Wheel Slide Protection Method by Effective Use of Adhesion Force

Shinichi NAKAZAWA
Assistant Senior Researcher, Brake Control, Vehicle Control Technology Division

1. Introduction

Ideally, high deceleration braking should be stable in all situations. However, since the adhesion force between the sliding wheel and rail varies significantly under wet conditions, it is difficult to completely prevent wheel slide and secure stable performance. To help resolve this issue, wheel slide protection (WSP) systems were introduced in the past and achieved reasonably satisfactory results. However, all the existing WSP methods provide protection using only velocity-based information. It is difficult to for these systems to provide perfectly constant protection when the adhesion force is subject to change. Therefore, we propose a new method of providing wheel slide protection. The method estimates the adhesion force by using the equation of the wheel's rotational motion.

2. Wheel slide protection estimating adhesion status

Since it is difficult to measure the adhesion force and braking force of an actual vehicle directly, the proposed method uses the brake cylinder (BC) pressure to estimate the adhesion. Specifically, the braking force is calculated from the BC pressure and converted into deceleration by using the equation of the wheel's rotational motion, the result of which is the "estimated deceleration". This is compared to the actual deceleration found from the speed sensor measurements and we can calculate the difference between the actual deceleration and the estimated deceleration. This difference is the slide deceleration (Figure 1). The magnitude of the slide deceleration is proportional to the magnitude of the adhesion force and this relationship is an important part of the decision-making logics incorporated in the wheel slide protection system (Figure 2) that we developed. In effect, the logic is that if the slide deceleration is negative (i.e., the actual deceleration is less than the estimated deceleration) at low slip ratios, then more air is supplied to the brake cylinder. However, if the slide deceleration is positive, then the brake cylinder pressure is held constant. At very high slip ratios air is always exhausted from the brake cylinder.

A bench test, using a full-scale wheel running on a roller rig, was performed to test the methodology. Immediately after the start of braking in simulated wet conditions (water sprinkled at a rate of 200 ml/min on the contact surfaces), a large slide occurred as shown in Figure 3 by the large drop in rotational velocity compared with the translational velocity. This slide caused an exhaust of BC pressure. Though the slide continued after that, the system monitored the status of adhesion, resupplied BC pressure and kept the pressure value high. The mean deceleration (based on the braking distance) over the duration of the brake application was 4.65 km/h/s. This braking performance compares well with that achieved under dry conditions using the same loads and pressing force. The mean deceleration under dry conditions was 4.62 km/h/s.

3. Conclusion

The proposed method of wheel slide protection described above requires detection of the BC pressure and provides wheel slide protection according to the adhesion status by using relationships derived from the equation of the wheel's rotational motion for each axle. The application of this method will lead to a performance upgrade of the whole braking system and is under review, although there are still many issues for practical use.

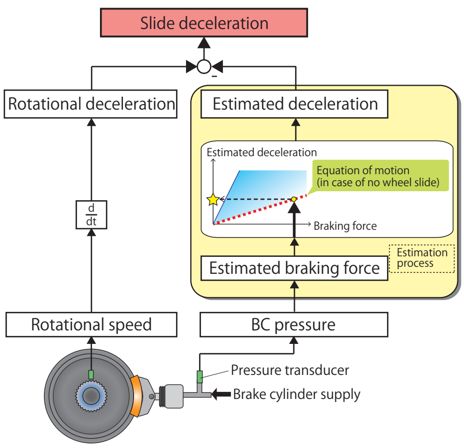

Fig.1 Process of deriving slide deceleration

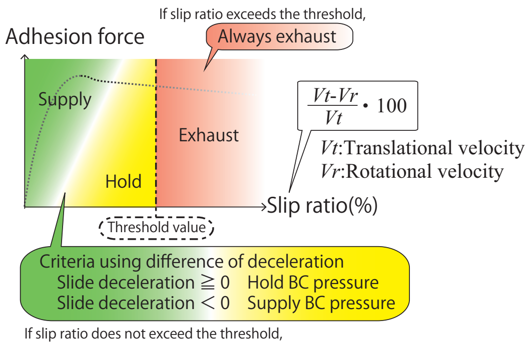

Fig. 2 Basic logics of new wheel slide protection system

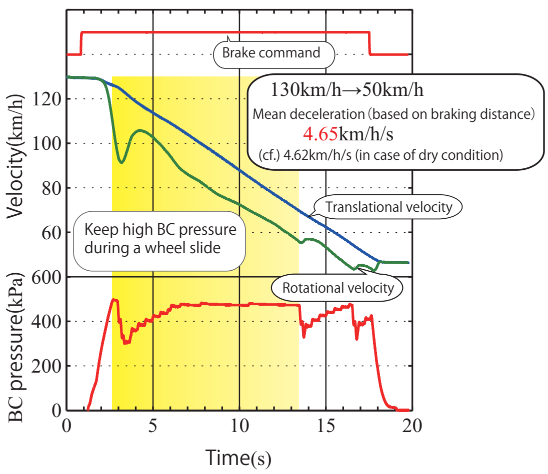

Fig.3 Example of wheel slide protection result