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# Identification of Tribological Properties of Vulcanized Rubber Using a Pin on Disc Tribometer for Abrasion Testing

**[1]*Budi Setiyana, [2]Muchammad, [3]Wahyu Dzikri**

[1,2,3]Mechanical Engineering Department, Faculty of Engineering, Diponegoro University, Jl. Prof. H. Soedarto, SH, Tembalang-Semarang 50275, Indonesia

***Abstract* - Vulcanized rubber which is commonly used for vehicle tire material is generally in the form of compound rubber derived from pure rubber reinforced with carbon black and silica. Based on hardness, there are 3 types of compounds on the market, namely hard, medium and soft. This study only discusses the performance of hard compound, soft compound and as a comparison, rubber for carpet materials. The performance that is very important to analyze is the tribological properties of rubber, namely contact capacity and abrasion resistance. For applications in vehicle tires, contact capacity is related to braking capacity while abrasion resistance is related to the age of the tire. The tensile test is carried out first to determine the strength of the material, then the tribological test is carried out using a pin on disc type tribometer. The tribological test was carried out with variations of the indenter (pin), namely ball indenter and blade indenter types with load variations up to a certain number of revolutions. Tests were carried out to find the friction coefficient and rubber wear level during the abrasion test. In general, hard type vulcanized rubber has better abrasion resistance than soft type. But on the other hand, the hard type of vulcanized rubber has a lower friction coefficient or capacity than the soft type.**

***Keywords:*** abrasion, pin on disc, tribology, vulcanization.

## I. INTRODUCTION

Friction is a phenomenon that is often encountered when two objects touch each other. The consequences of friction can vary, for example an increase in surface temperature or surface wear. The phenomenon of friction is often found in the motion of the wheels with the road, shafts with bearings, discs with brake linings and many more. Wear and tear occurs when two objects press against each other and rub against each other. The factors that affect wear are speed, pressure, surface roughness and material hardness. Friction that occurs will generate heat which also accelerates the rate of wear.

The magnitude of the wear level of a material can be tested using a wear test tool, namely a tribometer. Tribometer is the general name given to a machine or device used to perform friction tests which are the subject of tribological studies. There are various types of tribometers such as pin on disc, pin on flat, pin on cylinder, thrust washer, pin into bushing, rectangular flats on rotating cylinder, crossed cylinder, four ball (Mane et al., 2013). The way the pin-on-disc tribometer test tool works is quite simple. The pin functions as an indenter which is generally a harder object than the specimen being tested. The indenter is usually made of metal with a certain shape of the end (Johnson, 1985). The test specimen is made in the form of a disc plate attached to the disc. When operated, the indenter is given a certain load and touches the test specimen which rotates with the disc, causing friction. Continuous friction and pressure will result in wear and tear. Therefore the tribometer is referred to as a wear test tool.

Vulcanized rubber which is commonly used for vehicle tire material is generally in the form of compound rubber derived from pure rubber reinforced with carbon black and silica (Gent, 1992). Based on hardness, there are 3 types of compounds on the market, namely hard, medium and soft. This study only discusses the performance of hard compound, soft compound and as a comparison, rubber for carpet materials. The performance tested is the tribological properties of each rubber compound, namely contact capacity related to the coefficient of friction and abrasion resistance related to wear rate (Zhang, 2004). For its application in vehicle tires, contact capacity is related to braking capacity while abrasion resistance is related to the effective life of the tire (Blau, 2009). Ideally, the tribological properties of a good tire are those with high braking capacity and long life.

## II. MATERIAL AND METHOD

To identify the performance of the rubber compound, the tests carried out are in the form of a tensile test and a tribological test (friction test). The tensile test was carried out to determine the strength of the rubber compound, while the

 

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friction test was carried out to determine the tribological performance of the compound.

### 2.1 Tensile test

The rubber tensile test was carried out on 3 types of rubber materials, namely hard type, soft type and compound rubber for carpets. Each material was tested 3 times and the test was carried out until the test specimen broke. The results obtained are the strength or stress at break and elongation at break. Elongation at break is the ratio of the length of the specimen at break divided by the initial length of the specimen. The size of the tensile test specimen and photos of the rubber tensile testing machine are given in figure 1.

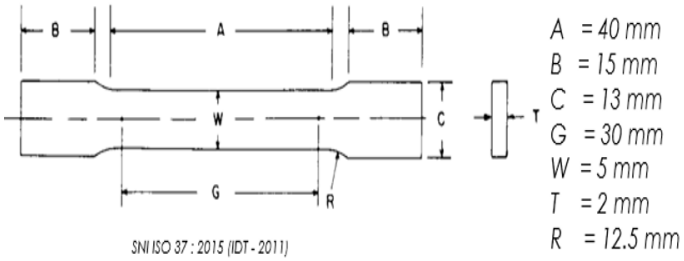
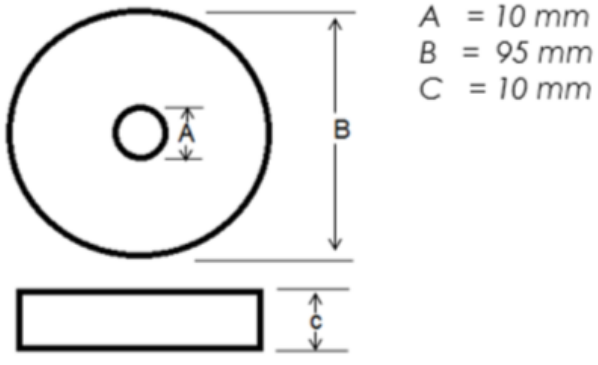



**Figure 1: Dimension of tensile test specimen**

### 2.2 Abrasion test

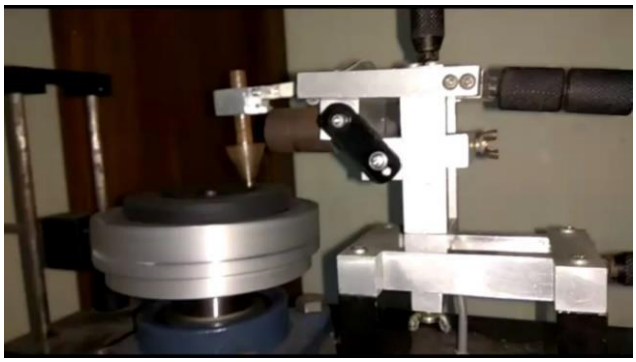
The materials tested were the same as those used for the tensile test, namely hard compound rubber, soft compound rubber and carpet rubber. The dimensions and specimens for the abrasion test or friction test are shown in Figure 2. While the friction or abrasion testing machine (tribometer) and the indenter used are given in Figure 3. The pin is in the form of an indenter with a ball-shaped end and a blade. The ball indenter used has 2 sizes of tip diameter, namely 3 mm and 6 mm in diameter. The selected disc rotation size is 200 rpm, while the loading for the indenter uses 3 loads, namely 100 grams, 300 grams and 500 grams. The test is carried out until the disc has a maximum rotation of 10,000 revolutions.




**(a)**

**(b)** **(c)**

**Figure 2: Data on the dimensions of the test specimen (a) and photos of the abrasion test specimen ball indenter (b) and blade indenter (c)**



**(a)**

**(b)**

**Figure 3: Abrasion tester type *Pin On Disc* (a) and indenter type of ball and blade (b)**

The abrasion test was carried out with various types of rubber material, variations in indenter loads and variations in indenter tip diameter. The data measured for the abrasion test are the friction coefficient and the weight of the rubber lost or peeled off due to wear and tear during the abrasion test. From the data from this test, calculations are then carried out to find the average value of the coefficient of friction, wear rate and abrasion resistance. Only some of the test results are shown here with the aim of looking for the tribological properties of each type of rubber.

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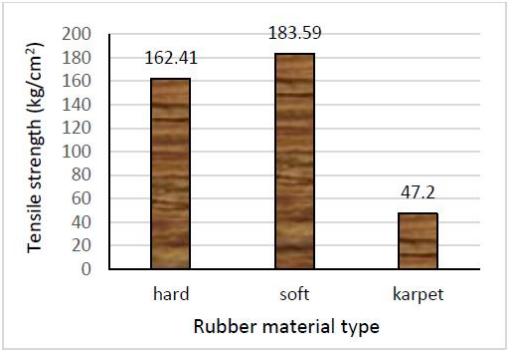
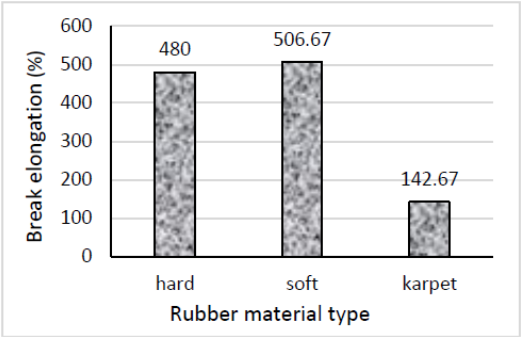
## III. RESULT AND DISCUSSION

### 3.1 Tensile test

The results of the tensile test for the three types of materials are given in Figure 4, in the form of tensile strength and elongation at break. From the figure, we can see that the soft material has the highest tensile strength and elongation at break compared to the hard material and carpet material. In general, it is found that for vulcanized rubber, the soft type material is more elastic than the hard type and also more ductile, because of its high tensile strength. Carpet material has a much different value than hard and soft materials because carpet material has a high hardness and is also brittle, so this material cannot be used as a material for retreading tires.




**(a)**




**(b)**

**Figure 4: Tensile test results diagram, tensile strength (a) and elongation at break (b)**

### 3.2 Coefficient of friction

The value of the coefficient of friction resulting from the friction test or abrasion test is given in Figure 5. The coefficient of friction of the test specimens was obtained from the results of the tribological properties test using a pin-on-disc device in the form of frictional contact between the test material attached to the disc and pins made of ST steel 60. The value of the coefficient of friction is obtained using the friction test software used when the wear test is being carried out. The displayed value is the average value of the test results with variations in load and indenter tip radius. From the graph it can be seen that the material that has the largest coefficient of friction is the soft material, because the soft material is very elastic and soft so it has a wider contact area. This malleability will give a large deformation of the rubber on contact, resulting in a large tangential force as well. This high coefficient of friction will provide strong braking capacity and grip between the tires and the road.

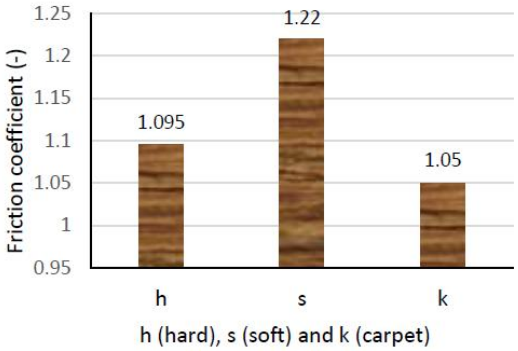



**Figure 5: Diagram of the average coefficient of friction for various materials**

### 3.3 Abrasion test

Abrasion resistance is closely related to the degree of wear that occurs during the abrasion test. In terms of tribology, the terms wear rate, abrasion resistance AR and abradability AA are known (Zhang, 2004). In this study, these parameters were obtained from measuring the weight of the worn rubber parts. The weight of the worn rubber material is obtained by finding the difference in the weight of the specimen before the abrasion test minus the weight of the specimen after the abrasion test (Liang et al., 2009).

In this study, the important parameters analyzed were abrasion factor (AF), abrasionability (AA) and abrasion resistance (AR). The abrasion factor value is given by the following formula,

$$AF = \frac{\Delta W}{N \times L} \qquad (1)$$

Where ΔW is the weight of material lost (grams), N is the indenter load (grams) and L is the path length traveled by the indenter (cm). While abradability (AA) is formulated by,

$$AA = \frac{\Delta W}{f \times N \times L} \qquad (2)$$

Where f is the friction coefficient. Meanwhile, another important parameter is abrasion resistance (AR) defined as follows,

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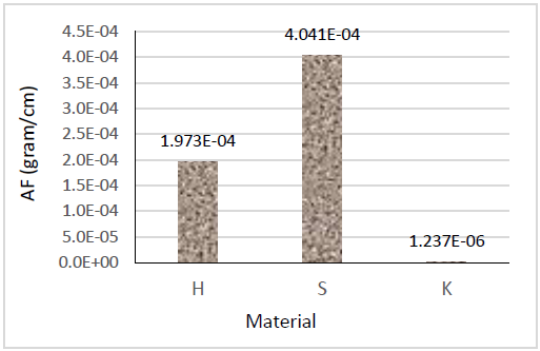
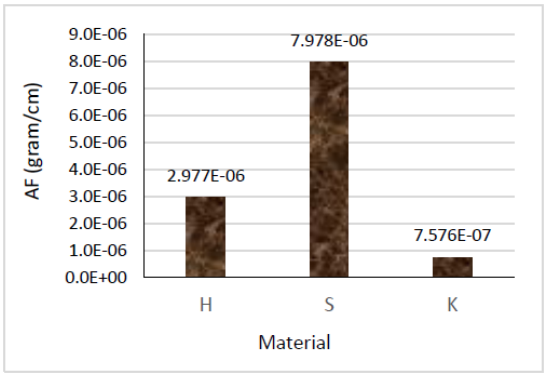
$$AR = \frac{f}{AF} = \frac{f \times N \times L}{\Delta W} \qquad (3)$$

Which is the opposite of the abradability value.

Based on the formulas above, this study will present global results regarding the characteristics of each tested rubber material. The first step is to measure the weight of the missing material by finding the difference in the weight of the specimen before and after being tested. Then calculate the length of the track L from the contact path by multiplying the length around the track by the number of rounds. So with the load data given to the indenter and the coefficient of friction previously obtained, the values for the abrasion factor, abradability and abrasion resistance can be found. The abrasion factor values for the three types of materials are given in Figure 6, specifically only for 500 gram loads. From the figure it can be seen that the AF value is highly dependent on the diameter of the pin. For a small pin diameter, which is 3 mm, the AF value is higher than the 6 mm diameter. The small pin diameter will make the rubber material easier to abrasion.




**(a)**

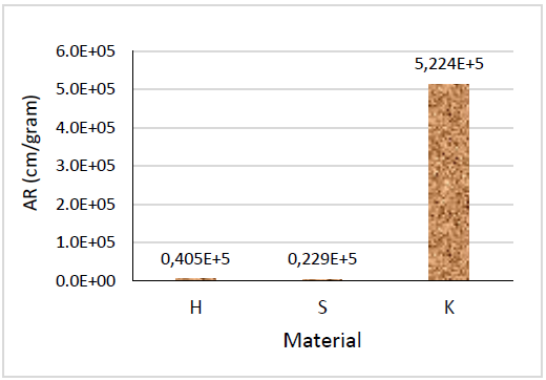



**(b)**

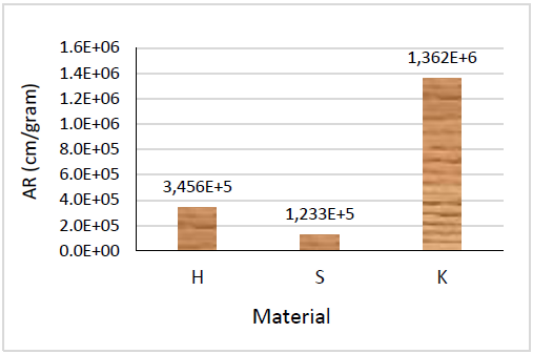
**Figure 6: Graph of the average abrasion factor for various materials at a load of 500 grams**
(For indenter tip radius (a) 3 mm and (b) 6 mm)

From Figure 6 it can be seen that the largest abrasion factor value occurs in soft materials and the smallest is in rubber materials. The abrasion factor shows the weight of material worn (lost) for one unit path length during the abrasion test. The term abrasion factor (AF) is similar to wear rate or wear / abrasion rate. The higher the AF value, the easier the material is to wear or abrasion. The term abradability also has a value that is proportional to the abrasion factor, which is the same value as the abrasion factor divided by the friction coefficient. It can be concluded that the soft type of vulcanized rubber material has a higher wear rate than the hard type, so that the soft material wears out faster than the hard material.

Abrasion resistance or abrasion resistance is the level of resistance of a material to be difficult to experience wear when experiencing abrasion. The higher the value of abrasion resistance, the more difficult it is to wear out. Abrasion resistance (AR) test results are given in Figure 7. This image only displays abrasion resistance for a load of 500 grams. From the figure it can be seen that in general, the highest AR values occur in carpet materials, while for vulcanized rubber, the abrasion resistance of the hard type material is higher than that of the soft type.




**(a)**




**(b)**

**Figure 7: Diagram of the value of abrasion resistance for various materials at a load of 500 grams**
(For indenter tip radius (a) 3 mm and (b) 6 mm)

By looking at the graph above, it can be concluded that materials that have high hardness also have high abrasion

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resistance as well. It can be seen that for the abrasion test with an indenter radius of 6 mm, the carpet material has the highest AR level at 1.362x106 cm/gram, the second material which has the second high AR is hard which is 3.456x105 cm/gram and the soft material has an AR of 1.233x106 cm/gram. Based on the diameter of the pin, a large diameter will provide greater abrasion resistance as well because the pin is more blunt so that the rubber material is difficult to abrasion. On the other hand, sharp pins (3 mm in diameter) tend to reduce abrasion resistance.

### 3.4 Wear pattern of the abraded surface

Figure 8 shows the contours of an abrasive surface or an abrasion-worn surface. The abrasion test was carried out using an blade indenter with a load variation of 100 grams, 200 grams and 300 grams. Loading of 300 grams produces a rougher surface followed by loading of 200 grams and finally 100 grams, this shows that the higher the load given, the higher the level of roughness/wear produced.

(a) (b) (c)

**Figure 8: Abraded surface contours for various indenter loads (a) 100 gr (b) 200 gr and (c) 300 gr**

Based on the results of the tensile test and abrasion test for the three types of rubber material above, it can be understood that the material for carpets is very different from vulcanized rubber. Rubber material for carpets has a very hard but brittle nature, which is indicated by its low elongation at break and high abrasion resistance. The hard type rubber material for vehicle tire material has tougher properties than the soft type which is indicated by low elongation at break, but has better abrasion resistance. But the hard material has less grip than the soft type, so the braking capacity is also less. So the main conclusion is that the hard material is more durable to use but the grip is lower than the soft type material.

## IV. CONCLUSIONS

In the testing process that has been carried out, there are several variations of the test parameters that are carried out, namely load variations, indenter radius variations and material variations. But in general, this paper aims to determine the properties of each type of material tested. Globally, the results obtained from the above tests are as follows:

a) Hard type vulcanized rubber material has a high level of abrasion resistance but has lower grip compared to soft material.
b) Soft materials have high gripping ability but lower abrasion resistance than hard types.
c) Carpet material has the lowest wear rate, because it has a very high level of hardness and is very brittle.
d) The durable vulcanized rubber material for tires is a hard material, while soft materials are good in terms of grip, due to their high coefficient of friction.

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