the results of kinematic analysis were used as a boundary conditions for FEA analysis during component design. They also showed body motions and examined wheel travels for heave, roll and steering inputs.

CONCLUSIONS

From all research papers it can be concluded that a double wishbone suspension system at front and rear are best suited for race car applications as well as for passenger vehicle with a frequency in the range of 1.5 Hz to 2.5 Hz. The overall suspension geometry including the steering geometry can be optimized using various software's (i.e. MATLAB, ADAMS, HYPERWORKS, and OPTISTRUT) by the iterative process to obtain the required performance parameters. Unpredictable forces that are extracted from Multibody Dynamics Software can be imposed on suspension components (i.e. hub, upright, control arms) to analyse behaviour of components and to study the stress induced, FOS, deformation, etc.

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