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An Experimental Study on Wheel Alignment and Shock Absorber Conditions for Fuel Performance Analysis of a Light Vehicle

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ABSTRACT
In this study, an EHCO PLUS- 2ZZ-GE-02 model light vehicle was used to analyze the fuel performance with the consideration of the effect of wheel alignment and shock absorber conditions. In the experimental setup, a computerized machine vision-based wheel alignment measuring system was used to detect the misalignment of the wheels and the fuel performance of the vehicle measured before and after wheel alignment. The analysis results reveal that fuel consumption depends on wheel alignment. Also, the wheel alignment has been greatly affected by shock absorber conditions. Through the experimental process, it is found that wheel misalignment under inflation pressure in the tire and improper shock absorber condition resulted in increasing the fuel consumption rate. However, the fuel consumption rate of the vehicle has significantly improved by adjusting the alignment of wheels.

Keywords: Wheel alignment, Computerized machine vision, Fuel consumption, Shock absorber, Light vehicle.

1. INTRODUCTION

The vehicle's active safety system function is an important aspect of stability and traveling of the vehicle. Recently, researchers show that vehicle stability and traveling safety are decreased with the increment of an automobile traveling speed. Many researchers have investigated that most of the road accidents may occur due to wheel misalignment and malfunctioning of the steering system [1,2]. However, researchers [1-3] have focused on tire wear-reducing to increase fuel performance and tire life of the vehicle, but it is possible when proper wheel alignment is maintained. Nowadays, IR sensors are used for easy data measuring of the vehicle wheel alignment. In [4-6], the researchers presented an alignment process and advantages of the existing system such as low cost, simple electronic circuit, high resolution with working reliability, and precision measuring and adjustment of an active safety system that functions for heavy and light vehicles. The researchers have studied a computerized machine vision process, and it can be used to easy data transferring process, which is better than the traditional method for finding the wheel alignment characteristics angles [2-5]. J. S. Young *et. al.* [7] presented a comprehensive example that shows the different characteristics angles by proper adjusting technique, which can greatly increase fuel performance, tire longevity and driving satisfaction. Thus, the researcher's analysis result shows that the tire rolling resistance is directly related to the fuel performance, and tire pressure and also found that the proper tire pressure and good materials can greatly improve the tire life and fuel performance [8,9]. Furthermore, some researchers in [10,11] discussed the suspension system which is an important issue for uneven and bumping road relating to wheel alignment functions. They also explained the vehicle optimum performance based on the suspension factors such as roll moment, understeer and oversteer, etc. O. Ikechukwa *et. al.* [12] analyzed the tie rod function and tire wear conditions and found that the tie rod function is an important issue for wheel misalignment and driving stability. Consequently, the researcher A. A.Vadhe [13] suggested that the proper suspension components can greatly improve vehicle stability and fuel performance considering the cornering acceleration and bumping condition factors. In the present study, a computerized machine vision-based wheel alignment measuring system was used to investigate the causes of wheel misalignment of the light vehicle based on shock absorber conditions. The fuel consumption of the vehicle was then analyzed before and after wheel alignment.

2. EXPERIMENTAL DESIGN

2.1 Wheel alignment process

Wheel characteristic angles are related to wheel alignment and it is perpendicular to the ground and parallel to each other. The wheel alignment functions such as caster, camber, toe-in, and toe- out, kingpin inclination are related to the steering system. The wheel alignment process is experimentally analyzed and checked manually for all wheel alignment related parts. Then, the vehicle is aligned by using a computerized wheel alignment machine. Figure 1 shows the experimental setup for the wheel alignment system [14]. In this experiment, an algorithm process is used to obtain the wheel angles through a computer machine vision system that utilizes the images captured by a video camera as shown in Fig. 2 and some measured data are presented in Table 1.

The sensors connecting boards have to be mounted on the wheels before applying the system as the vehicle wheels are balanced on the platform. The vehicle is then lifted park on alignment bay and set on turning table

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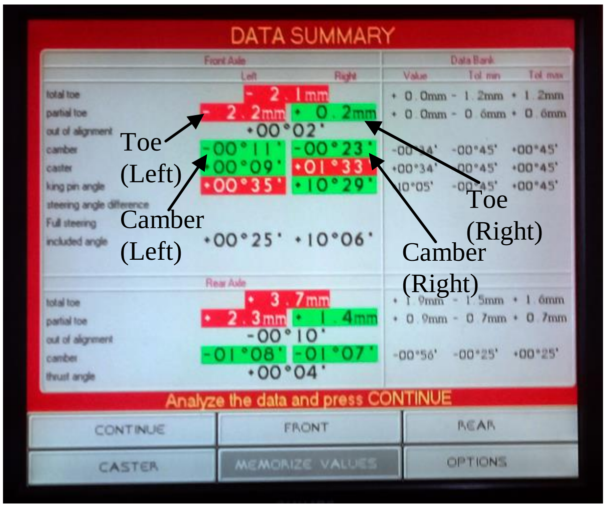
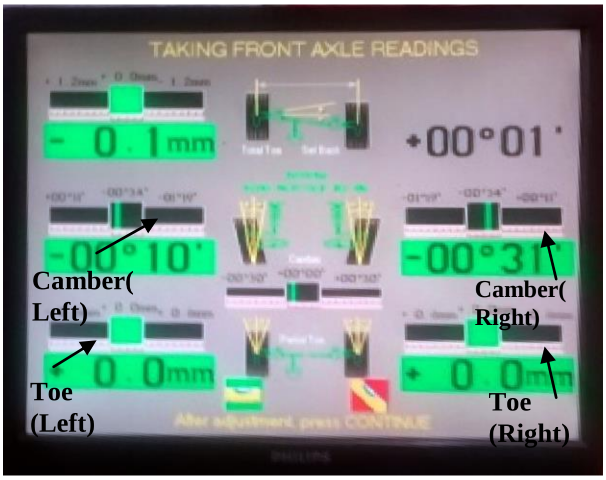
firstly. The four sensors are mounted on four wheels disk on the front and rear axle. The vehicle is lifted with the help of an air pressure jack.

Fig. 1: Experimental setup for wheel alignment system [14]



a) Before wheel alignment



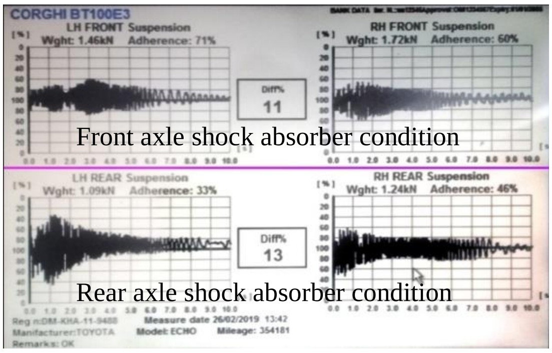
b) After wheel alignment

Fig. 2: Display before wheel alignment and after wheel alignment.

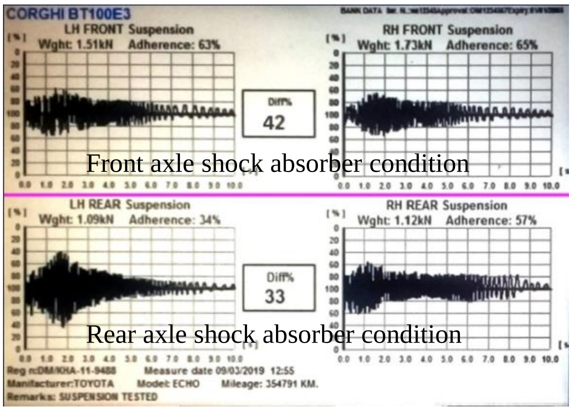
The commercial computer software for wheel alignment system is now used to measure the caster angles and these angles were adjusted by an open-end wrench and memorized with the logging steering wheel. Then the camber angles are adjusted by losing and tightening of the tie rod and push rod function with the steering system. Similarly, toe-in and toe-out are adjusted. Then the data was stored in the memory drive for each step of measurement.

2.2 Fuel performance

In the present study, an ECHO PLUS-2ZZ-GE-02 model vehicle was considered to analyze the effect of the wheel alignment system, and shock absorber condition on fuel performance. The vehicle has been tested under two different speeds 40 km/hr and 60 km/hr and after each test; the wheel alignment data and fuel consumption rate were recorded as shown in Table 2. The fuel consumption rate was determined after the running distance of 10 km. Thus, the shock absorbers divided into three types such as Type – 1, Type – 2 and Type - 3 were considered on fuel consumption analysis as shown in Table 2. Here, the three types of shock absorber meant by Type – 1 (Fully new shock absorber), Type – 2 (Working load capacity approximately 50%) and Type-3 (Working loading capacity 10%) respectively. Fig. 3 (a) shows that the front axle shock absorber condition difference 11% and rear axle shock absorber condition difference 13% which is considered before adjusted alignment and it is indicated bad (type - 3) shock absorber condition. Then, Fig.3 (b) shows that the front axle shock absorber condition difference 42 % and rear axle shock absorber condition difference 33% , that is considered after adjusted alignment and it is indicated medium (Type - 2) Shock absorber condition.



a) Before adjusted wheel alignment



b) After adjusted wheel alignment

Fig. 3: Display before and after alignment for shock absorber

3. RESULTS

Vehicle wheel misalignment may occur due to several causes. However, the vehicle running distance is one of the factors that have been considered to analyze the wheel misalignment at Rahimafrooz auto center [14]. The experimental data analysis at Rahimafrooz auto center found that the light vehicle wheels became misaligned when the running distance range was approximately 4000km to 5000km for smooth road condition [14]. The analysis results also suggest that the fuel consumption rate was significantly increased with wheel misalignment.

Table 1: Alignment display ECHO PLUS-2ZZ-GE-02, 1300cc light vehicle.

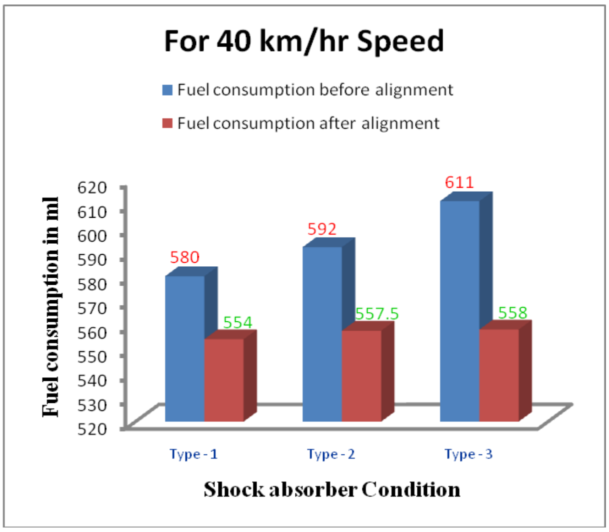
Condition	Position	Toe	Camber
Before alignment	L	-2.2mm	-00°11´
	R	+0.2mm	-00°23´
After alignment	L	+0.0mm	-00°10´
	R	+0.0mm	-00°31´

* L = Left; R = Right

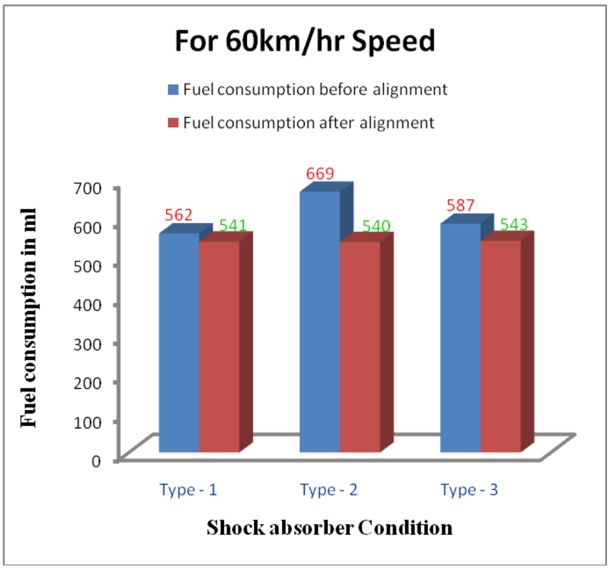
Table 2: Test result for ECHO PLUS-2ZZ-GE-02, 1300cc light vehicle (For shock absorber condition):

Vehicle parameters	Shock absorber (Type - 1)		% of fuel loss for misalignment	Shock absorber (Type - 2)		% of fuel loss for misalignment	Shock absorber (Type - 3)		% of fuel loss for misalignment
For distance 10km at speed 40km/hr and tire size-175/65R14, Fuel consumption rate	BA	AA	4.69 %	BA	AA	6.18 %	BA	AA	8.72 %
	580 ml	554 ml		592 ml	557.5ml		611 ml	562 ml	
For distance 10km at speed 60km/hr and tire size-175/65R14, Fuel consumption rate	BA	AA	3.88 %	BA	AA	4.21 %	BA	AA	6.14 %
	562 ml	541 ml		569 ml	546 ml		587 ml	553 ml	

Note: Before alignment =BA, After alignment= AA



a) Before and after alignment at speed 40 km/hr



b) Before and after alignment at speed 60 km/hr

Fig. 4: Shock absorber condition for fuel consumption.

The fuel consumption rate with the fixed vehicle model as the function of shock absorber conditions are presented in Table 2 and graphically in Fig. 4. In Fig. 4, it is shown that the fuel consumption rates as a function of shock absorber condition when the vehicle speed is 40km/hr and 60 km/hr, respectively. It is found that the fuel consumption rate is much higher when the shock absorber became bad condition (Working load capacity of approximately 10%). It should be noted that the vehicle wheels misalignment is directly related to the suspension system. Bad (Type - 3) shock absorber could increase the chance of wheels misalignment and hence increase the fuel consumption rate. Again, the analysis results suggest that fuel consumption has been significantly improved by adjusting the alignment of wheels for different conditions of the shock absorber. In Fig. 4(a), it is found that the light vehicle loses fuel efficiency by 4.69% (Type – 1 shock absorber), 6.18% (Type – 2 shock absorber), and 8.72% (Type - 3 shock absorber), respectively. In the case of increasing vehicle speed 60 km/hr, in Fig. 4 (b) shows the fuel efficiency of the light vehicle has deteriorated by 3.88% (Type - 1 shock absorber), 4.21% (Type - 2 shock absorber) and 6.14% (Type - 3 shock absorber), respectively.

4. CONCLUSIONS

The aim of the present study was to analyze the effect of the speed limit, and shock absorber conditions on the fuel consumption of the light vehicle with the effect of wheel alignment. Based on the analysis and experimental results obtained from the proper time wheel alignment adjusting system can be seen that a bad (Type - 3) shock absorber can increase the chance of wheels misalignment and hence increases the fuel consumption rate. However, the fuel consumption of the vehicle has significantly improved by adjusting the alignment of wheels. The results clearly show that fuel performance not only depends on one factor but also on multiple factors. Finally, it can be concluded that the manufacturer's standard alignment angles, good (Type - 1) shock absorber condition, and recommended speed limit can achieve better fuel performance, whereas unusual suspension components and speeds can greatly reduce the fuel performance. Also, the proper wheel alignment can improve the safety of the suspension system and reduces the tire wear and as a result, increases the mileage of the vehicle and provides driver satisfaction.

5. REFERENCES

[1] K. Patil and V. L. Kadlag, "Design of Wheel Alignment Measuring System using Infrared Transmissions", *International Journal of Technical Research and Applications,* e-ISSN: 2320-8163, Vol.4, Issue 5, pp 4-6. (2016).

[2] S. G. Barhe*et al*., "Measurement of Wheel Alignment using IR Sensor", *International of Journal of Engineering Technology, Management and Applied Sciences*, Vol. 4, ISSN 2349-4476 (2016).

[3] B. Krishnan. T *et al*., "Vehicle Integrated Wheel Alignment Alert System", *International Journal of Scientific & Engineering Research*, Vol.7, Issue 5, ISSN 2229-5518, (2016)

[4] S. Chatur, Computer based Wireless Automobile Wheel Alignment System using Accelerometer, *The International of Journal of Engineering and Science*, Vol. 4, pp 62-69 (2015).

[5] R. Furferi*et al*., "Design and Assessment of a Machine Vision System for Automatic Vehicle Alignment", *International Journal of Advanced Robotic Systems*, Vol. 10, pp 242 (2013).

[6] N. Salave and P. L. Sarode, "Experimental Study on Wheel Alignment of TATA Motors Heavy Commercial Vehicle", *International Journal of Latest Engineering Research and applications*, Vol. 2, pp 64-70 (2017).

[7] J. S. Young et al., "Camber Angle Inspection for Vehicle Wheel Alignments", *Sensor*, Vol. 17, pp 285 (2017).

[8] D. Rajasekar*et al*., "Rolling Resistance in Passenger Vehicle Tires", *International Journal of Mechanical Engineering and Technology (IJMET,* Volume 9, Issue 13, pp. 510–515 (2018).

[9] P. Kalita, "Study on Vehicle Computerized Wheel Alignment", *International Journal of Computer Engineering in Research Trends*, Vol. 3, pp 70-75 (2016).

[10] N. Deshmukh*et al*., "Design of Double Wishbone Suspension System of BAJA Vehicle", *International Journal of Advance Engineering Research Development,* Vol. 04, Issue12 (2017).

[11] Vegnesh B S *etal*., "Double Wishbone Suspension System : A Research, *International Journal of Recent Technology Engineering (IJRTE),* ISSN: 2277-3878, Vol. 08, Issue 2 (2019).

[12] O. Ikechukwu*et al*., "Investigation of a Vehicle Tie Rod Failure in Relation to the Force Acting on the Suspension System", *American Journal of Engineering Research (AJER),* e- ISSN: 2320-0847, Vol. 05, Issue 06 (2016).

[13] A. A.Vadhe, "Design and Optimization of Formula SAE Suspension System", *International Journal of Current Engineering and Technology (IJCET),* E-ISSN: 2277-4106, Vol. 08, no. 03, (2018).

[14] Experimental Setup of Wheel Alignment System of Light Vehicles at Rahimafrooz Auto Center, Chittagong, Bangladesh.