

G-VECTORIZING
CONTROL
PRESS INFORMATION



June 2016

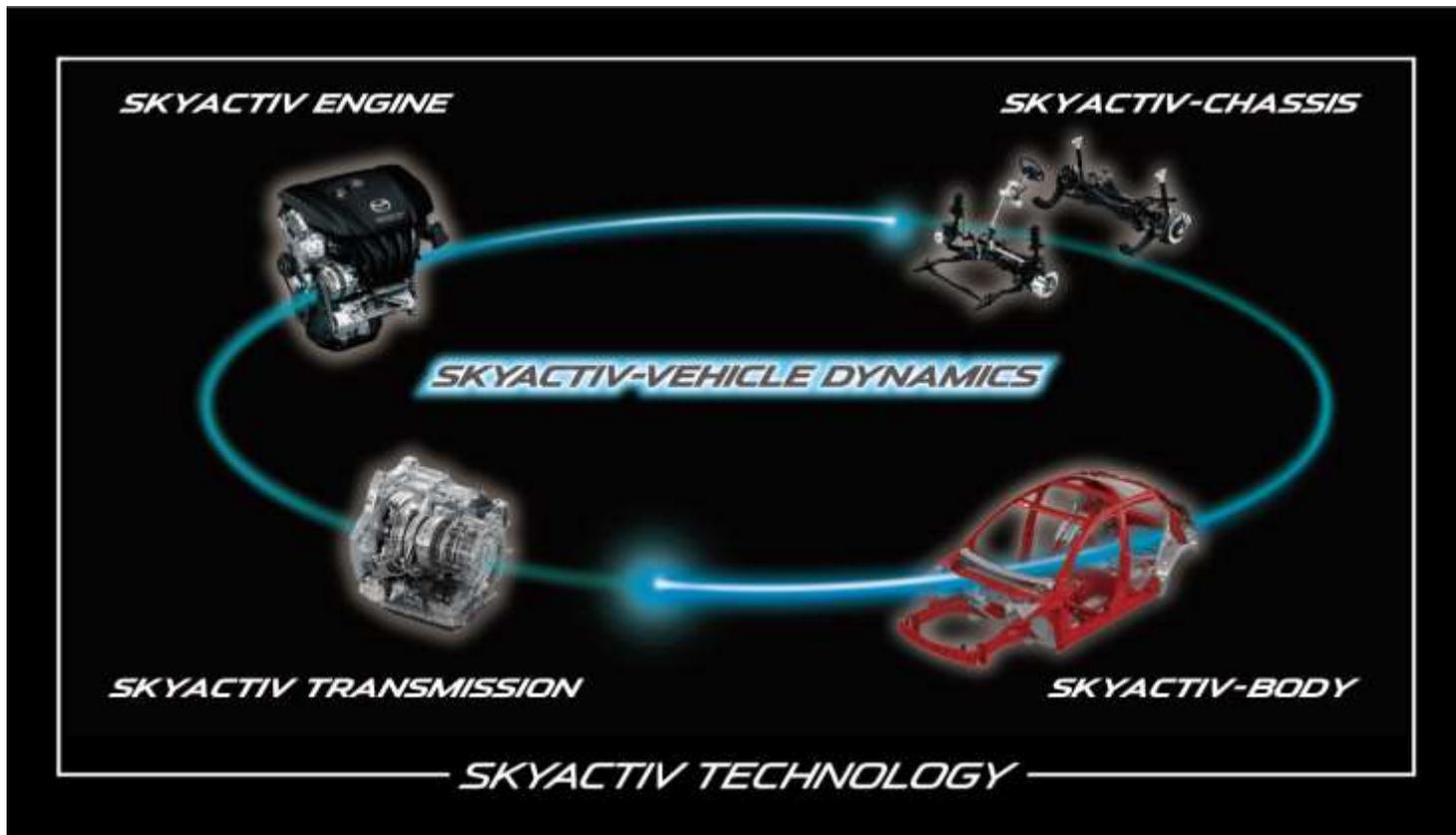
1. Introduction - The tireless pursuit of Jinba-Ittai

Mazda aims to offer vehicles that provide driving pleasure and enrich the lives of their owners. It has achieved this through the pursuit of Jinba-Ittai a feeling of unity between driver and vehicle. Whether turning, braking or simply cruising, the driver controls the vehicle as naturally and easily as if it were an extension of his or her own body. The Jinba-Ittai driving feel is the result of Mazda's unique, human-centered development philosophy, under which the company has produced a wide range of engineering advances, including SKYACTIV technologies.

2. SKYACTIV-VEHICLE DYNAMICS - Further evolving the Jinba-Ittai Experience and bringing driving pleasure to everyone

SKYACTIV-VEHICLE DYNAMICS represents a breakthrough in Mazda's tireless pursuit of Jinba-Ittai . SKYACTIV is the general term for Mazda's technology developed under the Sustainable Zoom-Zoom principle of providing all customers with driving pleasure as well as excellent environmental and safety performance. Part of the SKYACTIV series, SKYACTIV-VEHICLE DYNAMICS technologies provide integrated control of the engine, transmission, chassis and body to enhance the car's Jinba-Ittai feel—a sense of connectedness between car and driver that differentiates Mazda vehicles from others.

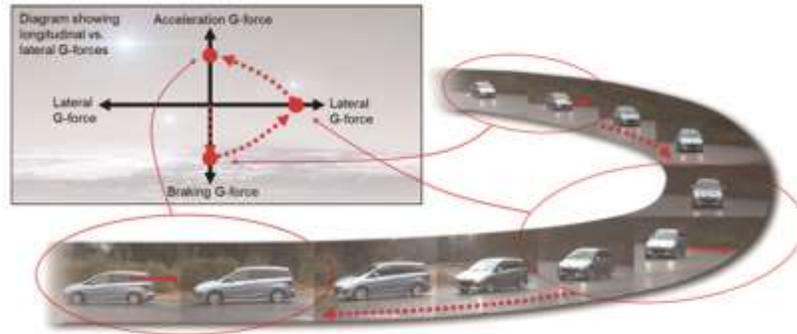
Fig.1 : SKYACTIV-VEHICLE DYNAMICS concept



2. G-Vectoring Control - Enhancing chassis performance using the engine

Mazda has always pursued smooth transitions between G-forces when braking, turning and accelerating, because it considers this an essential element of Jinba-Ittai . This results in what we refer to as a unified dynamic performance feel. In combination with consistent feedback and response in the operation of the brakes, steering wheel and accelerator, it enables the driver to control the vehicle easily and precisely.

Fig.2 : Unified dynamic performance feel



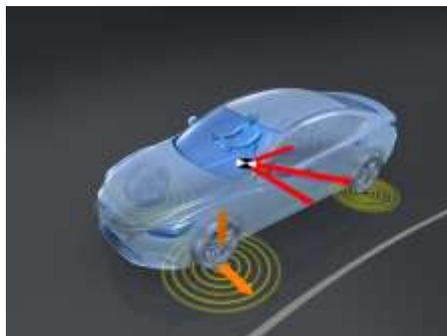
The first technology in the SKYACTIV-VEHICLE DYNAMICS series, G-Vectoring Control (GVC) further advances the unified feel that has always defined the dynamic performance of Mazda vehicles.

Its development was based on the revolutionary idea of using the engine to enhance chassis performance, allied to Mazda’s human-centered development philosophy that focuses not only on mechanical efficiency but posits how a vehicle should be in consideration of human characteristics. By adopting GVC, Mazda vehicles will exhibit even smoother transitions between G-forces in all driving scenarios.

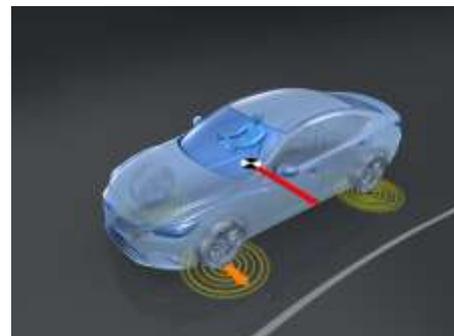
Until now, lateral and longitudinal acceleration (G) forces have been controlled separately. GVC is the world’s first* technology to adjust engine torque in response to steering inputs in order to control these forces in a unified way and optimize the vertical loading of each tire to realize smooth and efficient vehicle behavior. The vehicle moves more precisely as the driver intends, reducing the need for steering corrections, many of which are performed unconsciously. The driver feels more at one with the vehicle and more confident because the car follows his or her intended line precisely. Cumulative fatigue on long drives is reduced and smooth transitions between the G-forces acting on vehicle occupants reduce torso-sway, improving ride feel and passenger comfort. GVC also improves handling and stability on wet or snowy roads and the enhanced feeling of grip gives drivers peace of mind.

*As of June 2016. Based on Mazda's in-house investigation.

Fig. 3 : GVC conceptual diagram

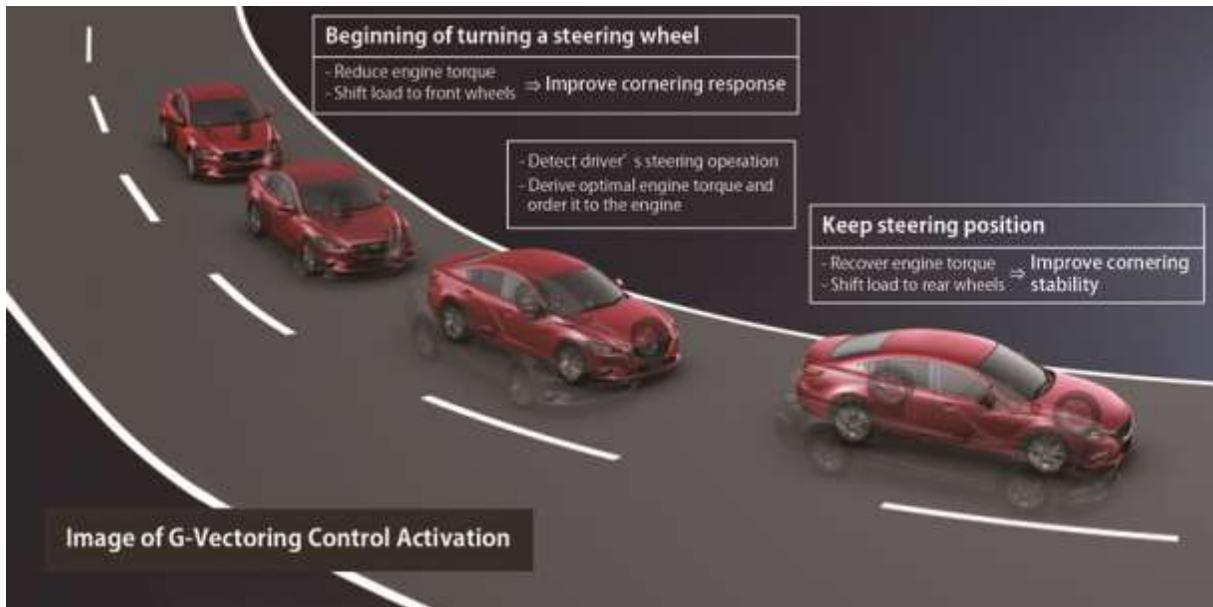


Turn-in with GVC control vehicle



Turn-in with regular vehicle

Fig. 4 : GVC operation



4. Mechanism of GVC system

GVC maximizes tire performance by focusing on the vertical load on the tires. The moment the driver starts to turn the steering wheel, GVC controls engine drive torque to generate a deceleration G-force, thereby shifting load to the front wheels. This increases front-wheel tire grip, enhancing the vehicle's turn-in responsiveness.

Thereafter, when the driver maintains a constant steering angle, GVC immediately recovers engine drive torque, which transfers load to the rear wheels, enhancing vehicle stability.

This series of load transfers extracts much more grip from the front and rear tires, improving vehicle responsiveness and stability according to the driver's intentions.

Fig 5 : Load transfer

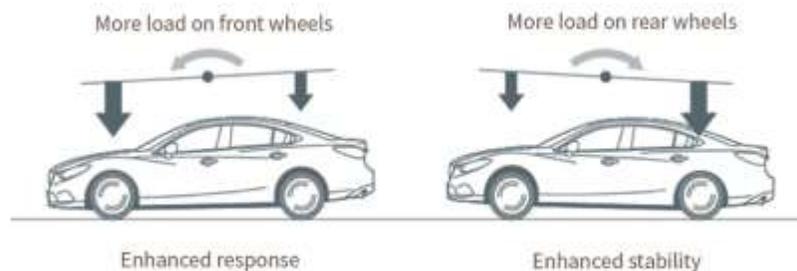
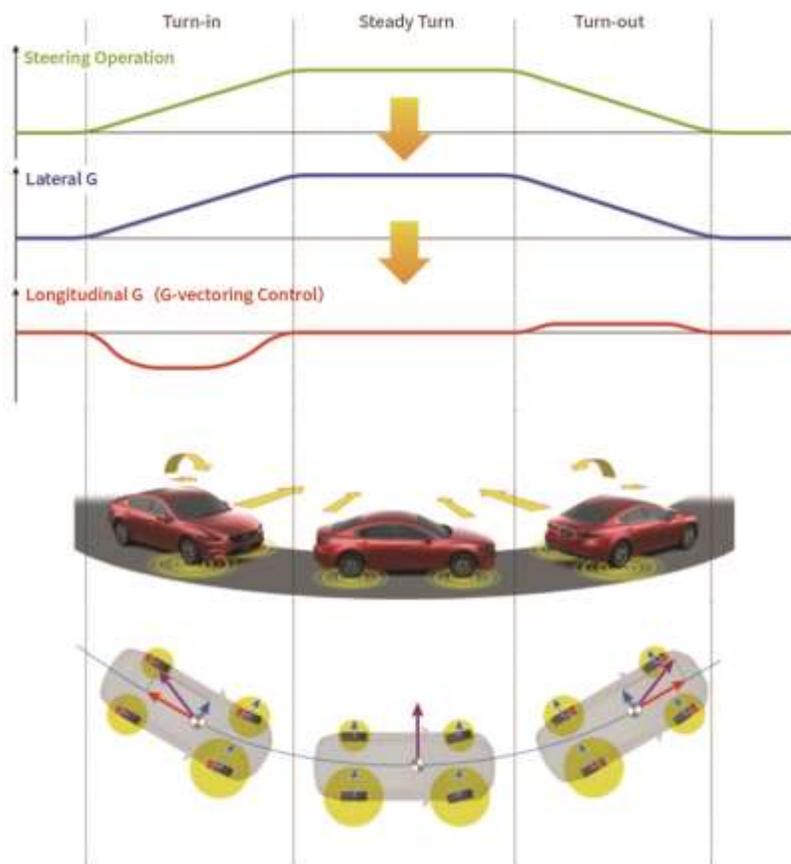


Fig 6 : GVC control equation

$$G_x = C_{xy} \times \dot{G}_y$$

* Where G_x is longitudinal G (required deceleration force), C_{xy} is control gain and \dot{G}_y is lateral jerk.

Fig 7: Correlation between steering angle and G-forces when cornering



- **A natural control effect based on a human-centered development philosophy**

The effect of GVC is very natural and does not impose any feeling of discomfort on the driver or other occupants. Based on Mazda's human-centered development philosophy, the reaction rate and amount of control has been aligned with human sensibilities.

The degree of control is extremely subtle, with a reaction time from the moment the driver operates the steering wheel faster than a person can perceive, and the resulting deceleration force usually at or below 0.01 G. One of the key features of GVC is that it enhances a natural driving feel by offering quicker and more precise control than is possible for a human driver.

- **High deployability of GVC**

GVC is only possible thanks to the existence of SKYACTIV engines, which enable precise control of drive torque, and the SKYACTIV-CHASSIS, which facilitates ideal vehicle behavior.

GVC is a highly versatile technology that can be deployed in any SKYACTIV model, irrespective of drive system or vehicle type. In addition, since GVC is a software control system, there is no weight increase due to the use of additional hardware components. Moving forward, Mazda plans to deploy GVC in most of its new-generation vehicles.

5. Benefits of GVC

Regardless of the skill of the driver, GVC demonstrates its effect consistently over a range of driving situations, from low-speed everyday driving to high-speed straight-line driving, on winding roads and during emergency avoidance maneuvers. This control technology offers the following benefits:

(1) Driver confidence increases as the car behaves as expected

The driver operates the steering wheel to keep the vehicle within its lane whether driving in a straight line or cornering. However, due to irregularities and undulations in the road surface, the vehicle does not always travel along the expected line, forcing the driver to make corrections with the steering wheel.

Since GVC provides enhanced response to slight steering wheel operations, it greatly reduces the size and frequency of steering corrections. This enables the driver to keep to his or her intended path with minimal corrections, giving a feeling of unity between driver and car and instilling greater driver confidence.

Fig 8 : Improved steering response due to GVC

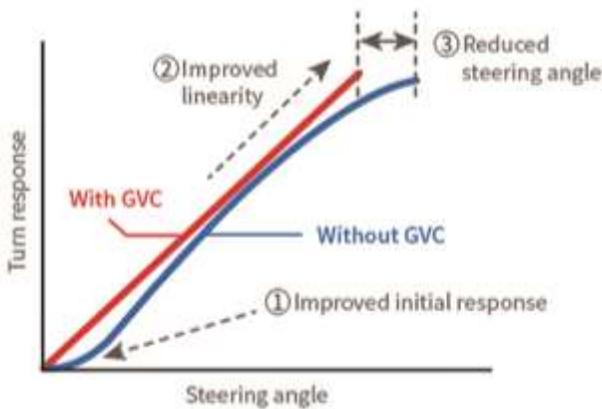
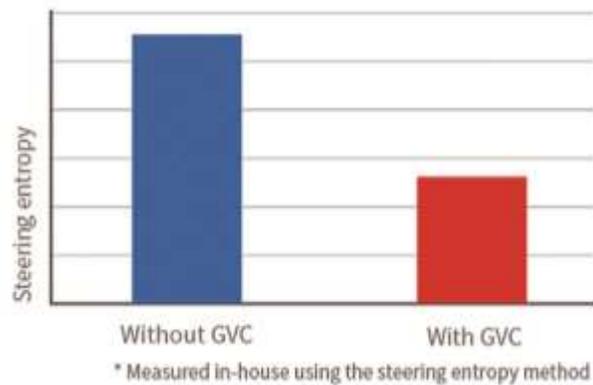


Fig 9 : Reduction in steering corrections with GVC



(2) Reduced fatigue and the enjoyment of a comfortable drive

Fatigue steadily builds up as the driver continues to make minor steering corrections. Since GVC helps alleviate these corrections, it reduces accumulated fatigue over long distances. And by smoothing the transitions between G forces, GVC suppresses the swaying of head and body experienced by vehicle occupants, enabling them to enjoy a more comfortable drive.

Fig 10 : Reduction in torso-sway with GVC



* In-house passenger seat comparison of left-hand turn at 30 km/h (lateral acceleration of 0.4 G)

(3) Enhanced peace of mind thanks to stable vehicle motion

Because GVC simultaneously enhances handling and stability by optimizing the vertical load on the tires depending on driving conditions, it demonstrates even greater effectiveness in rain and snow and on poor road surfaces. It also stabilizes the vehicle during evasive maneuvers. In any driving scenario, the system offers an enhanced feeling of the tires gripping the road, giving vehicle occupants a greater sense of security.

Fig . 11 : Effect of GVC during evasive maneuvers

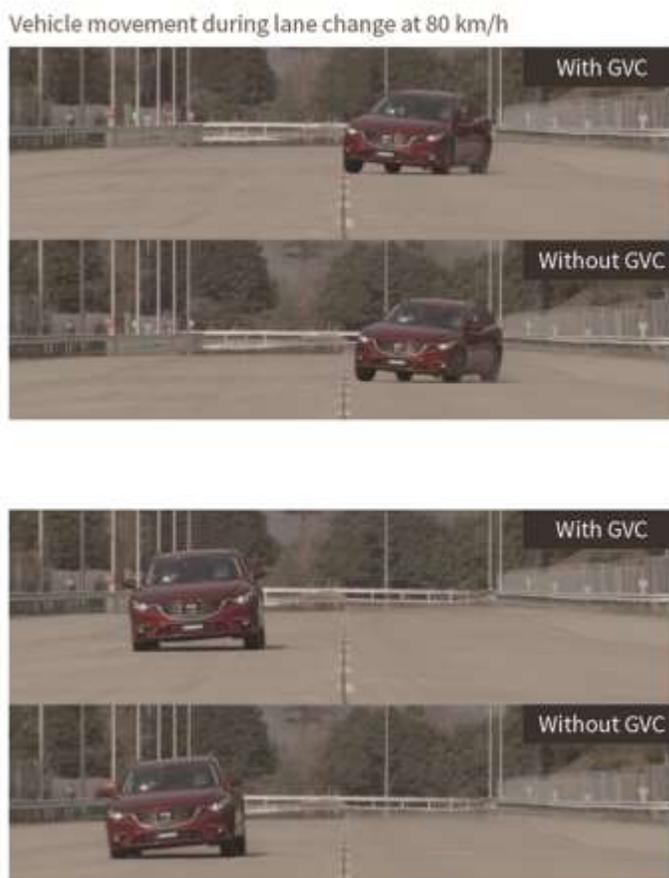


Fig . 12 : Effect of GVC on snow

Response: Front wheels react instantly and without slipping when the steering wheel is turned



Stability: Vehicle is stable and rear wheels do not slip when the steering wheel is returned to its original position



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