THE EFFECT OF AIR PRESSURE IN THE ELECTRIC TRAIN’S (KRL) BRAKING SYSTEM ON WHEEL DAMAGE

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Abstract. A flat wheel is a kind of wheel damage occurring when the train wheels are dragged along the rail as the axle wheel’s rotation stops. The wheels will skid when the brake block force is greater than the train force. The equation for the wheel skid is (F\text{brake} > F\text{train}), this applies when the wheels stop rotating, but the train still moves so that a flat spot may appear. This study finds that the electric trains from the JR 205 series has many flat spots on its wheels are the M trains (70%). It also reveals that the percentage of the brake block pressure in the unloaded KRLs is 130.4%. Provided that η > η_{\text{max}} (100%), this condition does not meet the standard of the International Union of Railway or Union Internationale des Chemins de Fer (UIC). If the percentage of the brake block pressure (η) exceeds 100%, the braking force will be greater than that of the axle load and this causes the skid. To overcome this condition, rechecking the braking force and providing additional equipment are needed to assure that the air pressure is controlled.

Keywords: flat wheel, air pressure, maintenance.

1. Introduction

With regard to Law No. 23 of 2007 concerning Railways, the type of railway facilities consists of locomotives, trains, carriages, and special equipment. The locomotive consists of those with electric and non-electric drives. Trains consist of locomotive-drawn trains and trains with their own electric and non-electric propulsion [4] [7].

Electric trains, or so called KRL in Indonesia, is either an electric-powered or self-propelled train. In each train set, multiple carriages are linked together with 8, 10, or 12 units of train. One train set consists of two types of trains, namely the rail motorcar (MC) and cabin trailer (CT). The arrangement of circuits in one train set is fixed, meaning that the arrangement cannot be changed or replaced by another type of train. Thus, when damage occurs, the entire circuit must not be operated [1] [2].

The train components, based on the Ministerial Decree No.41 of 2010, consist of the basic frame, body, bogie, coupling equipment, braking equipment, and safety equipment. Bogie or truck is a construction consisting of 2 (two) wheels or more combined with a bogie frame that is equipped with a
braking system and a system of reinforcement with or without a drive, and as a whole they serve to support the basic frame of the railway facilities [3].

Bogie is equipment used to support the body of the train. In the bogie, other equipment also integrates, namely, the wheel, suspension, brake cylinder, and the leveling valve. The type of bogie used in KRL is the bolsterless one. As the function of the bogie is imperative in a train, things that can cause its damage need to be studied as the causes of the train crash or derailment come from the bogie. On the JR 205 KRL series, one of the problems that occur in the bogie is the flat wheel that can cause derailment [4] [5].

2. Method
In this study, the primary data were collected through direct observation of the conditions of the KRL’s flat wheels and KRL’s braking systems. Then, the secondary data in the form of check sheets, technical specifications, SOPs and other supporting data were obtained through literature review. This method examines the transportation literature, especially journals, laws, and regulations related to railway transportation, such as the ministerial and government regulation and the railway law [6].

After being collected, the data were analyzed by means of the Fishbone Diagram. The Cause and Effect Diagram becomes a helpful tool to identify, sort, and display various possible causes of particular problems or characteristics of a certain quality. This diagram illustrates the relationship of a problem with all possible factors. Regarding this, to determine the effect of air pressure on the braking system, the following formulas are employed.

2.1 Determining the Braking Force [8]
2.1.1 The ratio of the brake-rigging arm
Brake rigging is the arrangement of the brake arms from the brake cylinder to the brake block. It has a certain arm length ratio, so that the force from the brake cylinder will be enlarged to the brake block, then a greater compressive force will be obtained. In the JR 205 KRL, the brake rigging’s function is the same as that of J-Relay Valve, and the ratio is 1:1.

\[
\text{i} = i_a \times \frac{a}{b}
\]

Where:
- \(i\) = Ratio of the brake-rigging arm length
- \(i_a\) = Number of the brake block pairs
- \(\frac{a}{b}\) = Arm length ratio

Source: Maintenance Instructions, Nippon Saryo, 1982

- Piston Force (\(F_k\)) [8]

\[
F_k = (A_e \times p_{\text{max}}) \times 10 - F_f
\]

Where:
- \(F_k\) = Piston Force
- \(A_e\) = Brake cylinder volume
- \(p_{\text{max}}\) = Maximum force
- \(F_f\) = Spring force

- Total brake blockforce (\(P\)) [8]

\[
P = \frac{F_k \times i_a \times \eta}{i \times i_a \times \eta}
\]

Where:
- \(P\) = Total brake block force (N)
- \(F_k\) = Piston force (N)
- \(i\) = Ratio of the brake-rigging arm
- \(\eta\) = Efficiency formula (%)
- \(i_a\) = Number of the brake block pairs
- \(F_f\) = Slack adjuster force (N)
**2.2 Determining the brake load** [8]

To calculate the brake load (B) of a passenger train, the following formula applies:

\[ B = P \times K \]

Where:
- B = Brake load (kg)
- P = Total brake block force (N)
- K = Constanta

| Brake block force (kg) | 750 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 5000 | 6000 |
|------------------------|-----|------|------|------|------|------|------|------|------|------|
| K                      | 1.58 | 1.50 | 1.37 | 1.27 | 1.19 | 1.13 | 1.10 | 1.04 | 0.99 | 0.91 |

*Source: UIC Standard*

**2.3 Determining the Braking Efficiency** [8]

Braking efficiency (\( \lambda \)) is expressed as a percentage (%).

For one train vehicle:

\[ \lambda = \frac{B}{G_r} \times 100\% \]

For the whole train set:

\[ \lambda = \frac{\sum B}{G_r(tot)} \times 100\% \]

*Source: UIC Standard*

For unloaded trains: Braking efficiency (\( \lambda \)) max = 120%
For fully loaded trains: Braking efficiency (\( \lambda \)) min = 50%

**2.4 Determining the percentage of brake block pressure** (\( \eta \))

The percentage of brake block pressure (\( \eta \)) is the ratio between the amount of the brake block force and the axle load and is expressed as a percentage (%). The maximum percentage of brake block...
pressure is 100%. If it exceeds, the wheel will stop moving or be blocked, causing a flat on the wheel. To calculate the percentage of brake block pressure ($\eta$), the following formula applies [8].

$$\eta = \frac{P}{G} \times 100\%$$

Where:
- $\eta$ = The percentage of brake block pressure (%)
- $P$ = Total brake block force (N)
- $G$ = Axle load (kg)

In fully loaded trains/carriages, the percentage of the brake block pressure will decrease because the brake block force ($P$) is fixed while the axle load ($G$) increases due to the added load. Thus, the $\eta$ maximum equals to 100%, and the $\eta$ minimum is 80%.

3. Results and Discussion

Based on the data, the flat wheel occurs in 38.9% of the total KRL, and most of them (62.9%) occur in the JR 205KRL series. The M trains experience most of the flat wheels (34 trains). Of the 34 M trains, 18 of them are M1 and 16 are M2 trains. To determine the effect of air pressure on the flat wheels of the JR 205 KRL series, some calculations were performed to determine the total brake block force or single brake block force. First, things to calculate are:

| a. Total brake block force ($P$) | b. Single brake block force ($D$) |
|---------------------------------|---------------------------------|
| 1) Train Tc and T               | c. Train Tc and T               |
| 2) Train M1                     | d. Train M1                     |
| 3) Train M2                     | e. Train M2                     |

3.1 Calculating the Brake Load ($D$)

Brake load is the multiplication between factor ($P$) and ($K$). The factor ($P$) is known yet the factor ($K$) is a constant that depends on the singlebrake block force ($D$). The value of ($D$) in the Tc train and T 30912.9 N is assumed as 4000 N, in M1 5554.4 it is assumed as 6000 N, while in M2 5708.26 it is assumed as 6000 N. Thus, the value of ($K$) can be defined as 1.04 on the Tc and T trains and 0.90 on the M1 and M2 trains, so that the brake load for the trains below are found.

- Tc and T trains
- M1 trains
- M2 trains

3.2 Calculating the Braking Efficiency ($\lambda$)

The braking efficiency is the ratio between the braking load ($B$) and the weight of one train($Gr$). The value of ($B$) is known and the value of ($Gr$) can be calculated from the weight of the unloaded train added by the weight of the fully loaded train. To find out the braking efficiency of the entire train set can be calculated by dividing the factor of the brake load value of the train set and the weight of the train set, including that of the locomotives. Therefore, the percentage is as follows: (SF 10).

In an unloaded train, $\lambda$ is less than $\lambda_{\text{max}}$ (120%), so that this condition meets UIC standards. Moreover, in fully loaded trains, as $\lambda$ is bigger than $\lambda_{\text{min}}$ (50%), this condition also meets UIC standards.

3.3 Calculating the Percentage of the Brake Block Pressure (SF 10)

In an unloaded train:
Because $\eta > \eta_{\text{max}}$ (100%), this condition does not meet the recommendations of UIC. If the percentage of brake block pressure is more than 100%, the braking force will be greater than its adhesive force, causing a flat wheel on the wheel bandage. In the researched data, the most experienced flat wheels occur on M trains. On the M trains, there is a double braking system, namely pneumatic and regenerative brake, for the M train the air pressure added to the BOD is converted to an electrical signal for the EPL.

In a fully loaded train:
Because $\eta > \eta_{\text{min}}$ (80%), this condition meets the standard recommendation of UIC. In a fully loaded train, the percentage of the brake block pressure will decrease because the brake block pressure is constant, while the axle load increases as the load does.

4. Conclusions and Suggestions
The flat wheel occurs because the braking force is greater than the adhesive force. Wheel skidding occurs when the brake block force is bigger in a moment than the train force. The braking efficiency in the JR 205 KRL series meets the UIC standard, but in the percentage of the block pressure in the unloaded train still exceeds the UIC standard so that it can cause bump wheels. Therefore, it is necessary to recheck the braking force during the maintenance and additional equipment may be needed to manage the air pressure when it exceeds the provisions.

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