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Modelling of SOLO's Car Suspension System

(Pemodelan Sistem Penyerap Hentak Kereta SOLO)

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ABSTRACT

The use of a virtual analysis approach to develop and modify vehicle sub-system is becoming popular nowadays as it is less time consuming, reduces the workmanship and overall testing cost compared to the experimental approach. In this paper, an actual virtual suspension system based on UiTM's Perodua Eco Challenge (PEC) competition full-body vehicle named SOLO was modelled using multi-body dynamic software, MSC/ADAMS Car. The virtual suspension system model was developed starting from identifying the components' hard points, parameter setting, and joint type between the suspension components. The complete model was simulated using a static vertical parallel movement test with 30 mm as the selected bump travel movement. Following that, the values of kinematic and compliance of toe, camber and caster change were obtained. It was found that the front toe change was negative when subjected to wheel bound at 30mm (-0.3^o), while the trend is opposite with the rear toe change (0.2^o). Camber and caster change shows similar trends for both front and rear suspension system. Further analysis was then done to study the dynamic performance and suspension improvement after the virtual suspension system is verified.

Keywords: Virtual suspension system; static vertical test; kinematics and compliance; MSC/ADAMS car

INTRODUCTION

The suspension system is one of the most vital parts to be considered when designing a race car. It must be comprised of a better kinematics design to keep the tires as perpendicular to the pavement as possible and to keep the tires on the ground at all times (Ni et al. 2013). The suspension system transfers the force and torque between the wheels and the chassis to control the relative motion of the wheels and absorbs the impact from the road surface and cornering forces (Mohamed et al. 2005) . In general, kinematics can be defined as the study of motion without reference to the mass or force, or it can also refer to the variation regularities of parameters such as toe angle, camber angle, and caster angle when the car is subjected to wheels movement, since the wheels and chassis have relative movement in the vertical direction (Tian et al. 2014). With the application and development of the virtual simulation technology and multi-body dynamic software, MSC/ADAMS Car is gaining attention as the approach of choice to develop a suspension sub-system of the vehicle and is used to analyze the vehicle's performance and effectively improve the suspension design speed and quality (Liang & Xin 2012). Numerous reports can be found in published literature on the use of MSC/ADAMS Car to analyze the dynamic performance of various vehicles. For example, Xiaobin Ning use MSC/ADAMS Car to analyze the dynamic of car suspension while Zhang Xiu-qin studied on ABS multi-axle truck using the same software platform (Ning et al. 2011; Xiu-qin et al. 2012). This approach avoids a lot of repetitive work which often occurs in the conventional experimental methods, enhances the design efficiency and shortens the time of product development cycle, thus reducing the cost and number of workmanship. The aim of this study was to model and analyze the actual suspension system of UiTM's Perodua Eco Challenge car named SOLO. The analysis was limited to the static vertical parallel movement test using the virtual test rig on MSC/ADAMS Car. The SOLO car was equipped with a double wishbone unequal length control arm independent suspension system for both the front and rear suspension systems. The length of the upper and lower arms was different to ensure minimal changes to wheel alignment when the suspension was bound and rebound. Figure 1 shows an actual SOLO car during the Perodua Eco Challenge competition.

FIGURE 1. UiTM Perodua Eco Challenge Solo's

METHODOLOGY

The methodology employed in the current study involved several important steps. First, the hard-points of an actual suspension component location were identified, followed by modelling of the suspension system using MSC/ADAMS Car, and simulating the working suspension model with specific suspension movement analysis test and generating the kinematic and compliance data for the selected output for further investigation.

SUSPENSION MODELLING

To develop a suspension model using MSC/ADAMS Car, a set of hard points of suspension component or coordinates in x, y and z directions must be identified (Mraz 2021). For this suspension system, a double wishbone unequal length control arm suspension type was used for both the front and rear sides. The hard-points were measured from the location of the centre of gravity (CoG) of the vehicle towards the mounting location of each suspension component. There were 24 hard-point values in total for both the front and rear suspension systems (Amni 2012). The values consist of upper control arm (UCA), lower control arm (LCA), and other components, as shown in Figure 2. Table 1 shows the selected hard-point value of double wishbone unequal length control arm for the front and rear suspension systems. Since the suspension geometry are symmetrical

TABLE 1. Front and rear suspension unequal control arm hard points (value is in *mm*)

		Front						Rear					
		Left			Right			Left			Right		
No.	Hardpoint	x	y	z	x	y	z	x	y	z	x	y	z
1	LCA_front	1233	230	-128.3	1233	-230	-128.3	328	300	-96.5	328	-300	-96.5
2	LCA_rear	573	250	-128.3	573	-250	-128.3	827	275	-96.5	827	-275	-96.5
3	UCA_front	1233	230	86.7	1233	-230	86.7	328	300	96.2	328	-300	96.2
4	UCA_rear	573	250	86.7	573	-250	86.7	827	275	96.2	827	-275	96.2

for the left and right hand sides, the values of x and z of the hard point would be the same. The y values for the right side of the car were negative because the origin of the coordinate was taken from the centre of gravity located nearly in the middle of the car.

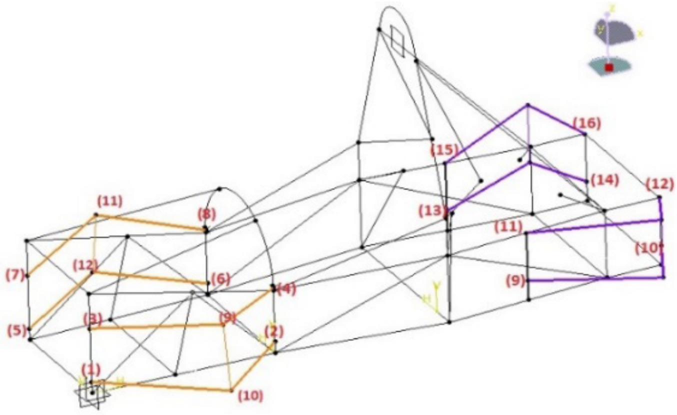

FIGURE 2. The location of suspension hard points in CAD model

The modelling of the suspension was initiated by generating the suspension model template using the hard-point value in the template view in MSC/ADAMS Car as shown in Figure 3. The properties of some other suspension components such as the spring stiffness, damper profiles, and joint type (Figure 4) were also defined during this stage (Ikhsan et al. 2015). It was important to ensure all the parameters' values were correctly defined as it will confirm the suspension geometry and determine the accuracy of the suspension performance to be exactly as the actual suspension. The next step was to save the suspension template model as a sub-system since only the sub-system can be used to be assembled as a fully working suspension system to be simulated and analysed on the virtual suspension test rig as shown in Figure 5.

SUSPENSION SIMULATION ANALYSIS

The virtual suspension model then underwent a kinematics simulation test using a virtual suspension test rig (MDI_SDI_TESTRIG) on MSC/ADAMS Car. Both the front and rear suspension systems were subjected to the vertical parallel wheel movement test, where both the left and right wheels were subjected to simultaneously parallel movement in the same vertical direction with 30 steps of 30mm bound and rebound travel values (total of 60mm of wheel travel), as shown in Figure 6. During the suspension kinematics simulation, the kinematic pairs and linear drive were selected and added between the test platform and ground to represent the ground's excitation effect on the wheels (Ravichandra et al. 2020).

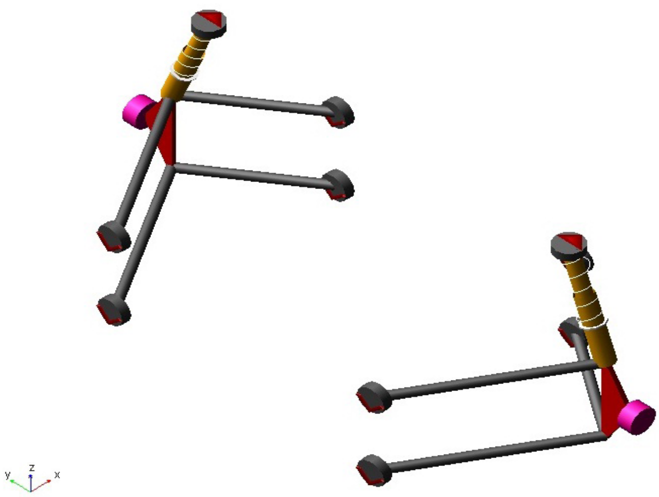

FIGURE 3. Front suspension template

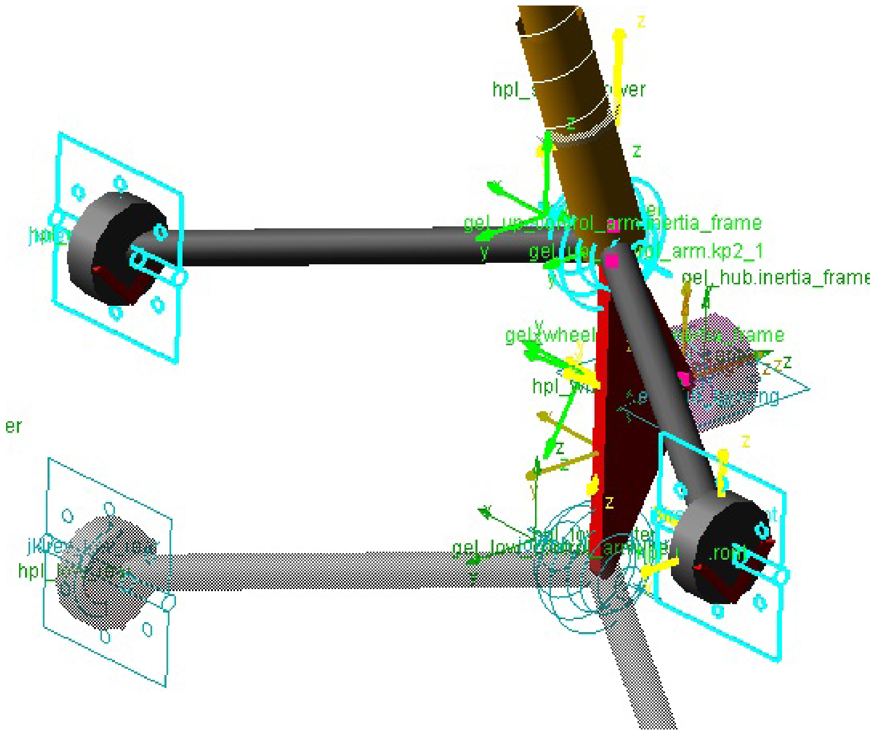

FIGURE 4. Joint type setting on the suspension template

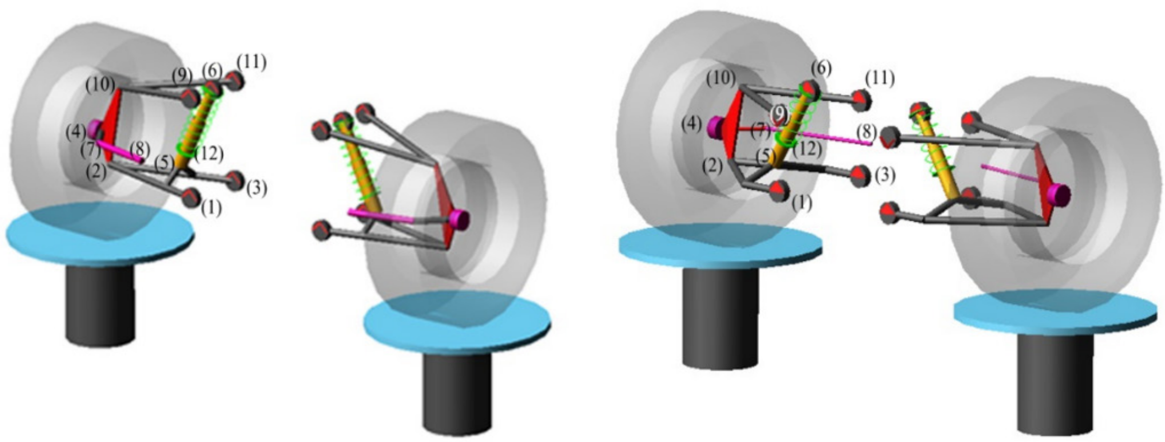

FIGURE 5. A full vehicle of actual virtual suspension system of SOLO Car
(Left : Front suspension system, Right: rear suspension system

(a)

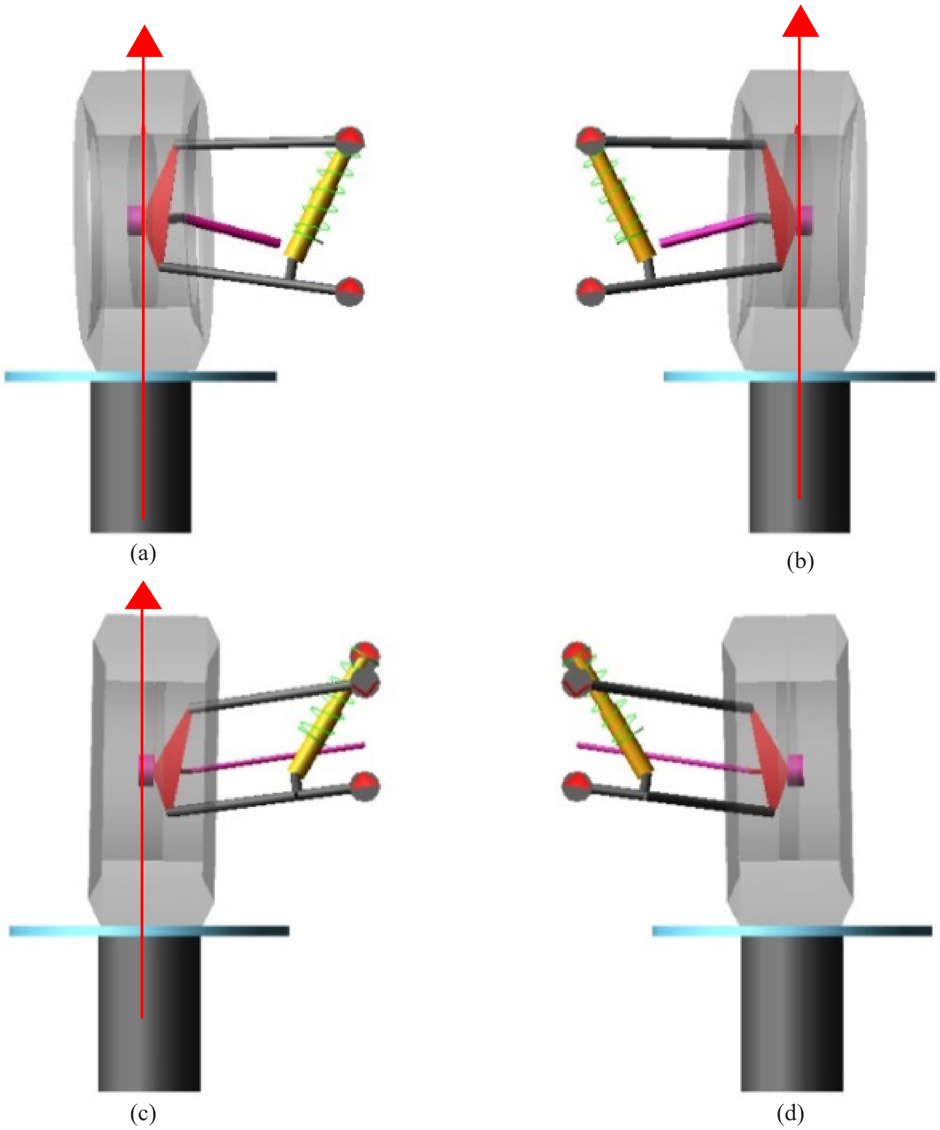

FIGURE 6. Suspension model after subjected to 30 mm vertical parallel wheel movement (bound), (Top : Front suspension system, Bottom: rear suspension system)

RESULT AND DISCUSSION

The simulation test on the virtual suspension test rig generated a set of kinematic and compliance data through post-processing analysis on MSC/ADAMS Car. For this study, only data of toe change, camber change and caster change to the wheel movement were plotted into graphs and analysed since they gave a significant effect on overall suspension performance and characteristic during the static event. 6 graphs were plotted for the front and rear suspensions. As mentioned before, since the suspension system was symmetrical and had the same other suspension component properties and setting for the right and left hand sides (for front and rear suspension system), the data points generated for toe, camber and caster change to the wheel movement would be the same and considered as one single plot-line on the graph. Figure 7 (a-f) shows the graph of toe, camber and caster change to the wheel movement when subjected to the vertical parallel wheel movement test on the virtual suspension test rig.

Based on the graph, the values of toe, camber and caster change when the wheel movement was at 0 mm, were 0^{o}, -2^{o} and $+2^{o}$ respectively for front suspension and all were 0^{o} for the rear suspension. This was due to the suspension design specification setting when the wheels were completely on flat and static conditions [7].

The toe change for the front suspension decreased towards negative toe when subjected to wheel bound of 30 mm with a maximum value of -0.30^{o}, while for the rear suspension, the opposite trend was obtained with a maximum value of 0.20^{o} respectively. The same trend was also observed when the wheel rebound to -30 mm (Figure 7(a) and Figure 7 (b)). The advantage of the negative toe or toe out is to improve the steering response, while positive toe or toe in offered a great straight stability while driving. For the camber change, both the front and rear suspension systems showed a negative camber when subjected to wheel bound of 30mm with a maximum value of -2.17° and -0.32° respectively (Figure 7(c) and Figure 7 (d)). The negative camber will help to compensate for the effect when cornering where the car will start rolling and induce the positive camber. This setting is good for the racing car (Balena et al. 2021). Besides, the negative camber also creates camber thrust that will improve straight stability of the car. However, the value of negative camber should be taken into consideration as excessive negative camber will cause tire wear in the inner side . The graph for caster change to the wheel movement also shows a similar trend and increased in positive value when subjected to wheel bound for both front and rear suspension systems with a maximum value of 2.25° and 0.36° respectively (Figure 7(e) and Figure 7 (f)). The setting of positive caster gave several advantages since it can improve high speed stability and cornering, increase tyre lean during cornering, thus increasing the negative camber when the steering angle is increased.

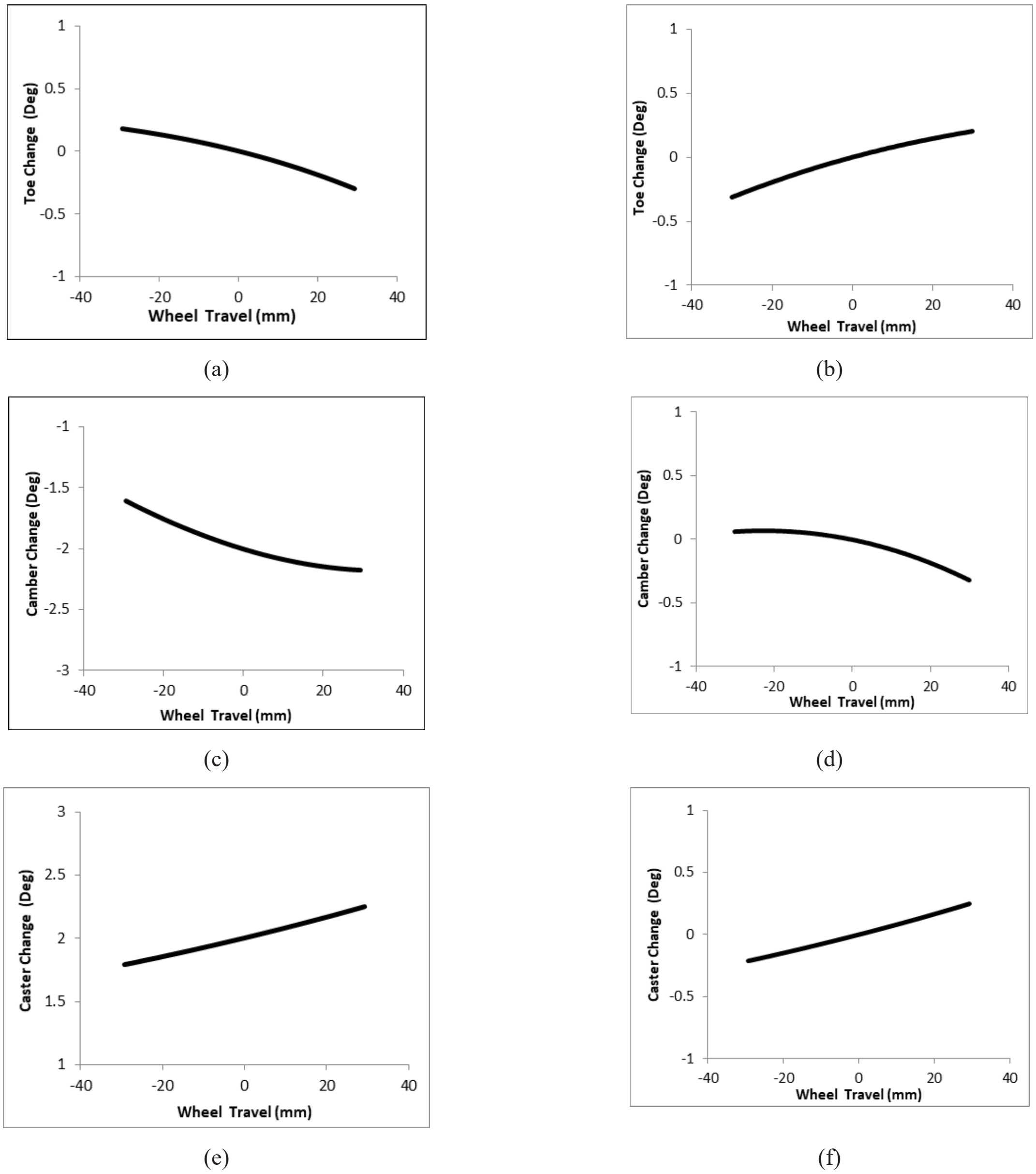

FIGURE 7. The simulation results of the suspension system when subjected to the vertical parallel wheel movement test using virtual suspension test rig on MSC/ADAMS CAR for (a) Front toe change, (b) Front toe change, (c) Front camber change, (d) Rear camber change, (e) Front caster change, and (f) Rear caster change.

CONCLUSION

The virtual front and rear suspension systems have been modelled based on actual UiTM's Perodua Eco Challenge competition car named SOLO and simulated on vertical parallel wheel movement test using virtual suspension test rig on MSC/ADAMS Car. Data analysis revealed that the values of toe, camber and caster change to the wheel travel were within the expected range. It also found, toe change has different kinematic value between front and rear suspension when subjected to the test, while the camber and caster change remain same, resulted overall good stability of the car. The use of multibody dynamic software give an advantage to the researcher to conduct quick simulations within a minimum manpower and overall cost. Future work aims to verify the virtual suspension model with the actual experimental testing so that it can be used to study the dynamic performance and suspension improvement of the Solo's car virtually.

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DECLARATION OF COMPETING INTEREST

None.

REFERENCES

Amni Inani. 2012. Design and analysis of a suspension system for Formula SAE 2012 car. Thesis submitted to Faculty of Mechanical Engineering, Universiti Teknologi MARA, Malaysia, 2012.

Balena, M., Mantriota, G. and Reina, G. 2021. Dynamic handling characterization and set-up optimization for a formula SAE race car via multi-body simulation. *Machines* 9:126.

Ikhsan, N., Ramli, R. and Alias, A. 2015. Analysis of the kinematics and compliance of a passive suspension system using adams car. *Journal of Mechanical Engineering and Sciences* 8:1293-1301.

Liang, J. H. and Xin, L. L. 2012. ADAMS-based double wishbone suspension motion simulation and optimization. *Applied Mechanics and Materials* 128:34-37.

Mohamed, N. A. N., Nor, M. J. M. and Mukhlis, R. Z. 2005. Compromising vehicle handling and passenger ride comfort using ER-damper. *Mechanics* 54:50-54.

Mraz, B. 2021. Development of the software for a Formula Student vehicle suspension optimal hardpoints positions determination. University of Zagreb. Faculty of Mechanical Engineering and Naval Architecture.

Ni, J., Chen, S. and Wu, Z. 2013. The Suspension Optimization of FSAE Racing Car Based on Virtual Prototyping Technology. Proceedings of the FISITA 2012 World Automotive Congress: Volume 8: Vehicle Design and Testing (II): Springer. p 1481-1490.

Ning, X., Zhao, C. and Shen, J. 2011. Dynamic analysis of car suspension using ADAMS/car for development of a software interface for optimization. *Procedia Engineering* 16:333-341.

Ravichandra, P., Khodke, M. and Chavan, D. 2020. The Kinematics And Compliance Test On A Suspension System Using Adams Car.

Tian, G., Zhang, Y., Liu, J. H. and Shao, X. J. 2014. Double wishbone independent suspension parameter optimization and simulation. *Applied Mechanics and Materials* 574:109-113.

Xiu-qin, Z., Bo, Y., Chao, Y. and Guan-neng, X. 2012. Research on ABS of multi-axle truck based on ADAMS/Car and Matlab/Simulink. *Procedia Engineering* 37:120-124.