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ESTIMATION OF THE ADHESION FORCE FOR A DISC BRAKE IN A SKID CONTROL CONDITION

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ABSTRACT−The performance of brakes has become important due to increased train speeds. The brake system of a train must possess a large brake force to stop the train safely within a limited stopping distance. However, an excessive brake force deteriorates the ride comfort and causes the train to skid. Therefore, it is necessary to control the brake force within the adhesion force limit. This paper presents an analytical method to estimate the relationship between the brake and adhesion forces of a disc brake system. This method has been applied to the actual disc braking control system of the Korea High-Speed Train (HSR350x), and the adhesion force is estimated in an actual skid condition.

KEY WORDS : Skid, Slip, Adhesion force, Brake force, Dynamic model, Wheel flat, Korea high-speed train (HSR350x), Stopping distance

NOMENCLATURE

V : train speed
V_0 : initial velocity of the vehicle
v_w : wheel speed
v_s : skid speed
β : train deceleration
t : time from braking start to the current point
F_b : brake force
P : cylinder pressure
A : cylinder area
n : number of discs
i : lever ratio
R : wheel radius
r : disc radius
μ : friction coefficient
F_s : reaction force of spring
I : mass moment of inertia
w : angular velocity of wheel
P_0 : pressure when skid is detected
T_1 : time constant of pressure decrease
v_c : speed difference at skid perception point
F_m : adhesion force
F_{d_b} : brake force from each disc brake equipment
mg : load applied to each wheel set
F_{m_2} : adhesion force of region II
T : requirement time for region III
F_{m_3} : adhesion force of region III
$v_{s\_\max}$: maximum skid speed
F_{m_4} : adhesion force of region IV
T_2 : time constant of pressure increase
v_{s4} : skid speed of end point in region IV
P_1 : minimum pressure
ΔP : pressure difference between minimum pressure and current pressure in region V
F_{m_5} : adhesion force of region V
α : adhesion force decreasing coefficient
t_c : time at skid perception point
F_{m_1} : adhesion force of end point in region I

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1. INTRODUCTION

The stopping distance of a railway vehicle is much longer than that of an automobile because the coefficient of friction is very small due to the metal contact between the wheel and rail. To stop the train safely and quickly within a limited traveling distance and to reduce its velocity to the desired velocity, it is necessary to apply a large brake force. If the brake force is excessively applied to ensure a short braking distance, then the ride comfort is deteriorated due to a high level of deceleration and jerk. Additionally, an excessive brake force is the primary reason for a slip occurrence if it exceeds the allowable adhesion force. The skid causes an increase in the stopping distance and reduces the safety and stability of the train. Additionally, it damages the rail surface due to a wheel flat. Therefore, the brake force must be controlled by considering the adhesion characteristics between the wheel and the rail to prevent the