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Design and Analysis of Double Wishbone Suspension System using Fea and Matlab

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***Abstract*— The present work demonstrate satisfactorily a double wishbone front wheel automotive suspension. The suspension is mounted on two platforms that can independently move up and down to simulate a road profile on each wheel. Double wishbone designs allow the engineer to carefully control the motion of the wheel throughout suspension travel. The study of existing Wishbone suspension system component design and its function to isolate road irregular surface generated shock and vibrations carried out. The Geometry of Double-wishbone suspension system along with the Shock Absorber is modelled using a Solidwoks tool as per the standard dimensions from SAE. In order to predict out the real time behavior of the system, variable like road profiles, stiffness, damping co-efficient and all are defined. Matlab-Simulink tool is used to begin with Multi body dynamic simulation for Double wishbone suspension system. The Oscillations and Vibrations so far developed from the Output of Matlab is taken as an input to carry out the Structural analysis of the model. ANSYS V14.5 is used to analyse the Static Structural conditions by defining the loading values over the constraints. The modal analysis is carried out with the Lower and connecting arm of the Double wishbone suspension system. The total deformation of the components as per the vibrating frequency is obtained accordingly.**

***Keywords*— Double wishbone suspention , ANSYS, Matlab, Simulink.**

INTRODUCTION

The suspension system works together with the tires, wheels, frame, suspension linkages, wheel hubs, brake system as well as steering system to provide driving comfort, stability, etc. The suspension system is the mechanism which physically separates the vehicle body from the wheels of the vehicle. The performance of the suspension system has been greatly increased due to the continued advancements in automobiles in the recently years. The suspension system will consider ideal if the vehicle body isolated from uneven road and inertial disturbances associated during situation like cornering, braking and acceleration. The design of the vehicle suspension system may be different for front and rear axis (independent or dependent suspension) in order to provide a comfortable ride to the passengers and avoid additional stresses in motor car frame, the car should neither bounce or roll or sway the passengers when cornering nor pitch when accelerating. In automobiles, a double wishbone suspension is an independent suspension design using two (occasionally parallel) wishbone-shaped arms to locate the wheel. Each wishbone or arm has two mounting points to the chassis and one joint at the knuckle. The shock absorber and coil spring mount to the wishbones to control vertical movement. Double wishbone designs allow the engineer to carefully control the motion of the wheel throughout suspension travel, controlling such parameters as camber angle, caster angle, toe pattern, roll center height, scrub radius, scuff and more.

I. PROBLEM INDENTIFICATION

A quality suspension must achieve a good behavior of the vehicle and a degree of comfort depending on the interaction with uneven road surface. When the vehicle is requested by uneven road profile, it should not be too large oscillations, and if this occurs, they must be removed as quickly. The design of a vehicle suspension is an issue that requires a series of calculations based on the purpose.

In vibrations, the simplest model representing a system is a linear, lumped parameter, discrete system model, which requires considerable analytical and computational effort for systems with more than two degrees of freedom. In such circumstances, the use of software programs, such as MATLAB and Mathcad are essential in obtaining numerical results in order to understand and predict system's physical behavior. For example, the natural frequencies and mode shapes of a four degree of freedom model of an automobile suspension system are, in general, pairs of complex conjugates for which hand calculations and extractions is a formidable task, if not impossible. Such studies can be easily done in MATLAB or a Mathcad environment.

Because of uneven road surfaces and profiles, a large load of the vehicle hits over the frame on which the suspension and other assemblies mounted. These loads are in dynamic in nature which have to be addressed with specific factor of safety. Thus it has became necessary to carry out the particular structural analysis and to cope up with the system response as per the vibratory conditions mentioned above.

Aditya Arikere et al [1] They proposes a framework for optimising the design of double wishbone suspension systems. The results show that the ethod based on NSGA-II converges to solutions better than that based on classical methods.

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Abhilash Gunaki et al [2] The main objective of their work is to design and analyze the entire double wishbone suspension system for an All Terrain Vehicle for improving the stability and handling of the vehicle. Stability of the vehicle and the ride comfort is given a prominent importance in this project.

Prof. A. M. Patil1 et al [3] in their paper a Under the static load conditions deflection and stresses of steel lower wishbone arm and composite lower wishbone arm are found with the great difference.

Vinayak Kulkarni1 et al [4] in Their paper deals with calculating the forces acting on lower wishbone arm while vehicle subjected to critical loading conditions (Braking, Cornering and Descending though slope).

Rajkumar Kewat et al [5] in their paper studies about the model of double wishbone used in off-road racing cars. Dynamic analysis of Wishbones is done in LOTUS-Shark V 5.01'. Analysis is also done by changing the design of double wishbone. By applying an extra link named toe link and S link for providing two mounting points.

Mohammad Iman Mokhlespour Esfahani et al [6] The quarter car with the double wishbone suspension system has been modelled for two different approaches to the suspension links to be rigid and flexible. Therefore, the dynamic analyses of these models have been investigated by the finite element method.

Ashish V. Amrute et al [7] In their paper describes the Leaf spring are one of the oldest suspension components they are steel frequently used, especially in heavy load vehicles. The automobile industry has shown increased interest in the replacement of steel spring with fiber glass composite leaf spring because of its high strength to weight ratio.

G. Harinath Gowd et al [8] in their paper described the Coil spring is special kind of springs used in automobile suspension system.

Jadhav Mahesh V et al [9]. In their paper we look on the stability of the composite Double wish bone on vehicles and their advantages. Efforts have been made to reduce the cost of Double wishbone.

Malaga. Anil Kumar et al [10] The automobile industry has shown increased interest in the replacement of leaf spring with independent suspension due to high strength to weight ratio. This work deals with the replacement of leaf spring with Double wishbone. Suspension system in an automobile also determines the riding comfort of passengers and the amount of damage to the vehicle.

Hemin M. Mohyaldeen's et al [11] thesis describes the analysis of lower automobile suspension arm using stochastic design improvement technique. Theobjectives of this study are to characterize thedynamic behavior, to investigate the influencingfactors of lower suspension armusing FEM incorporating design of experiment (DOE) and artificial neural network (ANN) approach and to analysis the lower suspension arm using robust design method.

Kumar Nithin et al [12] the aim of their study is to simulate the mechanical behavior of a control arm under certain load and boundary conditions by using finite element method. In this procedure, control arm is fixed its connection points as boundary condition and the ball joint is subjected to different load condition as load from tyre first comes to ball joint.

V. Veloso et al [13] in their study, a failure analysis of a longitudinal stringer of a prototype vehicle has been carried out. Failure took place at the bumpers fixation points of the vehicle suspension during durability tests.

Y. Nadota et al [14] in their experimental device was 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

II. OBJECTIVES

Suspension systems form one key subsystem of an automobile that are used to isolate the occupants from shocks and vibrations induced due to road surface irregularities. It is also used as a wheel locating and guiding mechanism when the vehicle is in motion. Hence keeping all these in mind, following are the objectives of this work

- To Study the existing Wishbone suspension system component design and its function to isolate road irregular surface generated shock and vibrations.
- To develop a CAD Model of system using a standard Design Package by getting all standard industrial inputs.
- To export the CAD model into a Matlab tool in order to begin with Multi body dynamic simulation.
- To predict out the real time behavior of the system by defining all the required variables.
- To Carry out the structural analysis of the system using ANSYS Workbench by observing inputs from Matlab-Simscape simulation.
- To proceed out the Modal Structural Analysis in order to predict out the deformation produced in the system components with vibrating frequencies.

III. METHODOLOGY

- The Geometry of Double-wishbone suspension system along with the Shock Absorber is modelled using a Solidwoks tool as per the standard dimensions from SAE.
- The CAD model so far developed is exported to Matlab-Simulink tool to begin with Multi body dynamic simulation for Double wishbone suspension system.

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- To predict out the real time behavior of the system, variable like road profiles, stiffness, damping co-efficient and all are defined.
- The Oscillations and Vibrations so far developed from the Output of Matlab is taken as an input to carry out the Structural analysis of the model.
- ANSYS V14.5 is used to analyse the Static Structural conditions by defining the loading values over the constraints.
- Modal Analysis of assemble components is carried out later on to predict out their deformation at particular frequency of vibrations.
- Life, Factor of Safety and other Alternating Stress parameters are obtained further processing with the Structural Analysis.
- MATLAB and SIMULINK code further developed to achieve real-time numerical results in order to understand and predict system's physical behavior.

IV. DESIGN AND ANALYSIS

Double wishbone designs allow the engineer to carefully control the motion of the wheel throughout suspension travel. 3-D model of the Lower Wishbone Arm is prepared by using CAD software for modal and stress analysis. The forces and moments are used as the boundary conditions for finite element model of the wishbone arm. By using these boundary conditions static analysis is carried out.

Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around.

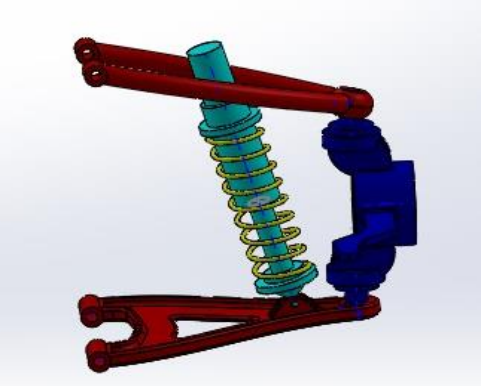

Figure 1: Model of Wishbone Suspension System modelled in Solidworks.

MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

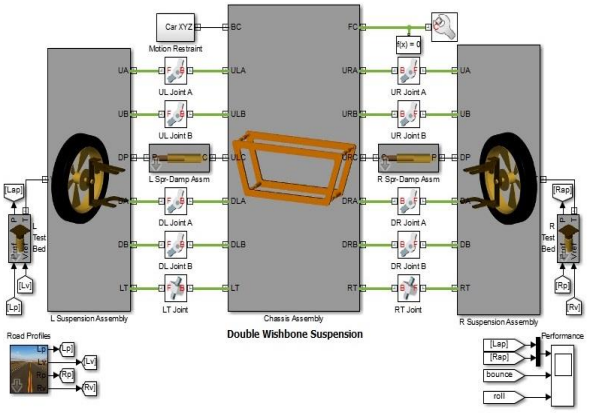

Figure 2: Simulink Model of Suspension System

Finite element methods are now widely used to solve structural, fluid, and multi physics problems numerically. The methods are used extensively because engineers and scientists can mathematically model and numerically solve very complex problems. The analyses in engineering are performed to assess designs, and the analyses in the various scientific fields are carried out largely to obtain insight into and ideally to predict natural phenomena. The prediction of how a design will perform and whether and how a natural phenomenon will occur is of much value: Designs can be made safer and more cost effective, while insight into and the prediction of nature can help, for example, to prevent disasters. Thus, the use of the finite element method greatly enriches our lives. ANSYS software with its modular structure as seen in the table below gives an opportunity for taking only needed features. ANSYS can work integrated with other used engineering software on desktop by adding CAD and FEA connection modules. It can import CAD data and also enables to build geometry with its "preprocessing" abilities.

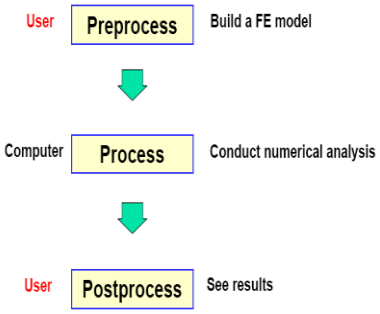

Figure 3: Process flow by ANSYS

V. RESULTS AND DISCUSSION

This section represents the results so far obtained by performing the simulation by Matlab-Simulink and Ansys Analysis.

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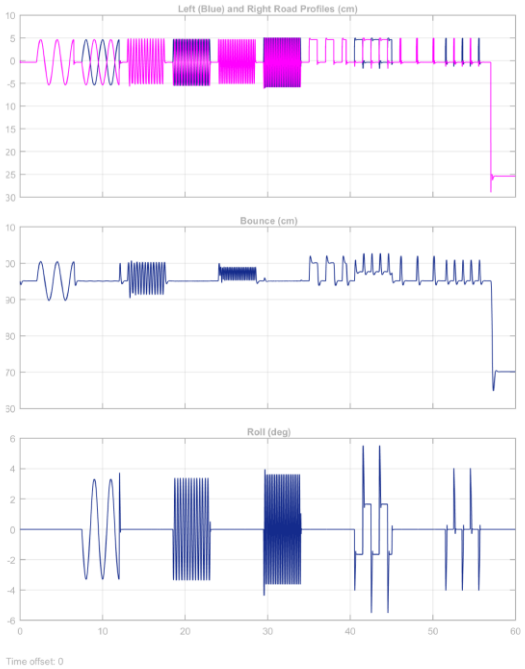

Figure 4: Output Curve of Matlab Simulation for Wishbone System

The above figure represents the Matlab-Simulink test bed to perform simulation study of the wishbone suspension system along with reference frame. As per the road profile definition, the Wheels undergoes up and down motion and are linked with the Suspension system of the vehicle. Thus Suspension systems form one key subsystem of an automobile that are used to isolate the occupants from shocks and vibrations induced due to road surface irregularities. It is also used as a wheel locating and guiding mechanism when the vehicle is in motion. The profiles so far generated is described in the Figure 4. The graph are plotted as a function of time along X-axis and Bounce, Roll and Road Profile input along Y-Axis.

Ansys structural analysis is carried out in order analyse the deformation and stresses so far generated according to the working conditions. This section is divided into two section, one which gives out the results obtained during Loading Conditions and another during the Modal analysis. Analysis is carried out for double wishbone suspension system and Shock Absorber Separately.

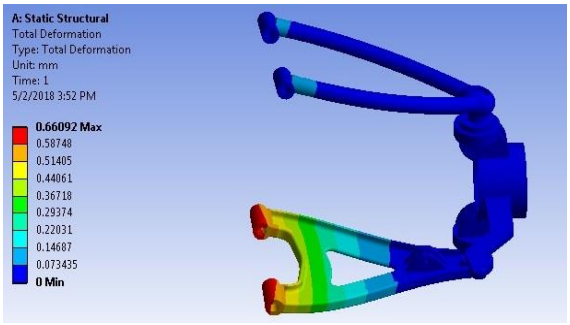

Figure 5: Total Deformation of Double Wishbone Assembly

From the above Figure 5, it can be noticed that the total deformation so far produced is maximum in lower bone as it is fixed to the chassis of vehicle. While it can be observed that the upper arm can more freely or flexible enough to take up the all loads. Hence deformation is minimum in upper arm. This concludes the fact that, there are more likely few mode shapes of vibration which can damage the upper arm. Hence to carry out with further Modal Analysis, only Lower Arm and Connecting Arm can be done.

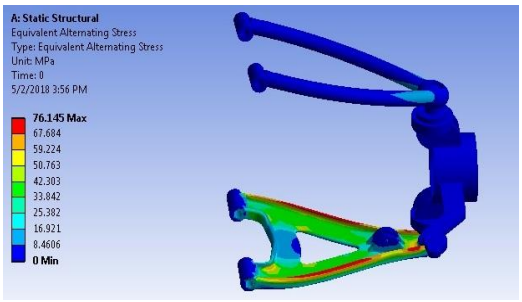

Figure 6: Equivalent Stress of Double Wishbone Assembly

As it follows from the above Figure 6, the maximum stress induced in the Lower arm which is maximum at a value of 76.145 MPa and is displayed on the lower arm.

To determine the natural frequencies and mode shapes of a structure modal analysis is used. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. The modal results are taken as an reference if want to pursue with a spectrum analysis or a mode superposition harmonic or transient analysis.

Modal Analysis is carried out to determine the deformation produced due to the vibrating frequency. Hence it found to be very optimum way to find the vibrating frequency of road profile to determine the maximum deformation which wishbone system can undergo deformation.

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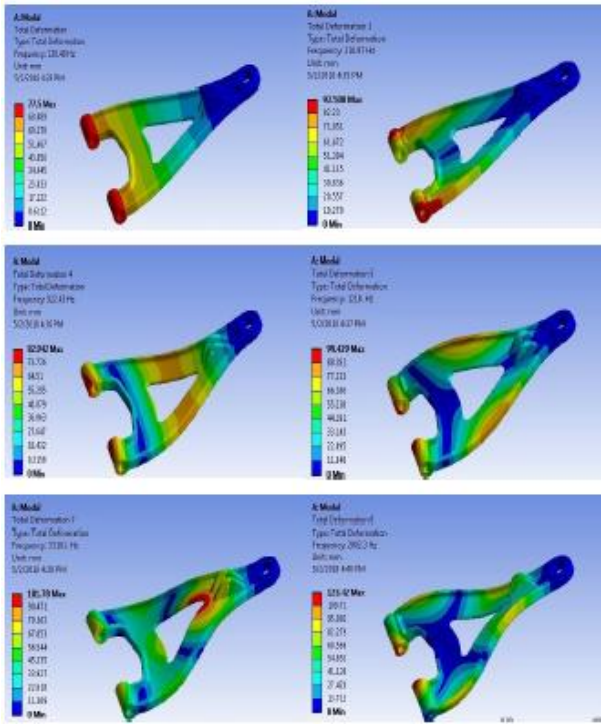

Figure 7: Modal analysis results of lower arm.

As depicted from the above figure 7, deformation so far obtained as per the frequency range is shown. Hence this clears case of vibrational analysis which depicts the deformation at a particular frequency of wheel oscillations.

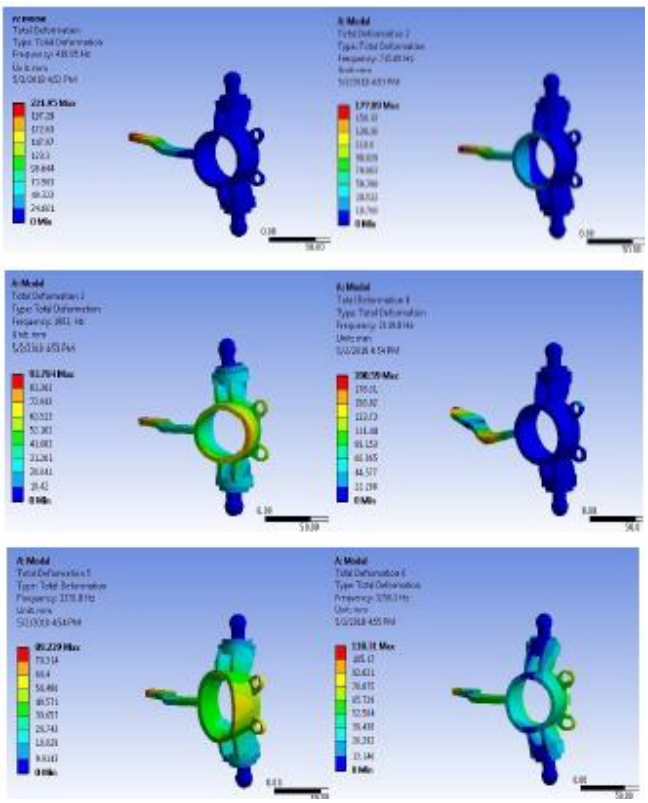

Figure 8: Modal analysis results of connecting arm.

Connecting arm Mode shape analysis with a particular frequency of oscillations is depicted in the above figure 8 and it follows the deformation at a particular frequency of wheel oscillations.

VI. CONCLUSION

The work illustrates satisfactorily a double wishbone front wheel automotive suspension. The suspension is mounted on two platforms that can independently move up and down to simulate a road profile on each wheel. As per the road profile definition, the Wheels undergoes up and down motion and are linked with the Suspension system of the vehicle. For a given pair of road profiles, the resultant roll and bounce of the Frame can be studied and the suspension parameters tuned for optimal performance. The inputs to the two platforms are the road profile and its derivative. Curve output of bounce and roll of the frame over which the suspension system mounted is drawn accordingly.

The structural analysis of the model is studied thoroughly in two ways. One is loading analysis and another modal analysis. Loading structural anslysis of double wishbone system suspension system as well as Shock absorber yields up with the Fatigue Life, Factor of safety and deformation results. The modal analysis is carried out, for finding out the natural frequencies, with the Lower and connecting arm of the Double wishbone suspension system. The total deformation of the components as per the vibrating frequency and the critical locations are obtained accordingly.

FUTURE SCOPE OF WORK

- The work can be extended to predict important performance parameters, namely camber and toe, and propose objective functions which try to minimize the variation of these as the wheel travels in jounce and rebound.
- Evolve a Test plan i.e an experimental set up for validating the Finite Element results so far generated and compare both accordingly.
- Further on, the model for benchmark shall be validated with an alternative method as Physical Experimentation.
- Generated robust design technique could be applied in the design stage of the product optimum process so as to maximize product reliability.

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