Hardness and wear rate of basalt/alumina/ shellfish powder reinforced phenolic resin matrix hybrid composite brake lining pads

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Abstract. This paper explain the behavior of hybrid composites phenolic resin with basalt/alumina/ shellfish powder reinforced on brake lining pad. Hybrid composite brake has been manufactured use compaction and sintering process through any steps, that an emphasis of 2,000 kg for 30 minutes at a constant temperature of 150° C. The research aims to investigate hardness characteristic and wear rate of hybrid composite that test using the Vickers according to standard ASTM E-384. The reinforced materials and matrix polymer composition is 60%: 40%. The results show for the average hardness VHN to 24.18, 25.11, 26.34, 27.21 and 28.83. The average hardness hybrid composite shows the hardness harder than asbestos materials. The value of asbestos lining pads wear is 0.00011 g/m, while the wear value of composite hybrid brake lining pads is 0.00009 g/m to 0.000071 g/m.

1. Introduction
One component of the vehicle that has a very important role for the comfort and safety of the rider is the braking system. This system serves to slow or stop the vehicle by providing a braking force that is forwarded to the friction plate and brake pad. Friction plates and brake lining are an important part of the braking system in motor vehicles so deserve more attention to protect consumers and reduce the percentage of causes of road accidents. Brake lining is a component that directly rubs against the rotating parts in the braking system according to the type and brake used. In general, the brake lining material is made of asbestos because it is superior in temperature resistance up to 800°C [1] and is also good in sound absorption and low in water absorption [2]. However, asbestos material has been closed because it has carcinogenic properties that have a negative impact on the environment and human health [3]. Then, the asbestos fiber material is replaced with aramid fibers, Kevlar, Twaron, rock wool, fiberglass, potassium titanate, carbon fiber, graphite, cellulose, vermiculite, steel fiber, BaSO4, resin, nitrile butadiene rubber.

Utilization of hybrid composite materials on motor vehicle components has become popular because it effectively increases the stress and strain due to the imposition of impact as well as reduce the cost of reinforcing material [4]. Hibridisasi is the process of forming a composite material with new traits which made merging two or more materials that have characteristics which differ in a matrix binder (thermoplastic or thermosetting) or otherwise of the reinforcing fibers bonded with two or more types / phase matrix of different [5]. Nowadays a lot of research on hybrid composite material with epoxy basalt reinforced that has been done. Czigany [6], has conducted research on the characteristics of epoxy composite with basalt fiber reinforcement, and the following year a hybrid composites reinforced basalt fiber, polypropylene matrix has been produced, in which the strength properties of the hybrid composites due to increased surface treatment after mechanical tests and
microscopic analysis. Besides it also studied the characteristics of basalt fiber hybrid composite laminates due to the imposition of tensile and flexural [7]. Liu, et al [8] and Atmika, et al [9] conduct research of mechanical properties of basalt fiber composite with the transport system where the basalt is very possible material applied to the transportation environment.

In connection with the development of new materials for brake lining, basalt was introduced as one of the hybrid composite formers. Basalt is a natural fiber produced by volcanic eruptions that have heat resistance up to 150°C [10], resistant to corrosion, low water absorption and resistant to chemical treatments and non-toxic [11]. In the last five years, research related to basalt characteristics has been carried out with the conclusion that basalt material has excellent physical and mechanical properties, high ductility, and high wear resistance [12], and can replace glass fibers [13]. Then the most important basal properties are having low thermal conductivity. This property is used to overcome potential brake lining problems lately.

In the context of the development of brake lining materials, the basalt powder hybridization method is used. Basalt powder is combined with other natural ingredients, namely shellfish powder and alumina which are bonded with epoxy as a composite material. Composite hybrids have been manufactured using five types of weight fraction ratio. This study aims to determine the characteristics of hardness and wear rate of the developed hybrid composite.

2. Materials and Method

Basalt as described above, comes from hardening of the lava mountain (figure 1). In this study, basalt powder, alumina powder and shellfish powder with a size of 0.0074 millimeters were used. Mechanical properties of basalt are shown in Table 1. Shellfish shell powder material consisted of 66.70% CaO, 22.28% MgO, 7.88% SiO₂, 1.25% Al₂O₃ and 0.03% Fe₂O₃. The phenolic resin material used in this study coded PR-51510, which is one type of resin in powder form.

In this study brake pad material is made by mixing, compacting and sintering processes. The shape and size of the test specimen are as shown in Figure 2. Composite composition shown in Table 2 is based on ASTM D standard 3171-09. In the process of making brake lining material it is pressed to load 2000 N for approximately 30 minutes, and the sintering process at a temperature of 150°C.

![Figure 1. Basalt](image-url)
Table 1. Mechanical properties of basalt material

| Properties of Basalt | Value (unity) |
|----------------------|---------------|
| Density              | 2600-2630 (kg/m³) |
| Tensile strength     | 500k-550k (psi) |
| Sintering Temperatur  | 1050 (°C) |
| Operation Temperatur  | -265-+700 (°C) |
| Modulus of elastisitas| 9100-1100 (kg/mm³) |
| Mohs Hardness @20°C   | 5-9           |
| Melting point        | 1170(°C) |
| Heat resistance      | 700-1000 (deg.C) |
| Elongation at break  | 3.15(%)       |

Figure 2. Specimen geometry

Table 2. The weight fraction ratio of hybrid composite

| Composition | Basalt powder | Clamshell powder | Alumina powder | Phenolic Resin |
|-------------|---------------|------------------|----------------|---------------|
| I           | 45            | 5                | 10             | 40            |
| II          | 40            | 10               | 10             | 40            |
| III         | 35            | 15               | 10             | 40            |
| IV          | 30            | 20               | 10             | 40            |
| V           | 25            | 25               | 10             | 40            |

Hardness test use Vickers method according to ASTM E384-99 (Standard test method for micro-indentation hardness of materials). The wear rate is tested by the pin on disc method. Each specimen was tested with a 36 N load in 83.3 minutes or 200 meters with a 120 rpm engine speed.

3. Result and Discussion

The average result of VHN (Vickers Hardness Number) of each composition and comparison with the hardness of the brake lining pads that asbestos material (X) are shown in figure 3, while the wear rate of brake pads is shown in Figure 4.
Figure 3a shows a hardness diagram of hybrid composite brake pads and brake pads from asbestos material. From the diagram the hardness value of composition I is 24.72, the hardness value of composition II is 25.40, the hardness of composition III is 25.67, the hardness of composition IV is 25.74, and the hardness of composition V is 26.55. Thus the amount of basalt powder has a significant influence on the level of hardness of the brake lining material made. Then from Figure 3b shows that the asbestos brake pad has a hardness value between composition I and composition II, so that basalt powder and shellfish powder are natural alternative materials that can be used as an alternative brake lining material for asbestos brake pads.

Figure 3. Vicker Hardness Number of the hybrid composite and asbestos
Figure 4 shows a graph of wear value for the five ingredients of hybrid composite brake pads and asbestos brake pads. From the picture shows that the decreasing amount of basalt content in the specimen the greater the wear value. The value of asbestos lining wear is 0.00011 g/m, while the wear value of composite hybrid brake pads is 0.00009 g/m to 0.000071 g/m. Thus the composite hybrid brake pads made have a better wear value compared to the wear of asbestos brake pads.

4. Conclusion
The reduction in the percentage of basalt powder and the addition of the percentage of shellfish powder, and the percentage of constant alumina results in a higher hardness value. The hardness value of composite hybrid brake pads is not much different from the value of asbestos brake pads. The reduction in basalt percentage in each composition results in increased wear value but not so significant. The wear value of hybrid composite brake pads made is still smaller than the wear value of asbestos brake pads, therefore hybrid composite brake pads have the potential as a substitute for asbestos materials for environmentally friendly brake pads.

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