論 文 の 内 容 の 要 旨

論文題目「 Skid Control of Small Electric Vehicle with In-wheel Motors」
（インホイールモータを用いた小型電気自動車のスキッド制御）

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In recent years, due to the growing needs on energy and the environment protection, the electrified driving system is gradually gaining attention from the automotive industry. Compared with the internal combustion engine, electric motors on electric vehicles (EVs) have great advantages such as fast torque response, easiness in obtaining accurate torque feedback, capable of generating both traction and braking forces and small size but powerful output.

In chapter 1, the small electric vehicles are introduced. For an urban area and narrow space, due to the small size of the small EVs and the advantages of the electric motor, the demands for the small EVs are increased. Although small EVs have many advantages on its size and the propulsion system, one question that must be considered is whether small EVs are sufficiently safe to drive. Most small EVs only provide seat belts as safety equipment and do not have an anti-lock brake system (ABS), which is a basic skid control method. Due to the space limitation on the driving tire, the hydraulic unit of ABS is difficult to install. For the same reason, small EVs employ a mechanical braking system rather than a hydraulic braking system. Even though the mechanical brake system is compact, the rigidness and the response performance of the mechanical brake system are lower than hydraulic braking system. As such, small electric vehicles may be considered to provide insufficient safety.

In chapter 2, the experiments have been developed to analysis the braking performance of the hydraulic-mechanical hybrid brake system. The braking systems on the experiment are divided into two categories, which are hydraulic-mechanical hybrid brake system without regenerative brake, and hydraulic-mechanical hybrid brake system with regenerative brake. From the experimental results, the stopping time and the stopping distance for the hydraulic-mechanical hybrid brake system with regenerative brake is better than without regenerative brake. Then, it can be considered that regenerative brake can improve the braking performance of the small EVs.

In chapter 3, the simulation model of hydraulic-mechanical hybrid brake system with ABS is developed. Generally, during braking on icy road, the friction between the tire and contact path is very small. During braking on an icy road, the hydraulic-mechanical hybrid brake system and regenerative brake cannot perform equally on dry asphalt. The braking force from the hydraulic-mechanical hybrid brake system and regenerative brake to the tire are often exceeds the force that make them rotate. To prevent the tire to

stop rotating rapidly, the simulation model of hydraulic-mechanical hybrid brake system with ABS is developed. In this model, the hydraulic unit of ABS was installed at the front tire. On the other hand, due to the space limitation on the rear tire, the hydraulic unit of ABS was installed between the master cylinder and rear power cylinder. From the simulation results, the combination of hydraulic-mechanical hybrid brake system with ABS only can prevent front tire from lock up. During ABS operational, due to the rigidness of the mechanical brake system, the time delay is occurring on the mechanical brake system. Moreover, the regenerative braking force produced from the in-wheel motor is very large. As a result, the rotational speed of the rear tire is decreased rapidly and will be locked up.

In chapter 4, to prevent rear tire from lock up, the simulation model of hydraulic-mechanical hybrid brake system with ABS and regenerative brake control is developed. Based on the characteristics of in-wheel motor, which are fast torque response and easiness in obtaining an accurate torque feedback, the regenerative brake timing control is developed. The control method of the regenerative brake control is similar as ABS, which is based on the slip ratio of the tire. If the slip ratio is greater than the optimum value, the regenerative brake turns off and the current produced is transferred to charge the battery. However, if the slip ratio is smaller than the optimum value, the regenerative brake is turned back on to regain the ideal braking force. From the simulation results, during braking on an icy road, the combination of hydraulic-mechanical hybrid brake system with ABS and regenerative brake control can prevent front and rear tires from lock up. Besides that, the steer performance of the vehicle also can be increased.

In chapter 5, several findings and outcome of the research have been summarized. To improve the safety and stability of the small EVs, the combination model of hydraulic-mechanical hybrid brake system with ABS and regenerative brake control is developed. From this study, an in-wheel motor can be an actuator of ABS to control the regenerative braking force and prevent the rear tire from lock up. The combination of hydraulic-mechanical hybrid brake system with ABS and regenerative brake control can improve the braking performance of the small EVs and prevent the vehicle from skidding during braking on an icy road.