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SIMULATION OF MOTOR VEHICLE BRAKE PRESSURE MONITORING SYSTEM

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ABSTRACT

The braking system is a system that is always evolving to improve safety and security in driving so as to minimize the number of accidents. The braking system aims to reduce speed and stop the vehicle. This study uses a simulation on the MATLAB Simulink. The purpose of this research is to find out how the braking system works to improve safety for riders. The principle of the hydraulic braking system is to work according to Pascal's law where fluid is used to continue the braking force of the brake pedal being pressed towards the master cylinder to produce brake pressure. This research begins by making equations in hydraulic braking followed by making a Simulink block braking system. Based on the research, data on the comparison of the number of vehicle loads on the braking system and comparison data on the variation of road conditions on the braking system show that if the vehicle load is heavier, the time needed to stop is longer, the braking pressure is greater, and the distance needed to stop is greater. If the road adhesion coefficient is smaller, the time needed to stop is longer and the distance needed to stop is greater.

Keywords: braking system, vehicle loads, hydraulic braking.

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INTRODUCTION

The development of car technology to improve safety and security in driving is growing [1]. Security and safety are highly prioritized considering that every soul floats in vain just because they are not obedient and are not disciplined in driving, causing accidents. Factors that affect driving such as the situation and condition of the road terrain that the driver passes, the physical condition of the vehicle which includes the braking system and other parts of the system, and most importantly the driver.

The braking system has a very important role in vehicles [2]. A good braking system is needed for the operation on a vehicle so that vehicles travel safely and comfortably in any traffic conditions on the road [3]. Increased automation of the braking system includes safety system functions. The brake system that is made must be able to respond very quickly, control the right pressure, and have little fault tolerance [4].

The braking effect occurs because there is friction that arises from two objects, namely the tire and the road surface. In general, all vehicles have a braking system that causes friction so that the vehicle's speed decelerates. The braking system aims to slow the movement of the vehicle and reduce the speed of the vehicle until the vehicle stops. The master cylinder is a device that controls to change the mechanical force exerted from the brake pedal into hydraulic force [5].

The use of four-wheeled vehicles every year has always increased. The results of a survey conducted by the Central Bureau of Statistics with a source referring to the National Police Corps stated that the number of four-wheeled vehicle users in Indonesia consisting of passenger cars, buses, and freight cars reached more than 25 million people. According to the police accident data that occurred in Indonesia, on average 3 people per hour died due to traffic accidents. One of the causes of traffic accidents is due to the mass of excess loads that have an impact on the braking system.

To increase the safety and comfort factor in driving, the authors designed a simulation that is used to monitor the braking system of a moving vehicle. Therefore, this study aims to observe and analyze the factors that influence the hydraulic braking system through simulation and modeling using the MATLAB application so that the number of accidents in Indonesia can be reduced from the data obtained.

The most basic requirements of the brake system are the deceleration that occurs in a moving vehicle until the vehicle is in a stopped position, maintains speed during a hilly descent, and maintains stable conditions on a vehicle on an incline [6]. Retarding involves a change in the kinetic energy and potential energy of the vehicle into heat energy including braking balance, distribution of brake force, use of tire or road friction, braking when turning, the process of changing the pedal force, stopping distance, and brake wear [6]. The speed of the vehicle over hills is maintained by involving the conversion of potential energy into heat energy as well as considering the temperature of the brakes, vaporation of hydraulic brakes, and adjustments to air brakes [6]. Braking creates the opposite force on the movement of the wheels of the vehicle to reduce the speed of the vehicle to stop the vehicle. The force applied to stopping a vehicle or reducing its speed is known as braking force. The braking efficiency of a vehicle is defined as the braking force generated from the braking of the vehicle as a percentage of the total vehicle weight [7].

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The hydraulic system functions to move the brake lining into position against the drum or rotor and apply a force to the brake lining causing friction. In order for a hydraulic system to function properly, the system must be closed and fully filled with a liquid and the fluid does not leak like air is entering or leaving [8]. The principle of the hydraulic braking system is to work according to Pascal's law where the fluid in the system is used to continue the braking force of the brake pedal [9]. force on contact pressure [10]. The components of the hydraulic braking system include the master cylinder, brake liner, wheel brake cylinder and brake actuator [11]. Hydraulic brakes are capable of working at high pressures up to 180 bar [12]. The hydraulic pressure transducer has a range of 0 to 208 bar which is applied to each of the three braking lines which are used to measure the pressure in the front and rear hydraulics. The pipe on the rear hydraulic brake uses two pressure transducers on each side which are used to measure the output of the load-sensing proportional valve [13].

The components of the hydraulic braking system include the master cylinder which functions as a fast pressure process in each braking section, as a rapid pressure reduction so that the brakes are released quickly, and as a volume balancer in brake fluid during temperature changes when room distance increases due to brake pads wear. The master cylinder is operated only on the brake pedal via gain on braking. The brake lining is a friction material that uses force on the braking to produce sufficient friction on the brake disc or drum brake and then converts the kinetic energy obtained from the vehicle into heat energy. The wheel brake cylinder is the pressure obtained on the master cylinder which acts on the plunger and produces a force in the application. The brake actuator works when the vehicle is braking then the primary cup seal on the push-rod plunger moves through the balancing port and seals the pressure chamber [15].

The braking factor is the ratio between the total drum or rotor drag on the application of force to one shoe or pad on braking which can be formulated by equation 1

$$BF = \frac{F_d}{F_a} \quad (1)$$

where BF is the braking factor (brake factor) which has a comparison value of Fd or the force of the total drum or rotor drag which has Newon units and Fa is the application of force to the shoe or pad in Newton units [16]. For standard caliper disc brakes with two brake pads obtained from the pulling force on the incoming and outgoing sides of the rotor, the braking factor is:

$$BF = \frac{2F_d}{F_a} = \frac{2\mu_c F_a}{F_a} = 2\mu_c \quad (2)$$

where μ_c is the coefficient of friction on the brake pads or brake lining [10].

Normal load occurs during braking. During braking, there is a shift from the rear wheels to the front wheels. The displacement of the normal load from the center of gravity is related to the suspension which ensures the position of the car body during braking [14].

When a vehicle experiences braking, the instantaneous load that occurs on the wheels switches according to dynamic load shifting requiring braking effort on each wheel that is balanced with its normal load for optimal brake conditions. Measurement of the deviation in the direction of the suspension at different load conditions on each side of the rear wheel aims to calculate the dynamic load displacement on each wheel and analyze the work results of the brake system [17].

MATERIAL AND METHODS

The research procedure carried out in this study has several stages, namely a literature study on hydraulic braking, formulating a hydraulic braking system, creating a hydraulic braking simulation model in the MATLAB simulink, entering data on hydraulic braking simulation, simulating hydraulic braking in the MATLAB simulink, and data analysis. Literature study on hydraulic braking and understand more about research topics and problems related to this research.

Formulate the equations that will be used in a hydraulic braking system. The equation used in hydraulic braking systems is based on Pascal's law. The equation obtained from the pedal force is then continued to the equation for the master cylinder pressure after which it is forwarded to the disc brake force. The equation for the braking force is obtained from the adhesion coefficient of the road rubbing against car tires and the weight of the car. After that calculate the inertia on the car's wheels and calculate the brake torque.

Creating MATLAB coding from the equations that have been obtained and making block diagrams to model the hydraulic braking system using simulink contained in MATLAB. Enter the necessary data to simulate the hydraulic braking. The data used in the simulation is the empty mass of the Rush car, which is 1,220 kg, the maximum weight that the Rush car can carry is 400 kg, the diameter of the caliper piston is 0.02222 m, the radius of the wheel is 0.3429 m, the maximum speed allowed on the road barrier-free according to the transportation agency, which is 100 km / hour or 27,778 m / s. Simulate hydraulic braking in the MATLAB simulink so that data in the form of graphs and graphs are analyzed based on literature studies and the equations that have been obtained.

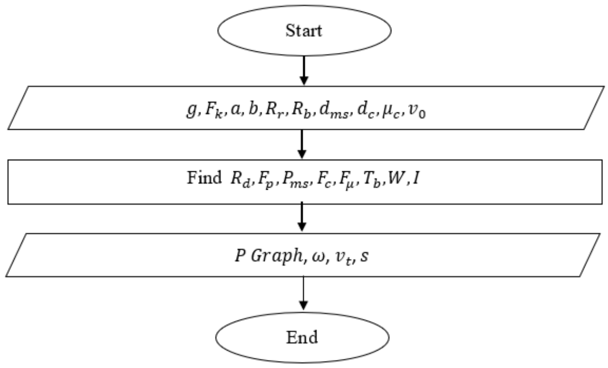

Figure-1. Block diagram brake system.

The braking system simulation is made in several steps. The first step is to enter data. Data is data that is already known which will then be used for the calculation process. Value is 9.8 m / s2, value is 50 N, value is 40 cm, value is 8 cm, value is 0.3429 m, value is 0.0127 m, value is 0.02222 m, value is 0.05715 m, the value is 0.3 m, and the value is 27.778 m / s. After that, proceed to look for the values in Figure 3.2. In this study, using input data in the form or compressive force from the foot of the driver to the pedal. This data is obtained from journals that discuss pedal equations.

RESULT AND DISCUSSIONS

Figures 2, 3, 4, and 5 are graphs of simulation results of braking with road variations on dry asphalt and dry concrete. The graph consists of a graph of braking pressure, a graph of vehicle speed, a graph of wheel speed, and a graph of braking distance. Figure-2 is the result of the graph with a car with no load, Figure-3 is the result of a graph with a light-loaded car, which is 200 kg, Figure 4 is the graph result with a car with a maximum load of 400 kg, and Figure-5 is the graph result with overloaded car i.e. load mass of 500 kg.

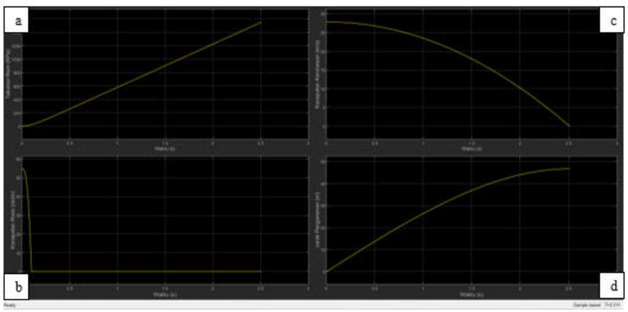

Figure-2. Graph of unloaded braking results with variations of roads on dry asphalt and dry concrete (a) Graph of braking pressure, (b) Graph of wheel speed, (c) Graph of vehicle speed, (d) Graph of braking distance.

Figure-2 shows that the car stopped at 2.510927833 s with the braking pressure reaching 1554.340735 KPa. The braking distance is 46.66648552 m. The time the wheel stops is 0.100545693 s so that the wheel stops at a distance of 2.79236501 m.

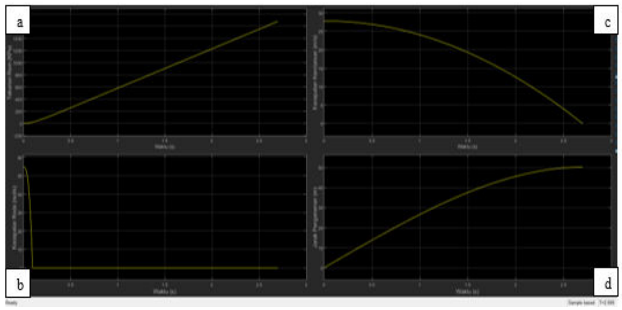

Figure-3. Graph of braking results with 200 kg load with variations of roads on dry asphalt and dry concrete (a) Graph of braking pressure, (b) Graph of wheel speed, (c) Graph of vehicle speed, (d) Graph of braking distance.

Figure-3 shows that the car stopped at 2,699473179 s with the braking pressure reaching 1675,897137 KPa. The braking distance is 50.15235537 m. When the wheel stops at 0.097401051 s so that the wheel stops at a distance of 2.705141323 m.

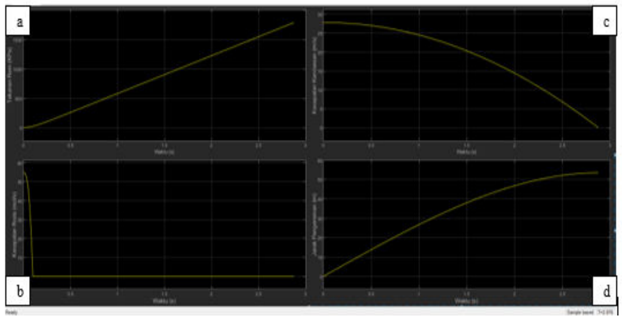

Figure-4. Graph of braking results with a maximum load of 400 kg with variations of roads on dry asphalt and dry concrete (a) Graph of braking pressure, (b) Graph of wheel speed, (c) Graph of vehicle speed, (d) Graph of braking distance.

Figure-4 shows that the car stopped at 2.876459897 s with the braking pressure reaching 1790.001616 KPa. The braking distance is 53.43350444 m. When the wheel stops at 0.100512225 s so that the wheel stops at 2.791577844 m.

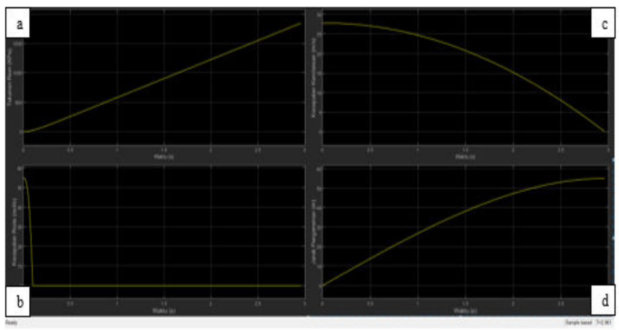

Figure-5. Graph of braking results with overload of 500 kg with variations of roads on dry asphalt and dry concrete (a) Graph of braking pressure, (b) Graph of wheel speed, (c) Graph of vehicle speed, (d) Graph of braking distance.

Figure-5 shows a stopped car 2,960787485 s with a braking pressure reaching 1844,368156 KPa. The braking distance reaches 54.99495963 m. When the wheels stop at 0.100505877 s so that the wheels stop at a distance of 2.79142706 m.

Table-1. The results of braking for road variations on dry asphalt and dry concrete.

No	Massa muatan (kg)	Tekanan rem (KPa)	Waktu roda berhenti (s)	Jarak roda berhenti (m)	Jarak pengereman (m)	Waktu berhenti (s)
1	0	1554,341	0,101	2,792	46,666	2,511
2	200	1675,897	0,097	2,705	50,152	2,699
3	400	1790,001	0,101	2,792	53,434	2,876
4	500	1844,368	0,101	2,791	54,995	2,961

The analysis of the results from the graphs in Figure-2, Figure-3, Figure-4, and Figure-5 are presented in Table-1. The table shows that load weight affects braking so that braking pressure, wheel speed, vehicle speed, and braking distance change with road conditions on the asphalt. dry and dry concrete. It can be concluded from the graph that the heavier the load on the car, the longer it takes to stop, the greater the pressure needed to brake, the farther the car is to stop, and the longer the wheel speed is to stop. This happens because the weight of the car's load affects the braking force so that the greater the load, the greater the time it takes for the car to stop which makes the braking distance farther, the pressure required during braking is greater, and the wheel speed to stop is also longer.

CONCLUSIONS

Based on the data obtained from the research, it can be concluded that a simulation of a hydraulic braking system using Simulink with Matlab programming has been made. The variation used in this research is road conditions. The smaller the road adhesion coefficient, the farther the braking distance and the greater the time required. The mass of the car's load affects the braking pressure and the length of time to stop the car. The greater the load mass, the greater the brake pressure required and the longer it will take to stop. The braking distance will be further away the greater the braking force.

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REFERENCES

[1] Carullo A. and Parvis M. 2001. An Ultrasonic Sensor for Distance Measurement in Automotive Application. IEEE Sensors Journal. 1(2): 143-147.

[2] Deepa A., Singh D. Y., Varma S. V. M., dan Khakhar, P. 2018. Analysis on Multi Linkage Brake System with Variable Pedal Ratio, Materials Today. Proceedings. Elsevier Ltd. 5: 13606-13611.

[3] Reif K., Brakes. 2014. Brake Control and Driver Assistance Systems Bosch Professional Automotive Information. Friedrichshafen: Springer.

[4] Liu C. 2008. Adhesion coefficient of automobile tire and road surface. J. Cent. South Univ. Technol. 15(1): 210-214.

[5] Heisler H. 2002. Advanced Vehicle Technology. Woburn: Butterworth-Heinemann.

[6] Limpert R. 1999. Brake Design and Safety Second Edition. Pennyslavia: Society of Automotive Engineers, Inc.

[7] Trivedi S. S. and Ulhe P. N. 2013. Analysis of Failure of Brakes due to Leakages of Cylinder through CFD. IOSR Journal of Mechanical and Civil Engineering. 8(1): 1-11.

[8] Puhn F. 1987. Brake Handbook. Tucson: HPBooks.

[9] Limpert R. 2011. Brake Design and Safety, Third Edition. Pennyslavia: Society of Automotive Engineers, Inc.

[10] Fischer R. dan Gscheidle R. 2006. Modern Automotive Technology, 1st English. Haan-Gruiten: Verlag Europa-Lehrmittel, 2006.

[11] Chen L., Zhang J., Li Y., Sun D. and Yuan Y. 2014. Hardware-in-the-loop simulation of pressure-difference-limiting modulation of the hydraulic brake for regenerative braking control of electric vehicles. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. 6(228): 649-662.

[12] Duifhuizen B. A. P. van and Hobo P. D. 2014. Modeling, Design and Control of an Individual Wheel Actuated Brake System. Eindhoven: Technische Universiteit Eindhoven.

[13] Albatlan S. A. A. 2012. Automotive brake pipes characteristics and their effects on brake performance. Ain Shams Engineering Journal, Faculty of Engineering, Ain Shams University. 3: 279-287.

[14] Delaigue P. and Eskandarian A. 2004. A comprehensive vehicle braking model for predictions

of stopping distances. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. 218(12): 1409-1417.

[15] Liu H., He R., Deng W., Yang S., Wu J. and Chen P. 2018. Research on a Novel Electro-Hydraulic Brake System and Pressure Control Strategy. SAE Technical Paper Series.

[16] Meng D., Zhang L. and Yu Z. 2006. A Dynamic Model for Brake Pedal Feel Analysis in Passenger Cars. J Automobile Engineering. 230(7): 955-968.

[17] Ehsani M., Gao Y., Gay, Sebastien E. and Emadi A. 2005. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles Fundamentals, Theory, and Design. Florida: CRC Press.