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DESIGN AND ANALYSIS OF DRUM BRAKE PADS FROM PALM KERNEL SHELL COMPOSITE BY USING REVERSE ENGINEERING AND FINITE ELEMENT METHOD

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Abstract

The braking system is crucial due to high vehicle accident rates, requiring effective materials. There are disc and drum brakes; disc brakes are common but costlier. This study focuses on motorcycle drum brakes, aiming to improve structure and materials to allow pad replacement without replacing the entire assembly, reducing costs by 10-30%. Using reverse engineering, a new disassemblable design was created. Palm Kernel Shell (PKS) natural fiber composite was chosen for its abundance and eco-friendliness. ANSYS FEM analysis showed PKS has good potential for brake pads, supporting further experimental testing.

Keywords: braking system, composite, ANSYS, reverse engineering, natural fiber.

Introduction

Data from studies conducted on national driving safety still show alarming results. The number of deaths worldwide reaches 1.35 million per year, including children and adults. The number of accidents in Indonesia is shown in Table [1].

Year	**Number of Accidents**
2019	116.411
2020	100.208
2021	103.645

Improvements are needed in safety features to reduce the number of accidents occurring nationwide. One safety feature that needs to be further developed to be safer is the braking system in vehicles. The braking system is an important part of a vehicle's safety features because it functions to regulate driving speed.

An analysis was conducted on drum brakes to determine the potential for development in the braking system. This analysis uses the GOM analysis and reverse engineering approaches. The vehicle brakes are made of HT 200 gray cast iron or any kind of composites, a material commonly used for drum braking systems [2]. The material used for brake pad development is palm kernel shell (PKS) powder, an organic composite option previously studied in prior research [3]. It is also known that PKS waste amounts to 8.4 tons per year [4], necessitating corrective measures to utilize the increasing PKS waste annually. The advantage of using organic composites is that they do not contain asbestos, which is harmful to the environment due to its carcinogenic properties and is banned in some countries [5].

The temperature of the drum brake is known to reach up to 200°C under extreme conditions [6]. Excessive brake temperatures reduce braking efficiency by impairing heat conversion from friction. To improve, a frame combining brake shoes and pads is planned so only pads need replacement. Adding grooves to brake shoes and pads helps evenly distribute and dissipate heat, enhancing performance and preventing overheating, as supported by prior research. [6]. The analysis was conducted using the FEA (Finite Element Analysis) method with ANSYS software. This was done to understand the behavior of the drum brake and the impact of friction on the brake [7]. The considerations analyzed include how heat is transferred from the developed brake design and deformation in the drum brake pads. The reason for this analysis is that these brake components tend to influence how the brakes will function in the future [8]. FEA was performed because it can save time and materials that will be tested later, making the testing more efficient and avoiding unnecessary time wastage [7].

Research Methode

Reverse Engineering and Analysis using GOM

GOM analysis was performed on an existing workpiece, namely the Vega SR brake shoes model. The GOM ATOS 3D scanner was used to capture the geometry of the brake shoes in its entirety and convert it into digital form. The measurement results obtained from the GOM are precise, with a surface measurement error of less than 20 µm [9]. The scan results will be in digital form and will ultimately be measured using GOM Inspect software. Measurements using GOM can be seen in Figure 1 as follows.

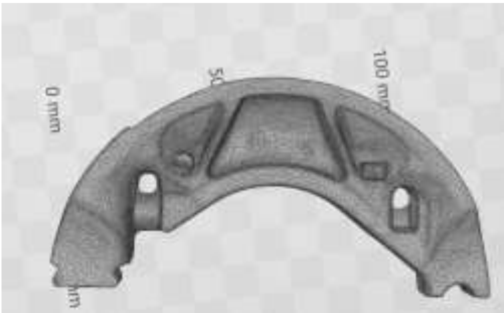

Fig. 1 Scan Result

The next step is to measure the scan results using GOM Inspect software. The results of the measurements with GOM Inspect were used to determine the dimensions of the scan. The ATOS 3D device was used to determine the dimensions of the brake shoes in detail. The scanned results measured using GOM Inspect can be seen in Figure 2.

Fig. 2 GOM Inspect Result

Measurement results were then subjected to a reverse engineering approach by redesigning the measurements using SolidWorks software. After that, the process of designing new brake shoes and brake pads was carried out using SolidWorks software. The results of reverse engineering modeling using software can be seen in Figure 3.

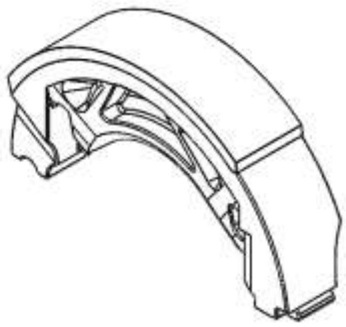

Fig. 3 Remodell Brake Pad

The old brake pad design shown in Figure 3 was followed by the development of a new brake pad with grooves added to the pad for maximum cooling of the brake pads and changes to the components between the brake pads and the mount, which were divided into two separate components that could be disassembled and reassembled. Figure 4 shows the development of the new brake pad model.

Fig. 4 Brake Pad Development

Analysis using FEA

FEA (Finite Element Analysis) was used to study the behavior of geometric properties under force and how design changes affect the geometry. ANSYS software ensured efficient simulation with easy revisions of geometry and material through multiple verification iterations. The tested material was Palm Kernel Shell (PKS) composite, with mechanical properties listed in Table 1. [3].

The parameters used to obtain the results were temperature and the equivalent stress value of the tested material. These parameters were selected because they influence the structure and research results to be obtained [11]. There are five material classifications in previous studies, divided based on the particle size of the composite. Each value has a tendency toward different material properties, so testing of each size grade in ANSYS is necessary. Testing is conducted to identify materials with potential for future prototype testing.

Table 1. *Material Properties Palm Kernel Shell*

Brake Material/Particle Size Grade	Density $[kg/m^3]$	Young Modulus [GPa]	Poisson's Ratio	Thermal Conductivity $[W/mK]$	Specific Heat $[J/kgK]$	Thermal Expansion $[10^{-5}/K]$
S 0.212	1536.33 ± 3.96	3.63 ± 0.01	0.395 ± 0.001	10.31 ± 0.02	6.505 ± 0.02	13.9 ± 0.01

S 0.300	1692.68 $\pm$ 5.88	3.40 $\pm$ 0.02	0.420 $\pm$ 0.002	8.54 $\pm$ 0.02	1.035 $\pm$ 0.02	10.49 $\pm$ 0.02
S 0.425	1551.05 $\pm$ 4.14	4.22 $\pm$ 0.02	0.458 $\pm$ 0.001	7.89 $\pm$ 0.01	1.710 $\pm$ 0.02	12.96 $\pm$ 0.01
S 0.600	1438.98 $\pm$ 6.50	3.68 $\pm$ 0.01	0.389 $\pm$ 0.001	8.78 $\pm$ 0.02	3.872 $\pm$ 0.04	16.33 $\pm$ 0.01
S 0.850	1238.34 $\pm$ 5.86	5.53 $\pm$ 0.02	0.405 $\pm$ 0.002	8.85 $\pm$ 0.02	5.057 $\pm$ 0.02	18.10 $\pm$ 0.01

The material commonly used for drum brake linings is a composite material with metal powder that has the material properties shown in Table 2.

Table 2. Composite material Properties

Brake Material/Particle Size Grade	Density $[kg/m^3]$	Young Modulus [GPa]	Poisson's Ratio	Thermal Conductivity $[W/mK]$	Tensile Yield Strength [MPa]
Composite Pad	2400	7	0.35	1	100

After obtaining the desired material parameters, the next step is to perform meshing of the geometric structure to be studied in ANSYS software [11]. The old brake pad model had 26,265 mesh elements, while the new model had 24,765. Simulations were iterated with progressively smaller mesh sizes. Boundary conditions were set to obtain simulation results. The basic simulation formula is provided [12]. The equation for solving the temperature problem during braking is as follows.

$$\rho c_p \frac{\partial T}{\partial t} + \nabla \cdot (q) = Q_{gen} \tag{1}$$

Where:

ρc_p = Product density and specific heat capacity $[\frac{J}{kg \cdot K}]$

∂T = Temperature$[K]$

∂t = Time [s]

q = *Heat flux vector* $[\frac{W}{m^2}]$

The working temperature of the brakes is set at 200°C as the maximum limit. The coefficient of friction during braking is set at 0.2 based on actual conditions in the field and previous research [13]. The old brake pad design has a maximum working temperature of 80°C, while the new design's maximum is 50°C. Temperature analysis covered both the brake pad and shoe assembly. Results were used for structural analysis with boundary conditions set as fixed supports and 2 MPa pad pressure, calculated using a specific equation [14].

$$P = \frac{F}{A} \tag{1}$$

Where:

$P = Tekanan\ [MPa]$

$A = Area\ [mm]$

$F = Force\ [N]$

Result and Discussion

The analysis using ANSYS was conducted on two different modeling geometries, namely the old and new models. An analysis of the effect of particle size on braking was also conducted to determine the effect of PKS particle size on the temperature, deformation, stress, and thermal strain of the brake pads and brake body as a whole. The ANSYS analysis data obtained is as follows.

Temperature

The temperature of the brake body was analyzed to determine the impact of the differences between the old and new geometries, as well as the differences in grain size of the PKS. The graph can be seen in Fig. 2. .

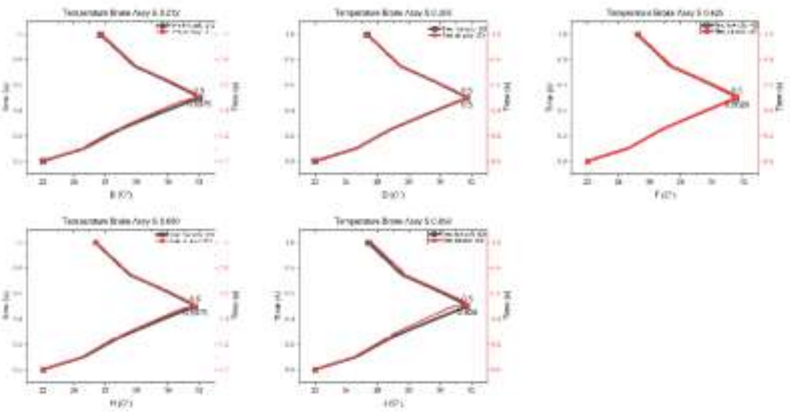

Fig. 5 Temperature Analysis

The graph compares temperature differences between old and new brake assembly models across various grain sizes using average temperatures from ANSYS. Most grain sizes show similar temperature differences, except for grain size S 0.850, which deviates slightly. Grain size S 0.400 exhibits no temperature difference during braking.

Total Stress

The next analysis is the total stress value of the brake assembly. This value is taken to determine at which point the brake assembly experiences maximum stress. It also determines whether the new brake assembly design has a lower stress value than the old design. The stress value diagram is illustrated as follows.

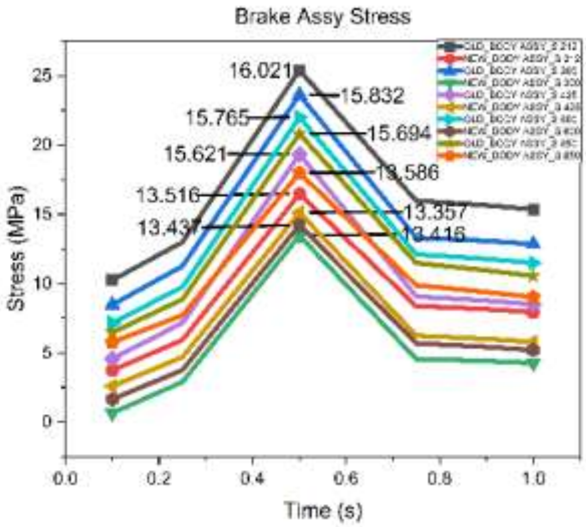

Fig. 6 Stresses occur on brake pad

The new brake assembly model shows lower stress values than the old model, regardless of grain size. Stress values do not follow a clear order by grain size. Higher stress increases deformation risk, so a brake with high stiffness and low deformation is preferred to prevent pad cracking. [15].

Comparassion

From the analysis that has been carried out, it is known that the latest brake pad model has a lower stress value with grain size S.300. The next step is to compare the new brake pad model with the old brake pad model that uses commonly used composite materials. The results of the analysis using ANSYS can be seen in Table 3.

Table 3. Iteration result

Number of Iteration	Composite Brake Pad Mesh Size			New model Brake pad		
	Mesh Size [mm]	Temperature [C°]	Stress [MPa]	Mesh Size [mm]	Temperature [C°]	Stress [MPa]
1	5	10	1	5	7	0.8
2	2	64	11	2	24	3.5
3	1	81	15	1	33.5	5
4	0.5	103	22	0.5	41	7
5	0.1	105	25.6	0.1	43	11

The results of five iterations were sufficient because the results of the iterations were sufficiently convergent so that the temperature and voltage values did not change significantly. The results of the iterations also showed that the latest brake pad model with PKS material had lower temperature and voltage values than brake pads that used commonly used composite fibers.

Summary

Reverse engineering is an effective method for developing drum brake pad designs by accurately mapping the old model. Designing pads for easy disassembly and reassembly influences structural strength. ANSYS analysis of the new design using Palm Kernel Shell (PKS) material shows similar temperature and stress values compared to the old design. However, the new design exhibits lower deformation and stress across all PKS grain sizes, indicating greater stiffness and structural stability.

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