UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MODELLING OF FRONT SUSPENSION MODULE USING FLEXIBLE MBD MOTION VIEW

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Degree of Mechanical Engineering Technology (Automotive Technology) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours. The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRACT

The title of this project is ‘Modelling of Front Suspension Module Using Flexible MBD Motion View’. Most times, the tire wear takes place due to the damaged shock absorber in the suspension strut. The side load acting on the spring is the main factor which causes the shock absorber to wear. This project converges into the problem and performs a new spring geometry with optimized spring force line to reduce the side load using analytical approach. In attempt to find and prove the optimized spring force line, two different spring geometries are compared analytically in strut level and verify the original spring force line in suspension level. The analytical comparison between the two spring designs involves experimental validation and evaluation in term of better spring force line with lesser deviation using HyperMesh. For the suspension level, the original spring model is simulated in a real ride condition and the spring force line is evaluated in the suspension system. The reduction of side load becomes the current target of the vehicle manufacturers and users where the tire thread sustained in a good condition after a long travel. A compromising shock absorber will keep excellent force absorption to preserve the comfort of the vehicle users. As a result of this analytical evaluation, the morphed spring design performs a side load reduction with the better spring force line.

DEDICATIONS

This dissertation is dedicated to all my family members and friends. It has always been my parents, Mr Lee Swee Seng and Mdm. Poon Sew Hong who nursing me with affection, trust and moral support whenever any challenges gets tougher. Their unconditional love reminds me that I could not easily disappoint them and even trying harder. All my fellow friends are deserved to be partnership in my success of the project especially my housemates. They have provide me a lot of miscellaneous aids and words of encouragement which make me to think in a positive manner when things go wrong. I also want to dedicate tis dissertation to my co-supervisor who willing to teach and assist me in any part of the software simulation which I am confused with.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ADAMS	-	Automated Dynamic Analysis of Mechanical Systems
AMC225xe	-	Aerospace Metal Composites
L	-	Free length of coil spring
FE	-	Finite element
MBD	-	Multibody Dynamic
MSC	-	MacNeal-Schwendler Corporation
UK	-	United Kingdom
US	-	United States
USA	-	United States of America
UTM	-	Universal Testing machine
SLA	-	Short-Long Arm
CATIA V5R19	-	Computer Aided Three-Dimensional Interactive Application Version 5

CHAPTER 1

INTRODUCTION

1.1 Background of the Research

In the tremendous fast growing automotive industries in Malaysia, the population of vehicle users increased from 9928238 in the year 2005 to 12763452 in year 2011 (Transport Statistic Malaysia, 2005-2011). As a result, demands on the vehicle specifications greatly heighten. They wanted the lowest possible maintenance fees with great reliability or lifespan of the vehicle components and at the same instant, their comfort is to be preserved.

In contrast, mechanical moving parts in the vehicle are insusceptible to wear which intend to reduce their lifespan. Among those contributive weary parts, one of them is suspension. Latterly, Macpherson strut is the most common suspension system assembled in passenger cars or motor vehicles (Prof. S. C. Jain et.al, 2004). According to Prof. S. C. Jain et.al (2014), the Macpherson strut is preferred due to its simplicity and can be pre manufactured into a unit at the assembly line. Its structure simply incorporates of an outer part in which firmly attached to a mounting in the body shell and the inner part secured to the upper part of the hub. The body of strut is reinforced by a coil spring which performs functionality to maintain the system at predetermined height and a cartilage-like shock absorber to absorb vibrations. Then, the structure of the strut further into a steering arm locked to the lower inner position of the strut.

According to the inventor of European Patent Specification, Kime, Aaron A. Monroe, OH 45050 (US), when the “side loads” or lateral forces exerted on the shock absorber, deviations in tolerance in most components in the absorber distort the piston and piston shaft off the center line. This radial misalignment of the rod and piston results in an act of rubbing between shaft and rod guide as the shaft strokes within the inner tube, then leading to an irreversible wear to both shaft and rod guide.

1.2 Problem Statement

In the past few decades, the automobile engineering stepped a steep technological growth (S. Pathmasharma et al, 2003). In order to achieve market share, improvements on the weary automotive parts must be implemented regardless higher demands from the vehicle's user. Of that, the requirements of a selective commercial car to be competed were the comfort of the passenger and reliability of the vehicles' parts. In such commonly used automobile parts such as Macpherson suspension, it failed to stand out to meet the current requirements. According to J. Liu et.al (2006), the side force initiated most at the top of the damper rod in Macpherson strut which produced an inner friction between damper parts as shown in Figure 1.1.

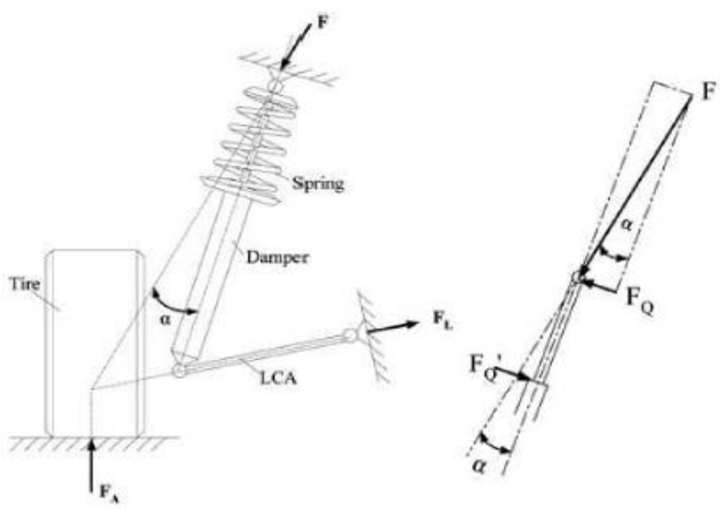

Figure 1.1 Schematic diagram for loads acting on the Macpherson strut suspension

When a vehicle is driven on an even ground level, the body of the vehicle impacted by the vertical vibrations as the road excitation fails to minimize the inner friction to operate the suspension perfectly. The traditional method to minimize the side load is to incline the spring to a certain inclination angle yet the side load still cannot be completely eliminated due to the limited installation space of the suspension. Therefore, it was essential to reduce the side load (source of friction) to compromise preservation to the damper in the strut and to strengthen ride performance.

In this research, a modeling of a Macpherson front suspension module using Hyper Works Motion-View to investigate the effect of the spring design towards strength and dynamic characteristic of the module. The dynamic characteristic is the determinant factor for a long-lasting suspension before a new replacement is needed. A passenger's comfort is impaired with the ability of the damper (shock absorber) of the suspension to absorb vibration transmitted.

1.3 Objective

Thus, in this research, the effect of spring design towards the strength and dynamic characteristic of the MacPherson front suspension module is to be studied. The spring design in mean an appropriate inclination location against the shock absorber axis should be precisely determined to minimize the loading and stress on the entire strut. The following objectives are as below:

a) To use Hyper Works Motion-View to model a MacPherson front suspension module with spring as flexible body.
b) To conduct a laboratory test to obtain a force characteristic and stress on the coil spring for the MacPherson suspension to validate simulation model.
c) To determine the best force line for MacPherson suspension module using simulation model.

1.4 Scope

From the beginning of the project, the modelling of the Macpherson strut in an application of a precise engineering simulation software, Altair Hyper and latterly, followed by an actual testing of a commercial Macpherson suspension using Universal Testing Machine (UTM). The result from the modelling module was then validated in compare with testing result for the analysis of strength and characteristics of the Macpherson suspension. The limitation of the force line was further improved in reconstruction of inclination of spring against the shock absorber axis in Alter Hyper (Hyper Work) software. In the project, the process of conduct was to lead into following achievements:

a) A validated simulation model of a Macpherson module used in current commercial vehicle.
b) An improved force line for spring design to escalate the strength and dynamic characteristic of the MacPherson suspension to prolong the lifespan of the Macpherson strut and possibly resist wear.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The literature review was studied earlier on the Macpherson suspension system as an option to a vehicle suspension. The continuity of the literature review followed by the characteristic of helical coil spring in Macpherson strut to be further discussed. The coil spring illustrated as a flexible multi body dynamic (MBD) in the related MBD softwares was reviewed in this chapter. The definition of a spring force line of a suspension strut and how formulated spring force line calculation can act as an evaluation to the suspension design are to be analyzed in this chapter. The final part in this chapter will include an experimental validation as verification to the model output parameters before the optimization is yet to be constructed to improve spring force line is to be discussed throughout.

2.1 Vehicle Suspension

A defined vehicle suspension had pictured as an arrangement of kinematic linkages and contributive force elements in the strut such as coil springs, shock absorbers and bushings attached to the body chassis and the wheels of a vehicle to provide a contact with the road track (Souharda Raghavendra., 2008). Imagine that the road surface was perfectly levelled and had no irregularities, then, there will not be a need of a suspension. However, this is not possible as even such fresh pavement would had imperfections which interact with the wheel. It is these perfections which imparted forces on vehicle components and causing handling imbalances of the vehicle (Prof.

S.C.Jain et al., 2014). Thus, any suspension system should have ability to capture, release, and introduce energy to the system. A suspension system was basically divided into three types which were the passive, semi-active and active suspension system. They were simply understood that a traditional type suspension which only consisting of springs and dampers was clarified as a passive suspension and as if controlled externally, it was merely called as a semi active or active suspension. A passive suspension system was an open loop control system (without feedback) and meant to be unadjustable by any mechanical part. In other words, the performance of the passive suspension can said to be totally dependent on the road profile. For an active suspension, it capable to provide an enhancing performance via aid from the force actuator which resulted as a close loop control system. This force actuator was an additional mechanical part assigned into the system which controlled by a controller. The controller will calculate and decide to whether provide or remove energy from the system with the help of sensors giving input. The sensors will preliminary sense and transfer the road profile data to the controller (Yogesh Sanjay Pathare and Nimbalkar Sachin R., 2014).

In the major classification of the different designs of the suspension systems, a dependent suspension system (solid axle) and an independent suspension system were employed. The dependent suspension system was designed to have both wheels (left and right) sharing the same solid axle. In such sharing, any movements from any wheel will conveyed to another wheel which in return both cambered together. Whereas an independent suspension system possessed a contradict effect to minimize the distribution of movement of any wheels to another wheel. Among the most common independent suspension systems applied in many modern motor vehicles, Macpherson strut and double wishbone suspension system were selected. The Macpherson strut mainly consisting of a strut assembly (spring and shock absorber) and a single lower control arm and was used by most Ford cars. The double wishbone system was known as “A-arms’ in United States (USA) and “Double wishbones’ in United Kingdom (UK). It often applied to sports cars and luxury sedans because its initial design of elastic-kinematic parts to adjust between handling and comfort excellently. The upper and lower control arms of the double wishbone suspension usually designed of unequal lengths (SLA, short-long arm). The double wishbone was merely defected in preference due to the complexity of its design, production cost, increased number of parts such as joints and bearing which impacted negatively on the tire wear due consumption of bushing rubber (Shpetim Lajqi et al., 2013).

2.1.1 Macpherson Suspension

In much earlier history of the Macpherson strut or suspension system, it was originally used by Fiat. Then, in early 1920s, a French maker, Cottin-Desgouttes inverted a similar leaf spring-based design which merging the steering pivot and suspension into a single component. It began to attained as Macpherson strut after Earlie S. MacPherson had started to include a unified coil spring and shock aborber assembly into strut in the 1940s. In his work in General Motor as head engineer of their “light car” project, he had developed an initial work on this new type of suspension system. However, his company, General Motors had then decided not to claim the light car project which latterly, he left his company to work with Ford. He was very fortunate that Ford granted him a patent which took him to receive the credit as the Macpherson strut inventor. Now, it is merely introduced as a commercial type of car suspension system in modern vehicles which employed the axis of a telescopic damper as the upper steering pivot (A.Purushotham, 2013).

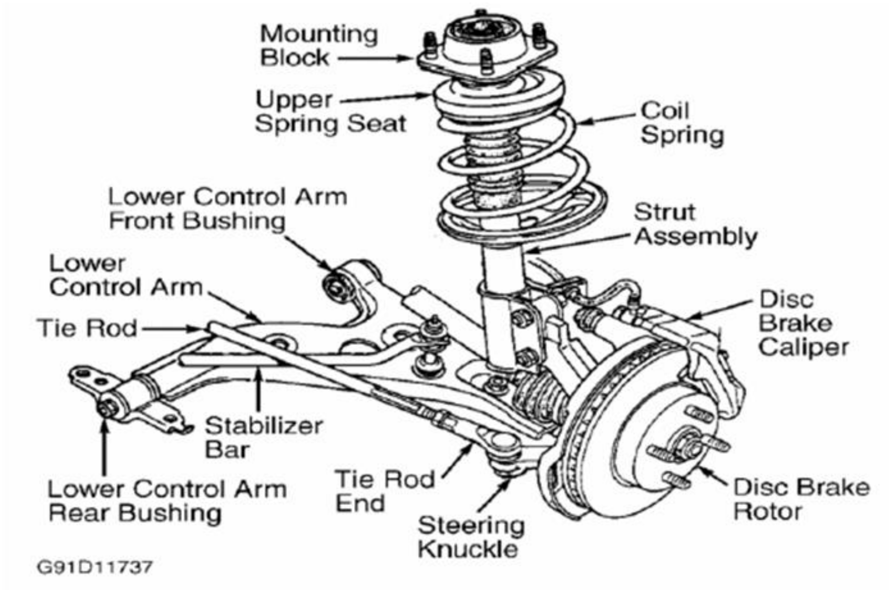

Figure 2.1 MacPherson suspension system (Jagwinder Singh et.al, 2015)

It was structurally built up with a substantial compression link stabilized by a secondary link with lower control arm which was mounted at the bottom to the hub or axle of the wheel as shown in Figure 2.1. The lower arm system contributed to both lateral and longitudinal movement of the wheel (A.Purushotham, 2013).

According to Keum-Shik Hong et al. (1999), the control arm served several functionalities in such ways of as an additional link which attached firmly to the body to support the structure of the strut, and permitted the unsprung mass rotational motion. The upper part of the hub was mounted to the inner part of the suspension system while the outer part extended upwards to meet the chassis of the vehicle. The thrust ball allocated in the mounting to allow the rotation of the strut. (Daniel A.Mantaras et al., 2004). The secondary link or wishbone was the one which adhere the knuckle to the body of the suspension system. A spherical joint had made the union between the knuckle and the wishbone while the mounting of the wishbone to the body was held by two bushings to alternately regulate rotation between the both elements. The tie rod was connected to the knuckle or the shock absorber to deliver the turning action of the steering wheel to the wheel. The coil spring was suspended on the body of the strut and the shock absorber which in the form of cartilage to be mounted within the strut.

The Macpherson strut will eventually worked together with the environment experienced by the vehicle. In accordingly to Dave Garza et al. (2011), when a wheel hit on the road disturbance especially a road hump, the wheel and suspension strut will trigger an upward motion and leading the spring coil to be compressed. The coil spring performed in a way to sustain an appropriate suspension ride height and control suspension travel in drive. Then, shock absorber moved together with the spring coil to monitor the spring action of being compressed or tensioned. Once the spring was compressed, an elastic potential energy was stored in where latterly immediate released to extend the spring in the same proportion of energy. It resulting in the lower strut chamber to be forced downwards. The upper and lower control arm bushings were the ones which provided a free vertical movement of the control arm and to absorb the unwanted vibrations and wheel impacts. The strut was supported by a stabilizer bar to minimize the body sway during and after passing the hump. When the vehicle about to cornering or turning (steering wheel was turned), the pivoted arms were to shifted inward and forward to the body chassis to ensure the wheel remained upright besides resisting the braking and accelerating forces. The entire assembly simply as that simple to be constructed into a unit, removing the upper control arm, thus providing more significant spacing for the engine compartment (Prof. S.C.Jain et al., 2014).

All the working principles above much dependent of movements at joints or hardpoints. In such that all the key datum features, including datum coordinate systems, datum mass and datum axes which required for assembly are collected in the part called hardpoints (Kuang Hua Chang, 2015). The hardpoints had produced massive effect on suspension characteristic and performance. Multi-body dynamics and suspension kinematics theory meant to analyze the correlation for the hardpoints of the suspension (Xintian Liu et al., 2013).