Effect of NBR (Nitrile Butadiene Rubber) on flexural strength of composite friction brake

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Abstract. The friction brake is one of the key components in vehicle braking system. Friction mechanism in the braking system demands the brake lining to maintain its friction coefficient and mechanical properties in various conditions. Research on the manufacturing process and material selection in the production of composite friction brake has been extensively conducted to obtain the expected characteristics. The purpose of research was to investigate the effect of the Nitrile Butadiene Rubber (NBR) on the flexural strength of brake composites which composed of NBR, phenolic resin, cashew dust, fly ash, cantala fiber, graphite and CaCO₃. NBR is commonly used as the filler composite in the production of composite friction brake. NBR is the copolymers of synthetic rubber made of acrylonitrile and butadiene which is resistant to heat and pressure. The three-point bending method was conducted to obtain flexural strength of composite friction brake materials according to the ASTM D790 standard. The result showed that NBR had effect on the flexural strength of the specimens. The flexural strength of the composite friction brake increases with increasing NBR filler content. NBR increases the flexural strength of composites due to its effect on improvement of the interfacial strength between fiber and matrix. The additions of 12% fractions volume NBR have the highest flexural strength.

1. Introduction

Composite friction brake plays an important role in the braking system which functions as a component that slows down the speed and stops it to a fixed point [1]. It is composed of four constituents including the reinforcing fiber, binder/resin, filler and frictional additives [2]. The selection of the constituents determines the flexural strength and characteristic of composite friction brake [3].

Filler functions to reduce the production cost and some are used to enhance the characteristics of composite friction brake. The volume fraction of filler affects the characteristics of composite friction brake [4]. The filler used in the composites of brake system has volume fraction ranging from 0 – 40% [4]. Filler materials are usually made of metals, alloy, ceramics, organic materials and inorganic materials. Organic filler materials include the CNSL (Cashew Nut Shell Liquid), dust and rubber. One of the rubber materials used as filler for composite friction brake is the NBR [6].

NBR is a copolymer of synthetic rubber of acrylonitrile (ACN) and butadiene which had known as an organic macromolecule elastic compound that has high resistance toward fatigue
and wear [7]. NBR can absorb the vibrations, besides it has excellent chemical stability. The use of NBR in composite materials enhances the mechanical characteristics of other composite materials including phenolic resin [9]. The mechanical characteristics and the wear and tear resistance of composite friction brake can be improved using NBR to modify the resin [10]. This research focused to investigate the effect of NBR on the flexural strength of composite friction brake.

2. Method and Experiment

2.1. Material Preparation

Fiber and powder materials were prepared by soaking cantala fibers in 5% NaOH solution for 4 hours. This procedure eliminated the lignin contents in the fiber [11]. The fiber was then washed off using water, dried up by indirect sunlight and then put into an oven at the temperature of 70 °C for 10 hours. The fiber was then cut in length of 2-3 mm. Filtration or meshing procedure was then conducted to the materials including NBR, graphite, cashew dust, phenolic resin and CaCO3 at 100 mesh sizes.

2.2. The Specimen fabrication

The compositions of main constituent in composites in volume percentage (% volume) are shown as seen in Table 1. Composite materials used in this research consisted of NBR, CaCO3, and the basic mixture of containing phenolic resin (25%), cashew dust (10%), fly ash (5%), cantala fiber (7%) and graphite (15%). This variation in amount of NBR was adjusted by compensation of the residual amount by inserting CaCO3 filler, wherein the total amount of NBR and CaCO3 was always kept constant 38% [10]. In the early process, all materials except the fiber were weighed to the intended composition before they were blended for 5 minutes. The fiber was then added to the mixture and blended for another 3 minutes. The mixture was then put into a cold mold to undergo pre-forming process at 20 MPa pressure for 5 minutes. The pre-forming process was then followed by the hot molding process at 20 MPa and 160 °C temperature for 10 minutes. Gaseous disposal was done 6 times every 10 seconds during the early stage of hot molding process before the mixture was pressed for 9 minutes.

| Composition | % Volume |
|-------------|----------|
| Basic mixture | NBR | CaCO3 |
| 1 | 62 | 0 | 38 |
| 2 | 62 | 4 | 34 |
| 3 | 62 | 8 | 30 |
| 4 | 62 | 12 | 26 |

After the specimen was obtained, the post-curing process was carried out. A post-curing procedure was done to improve the density of the cross-link bonds in phenolic resin [11]. The post-curing procedure was carried out through these following steps: heating up the specimen from room temperature 29°C up to 140°C in 1 hour. After reaching 140°C, the specimen was then heated up to 180°C for 6 hours and then gradually stepped down to reach the room temperature. The 6 hour post-curing process within the temperature of 180°C was successfully improved the flexural strength of the composite friction brake composite materials [12].

Bending test was administered to measure the flexural strength of the specimen based on ASTM D790 standard. The size of the specimen was as shown in figure 1. The surface of the
specimen fractures was observed using Stereozoom microscope and Scanning Electron Microscope (SEM). JTM-UTS 510 with 80 mm pad was employed in the test, in which crosshead speed was set at 5 mm/minute and load cell capacity of 100 kg as shown in figure 2.

![Figure 1. Specimen size](image1.png)

![Figure 2. Universal testing machine.](image2.png)

3. Results and discussion

The result of the bending test conducted in this study was presented in figure 3. The result showed that the flexural strength of composite friction brake increased with increasing volume fraction of NBR. It indicated that NBR affected to the increase of the composite flexural strength. This phenomenon could be attributed to the interfacial adhesion improvement between matrix and fiber due to NBR addition [13]. The previous paper reported that the modified resin with NBR was able to increase composite tensile strength [10].

![Figure 3. Effect of volume fraction of NBR on the flexural strength](image3.png)

The results of the bending test could be associated to the phenomena occurring at the fracture surface. It aims to identify and explain the enhanced flexural strength materials composite frictions brake. Figure 4 presents the result of macro observation of fractures surface specimen without NBR, while figure 5 showed the result of its observation using
SEM. This specimen has the weakest flexural strength because it did not contain NBR. The addition of NBR materials improved the interfacial adhesion between matrix and fiber [13]. Fiber pull-out indicated the weak interfacial adhesion that reduces the flexural strength. Figure 4 shows the fiber pull-out, and more detailed pictures of the fiber pull-out phenomenon is shown in figure 5.

Figure 4. Fracture surface on fraction volume 0% NBR

Figure 5. SEM image of fracture surfaces on Figure 4

Figure 6 shows the macro observation of the fracture surface of the 12% NBR specimen. The 12% NBR specimen had the highest flexural strength. Figure 7 presents the detail of observation fracture surface by using SEM. It showed that fiber fractures were found in the material. However, a few pull-out fibers were also found in this image. Fiber fracture indicated that there were good interfacial strength between fiber and matrix in the specimen. This phenomenon occurred because NBR was able to improve fiber – matrix interfacial strength in composite.

Figure 6. Fracture surface on fraction volume 12% NBR
4. Conclusions
NBR had effect on the mechanical properties of composite friction brake. The flexural strength of the composite friction brake increased with increasing NBR filler content. NBR improved the interfacial strength between fiber and matrix.

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