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ANALYSIS OF BRAKING SYSTEM ON ENERGY SAVING CARS "SAKERA", MECHANICAL ENGINEERING WORK, UM SURABAYA

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Abstract

A braking system in a vehicle has a very important role in maintaining the safety of drivers and passengers, and preventing accidents. The brake system functions to reduce speed (slow down) and stop the vehicle. A good braking system provides safety and comfort for the drivers. Therefore, it is necessary to design the right braking system for “Sakera” car. In this study, an analysis and calculation of the braking system was carried out to determine the required braking force at a speed of 50 km/hour and other speeds in a distance of 15 m. The data taken in this study was the specification of the braking system used in the Sakera car. The braking system analysis was carried out on flat roads with varying speeds, namely 30 km/h, 35 km/h, 40 km/h, 45 km/h, and 50 km/h with a distance of 15 m for braking. The conclusions of the analysis were obtained, namely the greater the speed of Sakera's car, the greater the braking force to stop the car, the hydraulic pressure on the hose, and the force of the driver's feet, as well as the braking force needed on road conditions with a slope angle of 20º, which is 839.362 N.

Keywords: *Car, Braking System, Braking Force, KMHE Sakera*.

1. INTRODUCTION

In the era of increasingly advanced technological development, the need for efficient energy is increasing, especially in the transportation sector. Energy-efficient cars are becoming the main choice to reduce dependence on fossil fuels that are increasingly scarce and expensive, as well as reduce exhaust emissions that can damage the environment. The car consists of several components, one of the important components is the brake.

The braking system on the vehicle has a very important role in maintaining the safety of the driver and passengers, and preventing accidents. The brake system serves to reduce speed (slow down) and stop the vehicle. A good braking system provides safety and driver comfort, therefore it is necessary to design the right braking system on the Sakera car.

Sakera car is an energy-efficient car created by mechanical engineering students of the University of Muhammadiyah Surabaya to take part in an energy-efficient car contest organized by the National Achievement Center (Puspresnas) of the Ministry of Education, Culture, Research and Technology (Kemdikbudristek) of the Republic of Indonesia. This car competes in the Urban Concept class, which means a car that resembles a car in general. In the energy-saving car contest, calculations are needed to determine the braking force required

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at a speed of 50 km/h with a distance of 15 m, which has never been analyzed before on Sakera car.

In the braking system of the Sakera car using disc brakes on each wheel hydraulically, the strength of the force on braking, as well as on the hose system must be taken into account. In this study, an analysis and calculation of the braking system will be carried out to determine the braking force needed at a speed of 50 km / h and other speeds with a distance of 15 m on the Sakera car.

2. MATERIALS AND METHODS

The steps in the study to solve the problem with the following stages:

The first stage of Identification, at the initial stage of identification, observations were made of the problems formulated as the objectives of the research. Literature studies include searching and studying literature reviews related to Braking Systems. This literature study is obtained from various sources. The second stage of Data Retrieval and Analysis, From the literature study and observation of the braking system, then data collection of brake specifications used by the Sakera car is carried out. After taking the necessary data, the calculation of the hydraulic braking system on the disc brake of the Sakera car is carried out to find the force required for braking. This stage is the end of the calculation and analysis of the hydraulic braking system on the disc brake of the Sakera car, namely by drawing conclusions obtained from the calculation results.

2.1. Sakera Car Specification Data

The Sakera car uses a hydraulic braking system with a single piston floating caliper, and 2 master cylinders are used for the braking system.

Figure 1. Sakera Car Size Dimensions

Spesifikasi mobil sakera sebagai berikut :

1. Vehicle length (p) : 2200 mm
2. Vehicle width (l) : 1300 mm
3. Vehicle height (t) : 1154 mm
4. Wheelbase : 1000 mm
5. Length of front axles : 1000 mm
6. Length of rear axles : 1000 mm
7. Vehicle weight (w) : 181,6 Kg
8. Driver weight : 55 Kg
9. Pedal to shaft distance (a) : 145 mm
10. Push-rod to shaft distance (b) : 40 mm
11. Master cylinder piston diameter : 14,4 mm
12. Caliper piston diameter : 33,8 mm
13. Disc brake diameter : 200 mm
14. Coefficient of friction brake lining (μ_K) : 0,4
15. Initial velocity (V_0) : 13.8 m/s
16. Rolling resistance coefficient : 0,015
17. Frontal area (A_F) : 0,931 m2
18. Density of air : 1,17 kg/m3

Here is the chassis and braking system of the sakera car:

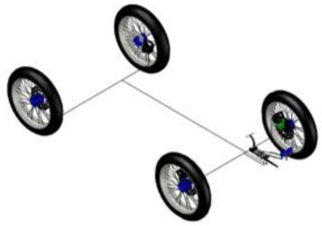

Figure 2. Sakera car braking system

Figure 3. Sakera car chassis

The following equation is used to obtain the results of the braking force of the sakera car:

2.2. Deceleration Calculation

To calculate the deceleration using the following equation [1] :

$$v_t^2 = v_0^2 - 2 \times a \times s \tag{1}$$

Where, s as total distance (m), v_0 initial velocity (m/s), v_t final velocity (m/s), and a deceleration (m/s^2).

2.3. Center of Gravity

Every object that has mass must have a center of gravity, as well as a vehicle. Before conducting thorough experiments and calculations, it is necessary to know about the position of the vehicle's center of gravity to facilitate calculations. Finding the COG position consists of several steps, which are as follows:

To calculate the L_f and L_r values of the vehicle, it is necessary to weigh the mass of the vehicle on the front wheels and rear wheels of the vehicle.

In this weighing, the value of W_f and W_r will be obtained, namely the weight distribution at the front and rear of the vehicle with the following formula [2]:

1. For front axle

$$L_f = \frac{W_r \times L}{W} \tag{2}$$

2. For rear axle

$$L_r = \frac{W_f \times L}{W} \tag{3}$$

Where, L_f as the distance from the COG to the front axle, Lr the distance from the COG to the rear axle, L the wheelbase, W_f the weight of the front vehicle, W_r the weight of the rear vehicle, and W the total weight of the vehicle.

Finding the value of h in determining CG requires weighing the vehicle on an incline condition. The results of the weighing are W_r and W_f. After that the value of h can be obtained by the equation where the pedestal used is the front wheel [3]:

$$h = r + hr$$

$$h = r + \left[b - L\left(\frac{W_r}{W}\right)\right]\cot\theta \tag{4}$$

Where, h as distance of COG from the ground (mm), r Wheel radius (mm), θ Angle of incline.

2.4. Rolling Resistance

Rolling resistance is always against the motion of the vehicle, therefore it helps the braking system. Defined as follows [4] :

$$F_g = \mu \times W \tag{5}$$

Where, F_g as rolling resistance (N), μ coefficient of rolling resistance, W vehicle weight (N), for the average value of the rolling resistance coefficient of passenger vehicles on asphalt road conditions is 0.08. [5]

2.5. Drag Force

Drag force is a resistance force exerted by air against all moving objects. [6]

$$F_D = \frac{1}{2} p v^2 C_d A_F \tag{6}$$

Where, F_D as drag force (N), p Air density (Kg/m^3), C_d drag coefficient, and A_F frontal area (m^2), for the aerodynamic drag coefficient on passenger cars is 0.3 - 0.6. [5]

2.6. Total Braking Force to Stop the Car

To calculate the total force required to stop the car using the following equation [7]:

$$F_b = m \times a - F_D - F_g \tag{7}$$

Where, F_b as braking force (N), F_D drag force (N), F_g rolling resistance force (N)

2.7. Braking Force On an Inclined Plane

To calculate the force required to stop the car on an inclined plane with is as follows [8]:

$$F_{b\theta} = m \times g \times (\sin\theta - \mu \times \cos\theta) \tag{8}$$

Where, m as the mass of the car (kg), g acceleration due to gravity (9,8 m/s^2), for the tire adhesion coefficient on asphalt and concrete road surfaces (dry), the highest adhesion coefficient μ_p is 0,85 and the lock wheel adhesion coefficient μs is 0,75. [9]

2.8. Braking Force Proportion

To calculate the proportion of braking force using the equation [10]:

Front brake force proportion

$$K_{bf} = \frac{W_F}{W} \tag{9}$$

Rear brake force proportion

$$K_{br} = \frac{W_R}{W} \tag{10}$$

Where, K_{bf} as the proportion of front brake force, K_{br} the proportion of rear brake force.

2.9. Braking Force on Wheels

To calculate the braking force on the front wheels and rear wheels using the equation [7]:

Braking force on the front wheels

$$F_{front} = K_{bf} \times F_b \quad (11)$$

Braking force on the rear wheels

$$F_{rear} = K_{br} \times F_b \quad (12)$$

Where, F_{front} as braking force on front wheels (N), and F_{rear} Braking force on the rear wheels (N)

2.10. Braking Force on Disc Brake

To calculate the braking force on the disc brake to stop the car, use the following formula [7]:

$$F_R \times r_R = F_P \times r_P \quad (13)$$

Where, F_P as braking force on brake disc (N), r_P disc brake radius (m), r_R wheel radius (m), and F_R Braking force on the wheel (N)

2.11. Force on Brake Pads

The friction force on the brake lining and disc that occurs depends on the coefficient of friction and the pressing force on the brake lining. Then calculate the pressing force of the brake lining as follows [11]:

$$F_P = F_K \times \mu_K \quad (14)$$

Where, F_K as the force on the brake lining (N), and μ_K coefficient of friction, for the coefficient of friction of asbestos blocks on metal material in the dry state which is 0.40 - 0.48 and allowable pressure of 0.28 - 1.1. [12]

2.12. Hydraulic Pressure

The compressive force produced by the brake lining comes from the brake fluid pressure in the Brake line which presses the caliper piston, so to find the hydraulic pressure is as follows [13]:

$$P_{brake\ line} = \frac{F_{master}}{A_{piston\ kaliper}} \quad (15)$$

Where, $P_{brake\ line}$ as hydraulic pressure (N/m^2), and $A_{piston\ kaliper}$ caliper piston area (m^2)

2.13. Force on Master Cylinder

Hydraulic pressure comes from the force applied to the master cylinder, so to find the force on the master cylinder is [14] :

$$F_{master} = P_{brake\ line} \times A_{piston\ master\ silinder} \quad (16)$$

Where, F_{master} force of the master cylinder (N), and $A_{piston\ master\ silinder}$ piston area of the master cylinder (m^2)

2.14. Pedal Force

The equation for finding the pedal force is [15]:

$$F_{master} = F_{pedal} \times \frac{a}{b} \quad (17)$$

Where, F_{pedal} pedal (kgf), a distance from pedal to fulcrum (mm), and b distance from pushrod to fulcrum (mm)

3. RESULTS

The following are the results of data processing calculations with varying speeds with a distance of 15 m:

Table 1. Forces obtained from varying speed with a distance of 15m

NO	RESULTS	VELOCITY (Km/h)				
		30	35	40	45	50
1	$a\ (m/s^2)$	-2,296	-3,136	-4,107	-5,208	-6,348
2	$t\ (s)$	3,614	3,093	2,702	2,400	2,174
3	$F_B\ (N)$	505,255	699,882	924,863	1179,97	1444,102
4	$F_{front}\ (N)$	261,217	384,935	542,895	743,381	968,992
5	$F_{rear}\ (N)$	244,038	314,945	381,968	436,59	470,777
6	$F_{Br}\ (N)$	130,608	192,467	271,447	371,69	486,663
7	$F_P\ (N)$	241,62	356,06	502,18	687,63	900,33
8	$F_K\ (N)$	604,125	890,15	1255,45	1719,075	2572,37
9	$P_{bl}\ (N/m^2)$	673633,92	992568,14	1399900	1916870	2509800
10	$F_M\ (N)$	109,652	161,567	227,872	312,022	408,538
11	$F_{pedal}\ (kgf)$	3,09	4,54	6,4	8,78	11,5
12	$F_{KT}\ (kgf)$	6,18	9,08	12,8	17,56	23

Based on the table above, the graphs are obtained as shown below:

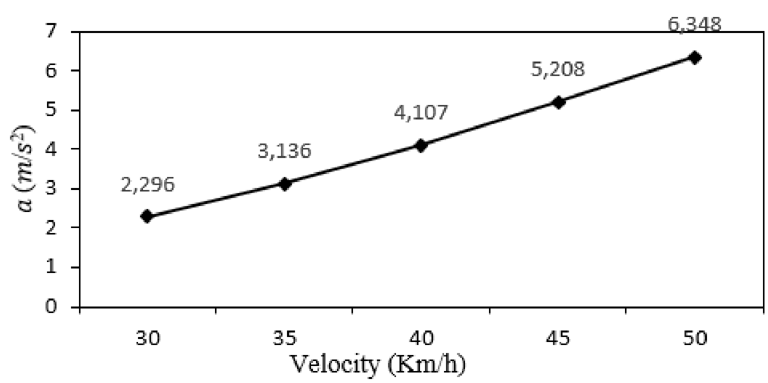

Figure 4. Graph of deceleration against velocity

From the figure above, it can be seen that the deceleration will increase in value as the vehicle speed increases. The lowest deceleration obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m, namely 2,296 m/s^2 and the highest deceleration occurs at a speed of 50 km/h, namely 8.82 m/s^2 with the same distance of 15 m.

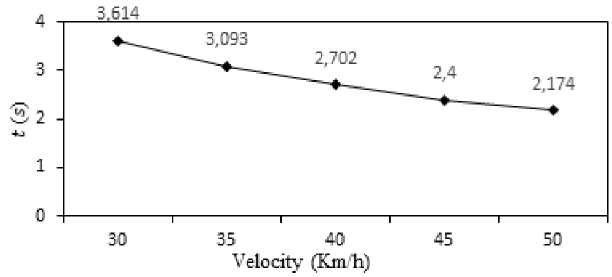

Figure 5. Graph of Braking Time against velocity

From the graph above, it can be seen that the higher the speed of the vehicle, the faster the time required for the vehicle to stop. At a speed of 30 km/h with a distance of 15 m the time required to stop obtained from the calculation is 3.614 s and at a speed of 50 km/h with a distance of 15 m the time required to stop is 2.174 s. For the actual time with a speed of 30 km/h obtained from the experimental results obtained a time of 1.87 s with a change in distance of 4.92 m, this can be due to the distance determined from calculations with experiments where the distance can change - change the time obtained will be different even though the speed is the same.

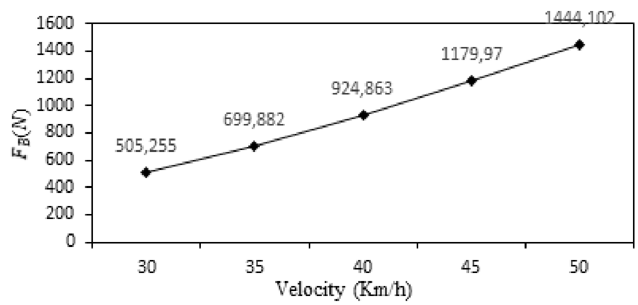

Figure 6. Graph of braking force against velocity

The lowest braking force obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m, namely 505.255 N and the highest braking force occurs at a speed of 50 km/h, namely 1444.102 N with the same distance of 15 m. The lowest braking force obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m.

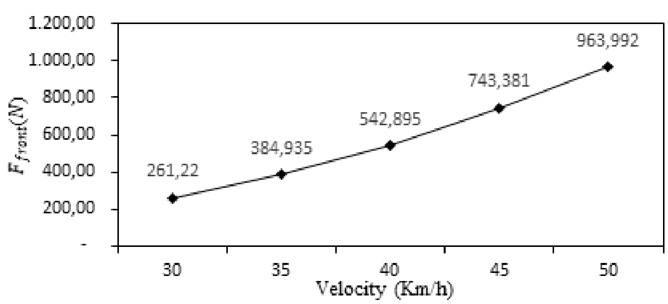

Figure 7. Graph of braking force on front wheel against velocity

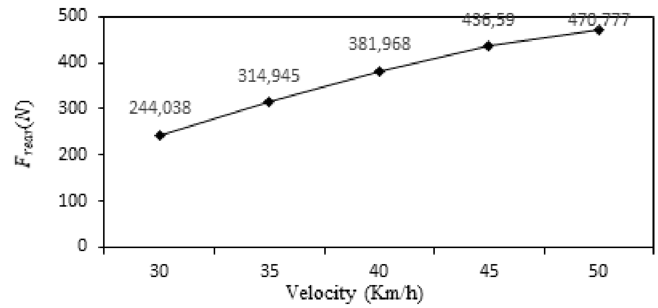

Figure 8. Graph of force on rear wheel against velocity

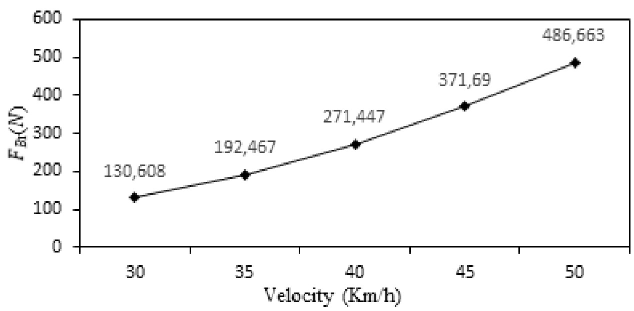

Figure 9. Graph braking force for each wheel against velocity

From Figure 7 to 9, it can be seen that the distribution of braking forces on the front, rear, and wheels will increase in value as the vehicle speed increases. The lowest braking force on the front wheel obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m = 261.22 N rear = 244.038 N on the wheel = 130.608 N and the highest braking force on the front wheel occurs at a speed of 50 km/h = 963.992 N, on the rear = 470.777 N, on the wheel = 486.663 N with the same distance of 15m.

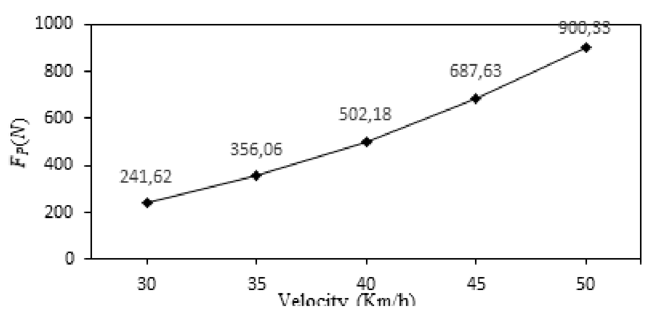

Figure 10. Graph of force on disc brake against velocity

From the figure above, it can be seen that the force on the brake disc will increase in value along with the high speed of the vehicle. the lowest brake disc force obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m, namely 241.62 N and the highest brake disc force occurs at a speed of 50 km/h, namely 900.33 N with the same distance of 15 m.

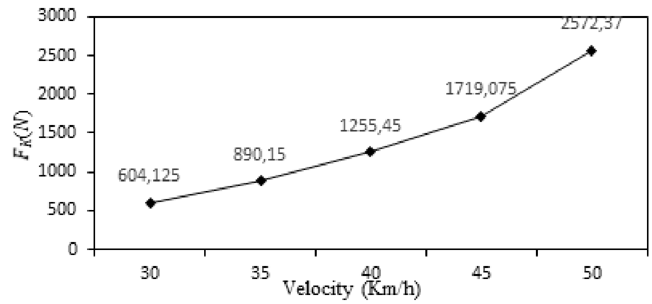

Figure 11. Graph of brake pad force against velocity

From the graph above, it can be seen that the brake lining force will increase in value along with the high speed of the vehicle. the lowest brake lining force obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m, namely 604.125 N and the highest brake lining force occurs at a speed of 50 km/h, namely 2572.37 N with the same distance of 15 m.

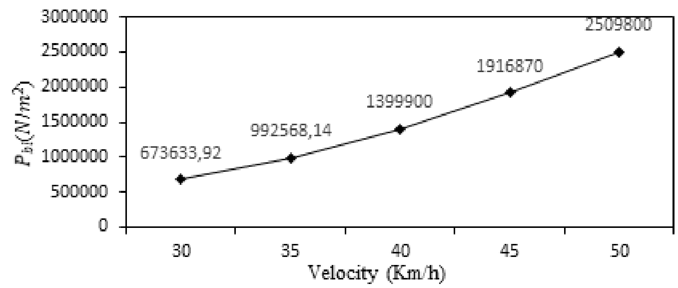

Figure 12. Graph of hydraulic pressure against velocity

From the graph above, it can be seen that the hydraulic pressure will increase in value along with the high speed of the vehicle. The lowest hydraulic pressure obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m, namely 673633.92 N/m^2 and the highest hydraulic pressure occurs at a speed of 50 km/h, namely 2509800 N/m^2 with the same distance of 15m.

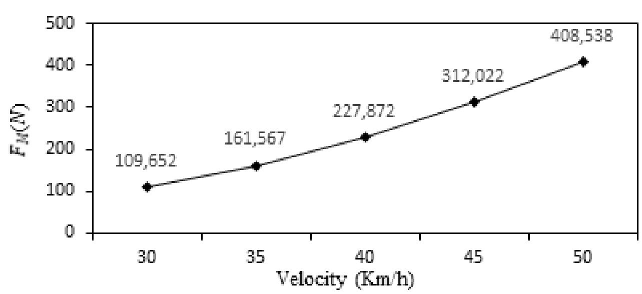

Figure 13. Graph of master cylinder force against velocity

From the graph above, it can be seen that the master cylinder force will increase in value along with the high speed of the vehicle. The lowest master cylinder obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m, namely 109.652 N and the highest master cylinder occurs at a speed of 50 km/h, namely 408.538 N with the same distance of 15 m.

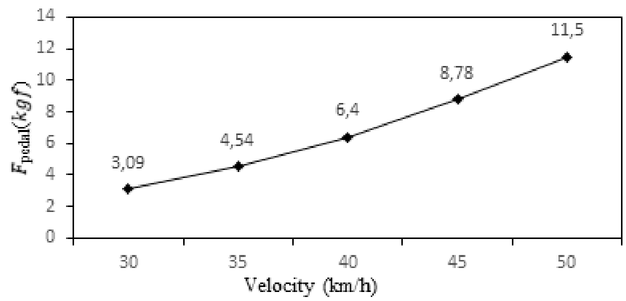

Figure 14. Graph of pedal force against velocity

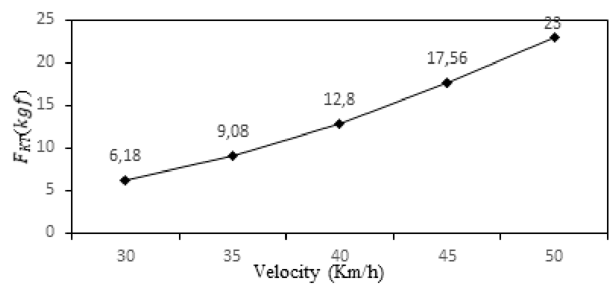

Figure 15. Graph of total pedal force against velocity

From the graph above, it can be seen that the total foot force required for the braking force will increase in value along with the high speed of the vehicle. the lowest total foot force obtained from the calculation is at a vehicle speed of 30 km/h with a distance of 15 m, namely 6.18 kgf and the highest total foot force occurs at a speed of 50 km/h, namely 23 kgf with the same distance of 15m.

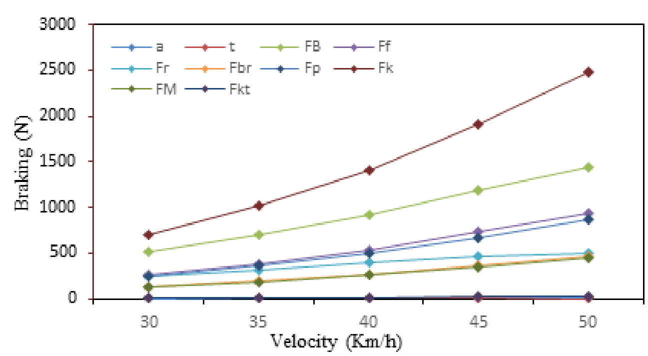

Figure 16. Graph of braking against velocity

From the results of the study, the graphs in Figures 4 to 15 show the changes in braking force to stop the car, hydraulic pressure on the hose, and pedal force at speeds of 30, 35, 40, 45, and 50 km/h with a predetermined distance of 15 m. It can be seen that the greater the speed, the braking force to stop the car, the hydraulic pressure on the hose, and the foot pressure from the driver will have a greater value as the speed increases.

4. CONCLUSIONS

Based on the results of calculations and data analysis can be concluded as follows: The hydraulic pressure on the brake hose of the Sakera car when braking at 30 km/h = 673633.92

N/m^2 , 35 km/h = 992568.14 N/m^2 , 40 km/h = 1399900 N/m^2 , 45 km/h = 1916870 N/m^2 , 50 km/h = 2509800 N/m^2 , this shows that the increasing speed of the Sakera car, the hydraulic pressure on the Sakera car brake hose will also increase following the speed. The braking force required to stop the Sakera car on a flat and straight road with a speed of 30 km/h = 505.255 N, 35 km/h = 699.882 N, 40 km/h = 924.863 N, 45 km/h = 1179.97 N, 50 km/h = 1444.102 N, this also shows that the greater the speed of the Sakera car, the greater the force required to stop it. The force required to stop the Sakera car on an inclined plane with an angle of inclination of 20º is 839.362 N. The pedal force required for braking from the driver on a flat and straight road with a speed of 30 km/h = 6.18 kgf, 35 km/h = 9.08 kgf 40 km/h = 12.8 kgf, 45 km/h = 17.56 kgf, 50 km/h = 23 kgf, this also shows that the greater the speed of the Sakera car, the greater the pedal force required from the driver to stop the Sakera car.

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