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Lifetime Evaluation of Rail Pads for High Speed Railway Vehicle

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Abstract

Useful lifetime evaluation of rail pad was very important in design procedure to assure the safety and reliability. It is, therefore, necessary to establish a suitable criterion for the replacement period of rail pads. In this study, we performed properties and accelerated heat aging tests of rail pads considering degradation factors and all environmental conditions including operation, and then derived a lifetime prediction equation according to changes in hardness, thickness, and static spring constants in the Arrhenius plot to establish how to estimate the aging of rail pads. With the useful lifetime prediction equation, the lifetime of e-clip pads was 2.5 years when the change in hardness was 10% at 25°C; and that of f-clip pads was 1.7 years. When the change in thickness was 10%, the lifetime of e-clip pads and f-clip pads is 2.6 years respectively. The results obtained in this study to estimate the useful lifetime of rail pads for high speed trains can be used for determining the maintenance and replacement schedule for rail pads.

Keywords: *Rail pad, Heat aging, Arrhenius plot, Lifetime prediction*

1. Introduction

Rail pads, that can prevent the breaking of railroad ties and roadbeds by reducing the shock of train loads transferred to railroad ties as well as securing the elasticity of all railroads, have been the center of much concern and research and have led to efforts to reduce vibration and noise generated by trains and rails due to the high speeds at which they travel (Chopra 1995, Yang, Noh, Kang 2000, Koo, Yun 2004). In this study, we performed property and accelerated heat aging tests of rail pads considering degradation factors and all environmental conditions including operation, and then derived a useful lifetime prediction equation according to changes in hardness, thickness, and static spring constants in the Arrhenius curve to establish how to estimate the aging of rail pads.

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2. Experiment

2.1 Mechanical test

Rail pads are one of the components that come into contact with the rail. Rail pads are used as a part of rubber composites in fastening devices connecting railroad ties as shown in Fig. 1(a). Rail pads reduce the amount of shock transferred from rails to protect railroad ties. These rail pads become hard and their elasticity becomes reduced as the passing tonnage and usage period increases, resulting in negative effects on the tracks (Kwon, Na, Kim 2004). It is, therefore, necessary to establish a suitable criterion for the replacement period of rail pads. There were, however, few studies on such criterion. In this study, we analyzed changes in hardness, thickness, and strength by the degradation of rail pads to quantify their aging. The degradation of rail pads

is a problematic phenomenon due to changes in mechanical properties, appearance, and shape by internal factors, including the composition of rubber composites as well as external factors including the environment: these factors play roles as several forms while each one acts independently (Brown, Butler, Hawley, 2001). Considering the load and temperature that have the most significant impact

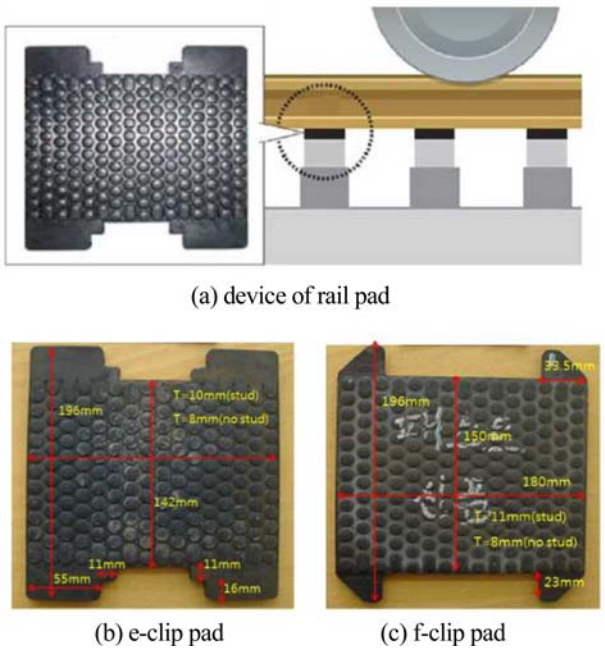


Fig. 1 Rail pad for high speed railway vehicle

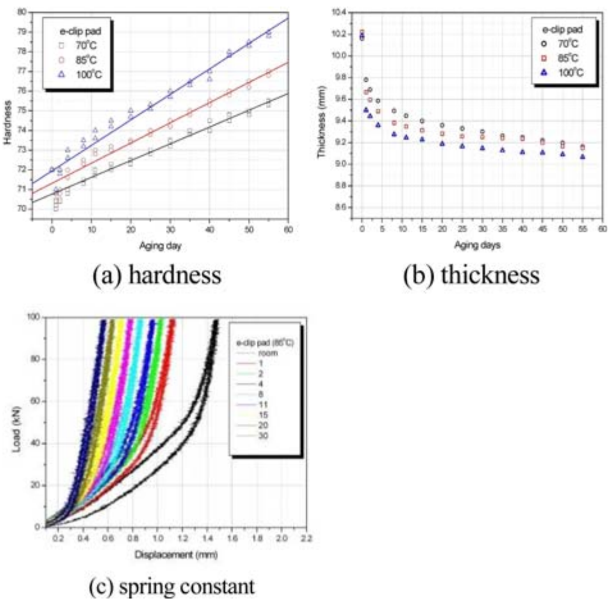


Fig. 2 Mechanical test of rail pad

on changes in the properties of rail pads, e-clip pads and f-clip pads for high speed trains as shown in Fig. 1(b) and (c) were thermally aged for 55 days at 70°C, 85°C, and 100°C as well as at room temperature, and then changes in physical properties such as hardness, thickness, and static spring constants of rail pads during specific periods were measured. Hardness and thickness under aging temperature and period were measured with compression set devices used in mechanical property tests of vulcanized rubber conforming to ISO 815. Rail pads were taken out of the aging testers and separated from compression devices. Figs. 2(a) and (b) show the changes in hardness and thickness depending on the aging period at room temperature: The changes are proportional to temperature and aging period. Fig. 2(c) shows changes in the static spring constant at the thermal aging condition: the constant drastically increases as temperature rises and the aging period is extended.

2.2 Useful lifetime prediction

In this study, the Arrhenius model was selected to estimate the useful lifetime of rubber material with data obtained by acceleration heat aging test, in which we adapted the an acceleration method where the rubber is thermally aged. In the Arrhenius model, the useful lifetime is determined by the time when specific change from the initial state of a property occurs over temperature, and the useful lifetime is represented by the master curve and the relation of time and temperature. Through this relationship the lifetime of rubber can be estimated at a particular temperature. The lifetime by natural aging at room temperature can be estimated using data obtained in acceleration tests. Assuming that the value of a property of rubber is P in the aging reaction, the Arrhenius equation can be represented as in (1):

$$ln\left[\frac{P}{P_0}\right] = -kt - \frac{dP}{dt} = kP\,, \tag{1}$$

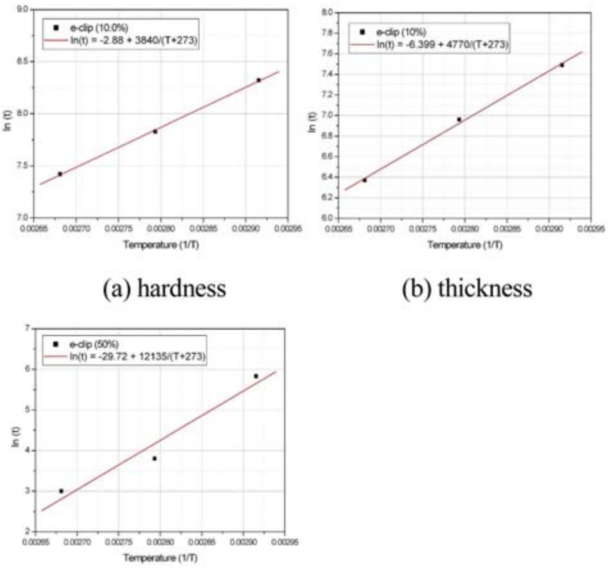
where, P : the value of a property of rubber, P_0 : the value of the property before aging, t : time, and k : reaction rate.

In equation (1), the reaction rate k is a constant that represents the going reaction of the value of the property. In 1889, S. Arrhenius obtained the empirical equation as in (2):

$$k = A \cdot e^{-E/RT}, \ln k(t) = -\frac{E}{RT} + C \tag{2}$$

where, A and C: constant, E : activity energy(J/mol K), R : constant of gas(8.314 J/mol K), and T : absolute temperature .

Using data obtained through accelerated heat aging tests in which useful lifetime is determined in short period with more severe conditions than actual cases, the useful lifetime of rail pads was estimated with the Arrhenius relation. To represent changes in the hardness and thickness of rail pads over temperature, the time in the x-axis was linearized in the logarithmic scale and the y-axis indicates



(c) spring constant

Fig. 3 Change of characteristics for rail pad after heat aging

Table 1. Useful lifetime prediction of rail pads

Pad type	Characteristics	Prediction equation	Lifetime (years)
e-clip	Hardness	$\ln(t) = -2.88+3840/(T_u+273)$	2.5
	Thickness	$\ln(t) = -6.40+4770/(T_u+273)$	1.7
	S/P constant	$\ln(t) = -29.7+12135/(T_u+273)$	6.9
f-clip	Hardness	$\ln(t) = -6.96+5066/(T_u+273)$	2.6
	Thickness	$\ln(t) = -14.1+7194/(T_u+273)$	2.6
	S/P constant	$\ln(t) = -22.0+9210/(T_u+273)$	0.8

changes in physical properties with respect to the initial conditions. Arrhenius curves in Fig. 3 were obtained from changes in the physical properties of rail pads over time at 70°C, 85°C, and 100°C. The useful lifetime estimation equation could be derived in Table I using the least square method. With the useful lifetime estimation equation, the lifetime of e-clip pads was 2.5 years when the change in hardness was 10% at 25°C; and that of f-clip pads was 2.6 years. When the change in thickness was 10%, the lifetime of e-clip pads was 1.7 years and that of f-clip pads was 2.6 years. When the change in the static spring constant was 50%, the useful lifetime of e-clip pads was 6.9 years and that of f-clip pads was about 1 year.

3. Conclusion

In this study, the useful lifetime of rail pads for rail fastening devices of high speed trains was estimated, considering their operation and environmental conditions. We concluded as follows:

1) The changes in hardness, thickness, and static spring constant were obtained via heat aging tests at various temperatures to estimate the useful lifetime of rail pads.

2) The useful lifetime prediction equations were derived according to changes in the physical properties of rail pads, using Arrhenius curves after performing acceleration tests by heat aging.

3) With the useful lifetime prediction equation, the lifetime of e-clip pads was 2.5 years when the change in hardness was 10% at 25°C; and that of f-clip pads was 1.7 years. When the change in thickness was 10%, the lifetime of e-clip pads and f-clip pads is 2.6 years respectively. When the change in the static spring constant was 50%, the lifetime of e-clip pads was 6.8 years and that of f-clip pads was about 1 year.

4) The results obtained in this study to estimate the useful lifetime of rail pads for high speed trains can be used for determining the maintenance and replacement schedule for rail pads. This would greatly contribute to estimated reliability of rail pads owing to advances in useful lifetime estimation skills.

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