Analysis of Hardness and Wear Properties of Composite Railway Brake Blocks Using Nylon Fiber Reinforced

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Abstract. The braking system is one of the supporting factors for safety and security on trains. In railway braking systems in various countries, composites have been used as brake shoe materials because composites meet several criteria to replace cast iron brake shoes. Nylon has been used in various automotive industries because of its heat resistance, self-lubricating properties, wear resistance, high strength and modulus of elasticity. Nylon has the potential to be developed into composite fibers that are applied in braking systems for railways. Composites are made from a mixture of 25% nylon fiber, 40% iron sand and 35% epoxy resin. The tests carried out are hardness test with shore D hardness test and wear test using Ogoshi High speed Universal Wear (OAT-U type). The results of the hardness test showed that the composite hardness was 88.5 HRR and the composite strength value was 2,26629 × 10^{-7} mm^2/Kg.

Keywords: Railway Braking Systems · Hardness · Wear · Nylon Fiber

1 Introduction

The braking system is one of the supporting factors for safety and security on railways. Cast iron has a high thermal conductivity, so it has been used for some time as a brake shoe material. However, cast iron has several drawbacks, including producing a high level of roughness in the tread. This can result in audible noise because the tread can roll violently. In addition, brake blocks that use cast iron in the braking process also produce airborne particles containing toxic amounts of iron oxide [1]. In railway braking systems in various countries, composites have been used as brake shoe materials because composites meet several criteria to replace cast iron brake shoes. In this case, the composite brake block produces less noise and airborne particulate emissions.

Alternative use of composites in various applications is increasingly in demand because of the nature of the composites themselves which can be designed and adapted to the needs and can be better than the basic constituent materials. Some of the advantages of this composite such as having good toughness, resistance to high temperatures, having

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good shear and tensile strength, good wear resistance and thermal expansion, corrosion resistance and relatively cheaper manufacturing costs.

The use of composites in the world of transportation has also begun to develop, especially for automotive brake components, trains and aircraft [2]. Carbon composites are widely used in brake block materials for transportation because they have several advantages such as high strength, wear resistance, heat resistance, and low density [3]. Likewise, in the railways industry, including in Indonesia, composite brake blocks are starting to be widely used as an alternative to conventional metal brake blocks. Therefore, currently research related to rail brake blocks made of composites is also growing, such as train brake linings with composites of hibiscus fiber and silica sand [4], composites of ferrous iron powder and coconut husk fiber [5], composite of empty palm cluster [6].

Nylon has been used in various automotive industries because of its heat resistance, self-lubricating properties, wear resistance, high strength and modulus of elasticity. In this study, the hardness and wear properties of composite railway brake blocks using nylon fiber reinforced will be studied.

2 Experimental Details

2.1 Materials

Please Composite is composed of nylon fiber, epoxy resin and iron sand. The volume fraction of each of these components is 25% of nylon fiber, 40% of iron sand and 35% of epoxy resin. Nylon fiber specifications are shown in Table 1. Composite fabrication using compression molding method. Compression molding is one type of method of making composite materials with a closed molding process. The molding has dimensions of 320 mm × 80 mm × 50 mm. The molding is coated with a mold release to make it easier for the specimen to be released. Composite materials are molded using a hydraulic press which has a capacity of 2 tons. The molded material was dried by heating at a temperature of 250 °C for 1 h. The specimen was allowed to stand for some time and then released

Table 1. Nylon Fiber Specifications

Properties	Unit	Values
Specific Gravity	gr/cm^3	1.14
Tensile Strength	Kgf/mm^2	6.65
Thermal Distortion Temperature	^{0}C	70
Elongation	%	200
Compressive Strength	Kgf/mm^2	7.05
Flexural Strength	Kgf/mm^2	7.6
Modulus elasticity	Kgf/mm^2	2.8
Heat	Cal/^{0}C	0.4
Printing temperature	^{0}C	61

Fig. 1. Nylon Fiber

Fig. 2. Composite Railway Brake Block Molding

from the mold. Test specimens are prepared with dimensions according to the standards used (Figs. 1 and 2).

2.2 Testing Procedure

The shore-D hardness test was carried out at the Mechanical Engineering Laboratory, Politeknik Negeri Malang complies with ASTM D 2240. The test specimen has dimensions of 50 mm × 50 mm × 20 mm. The shore-D hardness test was carried out using a durometer. The test was carried out at three different points and the test on each was carried out three times. The method of testing the Shore D hardness using the Durometer device is done by pushing or pressing the test device which has a needle connected to a spring at the bottom with a certain strength and time to get the hardness value [7]. The test results are shown in HD units and then converted into HRR units to analyze whether they meet the hardness values for composite railway brake blocks.

The wear test was carried out with Ogoshi High speed Universal Wear (OAT-U type), where the test object was rubbed against a rotating plate, then the gap formed was measured using a measuring microscope [8]. The test was carried out at the Engineering Materials Laboratory, Universitas Gadjah Mada with the specimen size referring to

ASTM G99 with dimensions of 30 mm × 20 mm × 10 mm. The wear value can be calculated using the following equation:

$$Ws = \frac{B \times b0^3}{8 \times r \times p_0 \times l_0}$$

Description:

Ws= specific wear price (mm^2/kg).
B = wear disc width (mm).
b_0 = wear width on the test object (mm).
r = radius of the wear disc (mm).
p_0 = compressive force in the ongoing wear process (kg).
l_0 = distance traveled in the wear process (mm).

3 Result and Discussion

The composite produced after going through the process of mixing materials, molding and drying is shown in Fig. 3.

The results of the Shore-D hardness test on composite materials A and B are shown in Table 2,

The composite hardness value was then compared with the standard composite brake block shown in Table 3.

The test shows that the composite hardness value is 88.5 HRR. The standard composite brake block for trains shown in Table 2 has a hardness value between 70–105 HRR. This shows that the composite with nylon fiber reinforcement that has been made, meets the standard hardness value of composite brake blocks for railways. Hardness is the ability of a material to resist scratching, abrasion, indentation or penetration. This property is related to wear resistance. Hardness also has a correlation with strength [10]. Nylon has advantages such as resistance to abrasion, in addition nylon is used as a composite filler because it has high tensile strength. Nylon has a polyamide base material whose main chain is C(O)-NH amide bonds. This bond shows a tendency to crystallize, which is strengthened by the formation of hydrogen bonds between oxygen and nitrogen

Fig. 3. Composite Railway Brake Block with Nylon Fiber Reinforced

Table 2. Hardness Test Result

	Hardness (HD)		
	First test Point	Second test Point	Third test Point
First test	74	73	74
Second test	74	77	76
Third test	73.5	73.5	75
Average hardness (HD)	73.7		
Average hardness (HRR)	88.5		

Table 3. Composite Brake Block Standard[9]

Properties (Unit)	Value
Density (gr/cm^2)	1.5–2.4
Friction coefficient	0.14–0.27
Hardness (HRR)	68–105
Wear (mm^2/ kg)	5.10^{-4}–5.10^{-3}
Pressure (joules/g.^{0}C)	0.17–0.98
Shear Strength (N/cm^2)	1300–3500
Thermal Conductivity (W/mK)	0.12–0.8

Table 4. Wear Test Result

Test Repetition	Average of b_0 (mm)	Time (minutes)	B (mm)	r (mm)	P_0 (Kg)	l0 (m)	Wear (Ws) (mm^2/Kg)
First	1.034	4.12	3	13.3	2.12	66.6	2.20765×10^{-7}
Second	1.040						2.24631×10^{-7}
Third	1.055						$2{,}34491 \times 10^{-7}$
Average wear value (mm^2/Kg)							$2{,}26629 \times 10^{-7}$

atoms of the two types of amide groups. This bond causes the mechanical properties of nylon to be quite high [11]. In addition, the addition of iron sand which contains a lot of silica increases the hardness of the composite. According to [4], the greater the weight fraction of silica sand, the higher the composite hardness value. This is because silica sand has properties that are harder than the material properties of the composite material if it is not given silica sand (Table 4).

The test results show that the composite wear value is 2,26629 $\times$ 10^{-7} $mm^{2/}Kg$. The standard wear of composite brake blocks for trains shown in Table 3 is 5.10^{-4}–5.10^{-3} $mm^{2/}Kg$. The wear value is the amount of a material that is eroded by the interaction of friction between the sample surface and other surfaces and is given a certain load and distance treatment. The composite wear value that has been made does not meet the criteria for composite brake blocks. This is presumably due to the random orientation of the fibers so that the bond strength of the fibers with the matrix is smaller. So the possibility of the volume of the material being separated from the specimen and the length of the scratches caused by surface contact are getting bigger. This is in accordance with research conducted by [12] that friction material specimens with random fiber orientation variations are known to have the lowest hardness and the highest wear value.

4 Summary

The wear value of the composite with nylon fiber reinforcement that has been made is 2.26629 $\times$ 10^{-7} mm^2/kg. While the hardness value is 88.5 HRR. The hardness value has met the composite brake block standard, while the wear value has not met the standard. In future research, it is hoped that variations in the composition of the composite and fiber orientation can be carried out so that their mechanical properties can be investigated further.

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