講演番号	189

文献番号	20225189

Integrated Vehicle Dynamics Control Ordered by Six-Component Force at Center of Gravity with Brakes Mounted on Each Wheel

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KEY WORDS: **Vehicle dynamics, Brake system, Motion control**, Integrated control, Six-component forces [B1]

To enhance vehicle stability, controllability and comfortability, various control methods and devices have been developed, for example, planar motion control with front-wheel and rear-wheel steering controls, driving force distribution controls and sprung motion control with supention controls. On the other hand, because of the coupling between planar and sprung motion, it is difficult to design integrated control of those motions. However, in the normal tire ranges, not only planar motion but also sprung motion has effect on driver's impression. Therefore, we proposed an integrated vehicle dynamics control method, called GDP, in the previous paper.

Brakes are the most promising actuators to expand application of the GDP as standard equipment. However, the GDP cannot be applied to brakes that generate only negative forces because it can be applied to only vehicles equipped with control devices designed to actively control the forces. Furthermore, the braking force has effects on not only planar motion but also sprung motion. No researches can be seen so far that achieve target sprung motion as well as planar motion by controlling braking force. Therefore, in this study, we proposed a method that makes it easy to install integrated control with brakes by applying the Active-Set Method to the GDP.

The GDP consists of three parts. Firstly, the GDP defines of target six degrees of freedom vehicle motion, secondly, calculates six-component force at the center of gravity (6CF) to achieve the target motion and optimum twelve-component tire force, finally, calculates command values for each actuator. Three-component planar force is calculated from longitudinal acceleration requested by the driver and the desired vehicle dynamic characteristics with respect to steering inputs. The remaining three-component sprung force is calculated from the inertial force and suspension reaction force applied by the three-component planar force and additional forces to control sprung motion. Tire forces are calculated as minimizing the deviation between the target 6CF and that generated by tire forces.

The constraints that the tire longitudinal forces must be less than zero is required to apply the GDP to brakes. The proposed method that applies the Active-Set Method to the GDP can calculate optimum tire forces under the inequality constraints by a relatively small number of iterations.

The effectiveness of the proposed method (BRK) compared to a vehicle that actively controls the longitudinal forces at each wheel like an in-wheel motor (IWM) is verified by full-vehicle simulation. The simulation has been conducted with a stepped steering angle input of 2° at time t = 1s, and a stepped acceleration input of 2m/s^2 at time t = 2s. The results of the longitudinal forces at each wheel and the vehicle motions are shown in Fig. 1 and 2 respectively. It is confirmed that the method can calculate tire forces under the constraints and the effect of BRK is almost equivalent to IWM and the deceleration caused by the braking force is small. Finally, we applied the method to actual car and proved that it enhances vehicle dynamics performance.

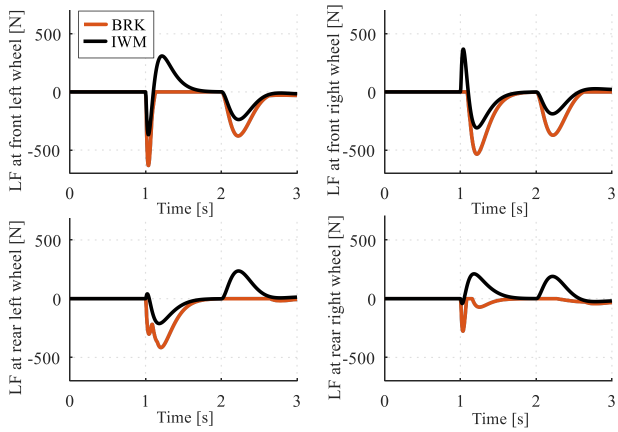

Fig.1 Control outputs – longitudinal forces (LF) at each wheel

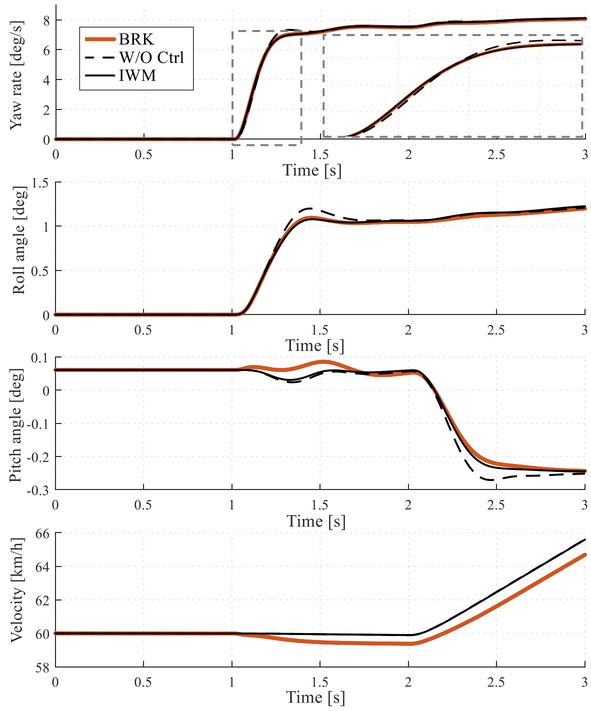

Fig.2 Vehicle motion