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Material Strength Analysis on Track Shoe Excavator Using Abrasive Wear Testing Using Pin-on-Disk Method

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Abstract
Undercarriage excavator costs a lot for the maintenance and repair of the overall cost of excavator maintenance and repair. One part of the undercarriage excavator that mostly requires maintenance is the track shoe. Track shoe is the crawler or outer wheel of excavator that serves as an excavator drive. This part is always in direct contact with the soil resulting wear and tear. This research discussed the comparison of track shoe material from the market products and the material that had already been quenching with the medium of water. The material in use was AISI 1526. The analyzing processes used micrography testing, hardness testing, wear and tear testing and corrosion testing. Examination of the microstructure of the sample was conducted using optical microscope, the hardness sample testing was conducted using rockweld hardness tester, wear and tear testing was conducted using pin-on-disk method, and corrosion testing was conducted using potentiodynamic polarization method. From the analysis results, the hardness value for the market product material was 41 HRC and the heat treatment material was 48.33 HRC. The rate of wear and tear for the market product material was 4.02×10^{-5} mm^3/mm and the heat treatment material was 3.30×10^{-5} mm^3/mm. The result of corrosion testing for the market product material was $0.52\frac{mm}{yr}$ and the heat treatment material was $0.38\frac{mm}{yr}$. From the testing results, the hardness value was inversely proportional to the wear and tear and corrosion value; the harder the material, the less the rate of wear and tear.
Keywords: AISI 1526, track shoe, excavator, micro structure, wear and tear testing, hardness testing, corrosion testing, pin-on-disk, potentiodynamic polarization

INTRODUCTION

The more rapidly the development of the era human face, the greater the human need, especially in the field of construction. According to the data of the Ministry of Public Works, it mentioned starting from 2012 there is a big difference between the availability of construction to the needs of construction in Indonesia until 2020 [1]. The graph of the data can be seen in the following Figure 1.

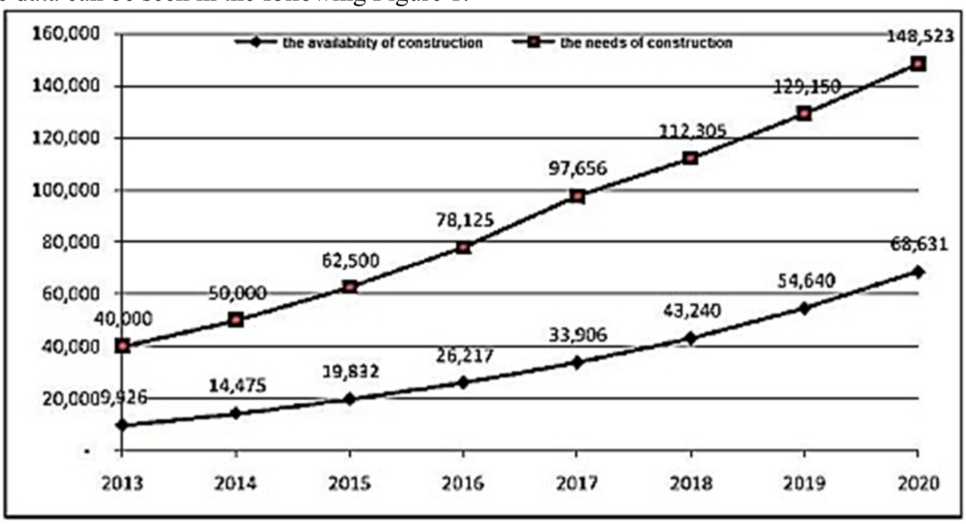


Figure 1: Graph estimation of the availability of construction and the needs of construction in Indonesia until 2020 [1]

The greatest need for construction equipment is the excavator [1]. It can be seen in the following Figure 2 where the excavator is in the blue part of the diagram.

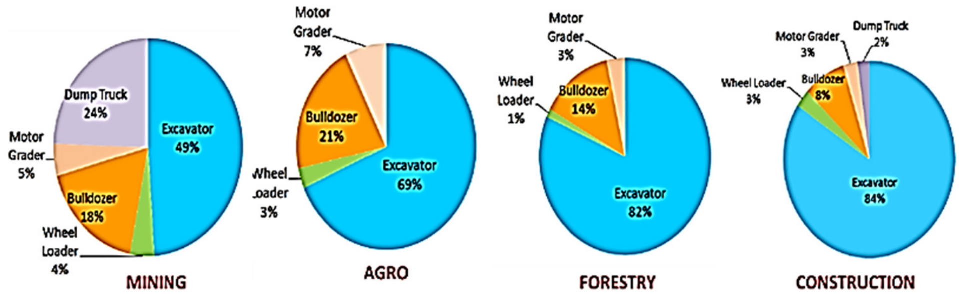


Figure 2: Comparison diagram of the use of heavy equipment in Indonesia [1]

High demand for excavators results in higher maintenance requirements for the excavator. The maintenance aims to reduce the problems in the operational of the excavator. In the United Kingdom, recently, there are many incidents related to excavators, primarily the detachment [2]. The detachment is directly related to the undercarriage/crawler of the excavator [2].

Undercarriage is one of the most common driving tools in construction equipment that serves to move the tractor forward, back, left and right which is usually used on excavators, bulldozers and other construction equipment. Undercarriage runs in a system. High mobility in severe field conditions can lead to damage to the vital part of an excavator drive; it is the chain link [3]. Chain link is a major component of the undercarriage [4-5] and wear and tear on the main chain link component is due to the magnitude of the force that occurs to the excavator while working and the value of material strength that is less suitable for field conditions [6-7].

Undercarriage maintenance and appropriate operational techniques can minimize wear and tear [8]. It also applies to the track shoe in which the track shoe is an undercarriage component that that makes direct contact to the soil. Track shoe is the outermost part of the undercarriage that serves as the "wheel" of the excavator. Track shoe is designed in such a way to be able to withstand the burden of the excavator and withstand the force of the soil when the excavator is running.

John Deere (2007) mentioned that 50% of the largest maintenance costs on excavators are on the undercarriage. In addition, track shoe is one part of the undercarriage that needs more attention because this part is always in direct contact with the soil [8].

Prasetya, in 2014, conducted a research on undercarriage maintenance and overhaul that has been damaged. In his research, he mentioned that undercarriage is part of the excavator that mostly needs maintenance compared to other excavator parts and must be overhauled every 18,000 hours of use [9].

Irfan Maulana et al. (2017) conducted a research on the analysis of undercarriage component damage of Hitachi EX200 excavator using FMEA method. From the results of the research, it was known that the track shoe became one of the undercarriage parts that have the second highest RPN percentage that mostly experience failure right after the sprocket [10].

Based on the author's explanation, there is one main problem along with the increasing needs of excavator in construction and also mining; it is the problem about the maintenance of vital components in excavator. Excavator track shoe is a vital component of the excavator that is in the undercarriage that often experience damage. In this research, the author examined the excavator track shoe or excavator “wheel” to determine better material as the material of making track shoe and the correct method of heat treatment. This research was conducted to find out the mechanical properties of metal, to assess the wear and tear value of track shoe using Pin-on-Disk method and to examine the value of corrosion rate by using potentiodynamic polarization method. The author will compare the track shoe of the author's research with the track shoe found in the market.

MATERIAL AND METHOD

Material

This research used AISI 1526. AISI 1526 is a carbon steel that has the content of Manganese above 1%. This steel consists of 0.22-0.29% C, 1.10-1.40% Mn, 0.040 P max and 0.050 S max. This steel is considered a class boundary because it can be hardened by carburizing or carbonitriding. It allows the use of thinner materials in production processes which save energy and reduce processing costs. Although its carbon content is only 0.26%, the welding process must be performed carefully, since the higher manganese can raise carbon levels to hazard levels; unless pre-heating and post-heating practices are performed. Its casting ability is excellent [11]. Its AISI density 1526 is 7.7 grams/cm^3. The composition of the material used in the research can be seen in Table 1 below.

Table 1: Composition of AISI 1526

Element	C	Si	S	P	Mn	Ni	Cr	Ti	Cu	Al	N	Fe
Composition (%)	0.26	0.27	0.01	0.01	1.24	0.03	0.39	0.05	0.06	0.03	0.02	97.59

According to Callister et al. (2009), steels containing carbon content above 0.25% are considered as medium carbon steels. Therefore, AISI 1526 can be considered as medium carbon steel [12]. In this research, the material was heated to a temperature of 885°C with 1 hour detention. The quenching medium was water. After the hardening process, tempering process was conducted with a temperature of 200°C with 1 hour detention.

Hardness Testing

The hardness testing process was performed by using the Rockwell Hardness Tester. The testing was conducted by taking the sample of 3 points. The specimen used for the hardness testing was beam-shaped with the size of 3x3x1 cm. The aim of the testing was to determine the hardness value of track shoe material from the results of the author's research compared to the hardness value of track shoe material in the market. The hardness value can be used as a reference to determine better track shoe material for use on all terrain, especially hard terrain. The reference can also be used to determine whether the research results and author methods are better than the track shoe material in the market.

Micrography Testing

This process was performed only to compare the microstructure of the material without heat treatment and from the material with heat treatment. There were several steps that must be conducted to get the figure of microstructure:

a. Grinding

The specimen was grinded gradually by using a grinding machine. The grinder ranged from the roughest (100 grit) to the smoothest (2000 grit). Grinding process was conducted to avoid scratches that can make the results of poor micro images.

b. Polishing

Polishing conducted so that the tested specimen was shiny and to reduce the scratches after the grinding process. The tested specimens were given autosol and then rubbed on a velvet fabric.

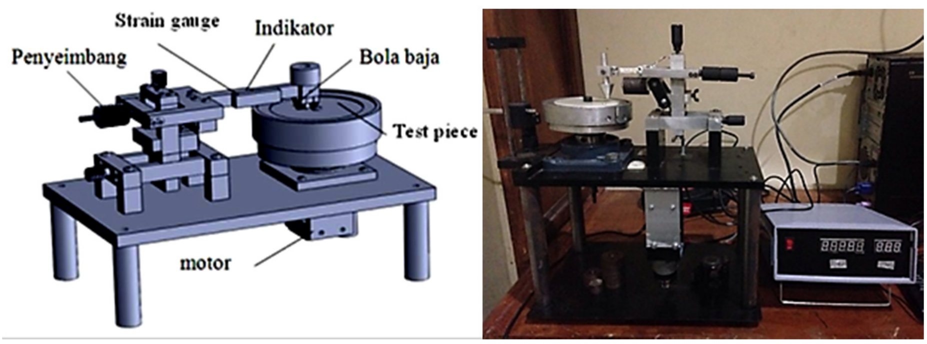
Then, micrography testing was conducted by using OptiLab tool to see the microstructure of track shoe material from the writer's research with track shoe material in the market.

Pin-on-Disk Method

Pin-on-disk is one of the testing methods to determine the rate of wear and tear of a material. Wear and tear that is tested on pin-on-disk is abrasive wear and tear. There are many researchers who used Pin-on-Disk method to test abrasive wear and tear. Nicholas J. Breaux et al. (2002) conducted Pin-on-Disk testing to measure abrasive wear and tear of 4 materials: nylon, aluminum, 401 stainless steel and low carbon steel [13]. J.O. Agunsoye et al. (2012) tested the abrasive wear and tear with a dry sliding contact to measure the effect of heat treatment on high chromium cast iron (NF253AHT) against wear and tear [14]. A. Jourani et al. (2015) tested abrasive wear and tear to measure 316L stainless steel wear and tear with dry sliding contact conditions [15].

KM Mashloosh et al., in 1985, conducted a research on excavator wear and tear by using Pin-on-Disk. In that research, they examined the bucket teeth's persistence by using emery paper as a substitute for the soil in the testing process. The results showed that the larger the force and the faster the disk rotation, the greater the wear and tear [16].

Eko Armanto et al. (2012) designed a Pin-on-Disk tribology testing machine because tribology testing machine is still rare in Indonesia. So far, research is generally focused on simulations [17]. The design of the Pin-on-Disk machine can be seen in Figure 3 below. The researchers conducted this research by using the Pin-on-Disk machine designed by Eko Armanto et al.



(a) (b)

Figure 3: (a) Pin-on-Disk machine designed by Eko Armanto et al. (b) Pin-on-Disk machine

The wear and tear that occurs on Pin-on-Disk type testing is abrasive wear and tear. The amount of lost volume of the abrasive material is the basis for determining the level of material wear and tear. It can be concluded that the bigger and deeper the wear and tear the higher the volume of the abrasive material from the tested specimen. Schematic illustration of the surface contact between revolving disc and pin can be seen in Figure 4 below.

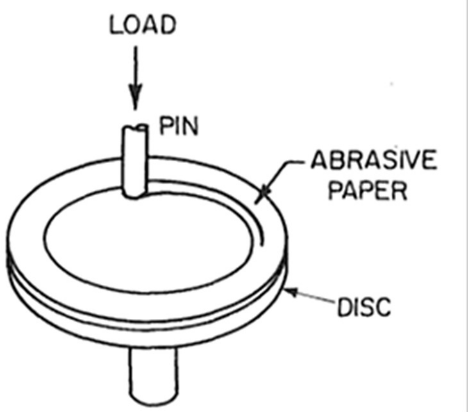


Figure 4: Schematic illustration of the surface contact in Pin-on-Disk testing [18].

Archard, in 1953, proposed an approach model for describing sliding wear and tear. He assumed that the critical parameters in sliding wear and tear were the stress field in contact and the relative sliding distance between the contact surfaces. This model is mostly known as the Archard's wear law [19]. The simplest form of this wear and tear model is:

$$\frac{V}{s} = k.\frac{F_N}{H} \quad (1)$$

$$V = k_D.F_N.s \quad (2)$$

$$V = \frac{m}{\rho} \quad (3)$$

V is the volume of material that is lost due to wear (mm^3), s is the sliding distance (mm), F_N is the normal load (N), H is the hardness level of the material experiencing wear and tear, k is the dimensionless wear and tear coefficient, k_D is the dimension-wear-and-tear coefficient (mm^3/Nm), m is the mass that is lost due to wear and tear (gram) and ρ is the material density ($gram/cm^3$). Wear and tear coefficient of k is a constant to match the calculation between the theory and the testing [19].

For engineering applications, high wear and tear has more advantages over wear volume. Thus, Archard divided both sides of equation (2.1) with the contact area in the A form, so the equation becomes:

$$\frac{h^w}{s} = k_D.p \quad (4)$$

h^w is the level of wear and tear, and p is the contact pressure [19].

Then in 1980, Sarkar modified the Archard wear and tear model with the consideration of friction coefficient between friction surfaces against each other. As discussed earlier, the relationship between the friction coefficient and the rate of wear and tear is more complex. Nevertheless, Sarkar has modified a wear model that linked between the friction coefficient and the lost volume of the material [20]. This wear and tear model was the development of the Archard wear and tear model, which then becomes:

$$\frac{V}{s} = k.\frac{F_N}{H}.\sqrt{1+3\mu^2} \quad (5)$$

μ is the friction coefficient, V is the lost volume of the material due to wear and tear (mm^3), s is the sliding distance (mm), F_N is the normal load (N), H is the hardness level of the material experiencing wear and tear, k is the dimensionless wear and tear coefficient [20].

Pin-on-Disk testing conducted by the author was using a Pin-on-Disk machine made by Eko Armanto et al. [17] with the shape of a cylindrical specimen with one side of the semicircular cylindrical base. The length of the specimen was 12 cm, the specimen's cylindrical diameter was 1 cm, and the semicircle radius on one side of the cylinder was 4 mm. The specimens were tested by giving a friction on a 100 grit silicon carbide (SiC) of 15,000 rounds in which in every thousand rounds the silicon carbide (SiC) were changed to anticipate the wear and tear of the silicon carbide (SiC).

By using Pin-on-Disk testing, the authors compared the results of the rate of wear and tear between the track shoe material from the author's research and the track shoe material in the market. The testing results can be used as a reference to determine which the material is stronger and resistant to wear and tear so that it can extend the life of the track shoe.

Potentiodynamic Polarization

Potentiodynamic polarization is a method for determining corrosion behavior of metals based on potential and anodic or cathodic current relationships. Metal corrosion occurs when there is an anodic current equal to the cathodic current even though there is no current outside the system. It is due to the potential difference between the metal and the solution as its environment [21]. This method can determine the corrosion rate by using a potentiometer of three electrodes; it is the calomel type of reference electrode (SCE), the platinum auxiliary electrode and the working electrode in the form of steel specimens. The data obtained from this method was anodic/cathodic polarization curve which described the relationship between the currents (µA/cm^2) as a potential function (mV).

The corrosion rate testing was performed by observing the intensity of the corrosion current (Icorr) of the specimen in the environment of Sodium Chloride (NaCl). The determination of Icorr pricing is important because Icorr has direct proportion to the magnitude of the corrosion rate of a metal in its environment. The calculations for the corrosion rate of this experiment can be performed by using a method based on the potential curve vs. the log intensity of corrosion current.

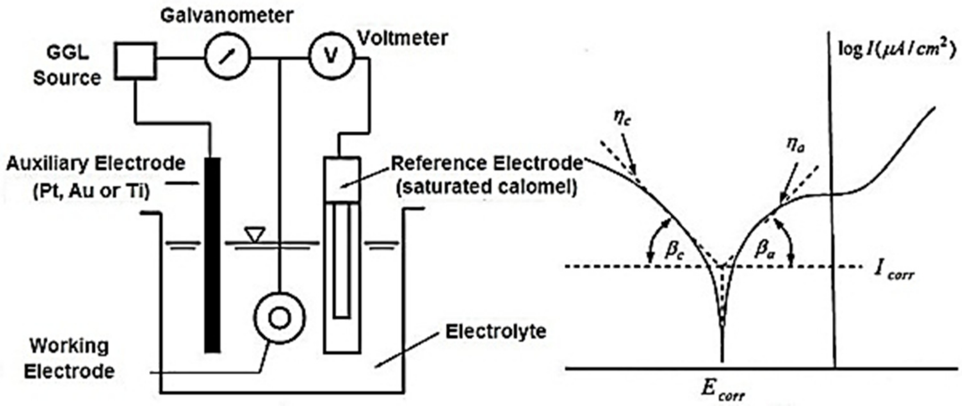


Figure 5: a) Schematic of corrosion test equipment, cell type of three electrodes, b) Polarization curve [22].

The corrosion current density (Icorr) is obtained from the potential curve logarithm of the current intensity curve by determining the intersection point of the reduction reaction tafel line (η_c) and the oxidation reaction tafel line (η_a) on the logarithm of the current intensity by determining the point of intersection of the line reduction reaction tafel (η_c) and the oxidation reaction tafel line (η_a) on the corrosion potential line. The values of η_c and η_a are determined by the following equation [23]:

$$\eta_a = \beta_a log \frac{i_a}{i_0} \quad (6)$$

$$\eta_c = \beta_c log \frac{i_c}{i_0} \quad (7)$$

η_a is the oxidation reaction tafel line, η_c is the reduction reaction tafel line, i_a is the current at the anode reaction, i_c is the current at the cathode reaction, i_0 is the current of the reduction change to the oxidation reaction, β_c is the tafel gradient of the cathode reaction, and β_a is the tafel gradient of anode reaction.

The rate of corrosion rate can be determined by the rate of the density of the corrosion current where the corrosion rates of a metal in its environment is proportional to the corrosion rate of the current density. It is in accordance with the following corrosion rate equation [23]:

$$r = 0,129 \frac{ai}{nD} \quad (8)$$

r is the corrosion rate (mpy), a is the atomic mass or the atomic weight, i is the density of the corrosion current ($\mu A/cm^2$), n is the atomic valence, D is the specimen density (gr/cm^3).

Comparison of corrosion rate for the alloys is firstly calculated by the equivalent weight with the following equation [24]:

$$EW = N_{EQ}{}^{-1} \quad (9)$$

$$N_{EQ} = \sum\left(\frac{\omega_i}{a_i/n_i}\right) = \sum\left(\frac{\omega_i n_i}{a_i}\right) \quad (10)$$

EW is the equivalent weight, N_{EQ} is the total equivalent value, ω_i is the atomic weight fraction, a_i is the atomic mass number, n_i is the atomic valence electron. Thus, the equation of the corrosion rate is:

$$r = 0,129 \frac{i_{corr}(EW)}{D} \quad (11)$$

The above result of the corrosion rate equation is mpy (mils per year). To change the unit it is necessary to convert mpy to matrix unit as the following.

$$1mpy = 0,0254 \frac{mm}{yr} = 25,4 \frac{\mu m}{yr} = 2,899 \frac{nm}{hr} = 0,805 \frac{pm}{sec}$$

By looking at the comparison table of mpy with other matrix units against the corrosion rate in D. A. Jones' book "Principles and Prevention of Corrosion" in 1992, we can determine the properties of corrosion rate of the material; as shown in Table 2 below.

Table 2: Mpy comparison with other matrix units against the corrosion rate [23]

Relative Corrosion Resistance	mpy	mm/yr	µm/yr	nm/h	pm/s
Outstanding	< 1	< 0.02	< 25	< 2	< 1
Excellent	1 – 5	0.02 – 0.1	25 – 100	2 – 10	1 – 5
Good	5 – 20	0.1 – 0.5	100 – 500	10 – 50	20 – 50
Fair	20 – 50	0.5 – 1	500 – 1000	50 – 150	20 – 50
Poor	50 – 200	1 – 5	1000 – 5000	150 – 500	50 – 200
Unacceptable	200+	5+	5000+	500+	200+

The authors' corrosion testing process was performed using the Versastat 4 tool with 3 cathodes. The specimen used in this testing was in cylindrical form by the diameter of 0.8mm and 0.3mm thick. The specimen was placed in a holder and immersed in NaCL in the testing tube. NaCL used was NaCL with 2.98% content. The result of this testing was a tafel chart which is further processed to determine the corrosion current and corrosion rate.

From corrosion testing, the authors compared between the track shoe material from the authors' research and the track shoe material in the market to determine each corrosion rate. Furthermore, from these results, it can be determined the track shoe material that was more resistant to the corrosive conditions caused by moist or wet terrain, conditions with high rainfall and conditions with high corrosive chemical content.

RESULT AND DISCUSSION

Track Shoe Geometry Modeling

The modeling was made on a 1:1 scale with the actual size. Dimensional data including length, width and height were generated by reference to the size of the track shoe dimension that was obtained from the field measurements and Komatsu catalogs. The data obtained were sufficient to meet the parameters that will be the size of the track shoe by using AISI 1526 steel material. Based on the above specifications, the track shoe model can be made by using CAD software. CAD software used for modeling is SolidWorks 2016 as in Figure 6.

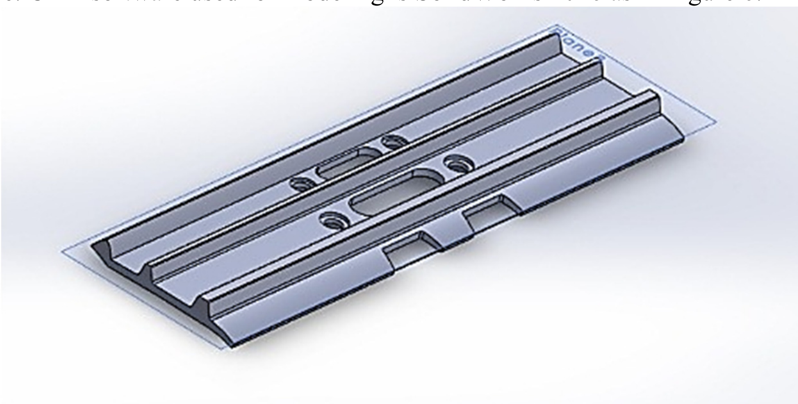
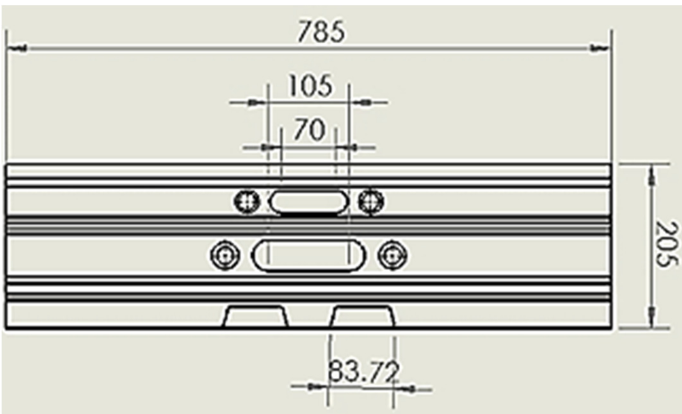
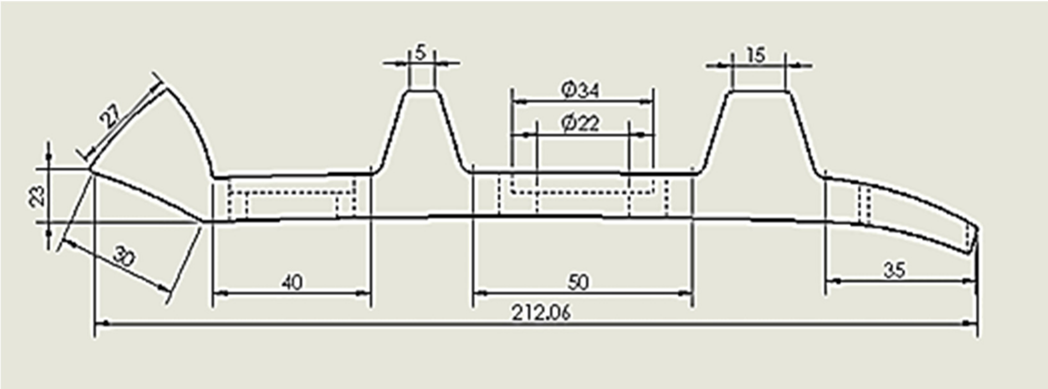


Figure 6: 3-dimensional modeling of the track shoe

The following also shows the size of the track shoe dimension from the top and side of the specification as shown in Figure 7.



(a)



(b)

Figure 7: The size of the track shoe dimension in mm (a) top view (b) side view

The Result of Hardness Testing

Hardness testing of this research was conducted by using hardness testing tool of Rockwell Hardness Tester by using scale C (HRC) and the loading of 150 Kgf by using diamond cone. The testing was conducted on the surface of the specimen. Each specimen had 3 (three) tests and the results are shown in Figure 8.

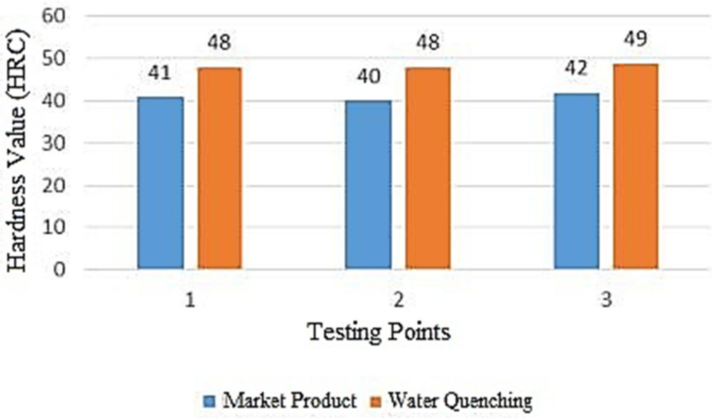
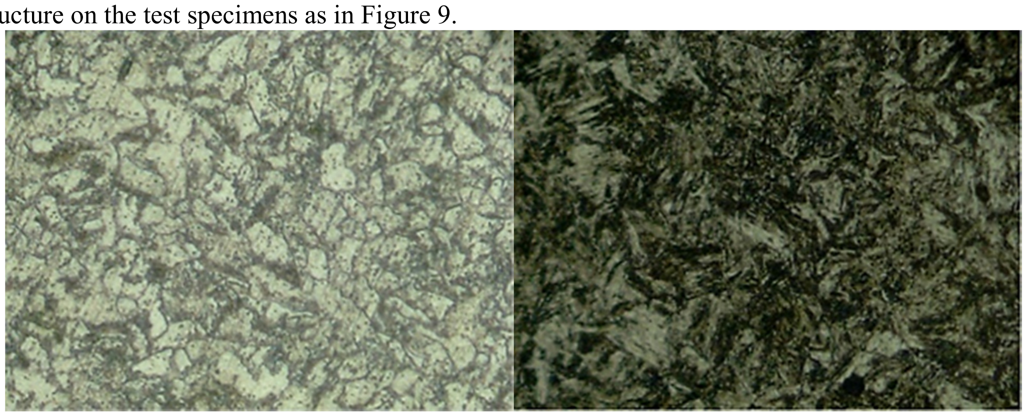


Figure 8: Graph of hardness value

It can be seen on the graph that the hardness level of the quenching material is higher than the product material in the market. Average hardness for market products is only 41 HRC while the material from the quenching result is 48.33 HRC. From the difference of hardness value, it can be seen that the material from the result of the authors' research has better mechanical properties than the track shoe material in the market. The results of this hardness test also greatly affect the results of wear and tear and corrosion testing at further stage.

The Result of Micrography Testing

Microstructure testing was conducted on market product specimens using heat treatment and specimens using water quenching medium. From the results of observations using a microscope, it was obtained the results of microstructure on the test specimens as in Figure 9.



(a) (b)

Figure 9: (a) Microstructure structure of market product (b) Microstructure of specimen after the treatment

From Figure 9 (a), the microstructure of the product market material is ferrite and pearlite while in Fig. 9 (b) the microstructure of the material from the water quenching process has formed a martensite phase.

The Result of Material Wear and Tear (Abrasive Wear) Testing

In this testing process, the load added to the pin was 300 grams and the applied number of cycles was 15,000 rounds in which each 1000 round the engine was turned off to replace the expired Silicon Carbide (SiC) paper. The number of Silicon Carbide (SiC) paper used was 100grit. The sliding speed was 100 Rpm. AISI 1526 (pin) and Silicon Carbide (disk) wear and tear testing specimens can be seen in Figure 10 below.

(a) (b)

Figure 10: (a) AISI 1526 wear and tear testing specimens in the form of pins (b) Silicon Carbide (SiC) in the form of disk

The result of decreasing material mass can be seen in Figure 11.

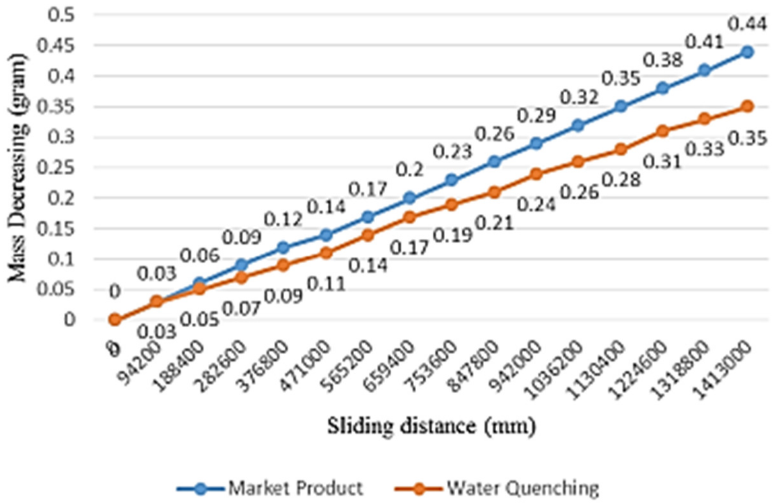


Figure 11: Graph of mass decrease to the sliding distance of AISI 1526 between market products and water media quenching.

Based on the table, the testing of market product materials and the water quenching materials experiencing mass decline of 0.44 grams and 0.35 grams and both showed the results of the average coefficient of friction of 0.064 from the beginning of testing until 15000 rounds. After the mass was converted to volume then the ratio of the decrease in material volume can be seen in figure 12.

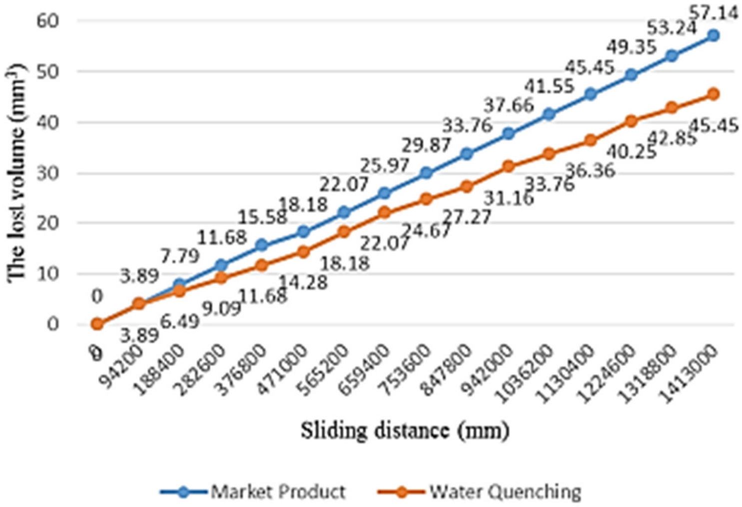


Figure 12: The lost volume graph on the AISI 1526 sliding distance between market products and the products of water quenching.

Based on Figure 12, it can be seen that the product market material had a volume loss of 57.14 mm^3 while the quenching material had a volume loss of 45.45 mm^3. It can be seen on the graph that the product market material was faster in experiencing wear and tear than the quenching material.

The next was looking for the value of the wear and tear coefficient with the formula of Sarkar equation. The load working on the pin was 300 grams to 2.943 N and the friction coefficient was 0.064 based on the test data. The following is the coefficient of wear and tear values that was obtained per thousand rounds that can be seen in Table 3.

Table 3: Coefficient of wear and tear values per thousand rounds

Round Cycle (x1000)	Wear and tear coefficient of AISI 1526 of market product (mm^3/Nm)	Wear and tear coefficient of AISI 1526 of water quenching (mm^3/Nm)
1	$1.39x10^{-5}$	$1.39x10^{-5}$
2	$1.39x10^{-5}$	$1.16x10^{-5}$
3	$1.39x10^{-5}$	$1.08x10^{-5}$
4	$1.39x10^{-5}$	$1.04x10^{-5}$
5	$1.30x10^{-5}$	$1.03x10^{-5}$
6	$1.31x10^{-5}$	$1.08x10^{-5}$
7	$1.32x10^{-5}$	$1.13x10^{-5}$
8	$1.33x10^{-5}$	$1.10x10^{-5}$
9	$1.34x10^{-5}$	$1.09x10^{-5}$
10	$1.35x10^{-5}$	$1.12x10^{-5}$
11	$1.35x10^{-5}$	$1.10x10^{-5}$
12	$1.35x10^{-5}$	$1.08x10^{-5}$
13	$1.36x10^{-5}$	$1.11x10^{-5}$
14	$1.36x10^{-5}$	$1.09x10^{-5}$
15	$1.36x10^{-5}$	$1.08x10^{-5}$
AVERAGE	$1.36x10^{-5}$	$1.11x10^{-5}$

Based on the above table, it can be seen that the average wear and tear rate coefficient for the market product of AISI 1526 is $1.36x10^{-5}$ mm^3/Nm and the product of AISI 1526 with water quenching is $1.11x10^{-5}$ mm^3/Nm. The following is the value of wear and tear rate that was obtained per thousand rounds by looking at the ratio of the volume loss to the sliding distance that can be seen in Table 4.

Table 4: Wear and tear rate per thousand rounds

Round Cycle (x1000)	Wear and tear rate of AISI 1526 of water quenching (mm^3/mm)	Wear and tear rate of AISI 1526 of market product (mm^3/mm)
1	$4.14x10^{-5}$	$4.14x10^{-5}$
2	$3.45x10^{-5}$	$4.14x10^{-5}$
3	$3.21x10^{-5}$	$4.14x10^{-5}$
4	$3.10x10^{-5}$	$4.14x10^{-5}$
5	$3.03x10^{-5}$	$3.86x10^{-5}$
6	$3.22x10^{-5}$	$3.90x10^{-5}$
7	$3.35x10^{-5}$	$3.94x10^{-5}$
8	$3.27x10^{-5}$	$3.97x10^{-5}$
9	$3.22x10^{-5}$	$3.98x10^{-5}$
10	$3.31x10^{-5}$	$4.00x10^{-5}$
11	$3.26x10^{-5}$	$4.01x10^{-5}$
12	$3.21x10^{-5}$	$4.02x10^{-5}$
13	$3.29x10^{-5}$	$4.03x10^{-5}$
14	$3.25x10^{-5}$	$4.04x10^{-5}$
15	$3.22x10^{-5}$	$4.04x10^{-5}$
AVERAGE	$3.30x10^{-5}$	$4.02x10^{-5}$

Based on the above table, it can be seen that the average of wear and tear rate for market product of AISI 1526 is $4.02x10^{-5}$ mm^3/mm and for product of water quenching of AISI 1526 is $3.30x10^{-5}$ mm^3/mm. Based on the data, it can be seen that there was a significant difference in wear and tear rate between the two materials. It can be concluded that bigger the wear and tear rate, the faster the material experiencing wear and tear, and vice versa.

From the results of the above wear and tear testing, it can be seen that the track shoe material of the authors' research results had more wear-resistant properties than the track shoe material in the market. Figures 11 and 12 illustrated a comparison graph between the two materials during the testing. The market track shoe material (blue striped) had a volume loss of 57.14 mm^3 higher than the track shoe material of the authors' research which only had a volume loss of 45.45 mm3. Next, the calculation using the Sarkar method also determined wear and tear rate of both materials where the wear and tear rate of the track shoe material in the market product was $4.02x10^{-5}$ mm^3/mm and the track shoe material of the authors' research was $3.30x10^{-5}$ mm^3/mm. The calculation of the wear and tear rate can be used as a reference to determine the material that experience wear and tear faster from the wear and tear rate of a material. The greater the wear and tear rates of a material the faster the material experiencing wear and tear.

The Result of Corrosion Testing

This corrosion testing aimed to find out the magnitude of corrosion rate value which is expressed in the units of mpy (mils per year). The testing in this research used Potentiodynamic Polarization method where the tested object was inserted into the holder and dipped into the electrolyte solution in the testing tube. The electrolyte solution was NaCl with 2.98% content in accordance with the data of NaCl solution content at Tanjung Mas Semarang port [25].

The following is the corrosion flow data from the testing by using the Potentiodynamic Polarization method as in Table 5.

Table 5: I-corrosion value for market product material and Water Quenching

I-corrosion	
Market Product	Water Quenching
49,298 µA	36,389 µA

After obtaining the data of corrosion flow from the testing, the corrosion flow can be determined from the data by using the equation 11 in which the equivalent weight of AISI 1526 is 24.771, the corrosion rate for the market product is 20.45 mpy and the material of water quenching is 15.10 mpy. If it is converted into matrix units then market product with the value of 20.45 *mpy* turns into 0.52 $\frac{mm}{yr}$ and the material of water quenching with the value of 15.10 *mpy* turns into 0,38 $\frac{mm}{yr}$.

By looking at the comparison table of mpy with other matrix units against the corrosion rate in D. A. Jones' book "Principles and Prevention of Corrosion" in 1992, we can determine the properties of corrosion rate of the material; as shown in Table 2 above.

By looking at the table, we can determine the properties of these materials against the corrosion rate. The market product of AISI 1526 has the corrosion rate value of $0.52\frac{mm}{yr}$ in which showed in the table in the Fair classification of $0.5 - 1\frac{mm}{yr}$. Meanwhile, water quenching result of AISI 1526 has the corrosion rate value of $0.38\frac{mm}{yr}$ in which showed in the table in the Good classification between $0.1 - 0.5\frac{mm}{yr}$. It can be concluded that water quenching product of AISI 1526 has better corrosion resistance than the market product material.

CONCLUSION

Based on the results of the research, it can be concluded that water quenching can increase the strength of a material. By comparing the authors' research material with the track shoe material in the market, there is a significant material strength difference in which the hardness testing value for the market material was only 41 HRC while the water quenching material was 48.33 HRC. The rate of wear and tear for the market product material was $4.02x10^{-5}$ mm^3/mm and the water quenching material was $3.30x10^{-5}$ mm^3/mm. The result of corrosion testing for the market product material was $0.52\frac{mm}{yr}$ and the water quenching material was $0.38\frac{mm}{yr}$. It can be concluded that the track shoe material from the result of the authors' research is better than the track shoe material of the market product.

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