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Application of definite integration on the effect of disc width and caliper shape on motorcycle braking in the automotive department of a vocational high school

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ABSTRACT

The application of mathematical material in everyday life is part of the expected curriculum achievement in contextual mathematics learning. One of them is integral learning. The benefits of learning materials for solving everyday life problems can help calculate the area or volume needed. One area where mathematical concepts can be applied is the modification of a motorcycle's braking system. Modifying the braking system is important in maintaining driving safety. In this study, the aim is to determine the effectiveness of the brake system by applying definite integrals to changes in the disc and caliper widths. In addition, to determine the performance results of each change in the width of the disc and changes in the shape of the caliper. In this study, researchers used a qualitative approach. Considering the operational enhancements observed in motorcycle disc brake systems, alterations to the caliper, independent of disc plate modifications, prove more efficacious than adjustments to disc plate width while maintaining the original caliper piston configuration.

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1. INTRODUCTION

The current curriculum created by the government requires that learning produce a project from that learning [1]. The Independent Curriculum encompasses a Pancasila student empowerment initiative, commonly known as P5. This project, which aims to strengthen students' Pancasila profiles, can be implemented within one academic year. The project includes themes that can be implemented. The Pancasila student profile strengthening project themes encompass the implementation or application of learning in everyday life [2].

The application of mathematical material in everyday life is one of the expected outcomes of the curriculum in contextual mathematics learning. The goal of contextual learning is for students to use mathematical concepts in everyday life. Even the Minister of Education and Culture Regulation No. 21 of 2016 explicitly states that communication skills,

understanding problems, generating mathematical ideas, solving them, and finding solutions are part of the goal of addressing emerging problems [3].

Contextual mathematics learning carried out by educators plays a very important role in students' knowledge, leading students to see this mathematics learning as having great meaning for everyday life and to consider the material as related to everyday life problems. [4]. In addition, in contextual mathematics learning, educators must also follow the developments experienced by students because, basically, students expect a special interest in mathematics material in solving everyday life problems that adapt to the developments of the times, with their various experiences [5].

According to Prasetyo & Juandi [6] Someone who studies mathematics is trained to think creatively, critically, and honestly, and can apply mathematical knowledge to solve everyday problems, thereby making mathematics a significant contributor to the progress and development of science. According to Ultra Gusteti [7] Developing mathematical abilities includes reasoning, being logical, thinking creatively, solving problems, and engaging in other mathematical activities. The application of mathematics can be done by formulating mathematical models by connecting everyday life problems with the use of mathematical material concepts, such as formulating three-dimensional problems [8]. One mathematical concept that can solve daily problems is the integral. Integrals are useful for solving everyday problems, helping calculate the area or volume of materials needed. However, some students still don't understand how mathematics can solve daily problems. This occurs even though the 2016 competency standards for elementary and secondary education graduates, according to the Ministry of Education and Culture, state that the competency standard for mathematics graduates is the ability to apply mathematical concepts in everyday life.

One area of application of mathematical concepts is the modification of motorcycle braking systems. Modifying braking systems is crucial to ensure driving safety. One such braking system is the front disc brake. Maintaining the disc brake system is vital. However, some vocational high school students modify disc brakes to enhance the appearance of their motorcycles without considering the potential risks. Modifying a motorcycle should improve its condition compared to its original condition [9].

It is very important to make modifications or changes to the braking system, because the braking system is a part of the vehicle engine that is very important in maintaining safety [10]. A survey found that 67% of traffic accidents occur among people aged 22-50. Motorized vehicles are a major cause of accidents, as nearly everyone owns a motorcycle. Therefore, motor vehicle accidents are common, making it crucial to maintain motorcycle engines, including their braking systems, to prevent accidents.

One way to reduce traffic accidents is to modify the braking system, as several factors contributing to them involve malfunctioning braking systems. The braking systems most frequently modified by students are disc brakes and calipers. Modifying a motorcycle engine isn't just about choosing components at random; it's about component strength and quality. Modifying a motorcycle engine can be done using a variety of literature. However, the average literacy level of vocational school students is still low [11]. Low literacy is caused by a lack of awareness of the needs that must be met. Therefore, applying mathematical principles to this problem helps make the best decisions for modifying and motivating students to improve their mathematical literacy and the performance of their motorcycle braking systems, as

mathematics and everyday life are interconnected. This study aims to apply definite integrals to assess the effectiveness of a braking system as disc and caliper widths change. The next objective of this study is to determine the performance of each shift in disc width and caliper shape.

2. METHOD

In this study, the researchers used a qualitative approach. Qualitative research is a research technique that aims to interpret reality through inductive reasoning [12]. The qualitative approach in this study aimed to interpret data on disc width type and caliper shape, which significantly affect incubation. This approach uses the disc method formula to determine the effect of disc volume on calipers.

In this investigation, scientists used both primary and secondary data. Primary data is data collected directly by researchers from interviews, surveys, experiments, and other sources [13]. Secondary data, on the other hand, is data that already exists and can be used by researchers. The data sources used in this study were observations and interviews.

This study has two objectives. The research objects in this study are disc brakes and calipers, as it focuses on the effects of braking on their performance. The subjects in this study are grade XII students of SMK Samudra Nusantara.

In this study, the researchers used a data collection technique called source triangulation to validate the data. Source triangulation involves verifying data obtained from informant sources [14]. Data collection techniques used in source triangulation include observation, interviews, and documentation.

In this study, the researchers used grounded theory as a data analysis technique. Grounded theory is an inductive method in qualitative research that aims to generate theories from primary data [15]. The data analysis process in this study used mathematical modeling. Mathematical modeling is the process of solving everyday life problems using mathematical theory [16]. The steps of mathematical modeling are as follows.

1. Define the problem at hand,
2. Identify the variables in the problem at hand,
3. Formulate the problem into a mathematical model,
4. Solve the mathematical model,
5. Implement the results

3. RESULTS AND DISCUSSION

3.1. Integral is used to determine the efficiency of adjusting the disc width and the vernier caliper.

The results of interviews with SMK Samudra Nusantara students and observations made directly by researchers indicate that several students know the relationship between the definite integral material, the width of the disc, and the shape of the caliper in the motorcycle braking system. However, some motorcycle business engineering students relate the context of mathematical material only to basic materials such as measurement, addition, subtraction, and decimal numbers. Students who do not know the relationship between mathematical material

and motorcycle components because, based on observations of mathematics instruction, educators never apply mathematical material to everyday life. Based on educators' observations of mathematics learning at SMK Samudra Nusantara, linking mathematical material to everyday life occurs only when completing assignments.

Other results from interviews with SMK Samudra Nusantara students and direct observation include the completeness of the tools used for motorcycle braking service practices, the range of student practical activities, various disc width sizes, and calipers with different piston shapes. The completeness of the tools used in motorcycle braking services is a T-40 star L key to open the caliper from the disc, an 8-ring wrench, a 12-ring wrench, a minus screwdriver, a plus screwdriver, a compressor, an internal snapring tank, a small hose, a brake blider, a motorcycle stand, and a shock wrench. Then the tools used for measurement are a 100 cm steel ruler, a micrometer, a dial indicator, and a magnetic base. The following data from observations and interviews are in tabular form.

Table 1. Original data of components and tools used

No.	Name of goods	Type/Size/Width
1	Disc	19 cm
		20 cm
		22 cm
		24 cm
		26 cm
2	Caliper	1 Piston
		2 Piston
3	L Star Key	T 40
4	Key Ring	8
		12
5	Screwdriver	Plus and Minus
6	Compressor	-
7	Tank Snapring Internal	-
8	Small Hose	-
9	Brake Blider	-
10	Motorbike holder	-
11	Shock Key	14

In understanding the application of definite integrals to find the effectiveness of changes in the disc plate and vernier caliper. In the application of definite integrals, namely, conducting a mathematical model of the volume of a rotating object. The mathematical model of the volume of a rotating object in a motor component is a disc plate. The working principle of disc brakes is by clamping the disc plate connected to the vehicle wheel. During clamping, a vernier caliper is used to move the piston and press the braking medium against the disc plate. To determine the brake's working principle, a formula is needed that relates pressure to the volume of the rotating object. Pressure is the formula. The force per unit area of a plane is known as pressure. The following is the formula.

$$P = \frac{F}{A} \qquad \text{Equation (1)}$$

Description:
P = Pressure (Pa)
F = Force (N)
A = Cross-sectional Area (area units)

To relate the volume formula for rotating objects under pressure, a formula is needed that relates volume to pressure. The formula for calculating volume is as follows.

$$V = A\,\Delta x \qquad \text{Equation (2)}$$

Description:
V = Volume (cm^3)
A = Cross-sectional area (area units)
Δx = Height (area units)

To relate the volume and pressure formulas, substitute the pressure formula into the volume formula. Before substituting the pressure formula, change the cross-sectional area value. The formula is as follows.

$$A = \frac{F}{P} \qquad \text{Equation (3)}$$

Description:
P = Pressure (pa)
F = Force (N)
A = Cross-sectional area (area units)

After the pressure formula is changed, the formula for finding the cross-sectional area can be substituted into the volume formula, namely:

$$V = A \times \Delta x \qquad \text{Equation (4)}$$

$$V = \frac{F}{P} \times \Delta x \qquad \text{Equation (5)}$$

The first and second steps are to identify the problem and, using the formula for the volume of a rotating object, determine the motorcycle braking system's performance. Before evaluating the motorcycle braking system's performance, the first step is to examine the radius of each disc plate, as shown in Table 1.

Table 2. Disc radius

No.	Component Name	Diameter	radius
1.	Disc plate	19 cm	9.5 cm
2.		20 cm	10 cm
3.		22 cm	11 cm
4.		24 cm	12 cm
5.		26 cm	13 cm

Based on the table above, the disc radius is used as a function of f(x). Mathematical modeling of a definite integral requires a limit interval. The limit interval is taken from the disc thickness limit of 0.3. The next step is to find the performance of the motorcycle braking system by formulating it into a mathematical model. The following table is presented to find the motorcycle braking system.

Table 3. Mathematical model

Radius \ Thickness	0,3
9,5 cm	$\pi \int_0^{0,3} (9,5)^2 \, dx$
10 cm	$\pi \int_0^{0,3} (10)^2 \, dx$
11 cm	$\pi \int_0^{0,3} (11)^2 \, dx$
12 cm	$\pi \int_0^{0,3} (12)^2 \, dx$
13 cm	$\pi \int_0^{0,3} (13)^2 \, dx$

Applying definite integrals to disc brakes facilitates the determination of braking system performance. The next step is to determine the performance of a motorcycle's braking system as a function of disc width and caliper shape. Furthermore, the next section also examines the effectiveness of changes in disc width and caliper shape on braking system performance.

3.2. Disc width and caliper shape affect motorcycle braking system performance.

Based on Table 3, there are five mathematical models for determining the volume of an object rotating on a disc. The fourth step is to solve the mathematical model. Here's one method for solving the mathematical model; all results are presented in a table.

$V = \pi \int_0^{0,3} (9,5)^2 \, d$
$V = \pi \int_0^{0,3} 90,25 \, dx$
$V = 90,25 \, x|_0^{0,3} \pi$
$V = (90,25 \, (0,3) - 0) \, \pi$
$V = 27,075 \, \pi$ (volume units)
$V = 27,075 \times 3,14$
$V = 85,0155 \, cm^3$

Table 4. Working disk volume

Radius \ Thickness	0,3
9,5 cm	85,0155
10 cm	94,2
11 cm	113,982
12 cm	135,648
13 cm	159,198

Next, find the piston force that presses the disc volume using the formula in equation 5. Before finding the piston force that presses the disc volume, namely, finding the clutch pressure from the piston pressure force on the clutch. In finding the clutch pressure, namely using the pressure formula $P = F/A$, with the note P being the principle of fluid power. The working principle of fluid power requires a force acting on the surface of a moving plane [17]. In calculating fluid pressure, it is necessary to know the force exerted on an area; this can be calculated as follows.

$$F = m \times g \qquad \text{Equation (6)}$$

Description:
F = force (N)
m = mass (kg)
g = gravity = 9.8 m/s^2

To determine the pressure, the data from observations of the piston's size and weight are presented in a table.

Table 5. Caliper size on piston type

Radius piston		Piston height		Piston weight	
1	2	1	2	1	2
1,65 cm	1,265 cm	2,09 cm	2,46 cm	0,05 kg	0,1 kg

The force on one piston is as follows.

F = 0,05 × 9,8
F = 0,49 N

The forces on both pistons are as follows.

F = 0,1 × 9,8
F = 0,98 N

The styles obtained are presented in the following table.

Table 6. Piston style

One piston style	Two-piston style
0,49	0,98

The resulting piston force is then substituted into the fluid pressure formula. The results for each piston are then entered into the fluid pressure formula. The clutch pressure calculation results are presented in a table.

$$P = \frac{F}{A}$$
$$P = \frac{0{,}49}{3{,}14 \times 1{,}65^2}$$
$$P = \frac{0{,}49}{3{,}14 \times 2{,}7225}$$
$$P = \frac{0{,}49}{8{,}54865}$$
$$P = 0{,}0573189918876\ pa$$

Table 7. Clutch pressure

One piston pressure	Two-piston pressure
$0{,}0573189918876\ pa$	$0{,}1950362672924\ pa$

Next, find the force exerted by the piston on the disc using the formula above. The results for each piston pressing on the brake pad are entered in the following table.

$$V = \frac{F}{P} \times h$$
$$85{,}0155 = \frac{F}{0{,}0573189918876} \times 0{,}3$$
$$F = \frac{85{,}0155}{0{,}3} \times 0{,}0573189918876$$
$$F = 16{,}24334252\ \text{N}$$

The fifth step is to perform all the calculations for the motorcycle's braking system. The results of solving the mathematical model above are presented in the table below.

Table 8. Implementation of mathematical modeling results

Piston / Radius	1	2
9,5 cm	16,24334252	55,27035261
10 cm	17,99816345	61,24138793
11 cm	21,78	74,1020794
12 cm	25,91735537	88,18759862
13 cm	30,41689624	103,4979456

Based on the table above, using the definite integral concept, which is the volume of a rotating object, we can determine the performance of a disc brake or disc rotor brake system. This calculation shows that each combination of disc width and caliper size has a different braking system performance. Each change in disc width or caliper shape results in improved performance.

After understanding braking system performance using the definite integral concept, the next step is to determine the effectiveness of each change between the disc and caliper by comparing the motorcycle braking system's performance results in the table above. The results of this comparison are presented in the following table.

Table 9. Comparison of disc braking system improvements

Improved braking system on disc brakes	Improved braking system on the calipers
1,75482093	39,02701009
3,78183655	43,24322448
4,13735537	52,3220794
4,49954087	62,27024325

Based on Table 9, the effectiveness of improving the working system of motorcycle disc brakes on changes between wider disc plates and the type of piston on the caliper that is changed by comparing the improvement in the working system of motorcycle disc brakes is greater in changing the caliper where the piston on the caliper is bigger compared to changing the wider disc plate, so that the improvement in changing the caliper without changing the disc plate is the most effective compared to changing the width of the disc plate with the piston on the caliper not changed. The improvement in the caliper is clearly seen in Table 9, where the change in the caliper is twice that of the wider disc plate.

The curriculum used in Indonesia is independent. An independent curriculum is a curriculum related to diverse intracurricular learning, where the content is more optimal and essential, to ensure students have sufficient time to understand concepts and strengthen competencies [18]. In the independent curriculum, schools are given the freedom to provide learning projects that are relevant and close to the school environment [19]. Learning projects in the independent curriculum encourage student character development in accordance with the Pancasila student profile because the Pancasila student profile serves as the main reference for providing direction for educational policy [20]. One of the themes of the Pancasila student profile is employment, in which students can connect the knowledge they have learned with real experiences in everyday life and the world of work. The Pancasila student profile theme is only for vocational high schools (SMK/MAK).

In the independent curriculum, educators are given freedom in learning activities. In the independent curriculum, educators must produce projects based on the learning. These projects can be based on the Pancasila student profile, so that mathematics learning at the Vocational High School (SMK/MAK) level can connect and demonstrate how the material can solve everyday life contexts. One mathematical topic that has been researched is the analysis of the volume of rotating objects, which examines the potential of this material to study the workings of two-wheeled vehicle components.

In this study, researchers discuss the application of rotating object volume to disc brake braking systems. Braking is crucial because it is a key component of a vehicle used to slow down the vehicle [21]. Disc brakes work by clamping the disc plate. To clamp the disc plate, a piston-driven caliper pushes the braking medium (brake ax) against it.

Braking system maintenance is crucial, including disc brakes. Students often replace discs simply for a sleeker look without considering the impact on braking performance. In fact, any change to a motorcycle component, including disc brakes, will improve its performance.

In this study, the researchers focused on two motorcycle components: the brake disc and the piston type in the caliper that pushes the brake pads. They used the rotating-volume method to examine the brake disc's operation. Next, they used static fluid formulas to explore how the piston compresses the brake disc's volume.

Research shows that any change in the shape of the disc brake or caliper, with different piston types, results in increased braking force because the piston presses on the disc. This study found that increasing the force of the piston pressing on the disc brake results in braking, because the piston changes without changing the disc brake.

This research has several implications, including for the education sector. One of the achievements of the Independent Curriculum is its encouragement of student character development aligned with the Pancasila student profile. The Independent Curriculum aims to provide students with sufficient time to understand concepts and strengthen competencies.

This research still has many shortcomings because it only focuses on two components that affect the braking system, so that for further study, researchers who are interested in applying how motor components work using mathematical concepts can apply mathematical concepts about the effect of temperature on motor components for each change between the type of disc or caliper and the type of piston.

4. CONCLUSION

The motorcycle component most frequently modified by students is the disc brake. However, brake component modifications are not limited to disc brakes alone. Another component that can improve braking is the piston-type brake caliper. Disc brakes have width and thickness, allowing for definite integrals. The use of definite integrals in disc brakes helps explain how they work. To examine how braking works, connect the volume formula to the pressure formula, and the result determines the effective change in the brake components. To evaluate the effectiveness of disc brake modifications, compare the performance of disc brake width changes with caliper changes. Based on the comparison of braking system performance, the most effective change is to replace the caliper without changing the disc brake.

In checking the braking performance of a motorcycle, one integral part of the material, namely the volume of the rotating object, can be used to check the work of the disc plate. Then, by substituting the static fluid formula into the volume formula to find the piston force when the piston presses the disc plate, we can determine the braking performance in which the piston force causes the brake pad pressure against the disc plate. The results of this study show that the performance of each change in the disc plate width and the caliper has increased. The increase in braking force comes from the caliper, because changes in the caliper produce a greater increase in piston pressure than changes in the disc plate.

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