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The Effect of Traffic on Wheel Flange Wear of LRT Jabodebek

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ABSTRACT (10 PT)

Light Rail Transit (LRT Jabodebek) is a light rail train that serves 2 operational crossings, namely Cibubur Line and Bekasi Line. The problem that occurs in Jabodebek LRT is abnormal wheel flange wear. This problem will have an impact on the wheel life to be shorter. Therefore, this study aims to analyze the cross that has the most influence on the wear rate of the Jabodebek LRT wheel flange and find out when turning will be carried out. The flange measurement data obtained from daily and monthly maintenance data will be analyzed using the simple linear regression method. The value of flange wear caused by Lintas Harjamukti-Dukuh Atas of 0.00285 mm in one trip is greater than Lintas Jatimulya-Dukuh Atas of 0.001295 mm. While trainset 1 will be turned after traveling 117,962 km or 3944 trips, trainset 2 will be turned after traveling 74,061 or 2424 trips, trainset 13 will be turned after traveling 237,295 km or 7908 trips, trainset 18 will be turned after traveling 85,911 km or 2707 trips. Therefore, the Harjamukti-Dukuh Atas section has a greater influence on the wear that occurs compared to the Jatimulya-Dukuh Atas section.

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1. INTRODUCTION

Jabodebek Light Rail Transit (Jabodebek LRT) is an integrated train transportation mode that moves on cross-rail lines in the Jakarta, Bogor, Depok, and Bekasi areas. Jabodebek LRT has 2 cross lines connecting Jatimulya Station - Dukuh Atas Station and Harjamukti-Dukuh Atas Station. The Jabodebek LRT construction involves four BUMNs including PT Adhi Karya, PT Len Industri, PT Industri Kereta Api, and PT Kereta Api

Indonesia [1]. This Jabodebek LRT train is a domestic product train, more precisely made by PT INKA. Jabodebek LRT consists of 6 trains per trainset. Consists of 4 driving trains and 2 trailer trains in the order MC1, M1, T1, T2, M2, MC2. Jabodebek LRT covers a distance of approximately 29 km from the Jatimulya - Dukuh Atas cross and the Harjamukti- Dukuh Atas cross approximately 25 km [2].

Maintenance and inspection are necessary to create a safe, reliable, and comfortable facility. Railways facilities function to move the mass from one place to another [3]. The transfer needs a wheel component as a driving medium that will be in direct contact with the railways. The train wheels play a role in supporting the train load including the load of carbody components and passengers. In addition, the wheels will also rub against the rail head when the train is running which will cause wear on the wheels and rails. Based on technical specifications, Jabodebek LRT wheels have a minimum diameter tolerance of 700 mm and a minimum flange wear of 8 mm [4].

The Jabodebek LRT cross-track has 24 curves with a radius of <300m. so friction with the rail will be more dominant in the flange area. This will cause the flange area to rub continuously with the rail which will result in high wear. This statement is evidenced by the wheel flange wear rate data on trainset 05 bogie 1 axel 2 and wheel number 3 before lubrication of the wheels shows the wheel flange thickness data on the 29th, 30th, and 31st respectively are 27.7; 26.9; 26.1 [5]. From this data, it is known that the thickness of the wheel flange decreases by 0.8 mm every day. This reduced thickness can certainly make the train unreliable in operation.

Wheels that do not meet the standards will be turned to form a new wheel profile. The turning done will certainly reduce the diameter of the train wheel. The more frequent the turning, the less the wheel life. Turning on Jabodebek LRT has experienced a turning queue. This happens because many trainsets have reached the limit of flange wear.

Jabodebek LRT is a train transportation mode that uses the Grade of Automation (GoA) 3 system known as DTO / Driverless Train Operation [6] and has a power source of 750 VDC. Jabodebek LRT consists of 6 (six) trains with the following configuration:

Figure 1 Jabodebek LRT Facilities

Description:

MC : Motor cabin car (train with control cabin and motor)

M : Motor car (train with motor)

T : Trailer car (train without motor)

This configuration is not separable or interchangeable but can be coupled with Jabodebek LRT trainsets for Rescue Train purposes.

Wheels are train components that receive the rotating force from the gearbox so that the train can move. Based on PM No. 175 of the Year 2015, the train wheels must have a lower hardness than the railroad. This is so that the rails do not wear out quickly, which can cause faster rail replacement.

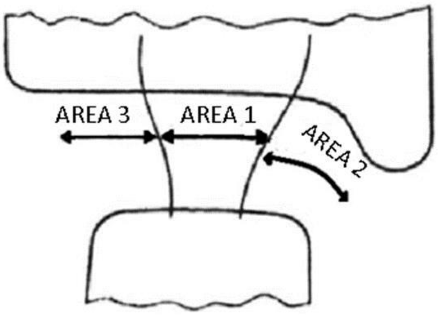

Figure 2 Wheel Contact Points

In the picture above area 1 is called the tread, area 2 is called the flange, and area 3 is called the chamfer which is useful for facilitating the wheel when passing through the arch. The specifications for the Jabodebek LRT wheels are in Table 1.

Wear is by definition the reduction of several layers on the surface of the material due to frictional forces that occur between the surface of a solid object and the surface of another object [7].The mechanism of wear can generally be explained as contact between two surfaces on an object. The result of the contact between these two surfaces is that the coating on the surface will gradually decrease due to the friction force on the two surfaces of the object. Therefore, the greater the pressure on the surface, the faster the material wears, and vice versa. As the train moves through the arch the inner wheel flange rubs against the rail, causing wear and tear.

Table 1 Jabodebek LRT Wheel Specifications

No	Parameter	Description
1	Weight	265.2 kg
2	Width	135 mm
3	New Diameter:	New: 780 mm Wear: 700 mm
4	Material	ER7 according to EN 13262
5	Flange:	New: 32 mm Wear: 24 mm

The track on the railways is a path consisting of an arrangement of railway plots and is useful for coordinating the course of the train. The railway track is not always straight, but under certain conditions or to change direction on the free crossing is forced to be curved. To produce travel comfort when passing through the curve, it is generally preceded by a transitional curve [8]. The curve itself is divided into 3 types, namely horizontal curves, vertical curves, and bridge curves.

Wheel Diameter is a tool used to measure the diameter of wheels in railway facilities. Wheel diameter in testing railways facilities is used as a measuring tool for wheel diameter. Because the wheels are constantly in contact and rubbing against the rail, this causes wear and tear on the wheels. This test is used to determine whether the wheels are worn or still suitable for use [9].

Figure 2 Wheel Diameter

The operation of this tool is as follows:

1. First clean the surface of the wheel from dirt that is attached.
2. Place the tool on the wheel surface following the shape of the wheel surface.
3. Make sure the magnetic plate is perfectly attached to the wheel ridge.
4. Make sure the three legs are perfectly attached to the wheel ridge.
5. Press the red “power” button, and this button also serves to reset the data displayed during wheel diameter measurement.
6. Press the green button to display the wheel diameter results.
7. If so, remove the tool and press the red button to reset the data. It is recommended to take three measurements on one wheel at each different point to get more accurate data results.

Simple linear regression is an equation that describes the relationship between independent variables (X) and one dependent variable (Y) [10]. For parameter estimation, a simple linear regression model containing one independent variable will obtain a simple linear regression equation mathematically formulated:

$$\mathbf{Y = a + bX}$$

Description:
Y = dependent variable
a = Constant
b = Regression coefficient
X = Independent variable

According to [11], normality testing can be a test that aims to determine the distribution of data and information or variables, whether the information is normally distributed or not. This test can be used with SPSS software with a sig value indicator> 0.05 called a normal distribution. According to [12] convey the Shapiro-Wilk test is generally used limited to samples of less than 50 to produce accurate decisions.

The linearity test procedure is used to determine whether the distribution of research data is linear or not. The aim is to show whether or not there is a direct relationship between the independent variable and the dependent variable. The results of the linearity test determine the choice of linear regression data analysis techniques that can be used or not [13].

2. RESEARCH METHOD

The method used for data collection is direct observation and measurement with data collection techniques divided into two activities, including Primary Data which measures wheel diameter and wheel flange measurements of Jabodebek LRT from January 2024-April 2024 on trainsets 1, 2, 13, and 18 using wheel diameter and wheel profile gauge tools. Secondary Data which includes Jabodebek LRT line data, Jabodebek LRT trainset mileage data, Jabodebek LRT operation pattern data from January 2024 to April 2024, and Jabodebek LRT wheel specifications.

Data processing is done by collecting data by grouping data into tables to be categorized using Microsoft Excel software based on the type of variable that is related. In this study, the operating pattern and distance traveled are independent variables while the dependent variable is the wheel flange size. Then the data will be analyzed using the normality test and linearity test using SPSS 26 software. If the data results pass the normality and linearity test, it will be continued with a simple linear regression test on SPSS 26.

The final stage after processing the data is to analyze the data to determine the results of the research that has been carried out by determining the conclusions of the analysis process that has been carried out. There are several pieces of data to analyze, namely cross data against the wheel flange and mileage data against the wheel flange. Interpretation of regression test results is used to predict future possibilities. The results of the simple linear regression analysis on SPSS 26 are interpreted to answer the problem formulation in this study.

3. RESULTS AND DISCUSSION

3.1 *Wheel Flange Wear Analysis Based on Distance Traveled*

One Jabodebek LRT trainset has 48 wheels with each train having 8 wheels. The wheels will be grouped based on the right and left wheels. The right wheel is 24 and the left wheel is 24, but the 24 wheels will be analyzed by taking the average or mean value of the wheel flange thickness measurement. The wheel flange wear rate can be seen in Figures 5 and 6 below:

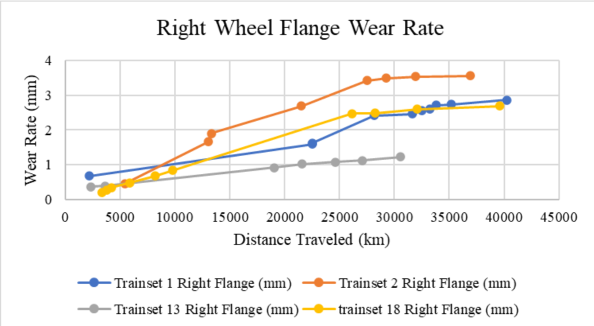

Figure 5 Right Wheel Wear Rate

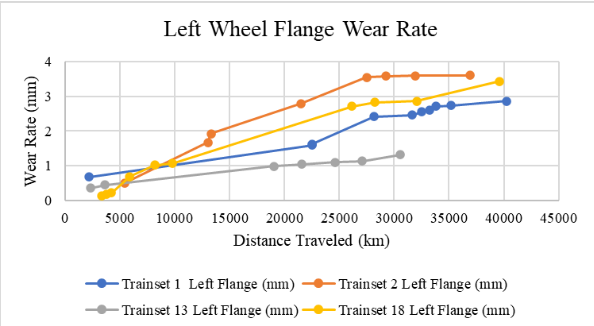

Figure 6 Left Wheel Wear Rate

Judging from the graph above, trainset 13 has the lowest right wheel flange wear rate, followed by trainset 1 then trainset 18, and trainset 2. Trainset 2 has the highest wear rate compared to the other three trainsets. This shows that there are factors that influence the difference in the wear rate of each trainset.

3.2 *Regression Test Results of the Effect of Mileage on Wheel Wear*

The following are the results of simple linear regression calculations of the four trainsets contained in the following table:

Table 2 Right Wheel Flange Regression Equation

Variable	Regression Equation
Trainset 1	Y = 0,416 + (6,414 x 10^-5)X
Trainset 2	Y = 0,318 + (1,017 x 10^-4)X
Trainset 13	Y = 0,294 + (3,153 x 10^-5)X
Trainset 18	Y = 0,042 + (7,822 x 10^-5)X

Table 2 Left Wheel Flange Regression Equation

Variable	Regression Equation
Trainset 1	Y = 0,159 + (6,647 x 10^-5)X
Trainset 2	Y = 0,342 + (1,034 x 10^-4)X
Trainset 13	Y = 0,314 + (3,239 x 10^-5)X
Trainset 18	Y = 0,018 + (9,291 x 10^-5)X

To find out how far the trainset mileage can be traveled before turning, it is necessary to know the maximum limit of wear on the wheel flange. According to Ministerial Regulation Number 24 of 2015 concerning "Railway Safety Standards" the wheel flange has a maximum flange wear limit of 8 mm. So that later the value of 8 mm will be substituted in the equation in the Y value.

a. Trainset 1

The following is the calculation of the simple linear regression equation:

Right Wheel Flange

Y=0.416 + (6.414 × 10^(-5))X

8= 0,416 + (6,414 × 10^(-5))X

X= (8-0,416)/(6,414 × 10^-5)

X= 7,584/(6,414 × 10^-5)

X = 118.241 km

Left Wheel Flange

Y=0.159 + (6.647 × 10^(-5))X

8= 0,159 + (6,647 × 10^(-5))X

X= (8-0,159)/(6,647 × 10^-5)

X= 7,841/(6,647 × 10^-5)

X = 117,962 km

Trainset 1 will perform turning after traveling 117,962 km. The trainset 1 flange wear per km is 0.0000678 mm/km (6.78×10^(-5) mm/km).

b. Trainset 2

The following is the calculation of the simple linear regression equation:

Right Wheel Flange

Y=0.318 + (1.017×10^(-4))X

8= 0,318 + (1,017 × 10^(-4))X

X= (8-0,318)/(1,017 × 10^(-4))

X= 7,682/(1,017 × 10^(-4))

X = 75,535 km

Left Wheel Flange

Y=0.342 + (1.034 × 10^(-4))X

8= 0,342 + (1,034 × 10^(-4))X

X= (8-0,342)/(1,034 × 10^(-4))

X= 7,682/(1,034 × 10^(-4))

X = 74,061 km

Trainset 2 will perform turning after traveling 74,061 km. The trainset 2 flange wear per km is 0.000108 mm/km (10.8× 10^(-5)mm/km).

c. Trainset 13

The following is the calculation of the simple linear regression equation:

Right Wheel Flange

Y=0.294 + (3.153 × 10^(-5))X

8= 0,294 + (3,153 × 10^(-5))X

X= (8-0,042)/(7,822 × 10^(-5))

X= 7,958/(7,822 × 10^(-5))

X= 244.402 km

Left Wheel Flange

Y=0.314 + (3.239 × 10^(-5))X

8= 0,314 + (3,239 × 10^(-5))X

X= (8-0,018)/(9,291 × 10^(-5))

X= 7,982/(9,291 × 10^(-5))

X= 237,295 km

Trainset 13 will perform turning after traveling 237,295 km. The trainset 13 flange wear per km is 0.0000337 mm/km (3.37×10^(-5) mm/km).

d. Trainset 18

The following is the calculation of the simple linear regression equation:

Right Wheel Flange

Y=0.042 + (7.822 × 10^(-5))X

8= 0,042+ (7,822 × 10^(-5))X

X= (8-0,042)/(7,822 × 10^(-5))

X= 7,958/(7,822 × 10^(-5))

X= 101.738 km

Left Wheel Flange

Y=0.018 + (9.291 × 10^(-5))X

8= 0,018 + (9,291 × 10^(-5))X

X= (8-0,018)/(9,291 × 10^(-5))

X= 7,982/(9,291 × 10^(-5))

X= 85.911 km

Trainset 18 will perform turning after traveling 81,076 km. Meanwhile, the trainset 18 flange wear per km is 0.0000986 mm/km (9.86 × 10^(-5) mm/km).

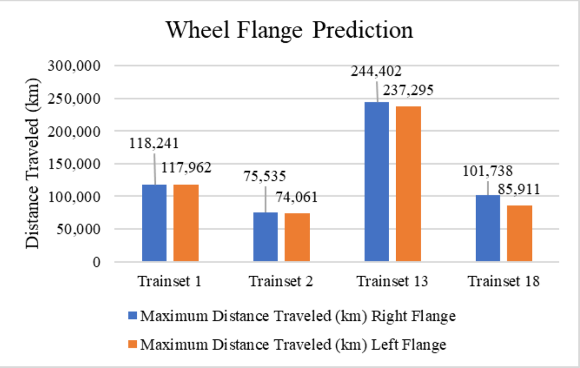

Figure 7 Diagram of Wheel Flange Prediction Results Against Mileage

From Figure 7, trainset 2 has the shortest mileage which indicates the wheel flange wear experienced by trainset 2 is greater than the three trainsets. While trainset 13 has the longest mileage which indicates that trainset trainset 13 experiences small wear compared to the other three trainsets.

3.3 *Relationship of Trainset Operation Frequency to wear and tear*

The Jabodebek LRT trainset operating frequency will be taken based on the date of measurement which will be accumulated and regressed with the wear that occurs. The wear of the right wheel flange and left wheel flange will be averaged to facilitate the calculation of trainset operations. There are 2 trainset operations including Jatimulya - Dukuh Atas and Harjamukti -Dukuh Atas. The results of the simple linear regression test of the number of trainset trips on flange wear can be seen in the table below:

Table 4 Regression Equation of Operating Frequency

Variable	**Regression Equation**
Trainset 1	Y= 0,112+ 0,002x
Trainset 2	Y= 0,728+ 0,003x
Trainset 13	Y= 0,092+ 0,001x
Trainset 18	Y= -0,123+ 0,003x

a. Trainset 1

The calculation of the regression equation is as follows:
Y=0.112+0.002X
8= 0,112 + 0,002X
X= (8-0,112)/0,002
X= 7,888/0,002
X= 3.944 Trips
Trainset 1 will be turned after 3,944 trips.

b. Trainset 2

The regression equation calculation is as follows:
Y=0.728+0.003X
8= 0,728 + 0,003X
X= (8-0,728)/0,003
X= 7,272/0,003
X= 2.424 Trips
Trainset 2 will be turned after 2,424 trips.

c. Trainset 13

The regression equation calculation is as follows:
Y=0.092+ 0.001X
8= 0,092+ 0,001X
X= (8-0,092)/0,001
X= 7,908/0,002
X= 7.908 Travel
Trainset 13 will be turned after making 7,908 trips.

d. Trainset 18

The regression equation calculation is as follows:
Y= -0.123+ 0.003X
8 = -0,123+ 0,003X
X= (8+0,123)/0,003
X= 8,123/0,003
X= 2.707 Trips

Trainset 18 will perform turning after making 2707 trips. All the results of the above calculations are contained in the following figure:

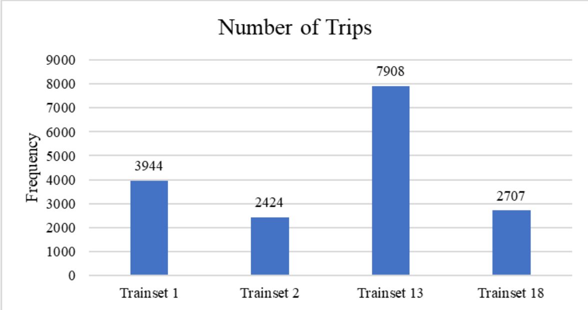

Figure 8 Trainset Frequency Chart

3.4 *Analysis of the Effect of Traffic on Jabodebek LRT Wheel Flange Wear*

The effect of the cross will be sought by comparing the number of trainset trips in one cross to the wear that occurs. Cross A (JTM-DKA) and Cross B (HAR-DKA). The comparison results are obtained from the calculation of the operating frequency against the wear that occurs in one trip. The calculation results can be seen in the table below:

Table 5 Cross Wear

Variable	Line A	Line B
Trainset 1	0,00125 mm	0,00281 mm
Trainset 2	0,0016 mm	0,00293 mm
Trainset 13	0,00108 mm	0,00262 mm
Trainset 18	0,00125 mm	0.00285 mm
Mean	0,001295 mm	0, 00285 mm

The table above shows the effect of Cross A and Cross B on the wear of the Jabodebek LRT wheel flange. Trainset 1 in the calculation obtained the wear value in making one trip on Cross A of 0.00125 mm and Cross B of 0.00281 mm. Trainset 2 obtained wear on Cross A of 0.0016 mm and Cross B of 0.00293 mm, Trainset 13 on Cross A obtained 0.00108 mm and Cross B of 0.00262 mm, and Trainset 18 obtained on Cross A of 0.00125 mm and Cross B of 0.00285. From the four trainsets, the average value of Cross A is 0.001295 mm and Cross B is 0.00285 mm. The value of Cross B is greater than Cross A which indicates that Cross B is higher in causing wear of the Jabodebek LRT wheel flange.

4. CONCLUSION

Based on the results of data analysis, there is a significant relationship between traffic and wheel flange. Based on the data obtained, Cross B (Harjamukti-Dukuh Atas) has a greater influence than Cross A (Jatimulya-Dukuh Atas) on the flange wear that occurs. This is evidenced in the calculation of the relationship of mileage to flange wear and the relationship of operating patterns to the maximum number of trips on trainsets 1, 2, 13, and 18 correlates with the Jabodebek LRT cross. In the calculation, the value of flange wear arising when passing Cross A (Jatimulya-Dukuh Atas) in one trip is 0.001295 mm and Cross B (Harjamukti-Dukuh Atas) is 0.00285 mm in one trip.

Based on the data obtained, trainset 1 will be turned after traveling 118,484 km or 3809 trips, trainset 2 will be turned after traveling 74,061 km or 2424 trips, trainset 13 will be turned after traveling 237,295 or 7908 trips, and trainset 18 will be turned after traveling 85,911 km or 2707 trips. The fastest trainset to be turned later is trainset 2 and the longest trainset is trainset 13. The larger the trainset through Cross B (Harjamukti-Dukuh Atas) the faster the turning.

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