NSK is a Japanese component manufacturer headquartered in Tokyo that primarily produces bearings and vehicle components. At the end of 2016, the company introduced its new wheel hub motor with an especially effective transmission mechanism (figure 1). Although this type of motor has a comparably small size, it can achieve a high driving performance. NSK's aim is not the series production of the motor as a whole but rather establishing its individual components on the market. The primary focus is on wheel bearings with an integrated reduction gear, one-way clutches, small roller bearings, and corrosion-resistant bearings.

More Safety and Comfort and an Improved Environmental Footprint

Since wheel hub motors are mounted directly on the wheel, some of the drivetrain components required for traditional vehicles with central engines are no longer necessary. This reduces the weight of the vehicle, which in turn results in lower energy consumption and an improved environmental footprint. At the same time, components such as a transmission tunnel are no longer required for rear-wheel drives, which adds more space in the vehicle's interior, improving comfort for passengers. There is also an improvement in vehicle safety, because the wheel drive can be controlled much more directly and individually than for a central combustion engine with the traditional drivetrain components.

High Performance Requirements for Small Motors

During the development phase, NSK faced a range of challenges. One of the most difficult tasks was to keep the motor as small as possible despite the high performance requirements. To deal with all types of everyday situations, the motor must be able to provide a high torque at a comparably low rotational speed during acceleration and when moving uphill. In contrast, maximum rotational speed and low torque are required when driving on highways. Because this range of requirements can quickly have a negative impact on the motor size, NSK focused its development on reducing the size of the wheel hub motor and its components.

The Solution: A Wheel Hub Motor with a Transmission Mechanism

While NSK was searching for a compact solution, it developed a wheel hub motor with an integrated transmission mechanism. This novel drive consists of two motors, two planetary gear trains, and a one-way clutch (figure 1). This setup makes it possible to reach the required high torque and a sufficiently high maximum speed. In contrast to combustion engines, electric motors can also rotate in reverse direction. The team used this as a basis for their development work. In high gear, both motors rotate in the same direction, in low gear, they run in opposite directions. Both motors of the wheel hub drive are connected to the wheel via the gear unit, which consists of two planetary gear sets and a one-way

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> "It was very useful for us that the Tandem-AutoBox is able to simultaneously perform control tasks and measurements. The fault analysis and correction was also very quick, easy, and reliable with the help of the dSPACE systems."
>
> *Yasuyuki Matsuda, NSK*

Highly Efficient Wheel Hub Motor

NSK is developing a compact wheel hub motor with an integrated transmission mechanism

Picture credit: © NSK Ltd.

Increasingly stricter environmental regulations for vehicles accelerate the trend towards electric drives in automotive engineering. In view of this, the Japanese company NSK developed a novel wheel hub motor with an integrated transmission mechanism, which was evaluated with a Tandem-AutoBox from dSPACE.

Technical Data

Wheel hub motor	
Maximum power (per wheel)	■ 25 kW
Maximum drive torque	■ 850 Nm
Maximum speed	■ 135 km/h
Weight	■ 32 kg

Test vehicle	
Wheelbase	■ 2550 mm
Track width	■ 1484 mm
Weight (without passengers)	■ 1013 kg
Battery voltage and capacity	■ 400 V 10.2 kWh

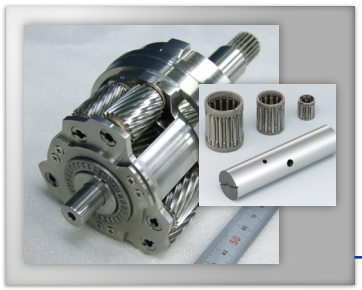
clutch. Being able to variably actuate the motors in two directions results in two different gear ratios. If the motors rotate in opposite directions, high torque is applied to the drive shaft, which can be used up to a limited rotational speed. For higher rotational speed, both motors can be run in the same direction and thus allow for higher vehicle speed. A wheel bearing with an integrated reduction gear eventually transfers the torque to the wheel. Thanks to this special motor-gearbox configuration, a dedicated shift actuator is no longer necessary. NSK assumes that a setup with two of these drives (one for each front wheel) can reduce the weight by 30% in comparison to a solution with a central vehicle motor of the same performance. Moreover, the transmission mechanism is able to smoothly shift gears during acceleration and braking because of the torque and rotational speed control of both motors.

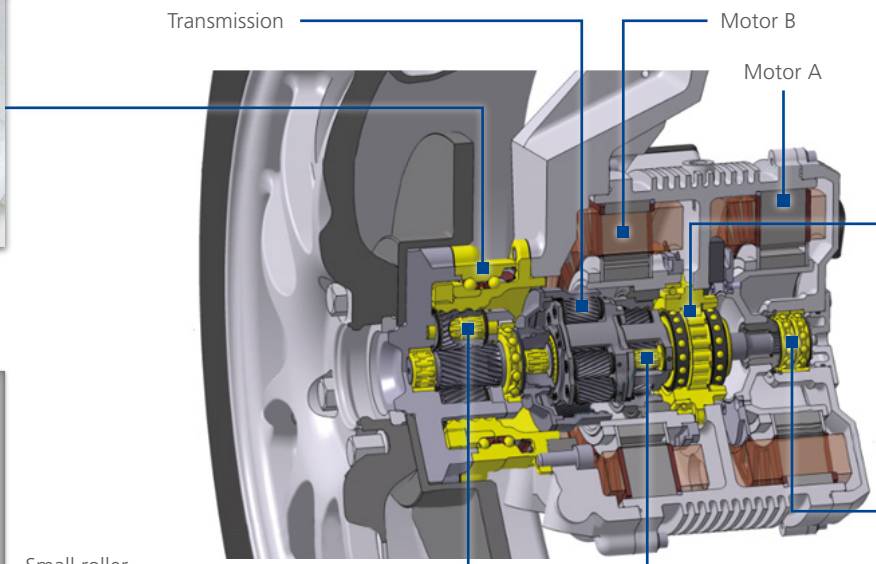
Tandem-AutoBox for Onboard Experiments

To evaluate the motor prototype, the development team built a test vehicle that has wheel hub motors mounted on the front wheels. When NSK produced the complex evaluation equipment, especially while building this test vehicle, it cooperated closely with a large number of companies and a university. dSPACE supported this project since the planning phase and still continues its support. To test the wheel motors in real-life operation, a Tandem-AutoBox was installed into the rear of the vehicle. The Tandem-AutoBox provided the major interfaces required for the test vehicle. Aside from controlling the electric motors in the wheel hub drives, the dSPACE system also took over the control of the electric power steering. The setup of the test vehicle is suitable for additional use cases that

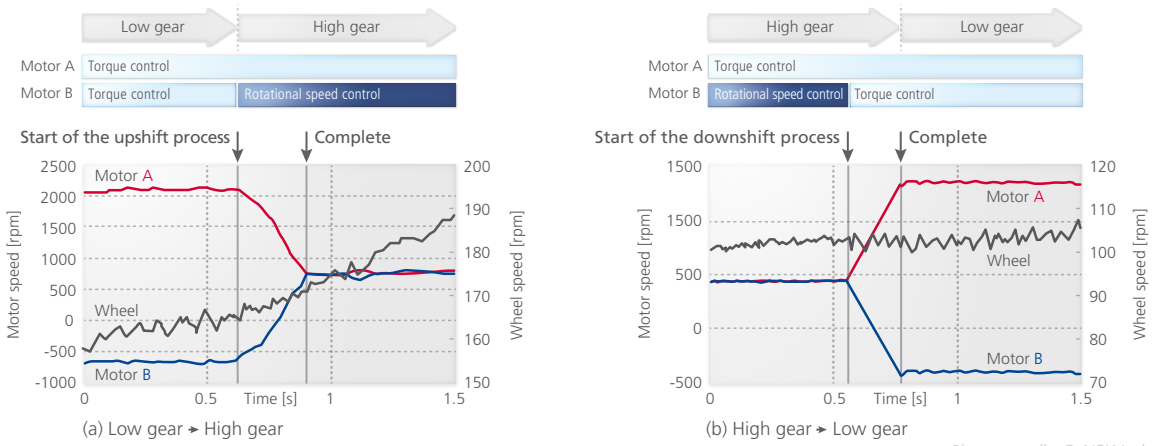
Figure 1: Setup of a wheel hub motor with an integrated transmission mechanism. NSK wants to establish the individual motor components on the market.

Wheel bearing with integrated reduction gear





Picture credit: © NSK Ltd.



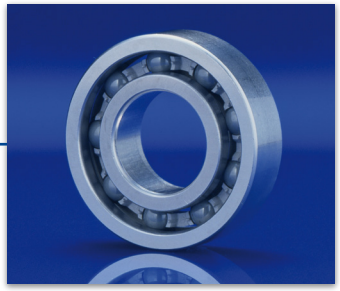
Picture credit: © NSK Ltd.

Figure 2: Processes when shifting up or down:
a) The two motors initially run in opposing directions. When motor B changes direction, the one-way clutch activates the planetary carrier. The motors now rotate in the same direction (high speed, low torque).
b) Both motors initially rotate in the same direction. When motor B changes direction, the one-way clutch stops the planetary carrier. The motors now rotate in opposing directions (low speed, high torque).

go beyond testing the wheel hub motors. To be ready for future challenges, NSK used a Tandem-AutoBox that can be operated with a 12 V vehicle battery.

One-way clutch

Corrosion-resistant bearing



Close Collaboration with dSPACE

When building the test vehicle, NSK trusted the expertise provided by dSPACE Engineering Services, who supported the development team throughout the entire development process. Together, the teams were able to quickly and easily change and enhance device configurations and update control strategies. For the result analysis, dSPACE's experiment software ControlDesk and the Tandem-AutoBox proved to be very helpful. It was particularly useful that the Tandem-AutoBox is able to perform control tasks and measurements simultaneously. This made fault analysis and correction faster, easier, and more reliable.

Conclusion

Because the test vehicle is an electric vehicle, it is usually either connected to the charging station, used for a test (driven), or is under maintenance to update the control software. Therefore, a vital point for the development of the control software was that it would be able to switch between these situations. The engineers also received easily readable code that they could adapt to the different operation states without any problems. This enabled the team to work efficiently during the complete development process. ■

Yasuyuki Matsuda, NSK Ltd.

Learn more about the functioning of the wheel hub motor in this video: www.dspace.com/go/dMag_20172_NSK

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