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Tuning a Le Mans Car Suspension in ADAMS

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Abstract— **An ADAMS model of South Africa's first ever Le Mans car was developed and used to tune the suspension parameters. Validation of the model is to be done by comparing simulation results to those obtained in track testing. The suspension parameters of note were the spring and damping rates for the third damper and the anti-roll bar (ARB) rate in the 3 damper suspension arrangement.**

Keywords**—Insert Keywords Here. Separate Keywords using a semi-colon. For example: linear; turbine**

I. INTRODUCTION

In the current financial climate, the development and production of racing cars has become reliant on software for design and simulation. Software packages have been in use in the top tiers of motorsport for many years, however smaller privateer teams are forced to adopt these techniques in order to remain financially viable.

South Africa's first contender for entry into the Le Mans 24 hour race, the BC LMP II, was designed and built by Bailey Cars (BC). The vehicle utilises a three spring suspension system containing on-board dampers and a vertical anti-roll bar (ARB). The contribution of each of these components is little understood. Software simulation provides an ideal environment to understand the effect each component has on the handling and performance of the vehicle. .

II. LITERATURE REVIEW

Modern race teams employ large numbers of engineers who create detailed mathematical and software models of their vehicles. In addition to this, advancements in computing power has driven the development of complex data acquisition systems, or telemetry. This telemetry data is closely guarded by race teams and their findings and developments are seldom published, if ever.

Milliken and Milliken [1] give a good background summary on vehicle dynamics, and was used comprehensively throughout this study.

Kowalczyk [2] outlines an approach used to tune the dampers and ARB of a Champ Car (which uses the traditional 2 damper suspension), through the development of mathematical models. He starts by using the traditional quarter car model before expanding to a 7 degree of freedom (DOF) model. This 7 DOF model illustrates the relative effects of front and rear damping as well as the effects of pitch, heave and roll. The analysis was then augmented with the use of a 7 post shaker rig.

Miller [3] presents an approach to tuning the suspension and ARB for an FSAE race car. Track testing was carried out to tune the vehicle suspension, with the ARB being the focal point of the study. Telemetry data was collected to be used on a 7 post shaker rig. He reports that similar results were obtained for the ARB setup from one day on a 7 post shaker rig as to that of 3 days of track testing. The shaker rig was also found to provide further information to that available from track testing.

Kelly et al [4] describe a process used to tune race car suspension with use of a 7 Post shaker rig. One of the advantages of this is cited as it being a cheaper and more informative alternative to track testing. The process makes use of wheel hub acceleration data from the vehicle on a particular track. This data is then inputted into the shaker rig to simulate the track inputs to the vehicle.

A 7 DOF model such as that developed by Kowalczyk [2] does not adequately account for the complexity of the suspension system used in the BC LMP II. While informative, it does not describe all of the vehicle's modes, necessitating the use of a more advanced simulation technique.

The use of shaker rigs does indeed provide a cheaper, less time consuming and more informative alternative to track testing; however it can still be a costly process. This is especially so for small privateer teams such as Bailey Cars.

Modern race teams employ a host of computer simulation software packages to predict vehicle performance, from CFD and FEM to multi-body dynamics packages.

There is no published data describing the use of software simulation to tune race car suspension. This paper outlines the development and simulation of an ADAMS/Car model for the South African designed and built BC LMP II.

III. ADAMS/CAR MODEL

Fig. 1 shows the ADAMS/Car model of the front suspension with the steering system on a suspension test rig. The geometry and layout of the third damper and vertical ARB can be seen in the figure.

Important features are the third damper and the vertical ARB, moreover their relation to, and effect on the rest of the suspension and overall vehicle handling. The vertical ARB not only couples the left and right wheels, but also pitch and roll. The relation between these two modes is of great interest in understanding how the vehicle will perform as various suspension parameters are varied. The parameters of greatest interest at this stage of the vehicle development are the front and rear ARB rates. The vehicle has undergone initial track testing without ARB's. This study seeks to understand the influence of the ARB's. Initial calculations show that a 100Nm/deg front ARB is required. This ARB has been fabricated; however track testing with the ARB is yet to be performed. No rear ARB is available as yet.

The ADAMS/Car model of the BC LMP II was built using the 2010 version of the FSAE template distributed by developers of ADAMS/Car, MSC Software. The FSAE template was chosen as the FSAE model utilises a pushrod suspension system, similar in principle to that of the BC LMP II. For the rear suspension and the remainder of the vehicle, the standard shared template in ADAMS/Car was used and modified as necessary.

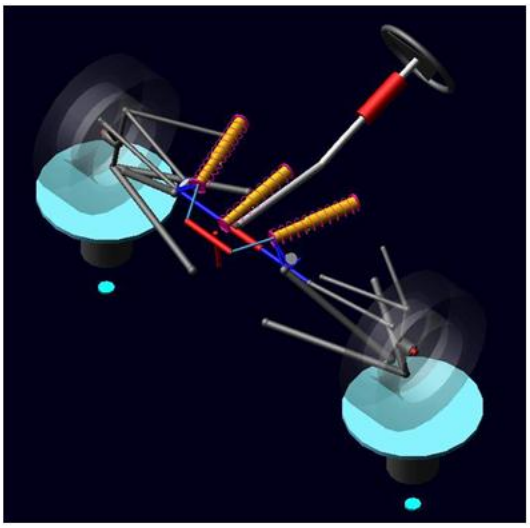

Figure 1. ADAMS Model of the BC LMP II Front Suspension

The GSTIFF integrator was used with an I3 Formulation for all dynamic simulations, with a maximum integration order of six.

IV. RESULTS

Fig. 2 below shows the ARB Stiffness vs. Maximum Body Roll of the vehicle during an ISO Lane Change Manoeuvre at 22.22m/s. It can be seen that there is a relationship of diminishing returns for both the front and rear ARB rates. A front ARB stiffness of approximately 1200Nm/deg would result in zero body roll. This however is an excessive stiffness compared to the front spring rate of 115 N/mm. A suitable ARB stiffness would therefore be a value of 250Nm/deg, resulting in a 55% reduction in body roll. A rear ARB rate of 250Nm/deg would also be suitable, resulting in a 20% reduction in body roll. This figure does not however account for the combined effects of front and rear ARB.

Fig. 3 below shows the combined ARB stiffness vs. body roll. The combined front and rear stiffness' sum to 500Nm/deg in each case. The value on the horizontal axis showing the proportion of front ARB to 500Nm/deg. The clear minimum being a 70/30 front to rear split, or 350Nm/deg Front, 150m/deg rear. As noted above, this is impractical and again, a 50/50 split of 250Nm/deg front and rear is suitable. This combination results in a 42% reduction in body roll.

Due to the high aerodynamic loading on the BC LMP II, minimising body roll is desirable, but is not the only important parameter in a handling analysis. Milliken and Milliken [1] note that oversteer /understeer considerations dominate vehicle stability and control and are one of the more important considerations that determine a vehicle's behaviour. Milliken and Milliken [1] present the yawing velocity response curve as an indication of a vehicle's oversteer /understeer characteristics. This is the relationship between the yaw gain, yaw rate/steering angle (1/s), to the vehicle's longitudinal velocity for a constant radius corner manoeuvre.

Fig. 4 below shows the yawing velocity response for various front and rear ARB stiffness'. The manoeuvre simulated was a constant radius corner with a radius of 30m. The initial velocity of the vehicle was 10km/hr, the ADAMS/Car smart driver then accelerated the vehicle to 80km/hr, beginning each run in first gear and changing up as necessary.

For each run, regardless of vehicle configuration, the low speed behaviour is neutral steer. This is shown by the linear relationship up to about 45 km/hr. A slope with a decreasing gradient indicates greater steering angle as velocity increases, thus understeer, and an increasing gradient shows a lesser steering angle as velocity increases, thus oversteer. It can be seen that in all cases, after 50km/hr the vehicle begins to understeer.

Of all the combinations of ARB stiffness simulated, only those that are of interest or that show any meaningful insight are presented in Figure 4. It is clear that the understeer characteristics of the vehicle are accentuated by adding front ARB and reduced by adding rear ARB.

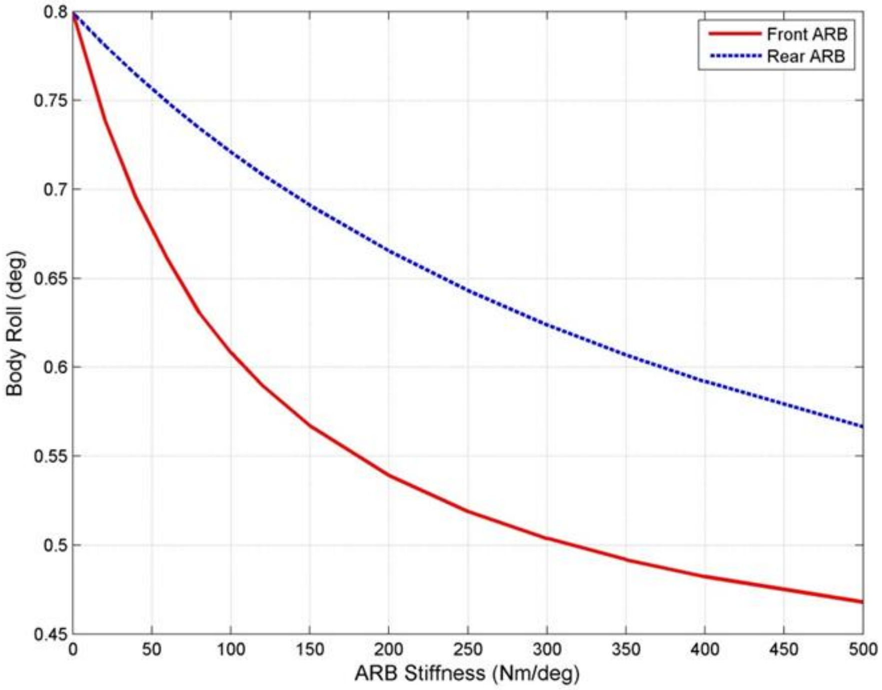

Figure 2. ARB Stiffness vs. Body Roll for ISO Lane Change Manoeuvre

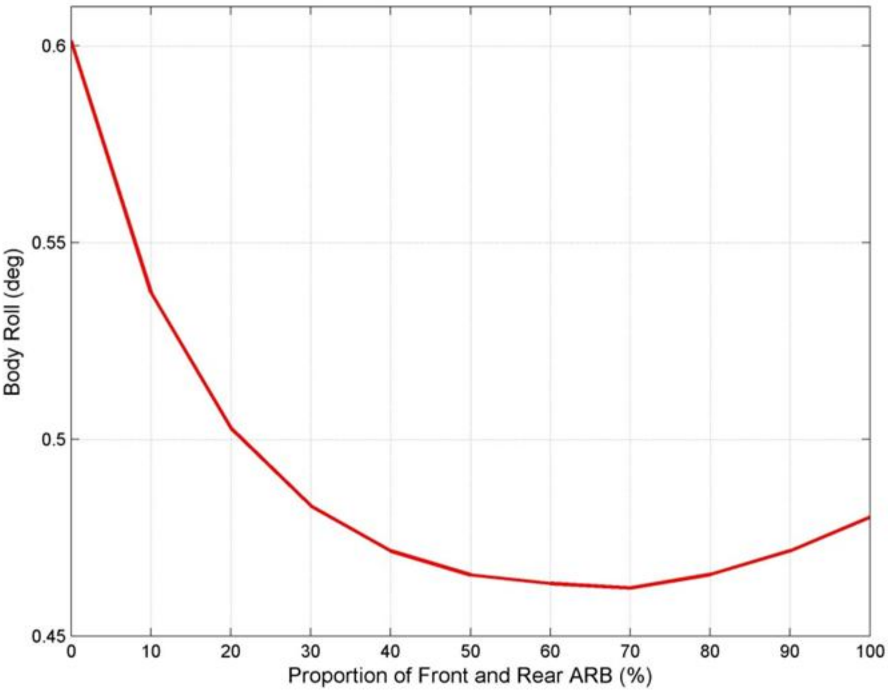

Figure 3. ARB Stiffness vs. Body Roll for ISO Lane Change Manoeuvre

The top curve, Front 0 Nm/deg Rear 250Nm/deg, shows the best resistance to understeer, however the vehicle experiences snap oversteer at 67km/hr. This indicates instability as the vehicle approaches the limits of grip. The next best setup for reducing understeer would be the combination of Front 0Nm/deg Rear 150 Nm/deg. This however as mentioned above is not practical for reducing body roll. It is therefore necessary to include some ARB stiffness. The combination that yields the best understeer response is that shown by the dashed line, Front 100Nm/deg Rear 150Nm/deg. Increasing the front ARB stiffness any further greatly decreases the vehicle's resistance to understeer. Further simulation with this combination yields a decrease in overall body roll of 30% from the datum of zero ARB stiffness.

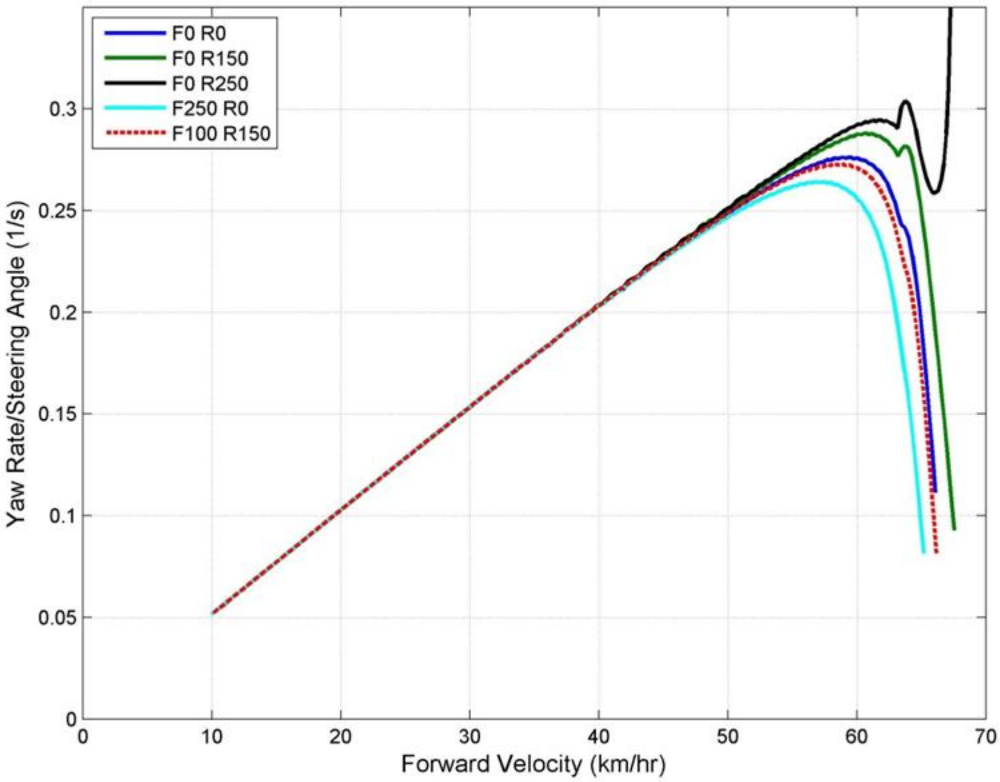

Figure 1. Figure 4. Yawing Velocity Response

V. CONCLUSION AND FURTHER ANALYSIS

The ARB Stiffness most suitable for reducing body roll is a combination of 250Nm/deg for both front and rear, giving a 42% reduction in body roll. It can be seen from Fig. 4 that this combination would adversely affect the handling characteristics of the vehicle. A combination of 100Nm/deg and 150Nm/deg for the front and rear respectively would give the best overall combination. This combination results in a 30% reduction in body roll.

Due to logistical complications, the BC LMP II vehicle was unavailable for testing at the time of writing. Track testing of the vehicle has been scheduled at this time. The ISO Lane change and constant radius corner manoeuvres will be completed in the vehicle and the results compared to the simulations presented in this paper. Upon completion, further simulation will be carried out as well as a fully parameterised study for front and rear spring stiffness, damper setting and ARB rates.

VI. ACKNOWLEDGEMENTS

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