HARDWARE IN LOOP SIMULATION AND PERFORMANCE MEASURES OF A TWO WHEELER USING VIRTUAL VEHICLE SIMULATOR

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ABSTRACT

This paper discuss in detail about the performance measures such as suspension effectiveness, brake effectiveness, and wheel wobbling of two wheelers without human intervention. The vehicle performance simulator has been designed in a solid modeling package which cater multi variant of vehicles through adjustable wheel base, modular clamping and load system, and also by servo based cam/drum roller. Simulation studies were performed by controlled force application to front and rear suspension there by measuring the suspension and damping effectiveness of the vehicle. The drum roller was used to accelerate front and rear wheel to the desired speed and by applying brake at specific load, break effectiveness has been measured. The wobbling of the wheel was obtained with the aid of laser sensor embedded on the simulator. The proposed work aims at replacing the human efforts to improve the quality and productivity in the automobile sectors. In this work a virtual prototype vehicle simulator is presented to eliminate the error on the various performance measures of the two wheeler vehicle which helps in increasing the product life cycle management.

Keywords: two wheelers, testing suspension effectiveness, break effectiveness, wheel wobbling.

INTRODUCTION

In the past decades, tremendous efforts have been made to optimize the parameters of suspension system, breaking system, wheel system to improve the riders comfort. There are three suspensions systems namely passive, semi active and active suspension system available in the automobile sector. Each system has its own advantages and limitations for example passive suspension does not need any external power and it is simple. However, it can operate only at certain frequency range. This drawback can be overcome by an active suspension system where in the control of the system is complex and cost is high. To overcome the above limitations of passive and active system, semi active suspensions have proposed in the early 1970's. The structure of the semi active system is simpler to control and also less expensive [1]. The other system which needs an attention is breaking system to decelerate the vehicle effectively in a short span. During the early 19th century various attempts have been made to achieve multiple braking with a one point control. The traditional form of wheel tread brake consisting of a block of friction material which could be cast iron, wood or a composition material hung from a lever and being pressed against the wheel tread by applying pressure in the breaking system [2] and [3]. In order to ensure the vehicle stability, alignment of wheel and straightness of wheel control is necessary. The suspension [4], breaking [5] and wheel system [6] and [7] have been studied extensively by various researchers and dealing about various testing methods which logs data either manually or by mean of automatic system to measure vehicle performance [8-14].

Objective way of testing the effectiveness of suspension, breaking and wheel wobbling has been carried out in the literature. The subjective way of conducting various testing as a combination is still stand still. The subjective manner, the riders can check the comfort by performing research and analysis and also manufacturing in mass production environment. The dynamic response of two wheeler under various road conditions can be effectively monitored using micro controller based data logging system. However, the cost of such systems are high and also the many known factors such as riders action, environmental conditions and also road parameter will influence the riders comfort and they are difficult to control. The proposed work overcomes the above stated problems by with an aid of virtual vehicle simulator. The simulator will have all the functionalities which resemble the actual vehicle. This paper is organized as section 2 discuss about the conceptual modelling of vehicle performance simulator with four subsystems. Each subsystems will be tested in an objective manner has been extensively described in section 3. Hardware in the loop simulation results are carried and examined in section 4. The conclusion has been made at the end to show that riders comfort is improved with a help of vehicle performance simulator model.

CONCEPTUAL MODEL OF VEHICLE PERFORMANCE SIMULATOR

The conceptual model of vehicle performance simulator comprises of four sub systems as shown in Figure-1.

1. Vehicle clamping system
2. Front and rear suspension effectiveness measuring sub System
3. Front and rear break effectiveness measuring sub System
4. Front and rear wheel wobbling measuring sub system

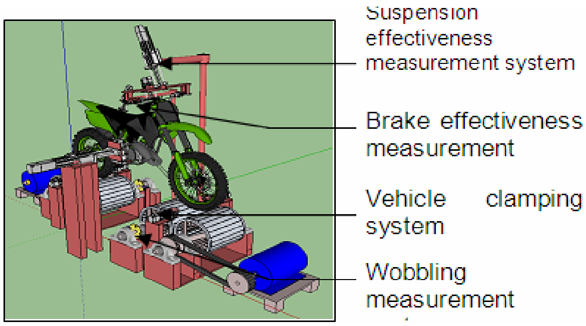

Figure-1. Vehicle performance simulator model.

In this vehicle performance simulator, power is given by the external actuator to transfer motion to two wheeler vehicle without cranking the engine. The proposed method overcomes the human difficulties compared to the existing methods at the time of testing which reduces the error in the analysis. Figure-2 and Figure-3 show the front and top view of vehicle performance simulator.

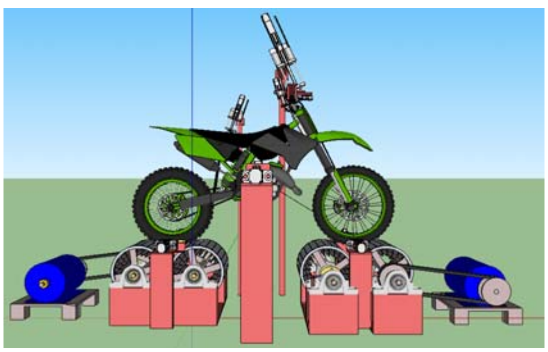

Figure-2. Front view of vehicle performance simulator.

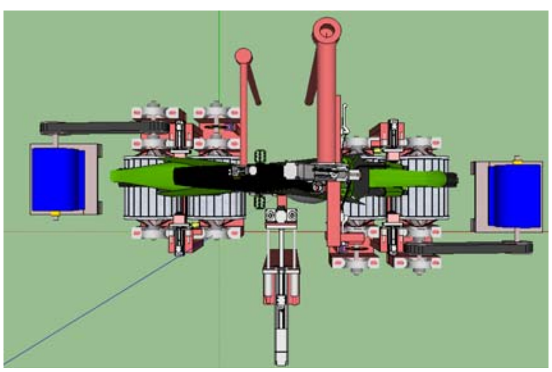

Figure-3. Top view of vehicle performance simulator.

Vehicle clamping system

For making stability during testing, special handle holder is provided at top and pneumatic cylinder with roller to support the rotating wheel is mounted at the bottom of the vehicle which is shown in Figure-4. The proposed system should have the capability to withstand high inertia forces for the speed of 15, 000rpm or more and also to hold 560kg of load or more.

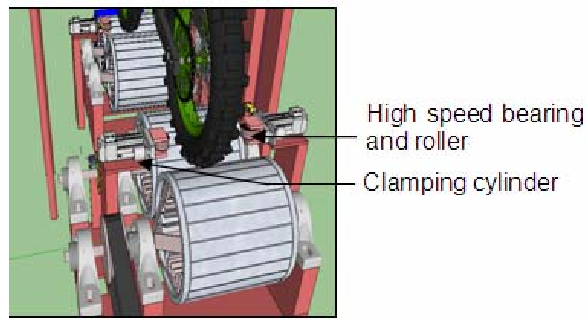

Figure-4. Vehicle clamping system.

Suspension performance measuring sub system

The conceptual model of suspension performance measuring subsystem consists of electro mechanical actuators, damper equipped with strain gauges and linear encoder [4]. The electro mechanical system is used to measure the analog data which will be converted into digital signal by means of Analog to Digital Converter (ADC). The digital signals will be sent to the computer via parallel port PCI 6221 or USB NI board. The data acquisition includes embedded specialized modules for mechanical measurement of certain sizes. The sampling frequency range of 0.1 to 9600 samples/second was used to perform the measurement and convert the signals for each channel. The typical data such as speed, force and linear displacement are measured. This device is used to apply the load through a pressure controlled servo based pneumatic cylinder to suspension. In order to avoid parallax error the cylinder is placed in collinear with suspension axis [15, 16, 17].

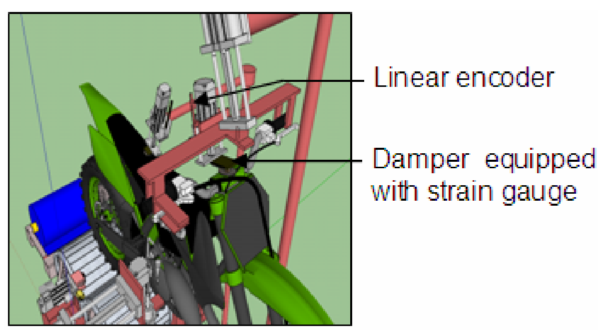

Figure-5. Front suspension test.

In this test a average human weight of 80kg is considered and the variable impact load is applied. The damper with strain gauge is mounted to measure the force experienced in the suspension system. The complete calibration has been carried out to avoid source of variation from the sensor. In order to obtain the extracted or reversible load on the suspension, a linear encoder is mounted at the side of pneumatic cylinder. The accuracy of the encoder can be selected as minimum as one micrometer. The above said measurements will be carried out for both rear and front suspension systems which are shown in Figure-5 and Figure-6.

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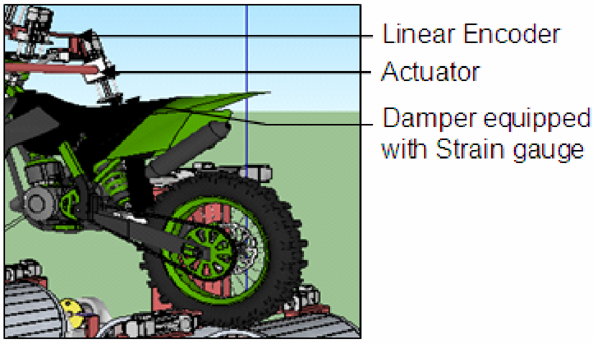

Figure-6. Rear suspension test.

Front and rear brake effectiveness measuring sub system

It consist of three major elements such as wheel actuator, break lever actuators, distance and speed encoding system.

The rotation of the vehicle is controlled with the help of Variable Frequency Drive (VFD) coupled to drive drum roller through time belt drive. The drive drum roller is supported with heavy high speed bearings with its housing. Diameter of the drum roller is calculated in relation with wheel diameter of the vehicle.

The speed of drum roller can be given as:

$$n_d = (2 \times \pi \times 60 \times n_m \times T_r) / 1000 \quad \text{kmph} \qquad (1)$$

The speed of vehicle wheel can be given as:

$$n_r = (2 \times \pi \times 60 \times n_m \times T_r) / (1000 \times I_d) \ \text{kmph} \qquad (2)$$

where

n_m = speed of AC induction motor in rpm
T_r = timer belt transmission ratio
r_d = drum roller diameter in meters
V_d = vehicle diameter in meter and
ratio of vehicle diameter to the drum roller diameter as $i_d = V_d / r_d$

The vehicle speed is controlled with the help of motor speed. The slip between the wheel and drum roller is negligible because the tyre is made up of rubber material. The wheel speed, braking force and measurement system are modular to perform the various tests as per the Motor rule - IS: 11716:1986. The measurements were carried as per the design test requirements and the brake tests were in-line with motor rules. In this measurement, both front and rear wheel of vehicle should have individual setup for wheel velocity and acceleration shown in Figure-7.

Break lever actuators

Pre calculated load has to be applied through pneumatic cylinder to actuate the break lever. According the type of vehicle the position of lever arrangement varies. Hence, pneumatic cylinder is placed in axis to achieve the lever actuation. The front and rear lever actuator structure is varied according to the type of the vehicle which is used to carry to out the test effectively.

Distance and speed encoding system

The vehicle speed and distance travelled is measured by means embedding a disc with holes sensor which gives four pulses per revolution which is shown in Figure-7. The system is interconnected to high speed counter to give the travelled distance and frequency to measure the speed.

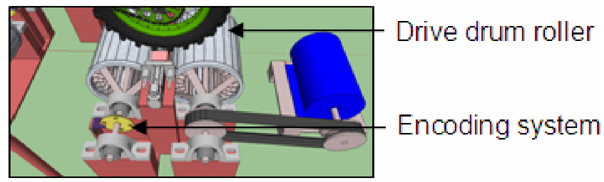

Figure-7. Distance and speed encoding.

Front and rear wheel wobbling measuring sub system

IR sensor will be used to measure the wheel wobble which is a direct distance measurement sensor as shown in Figure-8. The transmitter and receiver is embedded in a single unit to achieve fast measurement. The sampling frequency is varied between 0.1 to 9600 samples / second and range values of wobbling data are accounted for the measurement. This tolerance will be used to analyze the wobbling of the vehicle.

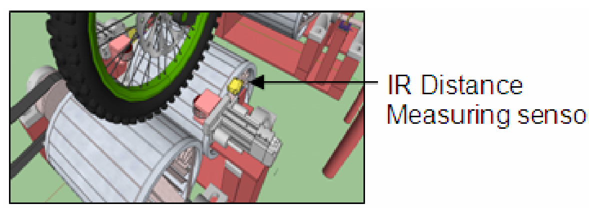

Figure-8. Wheel wobbling measurement.

Diverse testing of vehicle

Various vehicles testing namely suspension test, break test and wobbling test has been carried out using the designed vehicle performance simulator. The vehicle was clamped to achieve the proposed testing as shown in Figure-9.

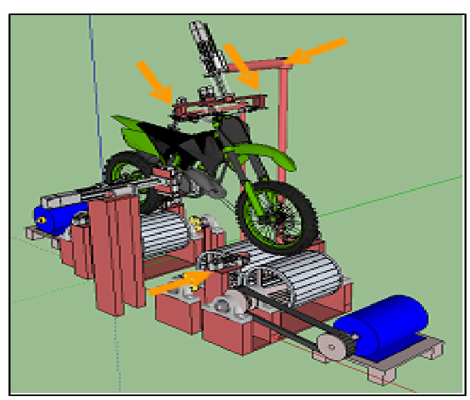

Figure-9. Clamping of vehicle.

Suspension test

Based upon the terrain condition of the road, different loading pattern was selected and corresponding load was transferred to suspension through piston and cylinder mechanism which is shown in Figure-10. The load and displacement was measured with the help of load cell and linear encoder setup mounted in the front and rear suspensions.

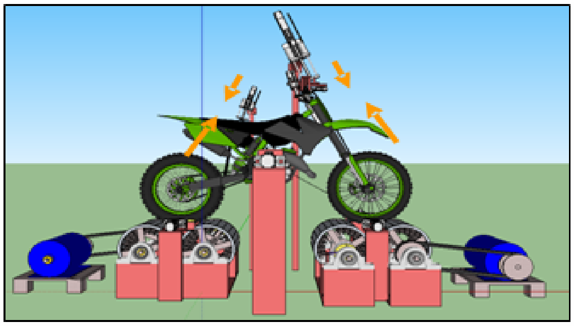

Figure-10. Load applied to suspension.

Break testing

In this test, vehicle was restricted to accelerate up to 40 kmph utilizing the drum roller and motor setup. When it reaches its maximum speed pneumatic cylinder applied pressure of 3.3 bar on the break pad through breaking setup. The speed as well as the breaking distance was measured using rotary encoder. The testing procedure was carried out for both front and rear wheels.

Wobbling test

In order to test the vehicle wobble, vehicle was ac celebrated to slow speed of 10kmph. Once it reaches the cut-off point, the embedded displacement sensor provided the maximum distance from the reference value of the wheel. The complete data acquisition system was used to measure the wobbling of front and rear wheels.

EFFECTIVENESS MEASUREMENT

Suspension effectiveness

In order to measure the effectiveness of the suspension with respect to design specification at vehicle level, different load pattern can be applied to the system.

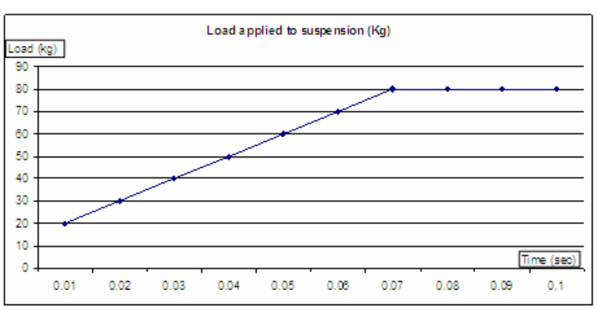

Figure-11. Time varying load to suspension.

In view of this, a rapid load of 80kg has been applied in a very short span through pressure controlled pneumatic cylinder as shown in Figure-12. In addition, a full dump and full rebound loads shown in Figure-13 are applied to measure the effectiveness of the suspension. This will act as a verification system at vehicle level with design specification and actual behaviour of vehicle.

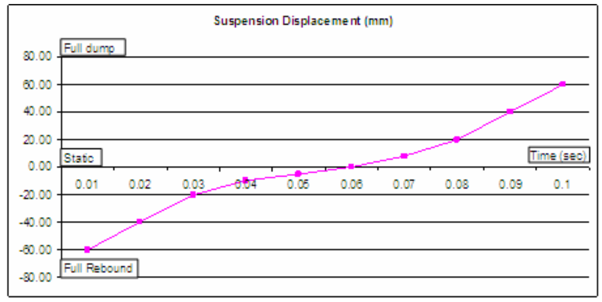

Figure-12. Suspension effectiveness.

BRAKE EFFECTIVENESS

Based upon the real time scenario, various breaking conditions such as sudden breaking, uncontrolled breaking, and controlled breaking are applied and brake effectiveness was measured.

Figure-13 shows that acceleration of vehicle from zero kmph to 40 kmph with the help of drum roller system and

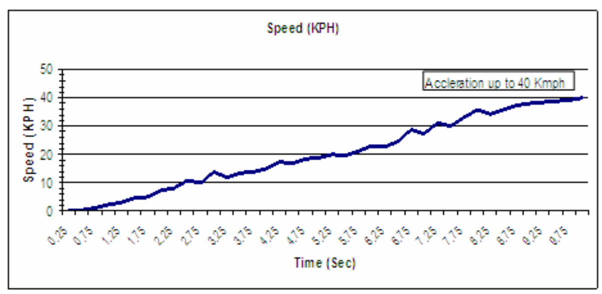

Figure-13. Vehicle acceleration curve.

braking was applied. The breaking pressure of 3.kgf/cm^2 was applied and Corresponding reduction in speed and stopping distance was measured which is shown in Figure-14.

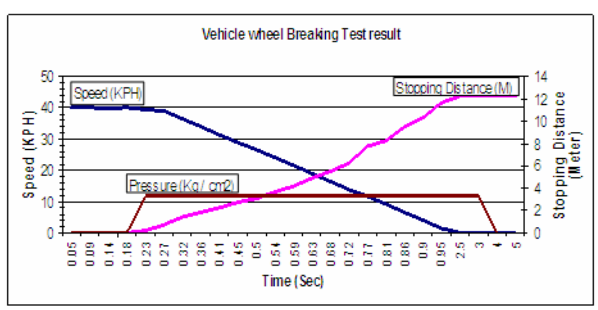

Figure-14. Brake effectiveness.

Wheel wobble

The vehicle has to maintain its stability without wobbling of wheel. The measurement of wheel flatness at its circumference provides the data of wobble is shown in Figure-15. In this case, vehicle was accelerated to 10kmph and maintained at the constant speed.

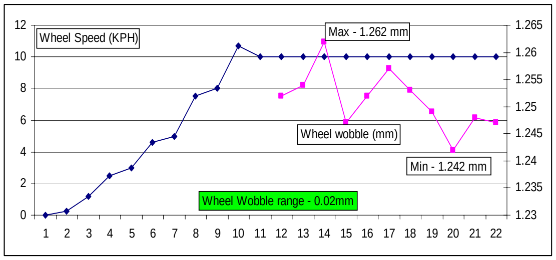

Figure-15. Wheel wobble at slow speed.

CONCLUSIONS

This paper addresses the measurement of suspension and brake effectiveness of the two wheeler system with an aid of vehicle performance simulator. In addition, wobbling test also carried out under various road conditions. The comprehensive hardware in loop simulation has been carried out to evaluate the performance of the vehicle without human intervention. Various tests in the normal speed conditions were carried out which provides great insight towards the characteristics of vehicle behavior in real time scenario. It is concluded that simulation studies will eliminate the error on the various performance measures of the two wheeler vehicle which helps in increase in productivity and in turn improves product life cycle.

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