International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 629-636 www.ijaem.net ISSN: 2395-5252

Performance Analysis of Electronically Controlled Braking System

Sylvester Emeka Abonyi[1], Christopher O Nwoye[2]
[1]*Department of Electrical Engineering Nnamdi Azikiwe University, Awka. Anambra State – NIGERIA*
[2]*Department of Industrial and Production Engineering, Nnamdi Azikiwe University Awka, Anambra State Nigeria*

Submitted: 05-01-2022 Revised: 17-01-2022 Accepted: 20-01-2022

ABSTRACT
Electronically Controlled Braking system is an automobile safety system that allows the wheels on a motor vehicle to maintain tractive contact with the road surface according to driver inputs while braking, preventing the wheels from locking up and avoiding uncontrolled skidding. Generally it offers improved vehicle control and decreases stopping distances on dry and slippery surfaces. It also modulates the brake line pressure independent of the pedal force, to bring the wheel speed back to the slip level range that is necessary for optimal braking performance.

I. INTRODUCTION

The development of electronically breaking system started in 1970's with the introduction of electronics for engine controls. Then in 1980's: Anti-lock braking was introduced for safe breaking of automobiles. In 1990's airbags become standard to reduce the number of deaths during accidents. In 2000's a rapid expansion of body electronics – seat motors (body Computers), instrument panel lighting, auto locking systems and keyless entry came into existence for comfort and safety. From 2005's to date infotainment, including sophisticated audio and video, Signals sent via satellite (such as the On Star System), GPS and mapping Capabilities, satellite radio, and Steer-by-wire, wireless connectivity are developed to make the automobiles more efficient.

The Electronic breaking system (EBS) in automobiles includes: anti-lock braking system (ABS), and traction control systems (TCS). In every automobile there are two usual force inputs to a motor vehicle: engine torque to provide acceleration (+ X acceleration) and brake friction to provide deceleration (- X acceleration). When an operator actuates the brake pedal, he or she is actually pushing on a lever that pushes a piston in a master cylinder to generate hydraulic pressure that is transmitted through the brake lines to the wheel actuators (either wheel cylinders or caliper pistons). The wheel actuators force a friction material (brake shoes or disk pads) against a rotating surface (brake drums or disk rotors) to generate a force that stops the vehicle. The energy to stop the vehicle is normally dissipated as heat in the drums or rotors. Thus, applying the brakes is really the act of dissipating the rolling energy of the vehicle as heat, hence slowing the vehicle down. EBS increases traffic safety through reduced stopping distance and improved brake stability [1]. This work analysis the anti-lock braking system (ABS),

II. ANTILOCK BRAKING SYSTEM (ABS)

Antilock braking system (ABS) prevents brakes from locking during braking. In normal braking situation the driver control the brakes, however during severs braking or on slippery roadways when driver the wheels to approach lockup, the antilock takes over here. The ABS modulates the brake line pressure independent of the pedal force to bring the wheel speed back to the slip level range that necessary to the optimal braking performance. The ABS does not allow full wheel lock under braking.

In simple terms, during emergency of braking, the wheel does not get locked even if you push a full auto brake pedal and hence the skidding does not take place. It allowed driver to control the car easier, even on roads with low adhesion, such a rain, snow and muddy road. The brain of antilock braking system consist Electronic Control Unit (ECU), wheel speed sensor and hydraulic modulator. ABS is a closed circuit hence it used the feedback control system that modulates the brake pressure in response to the wheel deceleration and wheel angular velocity to prevent the controlled wheel from locking.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 629-636 www.ijaem.net ISSN: 2395-5252

III. LITERATURE REVIEW

Many companies have developed and used anti-lock braking (ABS) and anti-slip acceleration control systems [2, 3]. A controller for vehicle motion should address safety and stability of the vehicle. As a part of highway automation, longitudinal and lateral guidance of the vehicle should be addressed. The input forces, which control the vehicle motion come from the road-tire interaction and have two components, one in the longitudinal direction and one in the lateral direction. The h-active force in the lateral direction depends on the cornering stiffness and can be controlled by the steering [4,5]. The tractive force in the longitudinal direction, on the other hand, is a nonlinear function of the wheel slip and can be controlled by maintaining the wheel slip at some required value. The throttle and the brakes ultimately control the longitudinal tractive force. Controlling the longitudinal traction can achieve various control objectives while assuring ride quality and passenger comfort.

The dynamics for the system are highly nonlinear and time varying, which motivates the use of sliding mode control strategy [6] to follow a target slip. Lyapunov stability theorem based [7, 8] and sliding mode based [9, 10, 11] controllers have been assessed by researchers. The sliding mode controller designed for vehicle traction control is made adaptive to reduce the control discontinuity around the switching surface of the sliding mode. Sliding mode based scheme is also used to estimate the road tire conditions for maximum acceleration and maximum deceleration.

[12] Has applied a predictive approach to design a non- linear model-based controller for the wheel slip. The integral feedback technique is also employed to increase the robustness of the designed controller. Therefore, the control law is developed by minimizing the difference between the predicted and desired responses of the wheel slip and it's integral.

[13] Proposed a static-state feedback control algorithm for ABS control. The robustness of the controller against model uncertainties such as tire longitudinal force and road adhesion coefficient has been guaranteed through the satisfaction of a set of linear matrix inequalities. Robustness of the controller against actuator time delays along with a method for tuning controller gains has been addressed. Further tuning strategies have been given through a general robustness analysis, where especially the design conflict imposed by noise rejection and actuator time delay has been addressed.

[14] Has developed a new continuous wheel slip ABS algorithm. Here ABS algorithm, rule-based control of wheel velocity is reduced to the minimum. Rear wheels cycles independently through pressure apply, hold, and dump modes, but the cycling is done by continuous feedback control. While cycling rear wheel speeds, the wheel peak slips that maximize tire-to-road friction are estimated. From the estimated peak slips, reference velocities of front wheels are calculated. The front wheels are controlled continuously to track the reference velocities. By the continuous tracking control of front wheels without cycling, braking performance is maximized.

IV. COMPONENTS OF ABS

The primary components of the ABS braking system are:

4.1 Electronic control unit (ECU)

i. It receives signals from the sensors in the circuit and controls the brake pressure at the road wheels according to the data analyzed by the Unit.
ii. ECU assists the vehicle operator to prevent wheel lockup by regulating the wheel slip.

4.2 Hydraulic control unit or modulator

i. It receives operating signals from the ECU to apply or release the brakes under ABS conditions.
ii. It executes the commands using three solenoid valves connected in series with the master cylinder and the brake circuits- one valve for each front wheel hydraulic circuit, and one for both of the rear wheels. Thus brakes can be actuated by controlling hydraulic pressure.

4.3 Power booster and master cylinder assembly

i. It is activated when the driver pushes down on the brake pedal. The master cylinder transforms the applied pedal force into hydraulic pressure which is transmitted simultaneously to all four wheels.
ii. It provides the power assistance required during braking.

4.4 Wheel sensor unit

i. Speed sensors are comprised of a magnet wrapped in a coil and a toothed sensor ring. An electrical field given off by the contact between the magnet and the toothed ring creates a AC voltage.
ii. The voltage frequency is directly proportional to the wheel's rotational speed.
iii. It monitors the rotational speed of the wheel and transmits this data to the ABS control module.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 629-636 www.ijaem.net ISSN: 2395-5252

V. MATHEMATICAL MODEL

The mathematical model for the antilock brake system was done taking into consideration the wheel slip, vehicle dynamics and wheel dynamics. Their simulink models were also developed which helped in the development of the system model, [15, 16].

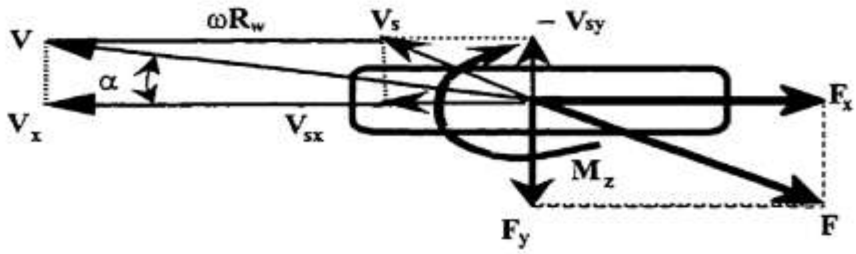

Fig. 1 Force and velocity components on tyre

5.1 Wheel slip

When the braking action is initiated, a slippage between the tire and the contacted road surface will occur, which make the speed of the vehicle to be different from that of the tire.

The longitudinal slip is defined as

$$S = \frac{V\cos\alpha - \omega RwV}{\cos\alpha}$$

The side slip angle is

$$\alpha = \tan^{-1}\frac{Vsy}{Vx}$$

5.2 Vehicle Dynamics

According to Newton's second law, the equation of motion of the simplified vehicle can be expressed by,

$$m_t\dot{V} = -F_t - F_a$$

The road friction force is given by Coulomb law

$$F_t = \mu N$$

The total mass of the quarter vehicle can be written as

$$m_t = m_{tire} + \frac{m_c}{4}$$

Thus, the total normal load cm be expressed by

$$N = mtg - Fl$$

Fl is the longitudinal weight transfer load due to braking

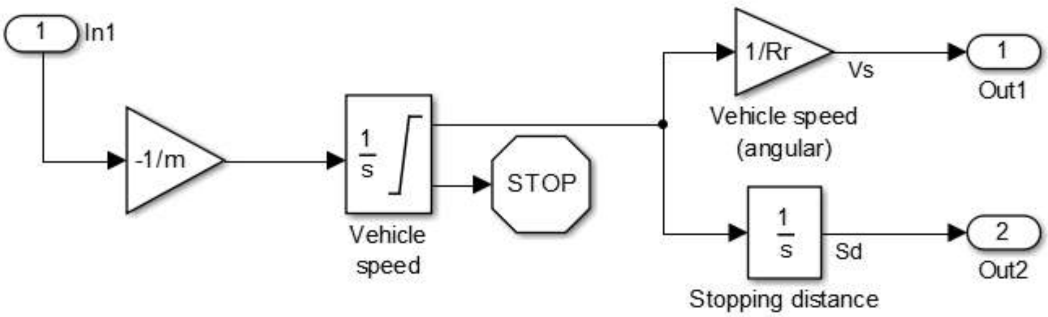

Fig. 2 Simulink model for vehicle dynamics

5.3 Wheel dynamics

According to Newton's second law, the equation of motion at wheel level for the rotational degree of freedom is given by,

$$Jw\omega = -T_b + F_t Rw$$

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 629-636 www.ijaem.net ISSN: 2395-5252

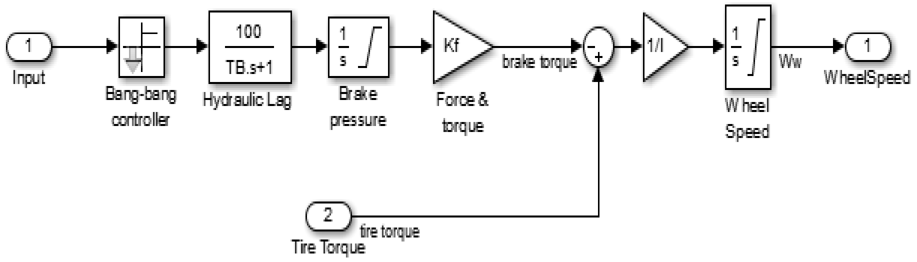

Fig.3 Simulink model for wheel dynamics

VI. SYSTEM MODEL

A single wheel antilock brake system is modeled using simulink considering the following inputs parameters.
Gravitational constant g = 3.86m/s^2
Initial velocity of vehicle v_0 = 10.53m/s^2
Wheel Radius R_r = 0.15m

Mass of vehicle m = 110kg
Maximum Braking Torque
$T_{bmax} = 3300\ f \times f_t$
Hydraulic Lag TB = 0.01 s
Moment of Inertia J_w = 5 ft^4

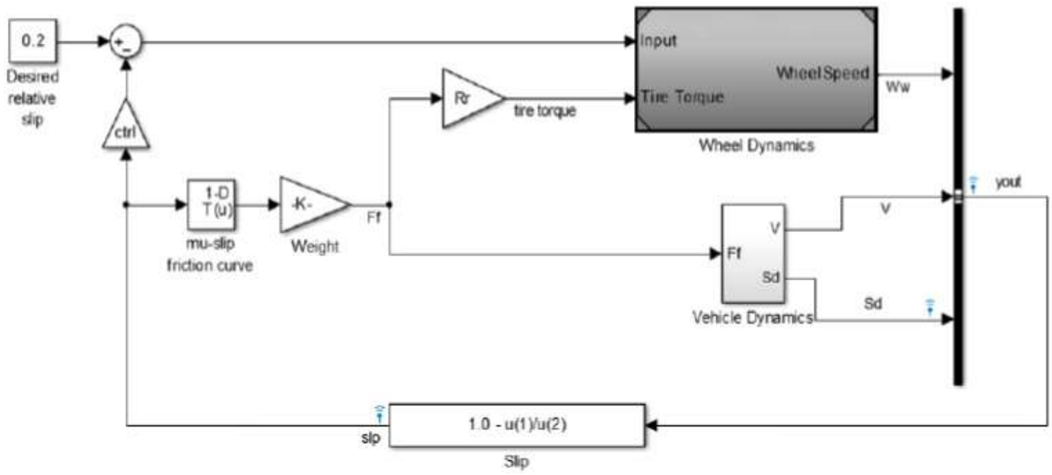

Fig. 4 modeling an anti-lock lock brake system (ABS)

Assumption: Only a linear model was considered and does not include actual road conditions. The system here is modeled only for straight line braking.

VII. RESULTS

Results were obtained from the Simulink for;

i. the vehicle speed and wheel speed without ABS
ii. slip without ABS
iii. Slip (with ABS)
iv. stopping distance (without ABS)
v. Stopping distance (with ABS)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 629-636 www.ijaem.net ISSN: 2395-5252

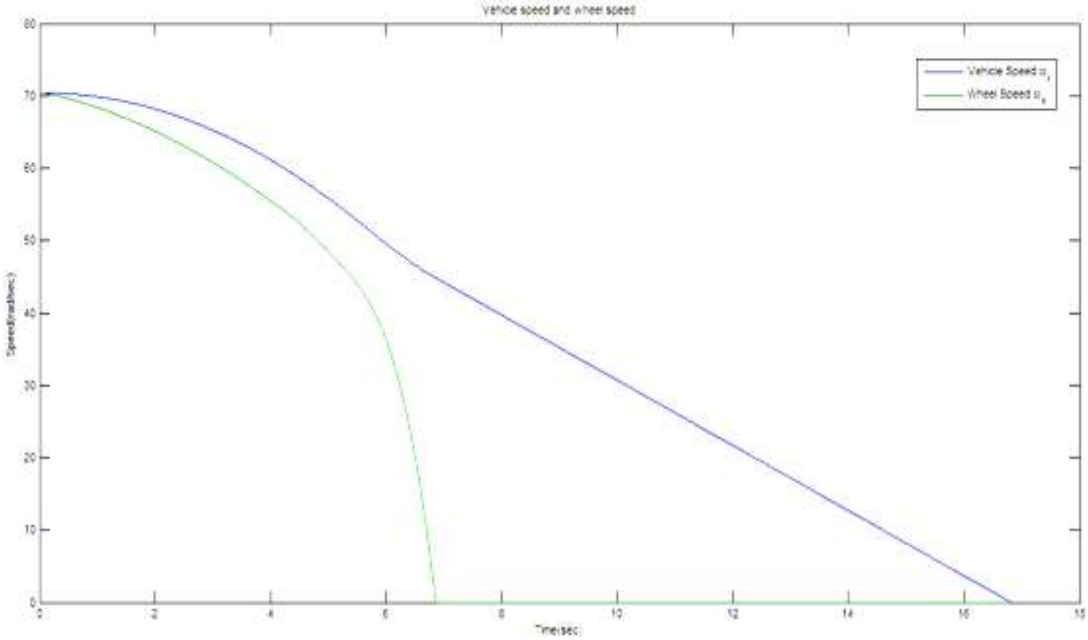

Fig.5 Vehicle speed and wheel speed (without ABS)

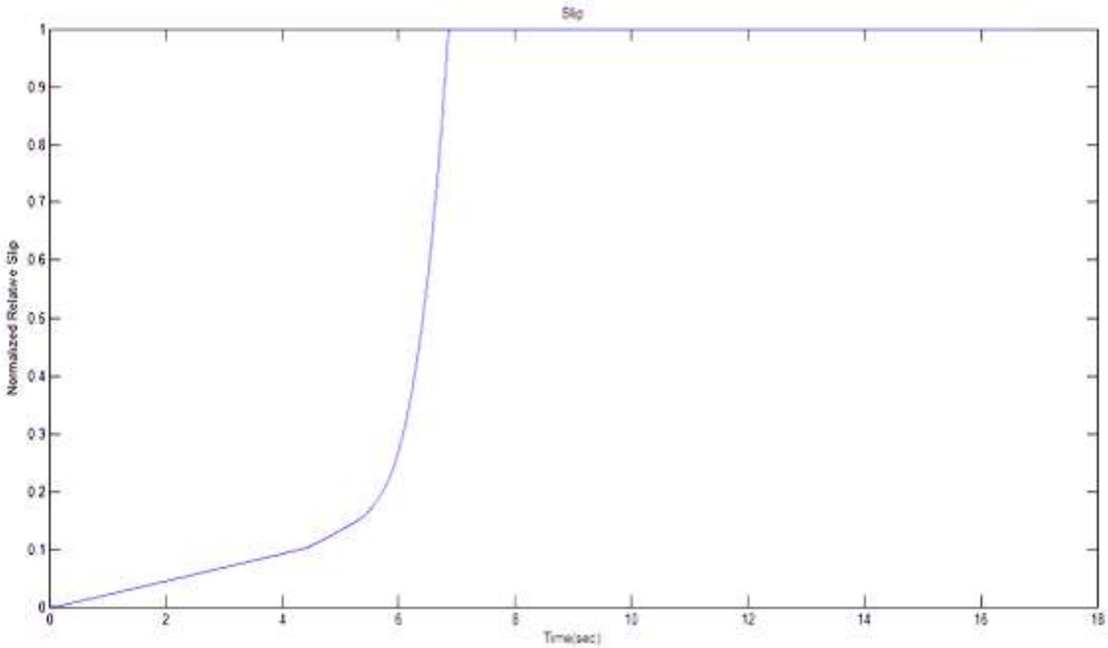

Fig.6 Slip (without ABS)

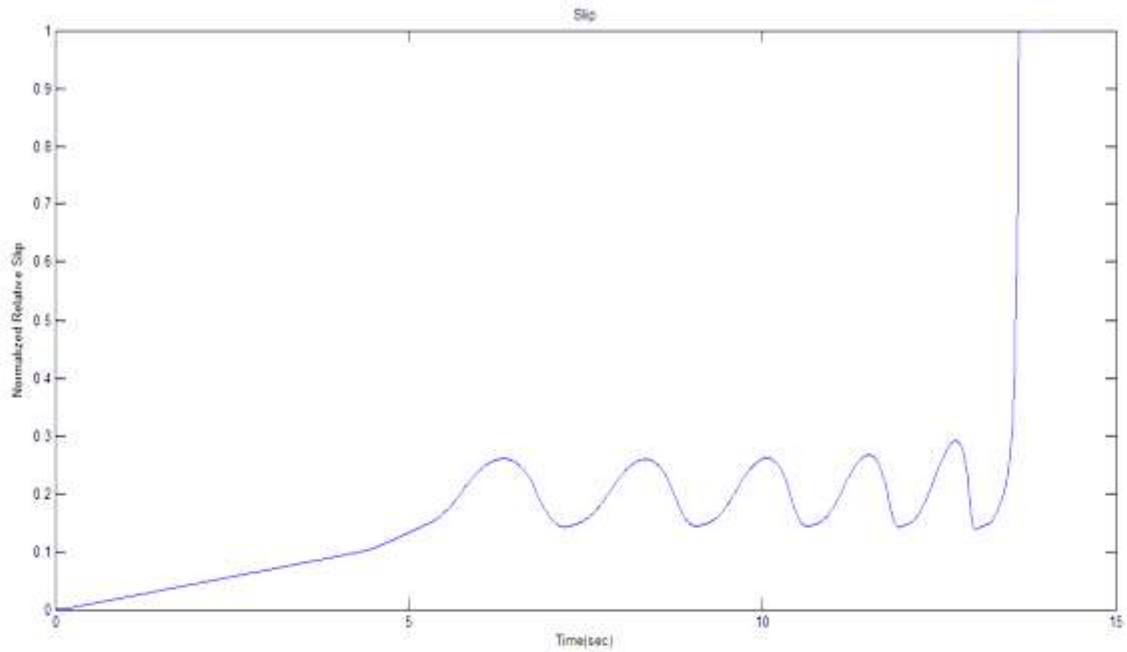

Fig.7 Slip (with ABS)

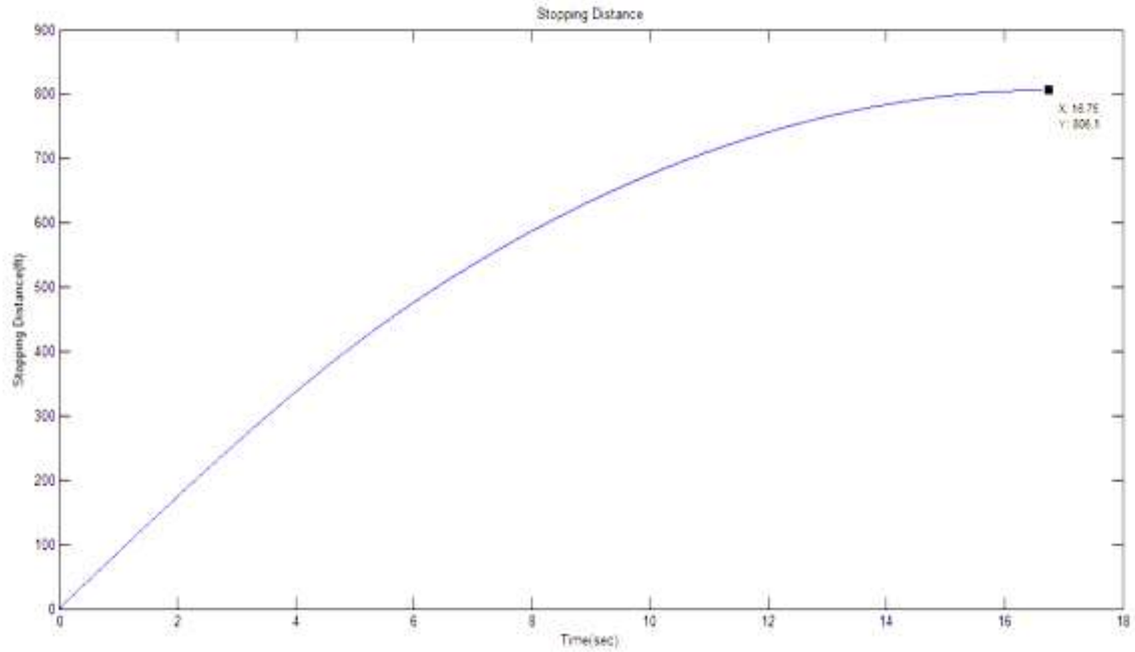

Fig.8 stopping distance (without ABS)

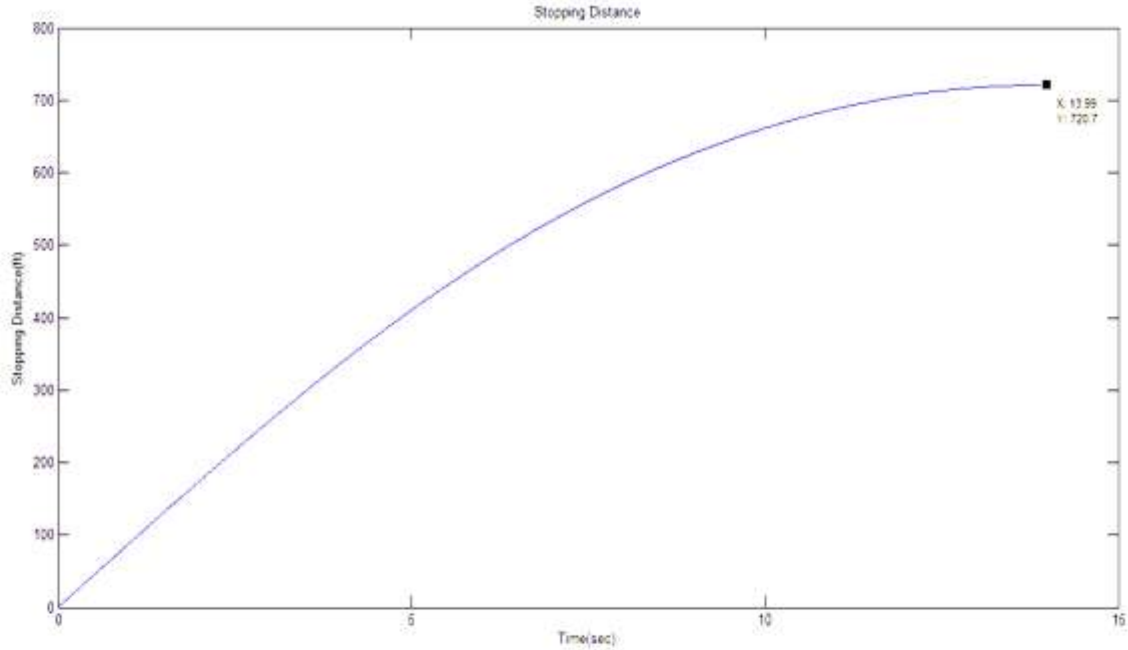

Fig.9 Stopping distance (with ABS)

VIII. CONCLUSION

From the performance analysis of a safety device (ABS), it is observed that ABS improves the braking performance. The stopping distance was has considerably reduced when ABS system was applied. The error in slip and desired slip is used to manipulate brake pressure in brake cylinder.

REFERENCE

[1]. A B Sharkawy (2010), “Genetic Fuzzy Self-tuning PID Controllers for Antilock Braking Systems” Engineering Applications of Artificial Intelligence, Vol. 23, pp. 1041-1052.

[2]. Leiber, H., and Czinczel, A. (1983), Four Years of Experience with 4-Wheel Antiskid Brake (ABS), SAE 830481.

[3]. Schurr, H., and Dittner, A. (1984), A New Anti-skid-Brake System for Disc and Drum Brakes, Braking: Recent Developments, SAE 840486.

[4]. Peng, H., and Tomizuka, M. (1990), Vehicle Lateral Control for Highway Automation, ACC Proceedings, San Diego., pp. 788-794.

[5]. Matsumoto, N., and Tomizuka, M.(1992), Vehicle Lateral Velocity and Yaw Rate Control with Two Independent Control Inputs, Trans. of the ASME , 114, pp.606-613.

[6]. Slotine, J.-J. E., and Li, Weiping, (1991). Applied Nonlinear Control, Prentice Hall, New Jersey,.

[7]. Taheri, S. (1990), A Feasibility Study of the Use of a New Nonlinear Control Law for Automobile Anti-lock Braking Systems, ACC Proceedings, vol. 2 of 3.

[8]. Taheri, S., A, and Law, E. H. (1990), Investigation of Integrated Slip Control Braking and Closed Loop Four Wheel Steering Systems for Automobiles during Combined Hard Braking and Severe Steering, ACC Proceedings.

[9]. Tan, H. S. (1988.), Adaptive and Robust Controls with Application to Vehicle Traction Control, PhD. Dissertation, University of California, Berkeley,

[10]. Tan, H. S., and Tomizuka, M., A Discrete-Time Robust Vehicle Traction Controller Design, ACC Proceedings, pp. 1053-1058, 1989.

[11]. Tan, H. S., and Tomizuka, M. (1990), An Adaptive Sliding Mode Vehicle Traction Controller Design, ACC Proceedings, vol. 2 of 3, pp. 1856-1861.

[12]. H Mirzaeinejad and M Mirzaei (2010), “A Novel Method for Non-linear Control of Wheel Slip in Anti-lock Braking Systems’, Control Engineering Practice, Vol. 18, pp. 918-926.

[13]. A Poursamad (2009), “Adaptive Feedback Linearization Control of Antilock Bracking System Using Neural Networks”, Mechatronics, Vol. 19, pp. 767-773.

[14]. David W Gilbert (2001), “Magneto-Resistive Wheel Speed Sensors”, “New

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1 Jan 2022, pp: 629-636 www.ijaem.net ISSN: 2395-5252

"Active" Wheel Speed Sensors Changing ABS Diagnostic Procedures", http:// www.asashop.org/autoinc/aug2001/ mech.cfm

[15]. Tianku Fu, (2000) "Modelling and performance analysis of ABS system with non-linear control",.

[16]. Tobias Eriksson, (2014) "Co-simulation of full vehicle model in Adams and anti-lock bake system model in Simulink",.