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Development of Regenerative Braking Co-operative Control System for Automatic Transmission-based Hybrid Electric Vehicle using Electronic Wedge Brake

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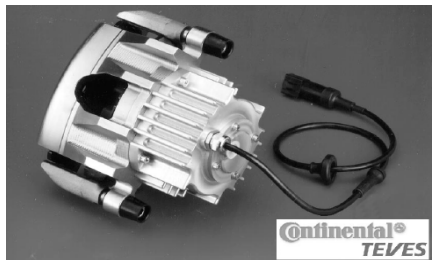
Introduction

Hydraulic brake system

- **Brake by wire**
- **ABS, TCS, ESP**
- **Regenerative braking**

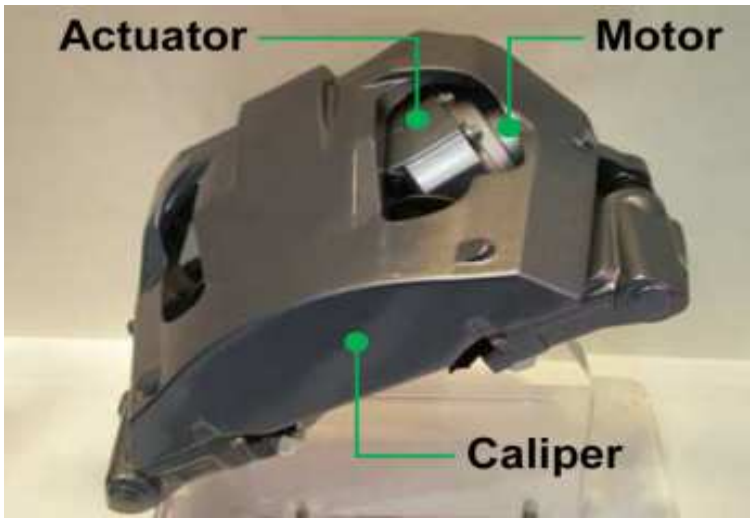
Electronic brake system



Introduction

EWB (electronic wedge brake)

Continental VDO EWB



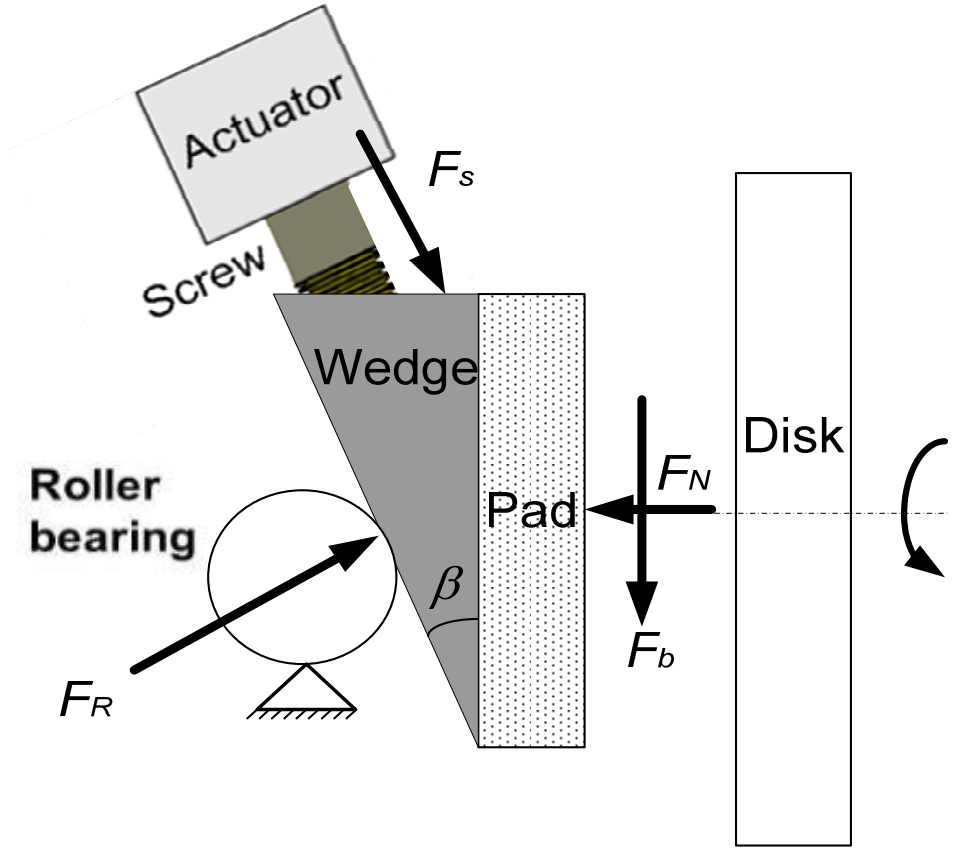
Hyundai Mobis EWB

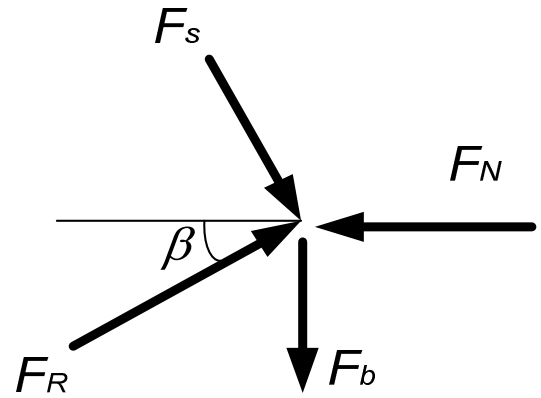
EWB needs less power than EMB to operate actuator

owing to its self-reinforcement mechanism

Introduction

EWB force balance





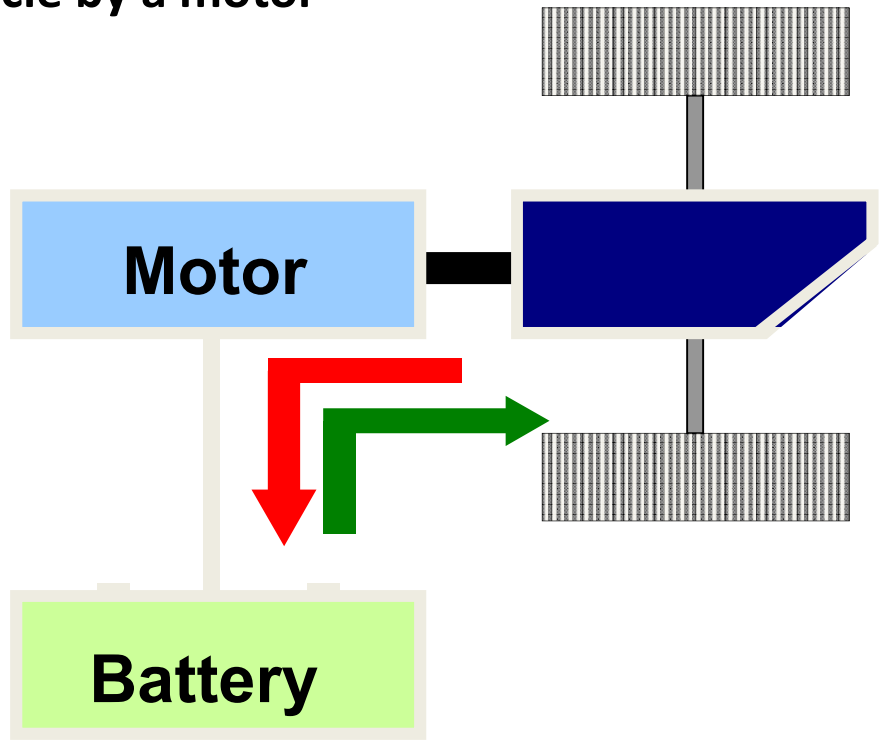
Introduction

Regenerative braking

- During braking, vehicle kinetic energy is recuperated and stored in battery
- The stored energy is used to propel the vehicle by a motor

Discharge from battery

Charge by regenerative braking



Introduction

Pure electronic brake requires :

- **Pedal simulator to maintain braking feeling like conventional vehicle**
- **Additional hydraulic brake for fail safe since there is no mechanical connection between pedal and brake system**

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Introduction

Combination brake system

AT-based HEV

Brake system

Front

Regenerative brake + **EWB friction brake**

Rear

Hydraulic friction brake

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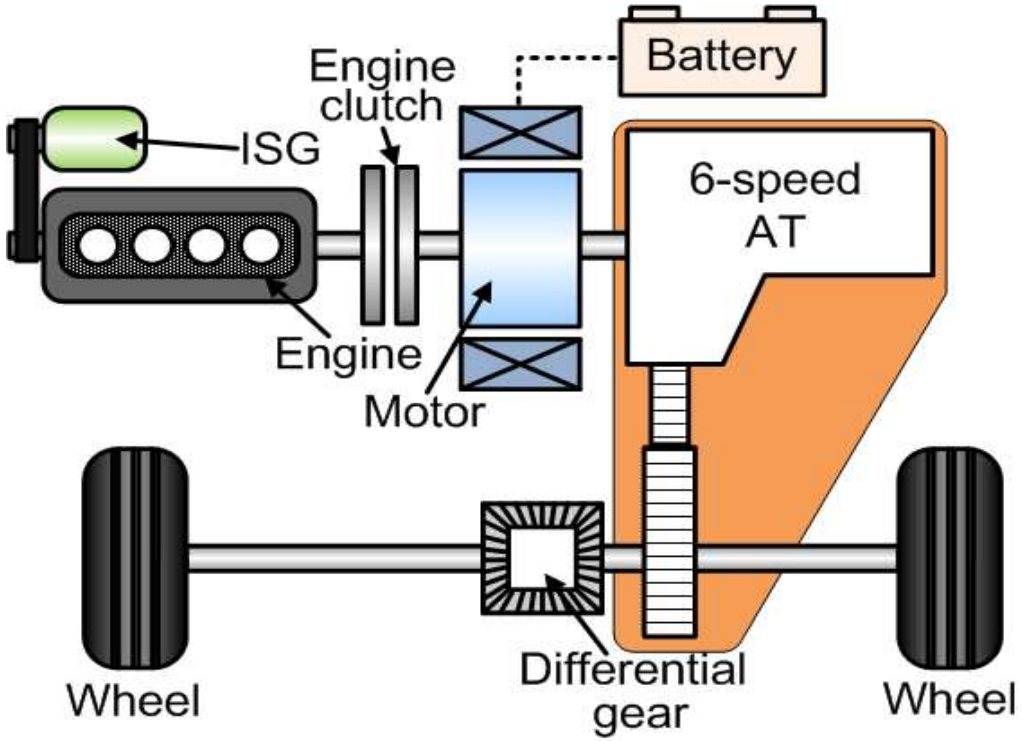
Purpose of study

- Develop a regenerative braking co-operative control algorithm for AT-based HEV using combination brake system which consists of EWB on the front wheel and hydraulic brake on the rear wheel
- Evaluate a regenerative braking co-operative control algorithm by vehicle test

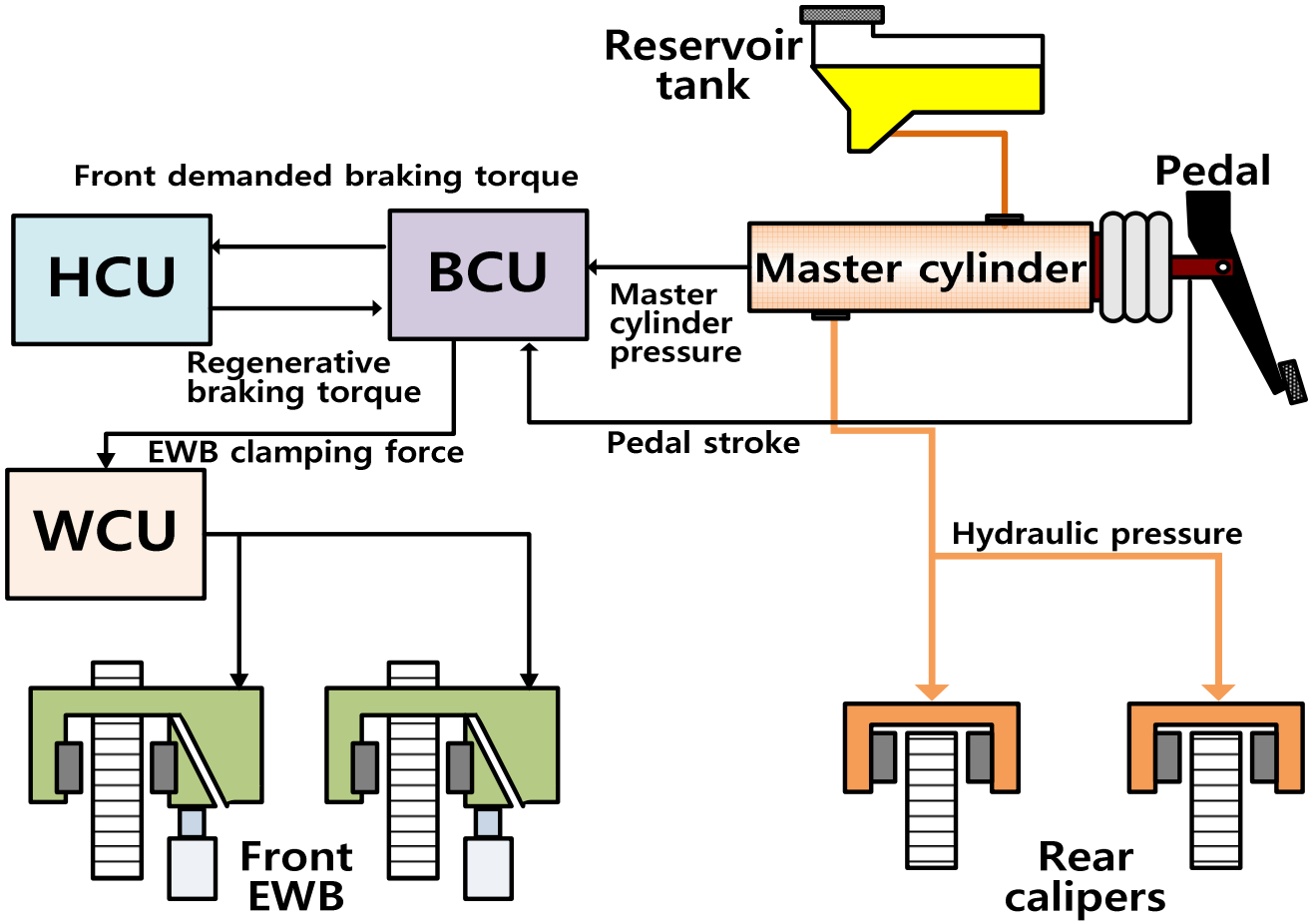
Structure of HEV



Engine	Volume	2000cc
	Max. torque	202Nm
Engine clutch	Wet type multi plate	
Motor	power	30kW
Transmission	6-speed AT	
Vehicle	Mass	1679kg

- 6-speed AT based parallel hybrid electric vehicle
- EV, HEV mode

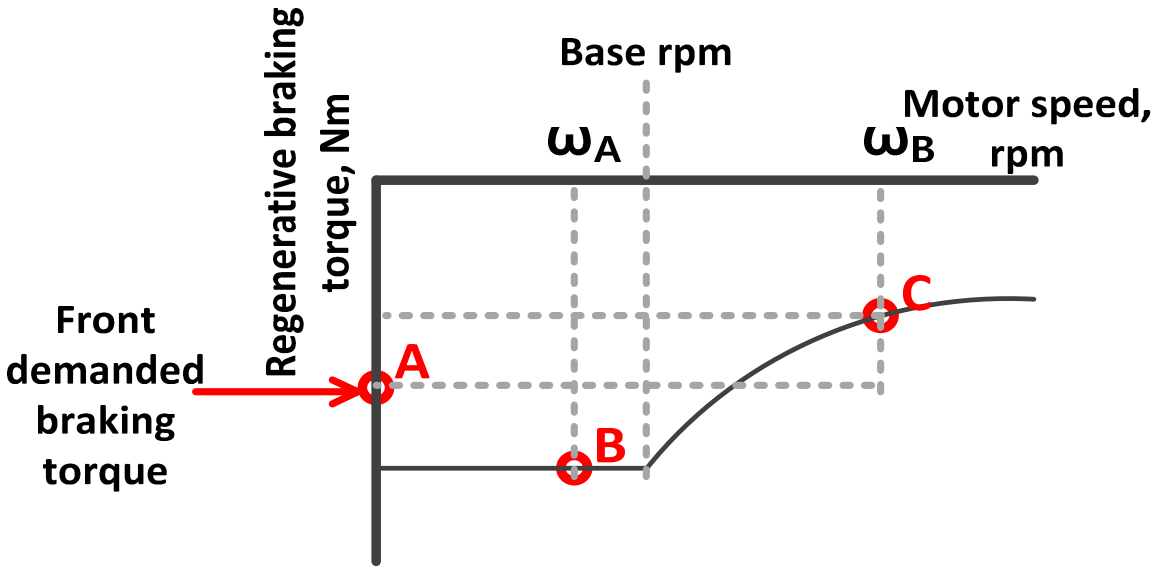
HEV brake system



- **Front braking**
  = Regenerative braking
  + EWB friction braking

- **Rear braking**
  = Hydraulic friction braking

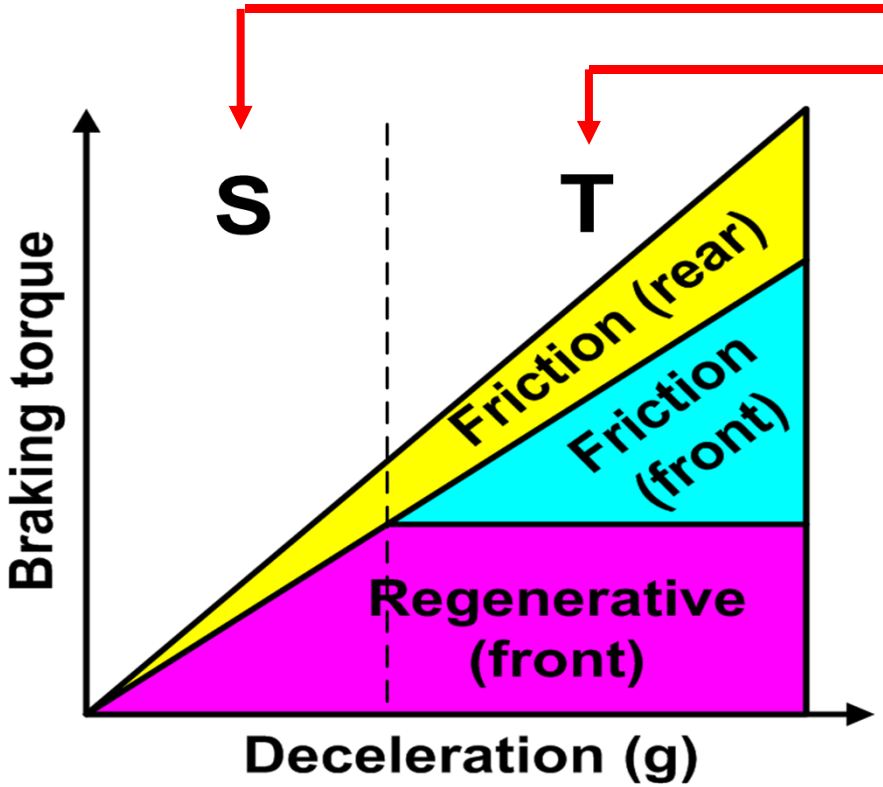
Regenerative braking torque control



. motor speed = ω_A
the front required braking torque (A) < maximum regenerative braking torque (B)
→ the front wheel braking is performed only by the regenerative braking

. motor speed = ω_B
regenerative braking torque (C) < the front required braking torque (A)
→the front wheel braking is performed by regenerative and friction braking.

Regenerative braking co-operative control algorithm

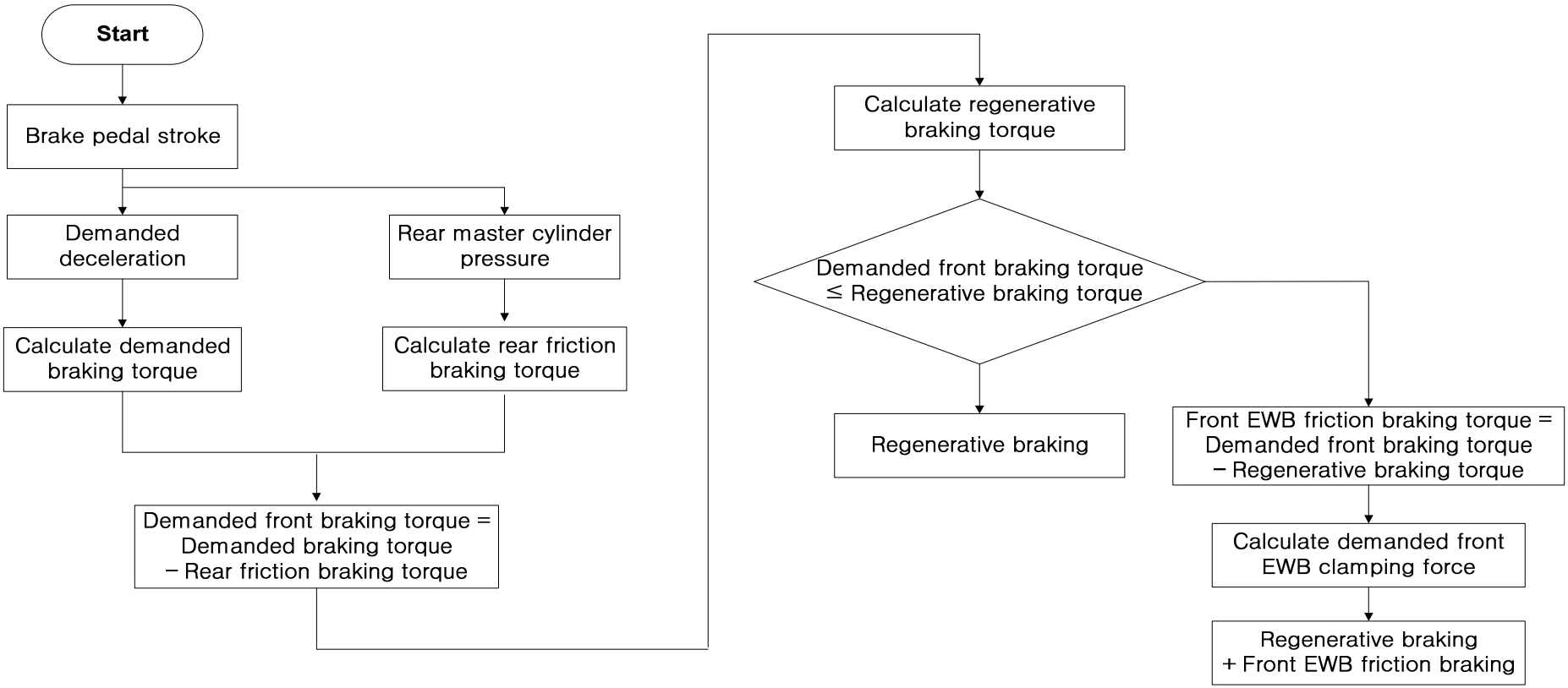


- Braking according to deceleration

. Front regenerative braking +
Rear friction braking(hydraulic)

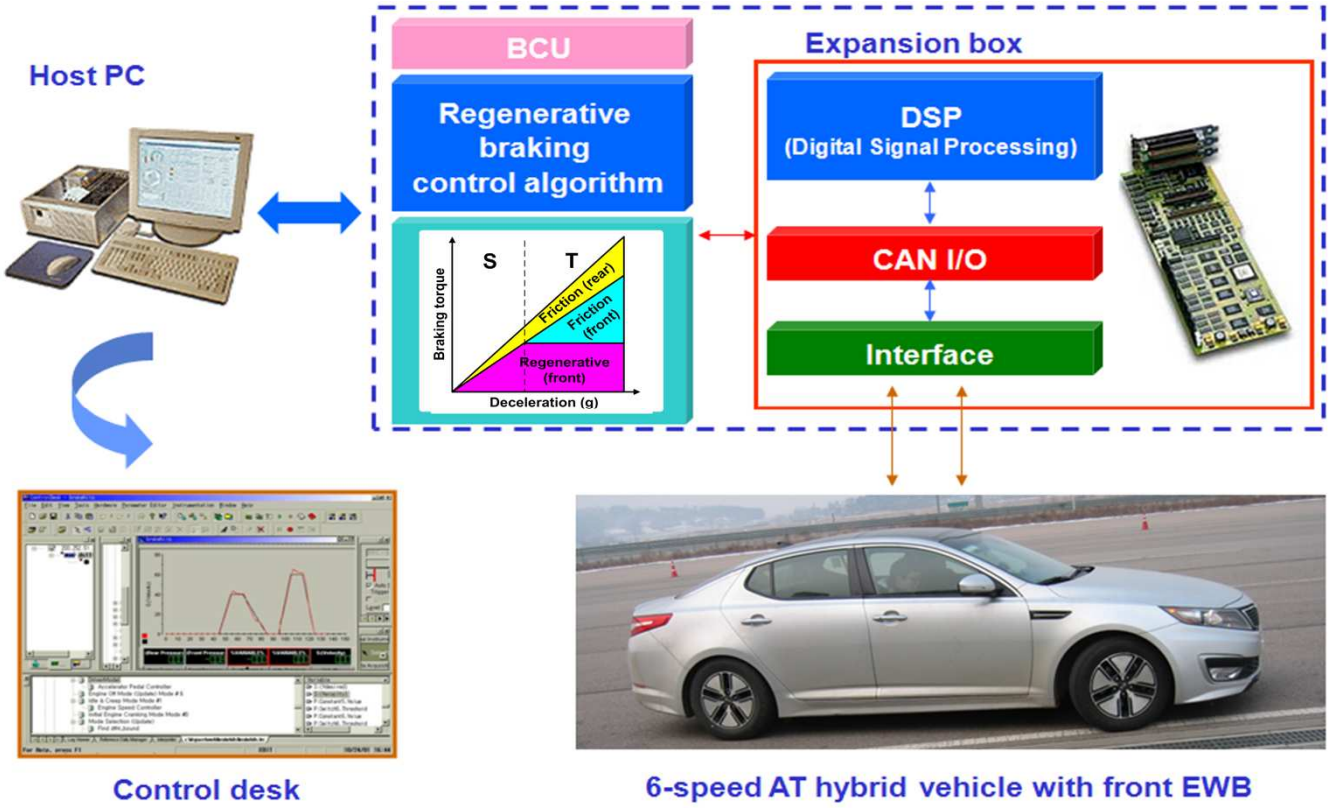
. Front regenerative braking +
Front friction braking(EWB) +
Rear friction braking(hydraulic)

Regenerative braking co-operative control algorithm



Vehicle test

Schematic diagram of regenerative braking co-operative control system

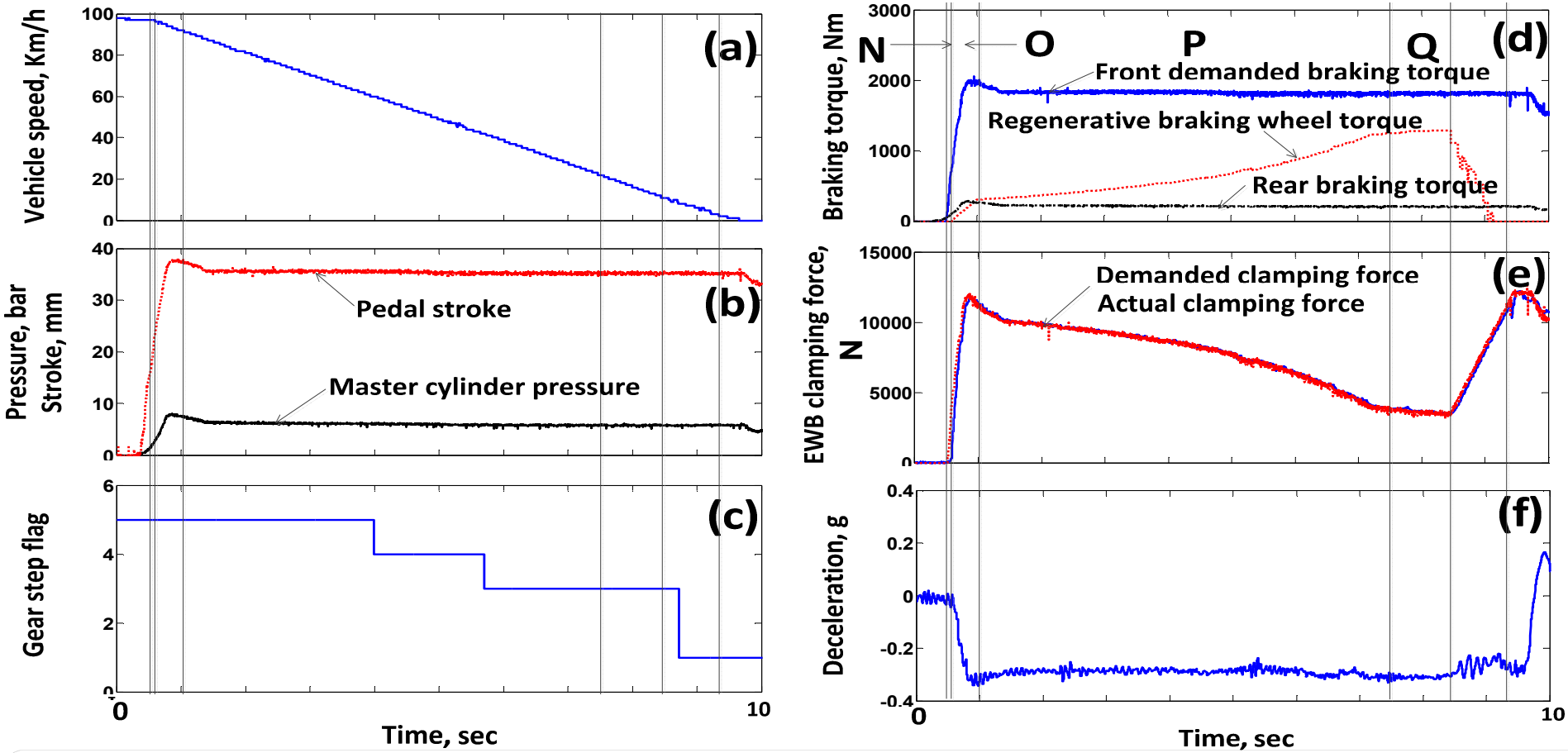


Control desk

6-speed AT hybrid vehicle with front EWB

Vehicle test results

(deceleration=0.3g)



Conclusions

- **The regenerative braking co-operative control algorithm was developed for AT-based HEV using EWB on the front wheel and hydraulic brake on the rear wheel**
- **The regenerative braking co-operative control algorithm was evaluated by vehicle test**
- **In vehicle test results, the rear wheel braking was operated at all times through the master cylinder by the driver's brake pedal effort, and the front wheel braking were performed by the regenerative braking and EWB friction braking according to the co-operative control algorithm**

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Thank you

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