

Development of Advanced Braking System for Hybrid Sports Cars

Lorne R. Dyar, Yuichiro Akita, Scott Paul, Joseph Lepito,
Yoshio Ishikawa, and Tomohiro Watanabe
Honda R & D Americas, Inc.

ABSTRACT

An advanced braking system had to be developed for a next-generation hybrid sports car with Sport Hybrid Super Handling All-Wheel Drive to achieve an intuitive brake feeling in a variety of driving conditions, ultimate track performance and reduction of CO₂ emissions per vehicle. This paper outlines the integration of brake-by-wire with traditional high-performance braking hardware and describes the technology needed to achieve these goals. Key focus areas to generate these results were: brake feeling control, corner hardware specification considerations and brake cooling.

CITATION: Dyar, L., Akita, Y., Paul, S., Lepito, J. et al., "Development of Advanced Braking System for Hybrid Sports Cars," *SAE Int. J. Passeng. Cars - Mech. Syst.* 9(3):2016, doi:10.4271/2016-01-1923.

INTRODUCTION

Advances in hybrid powertrain technology are being developed to achieve ultimate vehicle performance while reducing CO₂ emissions per vehicle. New powertrain technology enables instant acceleration and torque vectoring for direct yaw control to further enhance vehicle dynamics (Figure 1) and driver enjoyment. These systems also enable the manufacturer to tailor the chassis response to the driving scenario by allowing the driver to select one of the Integrated Dynamics System settings, which range from Quiet (electric) to Track.

The integration of these new devices, developed with traditional sports car fundamentals, enables the driver to experience consistent peak performance, new levels of controllable line trace while cornering and reduced CO₂ emissions through regenerative braking.

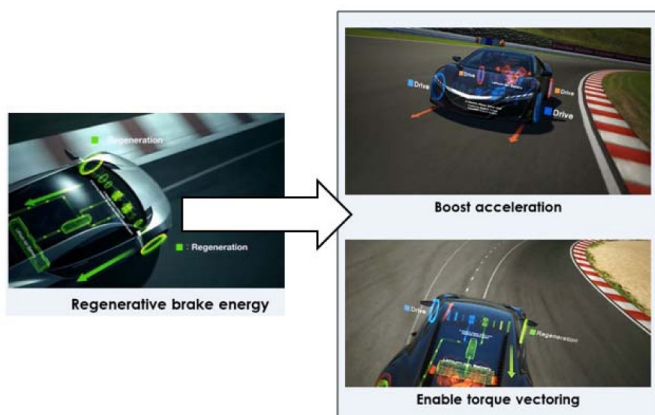


Figure 1. New powertrain technology enables instant acceleration and torque vectoring

To achieve high performance with a hybrid powertrain, the braking system must assist in powering the chassis control devices. The braking system must capture regenerative braking energy to boost performance without sacrificing vehicle dynamics control. In addition, the brakes must support the Integrated Dynamics System concept to allow the driver to easily control the vehicle's deceleration with the brake pedal.

Traditional sports cars typically utilize a brake pedal linked to a vacuum booster actuation system to control deceleration by hydraulic pressure control. This system, connected to a high-performance brake corner hardware system, generally offers typical sports car brake deceleration controllability under at-limit performance at the track. This single-priority tuning for one chassis response sacrifices controllability in other areas. Non-hybrid powertrains do not require regenerative braking control; therefore, they do not require novel actuation technology.

To maximize vehicle dynamic performance from a hybrid powertrain, electric actuation must be used to precisely control regenerative and friction brake blending. This system can support the Integrated Dynamics System concept by offering tailored pressure control maps to meet brake pedal deceleration controllability to be intuitive and consistent in all of the Integrated Dynamics System settings.

Intuitive brake pedal control means the driver has a clear and predictable sense of deceleration based on their braking intention. Consistency means the controllability and repeatability is maintained in a wide range of driving scenarios, from city streets to race tracks.

This paper outlines the intuitive brake feeling setting and provides a general overview of the system hardware that supports consistent braking control.

TARGET SETTING

The first development step is establishing targets for a driver-centered sports car that delivers a New Sports eXperience (NSX). In other words, one that faithfully translates the braking inputs of the driver with incredible fidelity and virtually zero delay, thus amplifying the capabilities of every driver, while greatly elevating the dynamic experience in a wide range of driving situations.

Intuitive brake feeling occurs when the driver can easily receive the intended deceleration response without unintentional sacrifices to handling or performance. This concept is based on kinesthetic, or tactile, learning, which is learning by performing a physical activity. Intuitive braking enables drivers at all levels, from novice to professional, to engage with the brake controls and extract the desired deceleration.

To accomplish an intuitive braking feeling, brake pedal operation must be coupled with human sensation. A progressive rate of pedal stroke and pedal force workload (work=stroke x force) is established to enable a buildup sensation to the braking force lock point (Figure 2).

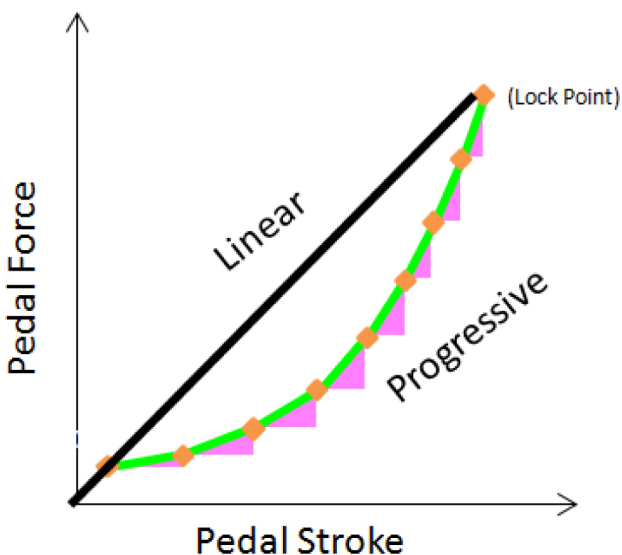


Figure 2. Brake pedal workload characteristic

The stroke and force modulation range was established based on traditional leg muscle memory movement. The pedal operation workload is constant, with smooth ratio changes that allow the driver to maintain the same amount of workload, as the stroke minimizes and the force increases, to establish the buildup feeling. This constant workload (area under the curve) provides an intuitive pedal operation modulation with the buildup sensation (Figure 3).

In general, sports cars are driven on city streets, winding roads and race tracks. Each of these scenarios has ideal vehicle performance targets. The brake feeling must be intuitive and consistent to allow a harmonious feeling with each scenario.

In the city scenario, vehicle controls are generally second nature and subconscious. Deceleration must be easy to control without unexpected system output. Additionally, pedal force must be set appropriately to prevent weariness in everyday stop-and-go workloads.

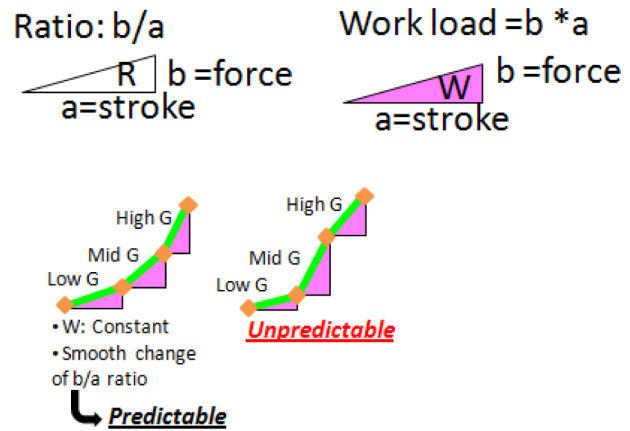


Figure 3. Brake pedal intuitive characteristic

In the winding road scenario, the driver is more engaged with the vehicle dynamics. The driver demands progressive and predictable control of the system while enjoying the vehicle handling performance. The system's progressive buildup of stroke and force must be harmonious with the progressive setting of the chassis. This smooth control complements the effortless transient movement.

In the track driving scenario, the driver is focused on maximizing peak performance to achieve the shortest lap time. This scenario demands ultimate control of threshold and trail braking to maximize tire grip. Additionally, the thermal changes that occur under high-energy driving must be minimally felt to enable braking consistency as the driver continues their lap time attack.

Target Summary

1. Intuitive brake feeling in multiple driving scenarios
2. Brake hardware that supports a consistent brake pedal feeling

APPROACH

Technology used in advanced braking systems can be broken down into four areas (Figure 4):

- Actuation system
- Corner hardware
- System cooling
- System integration

ACTUATION SYSTEM

An electro-servo brake (ESB) system was developed for cooperative control of regenerative and hydraulic brakes (Figure 5). Regenerative braking is required to charge the hybrid powertrain for electric motor propulsion, torque vectoring and reduced fuel consumption from an internal combustion engine.

In conventional brake systems, there is a fixed relationship between brake line pressure and pedal stroke. The ESB system achieves variable servo ratio control applied by conventional brake pedal

