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Friction Control between wheel and rail -modeling and application-

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1 INTRODUCTION

Tight curve sections that are inevitably constructed in subway lines may cause squeal noise, excessive wear at gauge corner of rail and sometimes may generate rail corrugation. As an alternative lubrication against conventional grease application that may cause the wheel slip or skid, water-based friction modifier has been applied to contact region between wheel and rail, since the friction modifier has positive characteristics of coefficient of friction increasing while traction or braking, on the other hand it keeps low coefficient of friction for curve negotiation. Authors have proposed an onboard friction control system [1, 2] as shown in Fig. 1 using water-based friction modifier KELTRACK [3]. The friction modifier can be sprayed from an end of bogie of the last car to the top of low rail at a tight curve section. The sprayed friction modifier has been dried out only in 1min after it sprayed to top of the rail. This time would be sufficient even for metropolitan subway that has very frequent train service at peak hour. The following trains running after the spraying train can take benefit of the friction modifier by passing over the friction modifier sprayed to the top of the rail at curve section.

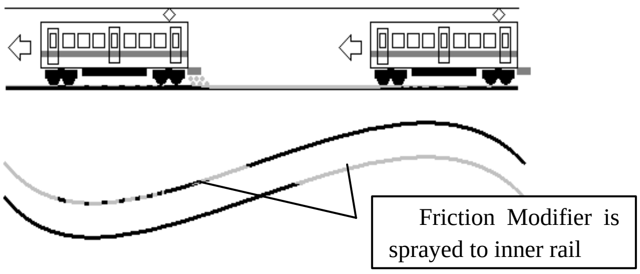

Fig. 1 Concept of Onboard Friction Control

2 INTRODUCTION OF IDEA OF BOUNDARY LUBRICATION THEORY

In order to examine vehicle dynamics with friction control and to make control method how much friction modifier should be used, the modeling of creep characteristics were made using the study of “Boundary Lubrication Theory”, which is intermediate condition between dry and lubricated as shown in Fig. 2. In the case that two bodies contacts each other directly in area of α A, where A is area of real contact, the friction force acting between the two bodies can be represented as next formula:

$$F = A_r \{\alpha s_m + (1-\alpha) s_i\}$$

Here, parameter α is just a rate of area of direct contact in area of real contact, and it doesn't correspond to the condition of friction modifier distribution in contact patch. In order to apply this theory into the FASTSIM algorithm, with the definition of the new parameter α called "Direct Contact Rate", creep force with friction modifier can be given with the addition of (1-α) times creep force of the condition just after friction modifier is sprayed and α times creep force of the dry condition. The calculation results are shown in Fig. 3.

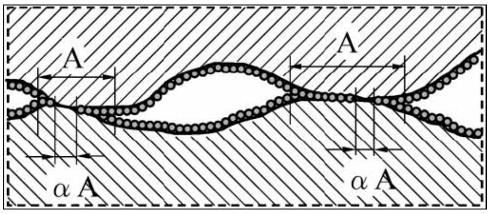

Fig. 2 Bowden's boundary lubrication model

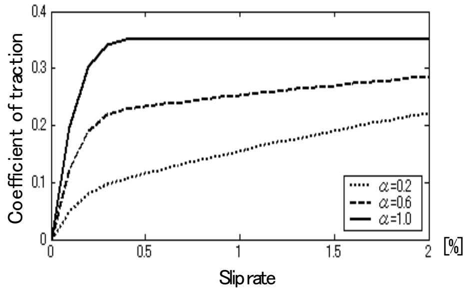

Fig. 3 Calculation results of creep characteristics

3 APPLICATION TO CONTROL SYSTEM

The proposed onboard friction control system is applied to commercial train sets of Tokyo-Metro as shown in Fig. 4. As the result of the friction control of the inner wheel, lateral force of the outer wheel also decreased, and the ratio of lateral force to vertical force (L/V) of the outer wheel that indicates the curving performance decreased dramatically. The result also shows the reduction of lateral force fluctuation of the inner rail that may cause corrugations. These results prove the effectiveness of the onboard friction control system.

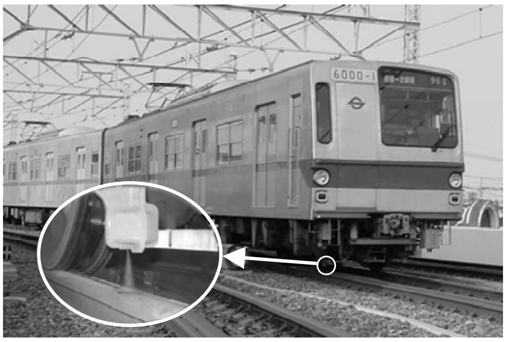

Fig. 4 Application of proposed onboard friction control system to Tokyo Metro Train

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