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The Effect of Graphite and NBR on the Hardness of Fly-ash/Phenolic Composite for Brake Lining Application

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Abstract. Composite development is very intense to replace heavy and expensive metallic materials. One application of composite is a brake pad for vehicle. The composite for brake lining was consisted of various components which are divided into reinforcement, binder, friction modifier and filler. Composite in this study was made with variation in weight of graphite, NBR, fly-ash and phenolic resin. The hardness and abrasive tests were carried out to investigate the mechanical properties of the composite. Observation of the composite surface was carried out using SEM. The hardness and wear tests show that an appropriate composition of the phenolic and NBR was result in high hardness and low specific abrasion of fly-ash/phenolic composite.

Introduction

Phenolic resin are used as binder in friction materials due to low cost along with good combination of mechanical properties such as high hardness, compressive strength, moderate thermal resistance, creep resistance and very good wetting capability with most of the ingredients [1]. The straight phenolic resin shows glass transition near 280 °C and undergoes rubbery state up to 320 °C until the resin goes through the post-curing of raw phenolic resin [2]. Based on the SEM observation, the uniform surface after the low temperature wear test indicates that the resin retains constituents well during sliding so that the wear process is mainly governed by the gradual removal of the ingredients that are exposed to the sliding surface. The partially detached surface area after high temperature wear test, suggests that the wear process mainly governed by the thermal decomposition of binder resin in the subsurface, producing relatively large patches as wear debris.

Density was decrease for composite which phenolic binder was replaced by rubber binder. The mechanical properties such as surface hardness, compression strength and flexural modulus reduced steadily with the replacement of phenolic binder by rubber binder in phenolic based composite [3]. The phenol resin significantly increases hardness because of high hardness of phenol resin after curing. Potassium titanate and CNSL tend to reduce hardness of composite [4]. Addition of friction modifier such as calcined petroleum coke increased the hardness of the composite because of a high compatibility with the phenolic resin. Whereas, other friction modifier material such as boron nitride and talcum powder was behave as the reverse because of a poor compatibility with phenolic resin [5]. Graphite carbon is refractory material and do not melt at temperature below 3000 °C, it has excellent coefficients of thermal conductance. In brake lining material, this property is useful to get frictional heat away from the brake surface. Graphite provide both frictional and structural material, at the same time, within the disc brake. Graphitic carbon have coefficient of friction which change little with surface temperature [6].

The purpose of this research is to study the effect of graphite and NBR on the hardness and wear resistance of the fly-ash phenolic composite. Low wear rate, high hardness and high thermal resistance of this composite are needed for brake pad application.

Experimental Procedure

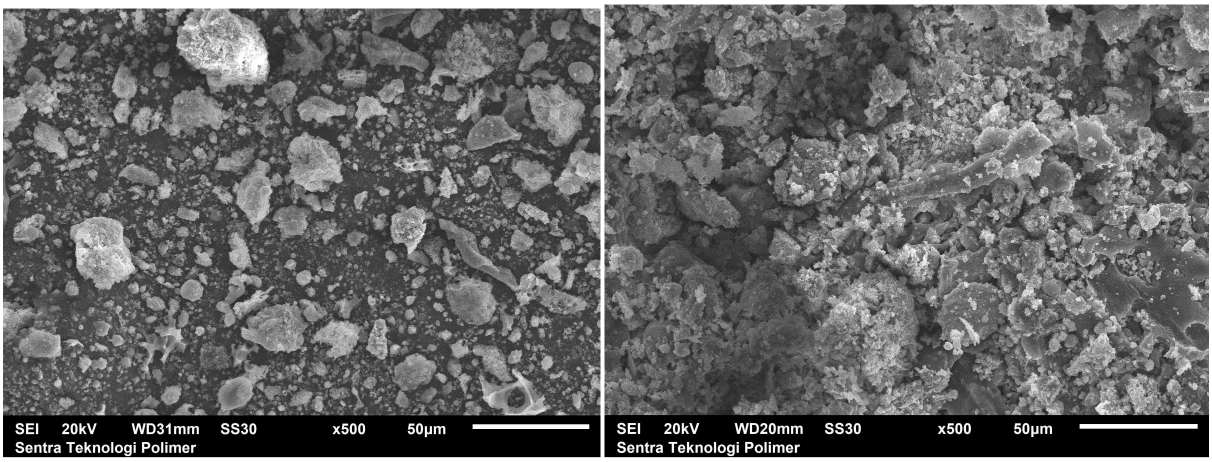
Materials of the composite were consisted of binder phenolic resin with average size of 250 µm and Nitrile Butadiene Rubber (NBR) SKD P830 with average particle size of 40 meshes. Filler was barite and reinforcement was fly-ash from coal power plant. Friction modifier was graphite, Fe powder and carbon black N330 with tensile strength of 1.5 MPa and extension of 10%.

Sample was prepared by first weighting the sample according to each composition and then sequently mixing all constituent for 10 minutes using a commercial blender. Then, the mixed powder was heated to temperature 250 °C and pressure was applied on it. Post curing was carried out at 150 °C for 4 hours.

The Energy-dispersive X-ray Spectroscopy (EDS) and Scanning Electron Microscope (SEM) were analyzed using JEOL JED-2300. Hardness test was accorded to ASTM D785 standard for Rockwell hardness of plastics. Ogoshi method was carried out to investigate the abrasive resistance of fly-ash/phenolic composite. The abrasive test was according to ASTM G99 which is the standard test method for ranking resistance of plastic materials to sliding wear using a block-on-ring configuration. For TGA test, the sample was heated from 30 °C to 800 °C, heating rate was 10 °C/min and purge rate 50 ml/min.

Result and Discussion

From SEM observation (Fig. 1(a)), fly-ash particle has an irregular form and size. The surface of fly-ash was rought and the average particle size was 120 meshes. Fig. 1(b) shown the morphology of fly-ash/phenolic composite, the mixture of seven components in composite visually shows an adequate compatibility between the components.



(a) (b)

Figure 1 SEM micrograph of morphology of (a) fly-ash (b) fly-ash/phenolic composite

The EDS analysis shows that fly-ash was consisted of SiO_2 of 68.15% as shown in Table 1. High content of SiO_2 in fly-ash revealed that fly-ash can be used to reinforce phenolic composite because of high hardness property of SiO_2. Fly-ash was consisted of Silicon of 16.05 wt% and Aluminum of 12.91 wt%. Non metal elements content in fly-ash were Carbon and Oxygen.

Table 1 Composition of the compound in fly-ash using EDS.

No	Name of Compound	Phase	Mass Fraction (% wt)
1	Quartz	SiO_2	68.15
2	Gypsum	CaH_4O_6S	20.67
3	Gehlenite	$Al_2Ca_2O_7Si$	11.18

The composition and hardness of fly-ash/phenolic composite is listed in Table 2. Majority of the content in composite was phenolic and barite as a binder of composite. The variability of NBR percentages were 0, 5, 10 and 15 % in weight as reverse to the graphite content of 15, 10, 5 and 0 % in weight.

Table 2 Rockwell hardness of fly-ash/phenolic composite

Material	Binder and filler [wt%]	NBR [wt %]	Graphite [wt %]	Reinfor-cement [wt%]	Friction modifier [wt%]	Hardness [HRCS]
NBR0	70	0	15	5	10	31,58
NBR5	70	5	10	5	10	48,56
NBR10	70	10	5	5	10	55,21
NBR15	70	15	0	5	10	38,66

As can be seen in Table 2, the composite that contained 10% of NBR and 5% of graphite has the highest hardness. Increasing of grafit content was decreasing the amount of NBR, hence the compatibility was decreased. This can be seen from NBR0 sample that showed low hardness because of a low compatibility between component due to the absence of NBR. NBR increase the wet ability between ingredients in composite. NBR improves the binding of components in composite. However the increasing of NBR to 15% (sample NBR15) was showed a low hardness because of the absence of hard graphite. Thermal decomposition of NBR10 sample (the composite sample that has the highest value of hardness) can be seen from TGA result in Fig. 2.

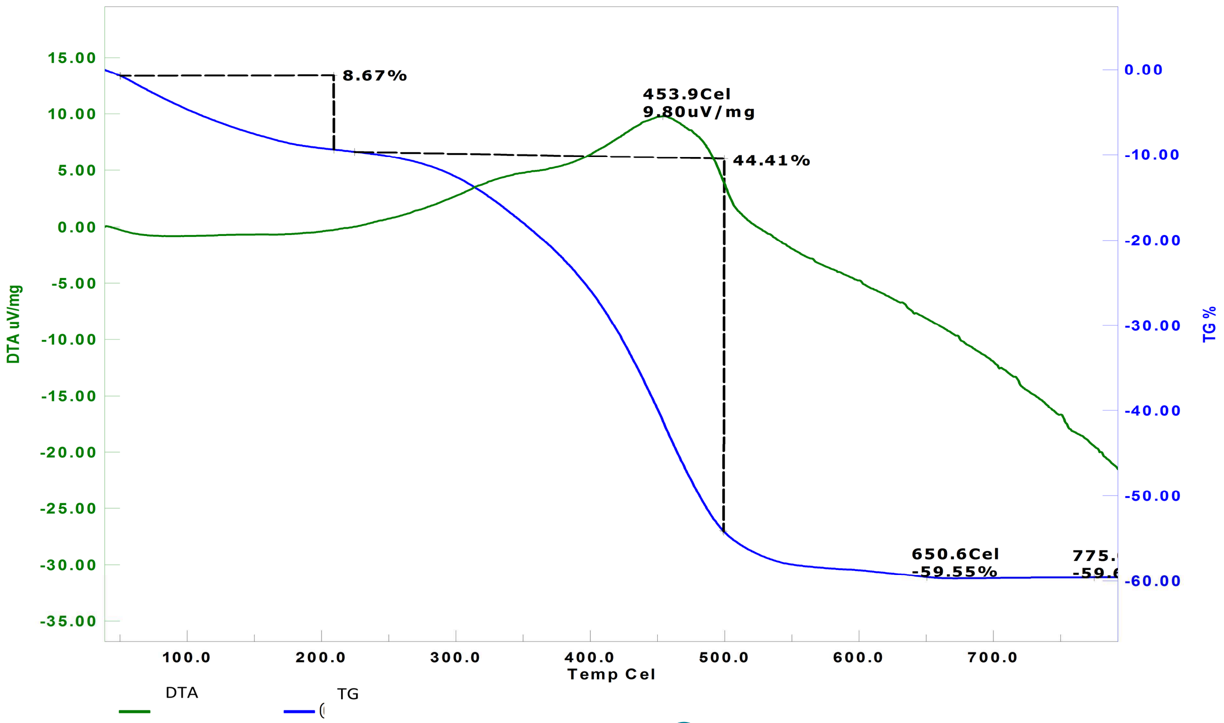


Figure 2 TGA test on NBR10 sample of fly-ash/phenolic composite

The specific abrasion of the fly-ash/phenolic composite in Fig. 3 shows that the composition of 5% NBR and 10% grafit of fly-ash/phenolic composite was resulted in lowest specific abrasion 0f 1.55E-7 mm^3/mm. Graphite content up to 10% is suggested to increase the wear resistance of fly-ash/phenolic composite because of high hardness properties of this material. NBR content up to 5% was given a sufficient bonding of the component in fly-ash/phenolic composite.

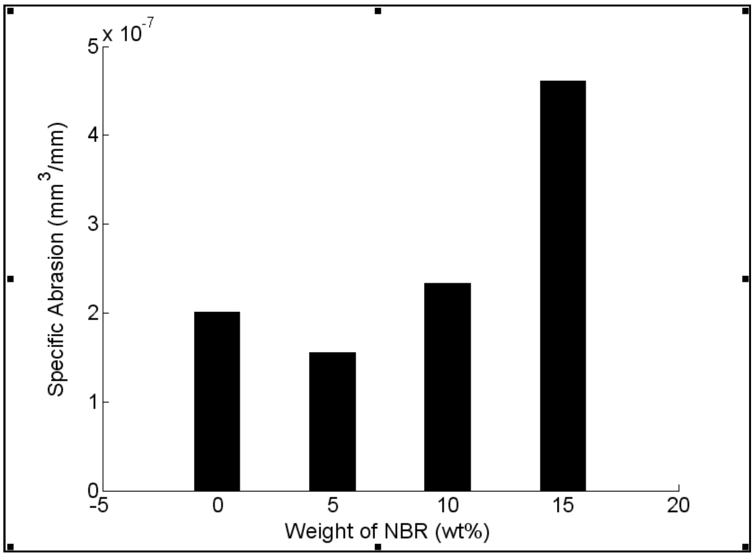


Figure 3 Specific abrasion as a function of NBR weigth in fly-ash/phenolic composite

Summary

Fly-ash/phenolic composite consisted of binder, filler, reinforcement and friction modifier. The effect of NBR as a binder and graphite as a friction modifier was investigated. The highest hardness of 55,21 HRCs was obtained from composite that consisted of 10% NBR and 5% graphite. The lowest specific abrasion of 1,55E-7 mm3/mm was obtained from composite that consisted of 5 % NBR and 10% graphite. The NBR was increased the compactibility and graphite was increased the hardness and abrasion resistance of composite. The SEM observation shows an adequate compatibility between particles in composite.

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