

Feature SETTING THE FUTURE IN MOTION

When NSK celebrated its 100th anniversary in 2016, we created “NSK Vision 2026” to guide our efforts over the next 10 years.

As a part of this vision, “Setting the Future in Motion” embodies our goal of going beyond merely meeting customer needs. Instead, we take a wide view. We aim to be a company that proactively creates and proposes new value based on end-user needs. To that end, all of us should possess flexible thinking and aim to take on new challenges.

Amidst great changes in markets and society, we strive to fulfill our responsibilities and contribute to society through our businesses and products. Through our efforts, we hope to become a vital presence in the world.

In our first feature, we’ll introduce NSK’s ongoing efforts to create and provide value for automobiles during this once-in-a-century period of dramatic technological innovation. After, we will spotlight the Global Team working to cement “NSK Vision 2026” within the Group and tie it to our real-world activities.

Feature 1 NSK Value Creation for Technological Innovation in Automobiles —Change as a Chance to Soar

The transformation of automobiles is progressing at a speed and scope beyond expectations.

NSK is drawing fully on cultivated “running,” “turning,” and “stopping” technologies to propose a “Future in Motion.” Through these, we aim to advance “mobility societies” and sustain growth.

Broad trends toward Connected (C), Autonomous (A), Shared (S), and Electric (E) (CASE) operation are gaining speed. Technologies related to these changes are thought to be heading down two paths.

In the first, technology trends have constantly evolved over time. In automobiles until now, “mobility,” “possession,” and “experience” have been valued. Changes to improve automobile performance and value occur through the improvement of existing technologies based on the continuous evolution of basic mechanisms.

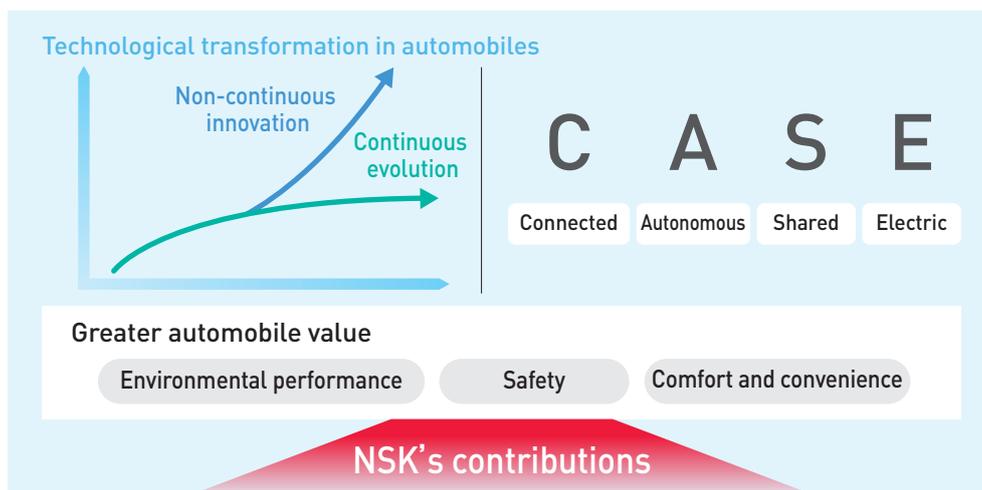
The other path is of non-continuous technological innovation. New technologies such as electric vehicles (EVs), new materials, and autonomous driving are creating dramatic structural changes. Automobiles can now be controlled through signals and over networks. Within these connected

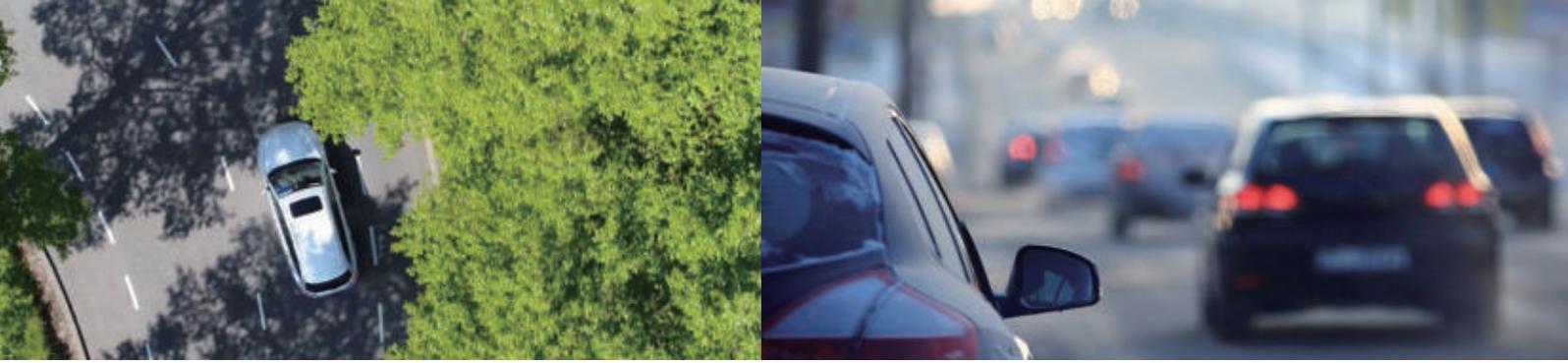
areas, there is a broad spread of value generated by enormous amounts of driving data. Then, there are the changing ways in which automobiles are being used. Rather than being owned, they are shared through joint use or ride sharing. These and other unprecedented and non-continuous changes are moving forward.

Such broad changes are greatly impacting society and relevant industries. In terms of automobiles, we are seeing a demand for ever-higher value with environmental performance, safety, comfort, and convenience in mind.

NSK sees these changes as a great opportunity. As we improve existing products, we are also equipping products to automobiles for the first time. Through new and upcoming technologies, we will continue to make contributions as a mechanical parts manufacturer.

Increasing Value Through Technological Innovation in Automobiles





Growing Automotive Businesses by Continuous Technological Advancement

As innovation in automobiles proceeds, the technological requirements for basic mechanisms also rise. The important parts of automobiles will continue to evolve. NSK will be there as we constantly strive to expand through our component technologies.

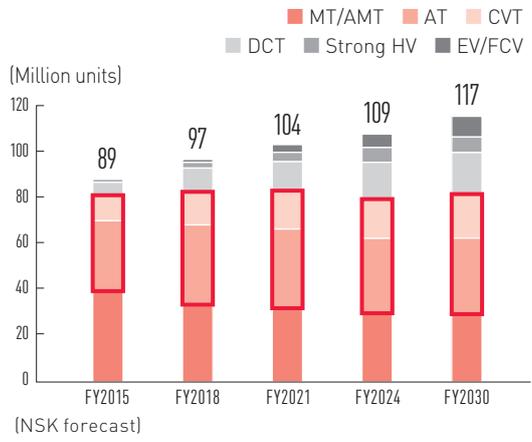
1 Expansion of Automatic Transmission (AT) Business

Automatic transmissions (ATs) control automobile acceleration and deceleration by automatically switching gears. As environmental regulations become stricter, customers need ATs that are more compact and light, have more efficient friction control, and have better multistep AT fuel efficiency and comfort. Currently, three factors are increasing the need for ATs. By developing high-performance products to meet customer needs, NSK has an ongoing annual growth rate of 10% from bearing products, in particular needle bearings, and AT-related components.

Background of NSK's AT Business Expansion

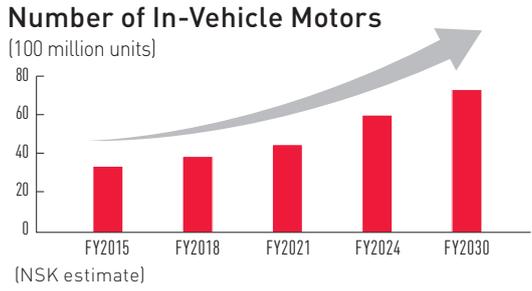
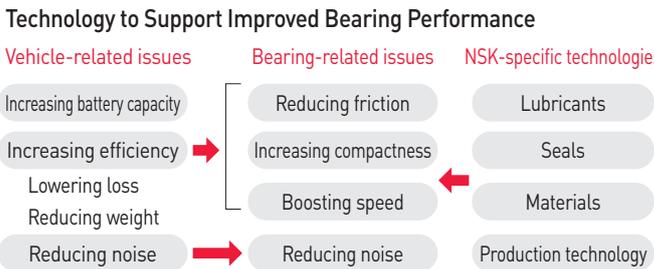
1. Expansion of automatic transmissions used in emerging markets
2. Progress in shift to multistep AT (multistep AT = seven or more speeds)
3. More new business won from the largest customers

Transmission Market Forecast (By Type)



2 NSK Bearing Technology Supporting EVs and Electrification

To allow vehicles to travel longer distances, EVs need to be more efficient and lighter. EVs are also required to be quieter by reducing the noise of mechanical parts. Bearings face similar pressures for more compact products with less friction, higher speeds, and less noise. Also, as more vehicle functions become electric, in-vehicle motors will increase dramatically. NSK will leverage its cultivated base technologies and inherent strengths and aim for ever-higher bearing performance in these new fields.



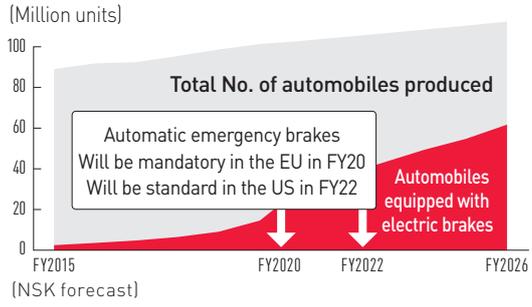
3 Major Deal: Mass Production of Ball Screws for Electric Brake Boosters Begins

To improve safety, automatic emergency braking systems are increasingly becoming mandatory in vehicles. Brake boosters (brake pedal amplifiers) are becoming electrified, and demand is increasing. Forecasts call for 50%–60% of vehicles produced worldwide to be equipped with electric brake boosters by the mid-2020s.

Ball screw brake boosters are recognized for their outstanding responsiveness and control. NSK received orders for 4.5 million ball screws and started mass production for some of these in 2018. While building a global production structure, we will work to strengthen sales in this area.

* Please see P. 18 for details.

Demand Forecast for Electric Brakes





Feature 1

NSK Value Creation for Technological Innovation in Automobiles

—Change as a Chance to Soar

Taking “Running,” “Turning,” and “Stopping” to the Next Era

NSK has been working in a number of R&D fields while imagining a future where autonomous and electric vehicles are common.

Based on our Four Core Technologies, we have honed an array of knowledge. We will use our expertise to improve stability, comfort, and more in our proposals for next-generation automobiles.

Wheel Hub Motor Fit

- Compact in-wheel motor for EV drive systems
- Flexible drive force distribution with four-wheel independent drive
- Two built-in motors and a compact built-in transmission

▶ Customer Needs and New Technology

There are a variety of EV drive systems; some have multiple motors and differing deceleration mechanisms exist. In-wheel motors have their drive motors inside the wheels. Four-wheel independent drives will offer flexible drive power distribution and increased energy transmission efficiency. These drives will also allow for better steering performance, more cabin space, and other merits.

▶ Product Characteristics

The “Wheel Hub Motor Fit” is a drive system equipped to the wheel itself. This is just one more example of how we constantly evolve and improve with practical applications in mind. With a more compact motor embedded inside the wheel, this NSK technology features a proprietary two-motor system. These motors can be controlled in tandem to change speeds through a mini internal transmission mechanism. In addition to enabling bursts of power and driving speed, drive power can be controlled per wheel for high-dimensional performance that improves stability and collision avoidance. Due to its small size, this technology can be equipped in a variety of vehicles. We are making steady progress toward a practical application.



Ball Screws for Electric Brake Boosters

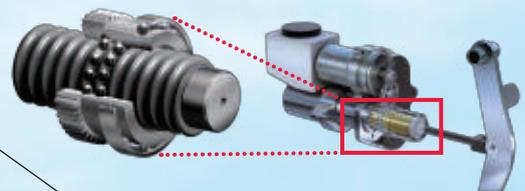
- Contributing to the spread of automatic brake systems
- Solution to electrify brake boosters
- Excellent responsiveness and control gained through highly efficient ball screws

▶ Customer Needs and New Technology

Automatic brake systems not only help reduce accidents, but they are also essential in autonomous vehicles. Now, installation rates are going up, and they are getting more popular. Moreover, as more and more vehicles become hybrid or electric, brake boosters are moving away from traditional vacuum boosters to electric types. Responsiveness is crucial in these fused electric brake boosters.

▶ Product Characteristics

There are a number of kinds of electric brake boosters, but ball screws are the most promising for high-level regenerative brake systems and emergency auto braking. Ball screws are highly efficient at converting rotational motion to linear motion. This means they can convert motor pressure to braking pressure and respond with precise control. These features make them vital for high performance in electric brake boosters and for braking systems overall. Brakes are a mechanism for “stopping” in automobiles, but brake electrification has also made independent control of the tires simpler. This system enables high attitudinal control by allowing the braking force on each wheel to vary. We continue to develop these key ball screws to support improved brake systems.



Parallel Link type Active Suspension

- Ideal attitudinal control in automobiles
- Easy adjustments for wheel angles, track, and wheel base*
- Can be applied to steering systems for steer-by-wire functionality

▶ Customer Needs and New Technology

Attitudinal control has a direct impact on performance and comfort while riding in an automobile. If the wheel angle, track, and wheel base* can be easily adjusted, driving performance can be improved. The positioning of autonomous vehicles can also be controlled, ideally for greater passenger comfort. Moreover, we also expect this technology to be applied to steering systems such as steer-by-wire.

*Track (distance between the left and right tires), wheel base (distance between the front and rear wheels)

▶ Product Characteristics

Parallel Link type Active Suspension combines NSK’s world-class ball screw technology with a motor to realize optimal control of the wheel angle. Of course, the system offers the standard left-right turning a driver needs at intersections, but it can also adjust the wheels to have a negative camber angle for greater stability at high speeds, such as on highway curves. In addition, the actuators can be repositioned so the vehicle track and wheel base can be adjusted. For example, the shorter the distance between the front and rear wheels, the tighter a vehicle can turn, which also makes it easier to parallel park. Further, Parallel Link type Active Suspension achieves a high degree of running stability by reducing vibrations while driving. It also offers excellent attitudinal control by serving a much wider range of motion through all four wheels.





Steer-By-Wire

(Force feedback actuator, road wheel actuator)

- Proposal for road surface reaction feedback actuator in addition to steering mechanism
- Clear signal transmission between two actuators (control system redundancy)
- Electric tilt and telescopic configuration to store the steering wheel

▶ Customer Needs and New Technology

In the future, steering devices and brake mechanisms will likely be controlled by electric signals. On the plus side, steer-by-wire devices take up less space in the engine area. However, we must work to give steering systems a natural sensation of speed and road surface conditions. In addition, more complicated autonomous vehicles will require steering wheel storage and retrieval functions.

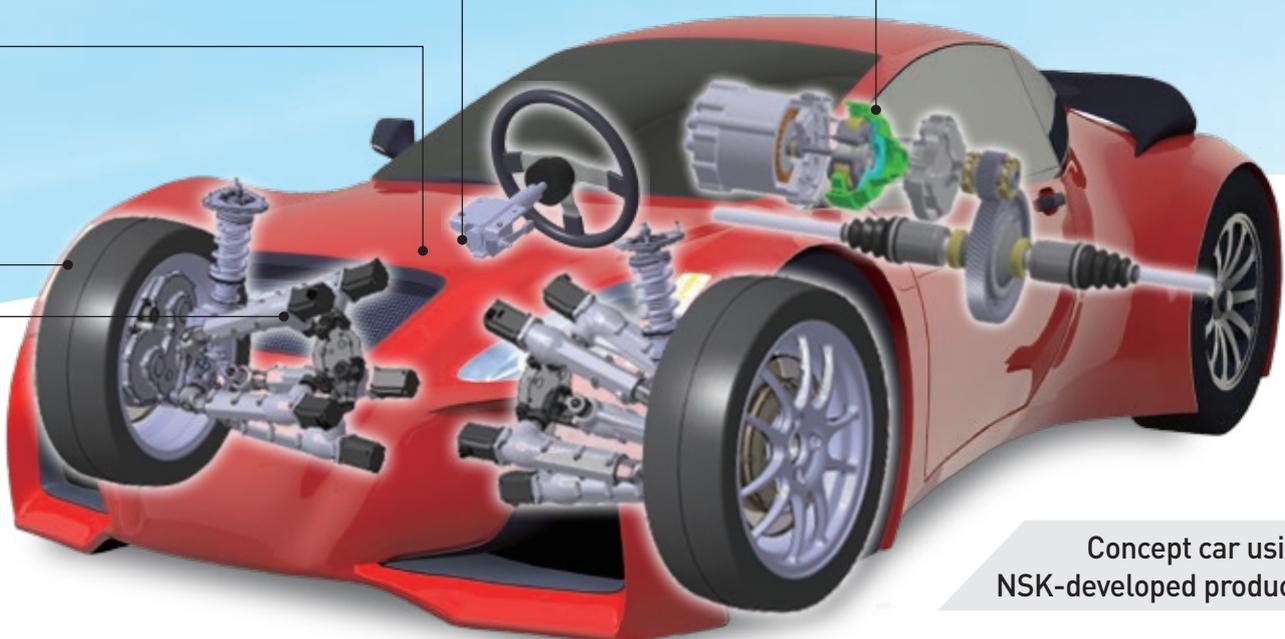
▶ Product Characteristics

NSK started with a ball screw steering gear and branched out into a variety of steering components, including steering columns, intermediate shafts, and joint parts. Recently, we have seen electric power steering (EPS) contribute to advanced "turning" in automobiles. Force feedback actuators and road wheel actuators for steer-by-wire systems now incorporate our cultivated steering technologies. As mentioned, we are working on steer-by-wire systems that feel natural when steering. We are also making clear and steady signal transmission control systems that guarantee functions during a failure. Finally, we are also working on electric tilt and telescopic functions to allow the steering wheel to be stored, retrieved, and adjusted.

Force feedback actuator



Road wheel actuator



Traction Reducer

- Compact, lightweight, ultra-high-speed revolution EV drive unit with optimized deceleration mechanism
- Quiet operation with traction drive mechanism
- Applied technology for mass production of actual half-toroidal CVT systems

▶ Customer Needs and New Technology

EV drive motors need to be compact and light to improve power consumption and have enough output. If the motor must support a high number of revolutions per second, improving energy transmission efficiency in integrated deceleration mechanisms is even more important. Moreover, motor-driven vehicles need to be even quieter when running.

▶ Product Characteristics

As electric vehicles become more common, the balance between cost and cruising distance must be addressed. NSK is moving ahead with a Traction Reducer. Instead of using gears, this reducer uses a special oil that becomes solid only for a moment when compressed. The "rolling" that results allows for more efficient power transmission. This reducer is also extremely quiet, regardless of revolution speed or torque. By combining this breakthrough traction decelerator with a high-speed motor, overall electric vehicle drive systems can be even more compact and light. The smooth transfer of power gained through Traction Reducer also reduces power consumption.



Concept car using
NSK-developed products