Technical Trends and Outlook for Automotive Driveline Products

Y. NAKAOKA

In order to respond to market demands, such as vehicle electrification, "CASE (Connected, Autonomous, Shared & Services, Electric)" and "MaaS (Mobility as a Service)", JTEKT is pushing ahead with the electrification of driveline products for use on automobiles, as well as the strengthening of fundamental technologies for existing products. We aim to "leap to a leading company in the world as a driveline system supplier". This article introduces our automotive driveline product development initiatives as we strive to "leap forward and become world-leading company as a driveline system supplier."

***Key Words**: driveline, vehicle electrification, CASE, MaaS, E-AWD*

1. Introduction

Of a vehicle's three major elements, run, turn, and stop, driveline products are in charge of the "running" role and transmit power generated in the engine and motor to the tires. In order for a vehicle to have low fuel consumption and run safely, there is a need to distribute the suitable driving force for the road surface condition and running condition to all driving wheels. JTEKT incorporates the many core technologies we have cultivated in the bearing and hydraulic/electronic control fields into our driveline products and is engaging in product development in line with our corporate philosophy of "Seek to contribute to the happiness of people and the abundance of society through product manufacturing that wins the trust of society."

In line with the diversification of power sources through the spread of hybrid vehicles (HV), electric vehicles (EV), and fuel cell vehicles (FCV), and the development of advanced driver assistance systems (ADAS) and self-driving systems of recent years, demands have emerged to respond to CASE (Connected, Autonomous, Shared & Services, Electric) and MaaS (Mobility as a Service), which are presumed to trigger great change in the auto industry (**Fig. 1**).

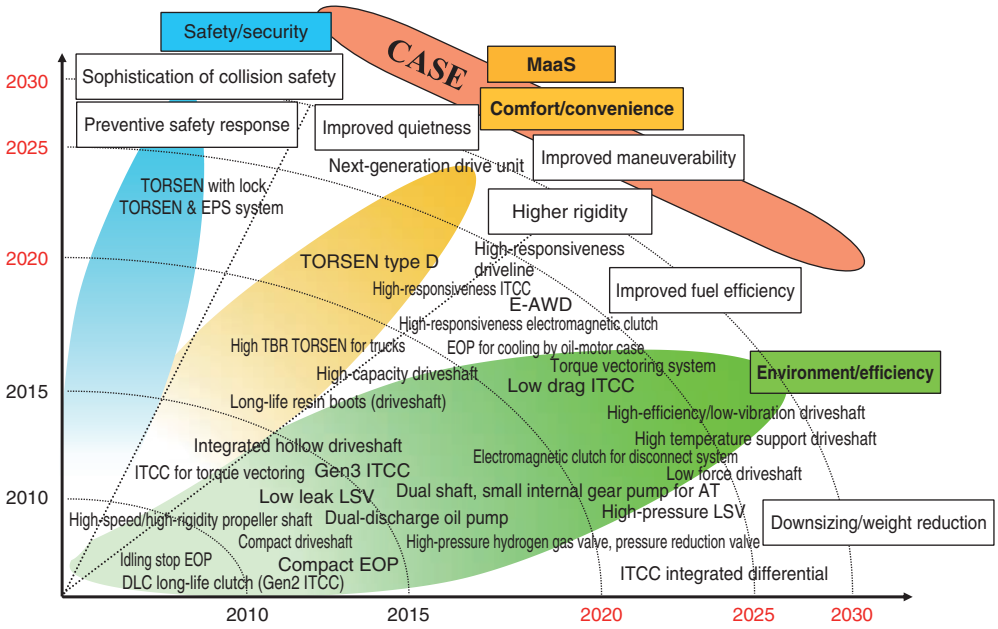


Fig. 1 Road map of driveline products

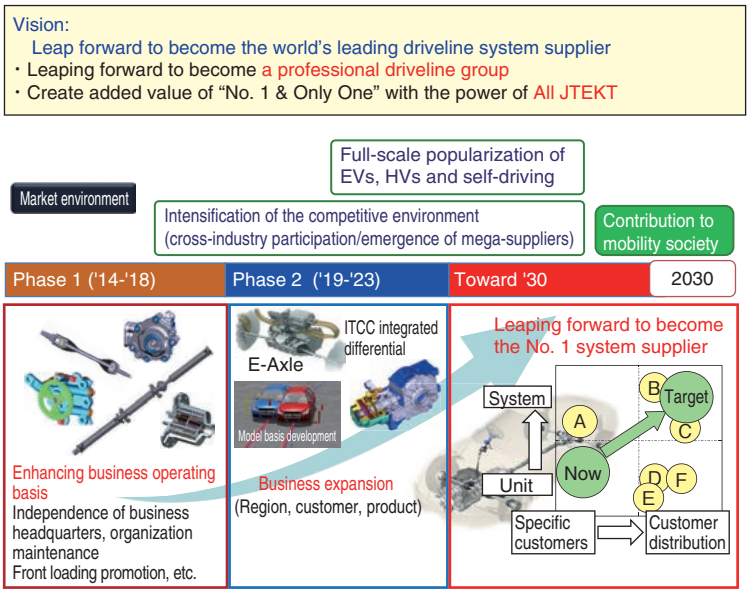


Fig. 2 Aim of JTEKT driveline products

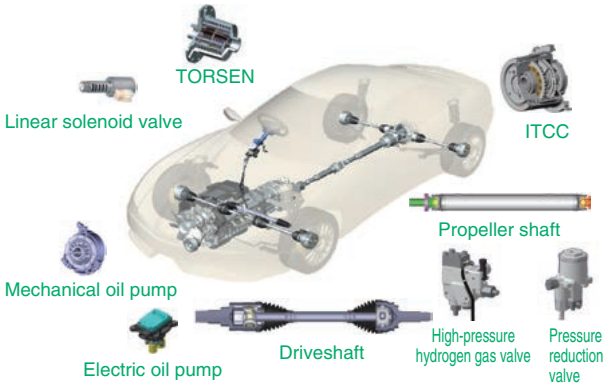


Fig. 3 JTEKT driveline products

At JTEKT also, with the aim of leaping forward to become the world's leading driveline system supplier, we are strengthening our technological and development systems anticipating the future (**Fig. 2**).

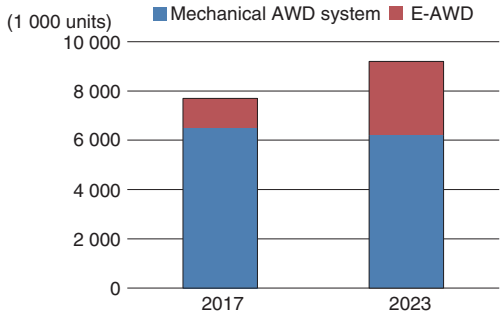
This paper introduces technological trends of JTEKT's driveline products, the initiatives thereof, and future outlook.

2. Driveline Parts for Automobiles

JTEKT has developed and launched driveshafts and propeller shafts, the electronic torque control coupling ITCC (Intelligent Torque Controlled Coupling) and TORSEN, to transmit engine power to tires as driving force, as well as mechanical oil pump (MOP), electric oil pump (EOP), and linear solenoid valve generating hydraulic pressure for AT/CVT applications. In recent years, we have also been developing and producing high-pressure hydrogen gas valves and pressure reduction valves, etc. for mounting on fuel cell vehicles (**Fig. 3**).

3. Strengthening of Fundamental Parts

Through future technological innovations and vehicle electrifications due to fuel economy regulations of each country, it is predicted that the electrification of AWD vehicles will advance with certainty, however conventional systems will remain a large percentage for the time being (**Fig. 4**). Accordingly, JTEKT believes there is a need for a response anticipating demand for both electrified and conventional AWD systems, and is pushing ahead with foundation strengthening activities, as detailed herein.



Excerpt from materials from the 1st New Era of Automobiles Strategic Meeting by the Ministry for Economy, Trade, and Industry

Fig. 4 AWD demand forecast

3. 1 Driveshafts Supporting High-efficiency

In regards to driveshafts that transfer rotational force generated in the engine to the tires at equal speed, we have achieved low vibration by revising the dimensions of the outboard (wheel side) joint which contribute to internal friction (funnel angle, ball diameter, ball contact angle, etc.). For the inboard (differential side) joint, we achieved high efficiency even in high temperature environments without shortening life span by incorporating a design that suppresses surface pressure (P value) contributing to self-heat generation amount and slide velocity (V value) (**Fig. 5**).

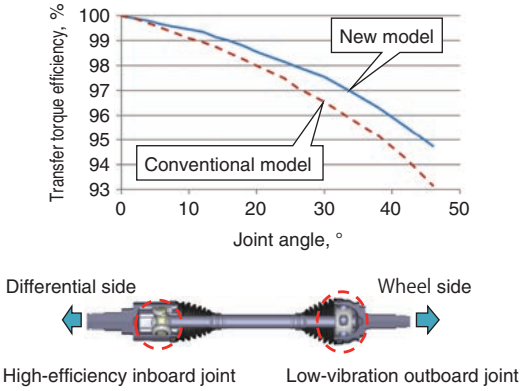


Fig. 5 High-efficiency driveshaft

3. 2 Torque Control Device (TCD)

3. 2. 1 High-responsiveness Electromagnetic Clutch for Disconnect

For the electromagnetic clutch, a device to switch between AWD and 2WD, there is variation in response time due to change in the oil immersion state within the clutch affected by the horizontal gravitational force generated when the vehicle turns. As such, JTEKT released a new electromagnetic clutch product after incorporating the below improvements. First, in order to minimize response time variation, we optimized the groove shape for the armature part attracted by the internal coil, thus reducing oil discharge resistance. Moreover, by making the outer plate wavy, torque isolation time is shortened, response speed is quicker, and outstanding control performance is achieved (**Fig. 6**).

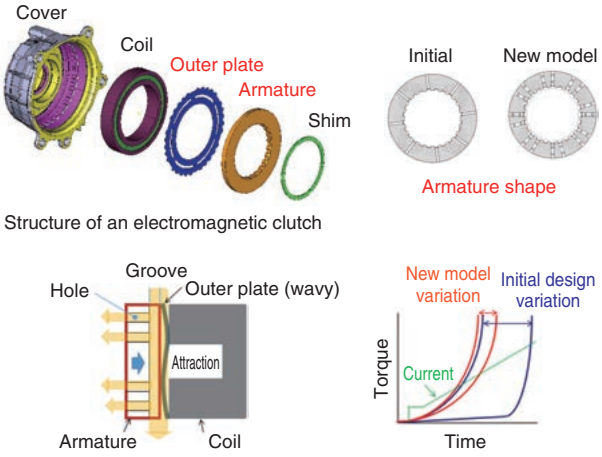


Fig. 6 High-responsiveness of electromagnetic clutch for disconnect

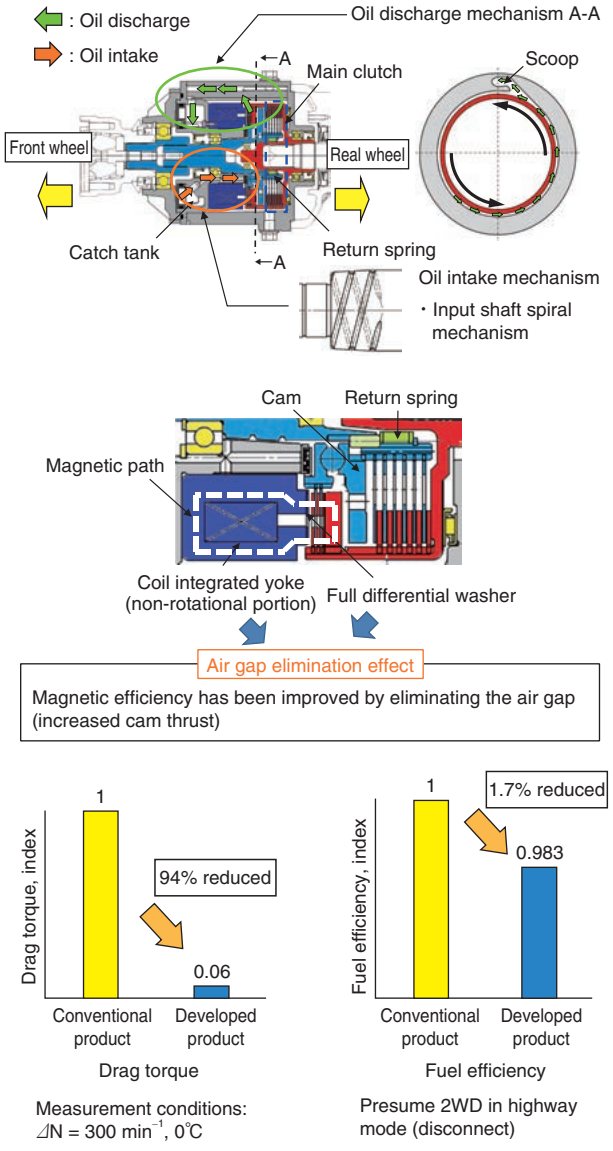


Fig. 7 Low drag ITCC

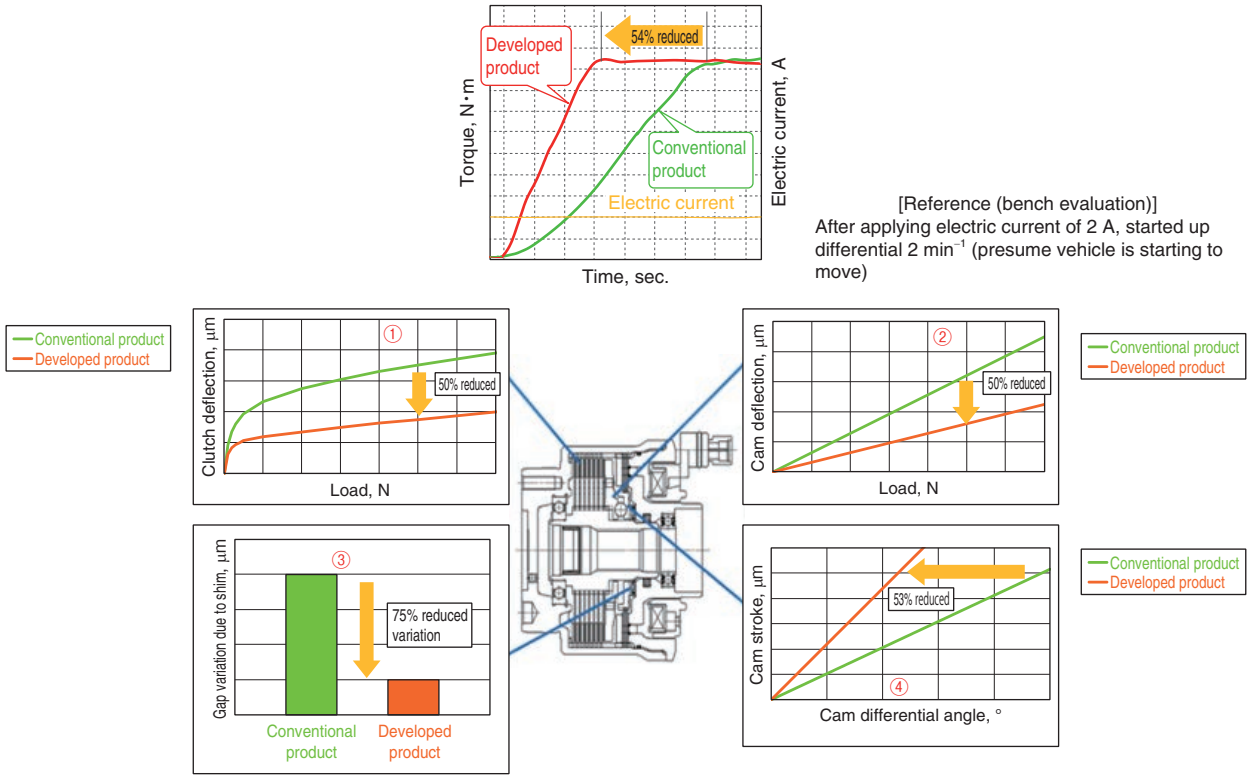


Fig. 8 High-responsiveness ITCC

3. 2. 2 Low Drag (Low Friction) ITCC

ITCC, a part controlling torque transferred to the rear wheel with an electronic cam actuator and wet, multiplate clutch, previously faced the issue of high drag torque. As such, JTEKT optimized oil discharge/intake mechanism by adding a catch tank to the clutch housing and making the input shaft a spiral groove shape, as well as cancelling out cam thrust (start-up) from drag torque with the addition of a return spring. These efforts made it possible to dramatically reduce the drag torque between the main clutch and cam, and contributed to improving fuel economy of AWD vehicles (**Fig. 7**).

3. 2. 3 High-responsiveness ITCC

In order to further improve the launching performance and turning ability of AWD vehicles, JTEKT optimized ITCC components (increased clutch/cam rigidity, improved accuracy of internal clearance control, increased cam groove angle), thus contributing to greater driveline responsiveness (54% higher responsiveness than the current ITCC actuation time) (**Fig. 8**).

3. 3 Compact/Lightweight TORSEN

Until now, TORSEN type B for front differentials has succeeded at improving driving stability as a left/right wheel differential limiter due to the torque bias effect. Moreover, by revising the engagement structure of the compound planetary gear, and developing the compact/lightweight TORSEN type D, we have replaced the conventional front open differential to improve the linear acceleration stability and turning ability of FF vehicles, thus contributing to safe and secure operation (**Fig. 9**).

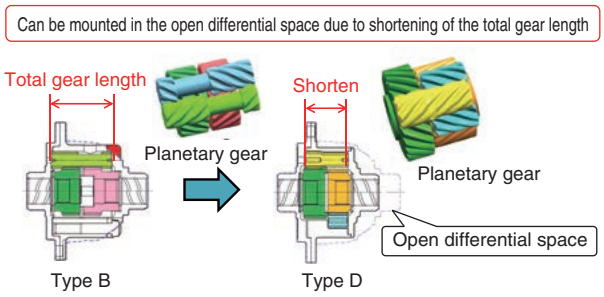


Fig. 9 Compact, lightweight TORSEN Type D

4. New Product Development for Business Evolution

4. 1 E-AWD

Insofar as response to CASE, in the "Electric" area, JTEKT is leveraging our technologies and knowledge cultivated through conventional AWD systems to develop the electric AWD system of E-AWD (Electric-ALL WHEEL DRIVE). This is an electric AWD system that works by driving the rear wheel of an FF vehicle with a motor. The E-AWD, which comprises of a drive motor, inverter, and reduction gear, has an integrated compact motor and inverter. Its size is reduced due to combination with a reduction gear that is on coaxial output with the motor and can be mounted on vehicles with low floors (**Fig. 10**).

It is also possible to set a disconnecting clutch with a simple design, and by stopping the motor during high-speed travel, sliding resistance and kneading resistance are reduced, and fuel economy is improved. Moreover, through combination with the TORSEN and twin clutch mentioned later, we are developing high added value specifications.

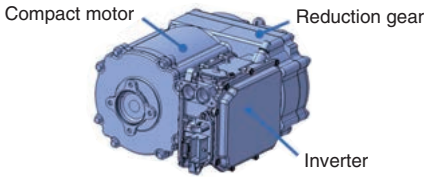


Fig. 10 Compact E-AWD

4. 2 Development of a Torque Control Device

In regards to torque control devices (TCD) such as ITCC and TORSEN, to respond to the needs such as those shown in **Fig. 11** (expansion of low fuel consumption needs, electrification), JTEKT is engaging in activities to generate synergism between each driveline device. Moreover, by not simply focusing on driveline, but also proposing an optimal control system for the entire vehicle including steering and braking systems, JTEKT wishes to meet the requirements of electrification, high performance, and advanced driver assistance.

4. 2. 1 Compact/Lightweight/High-efficiency ITCC Integrated Differential

Insofar as rear drive units (ITCC and differential) for FF vehicles, by sharing or omitting parts for which functions conventionally overlapped (shaft, bearing, etc.), as well as making improvements through optimization of casted parts-die separation direction, we have achieved significant weight reduction. Furthermore, the efficiency of the overall system has been improved by reducing the sliding resistance of the tapered roller bearing and partially adopting ball bearings. We also incorporated the latest high responsiveness function established on the ITCC stand-alone system (**Fig. 12**).

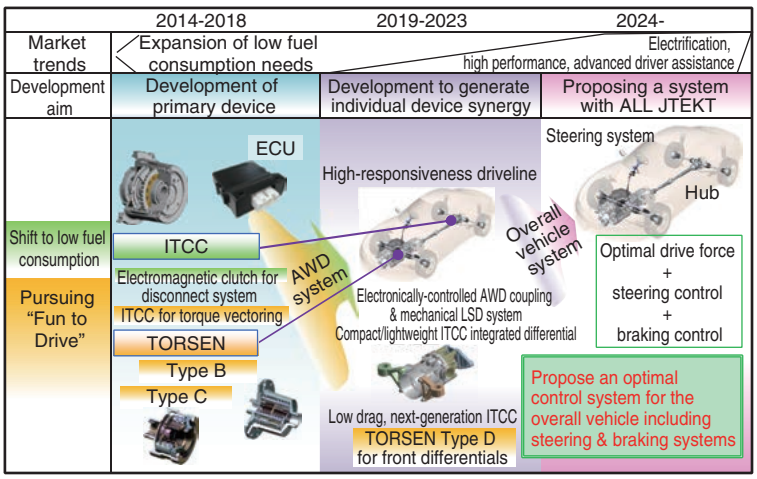
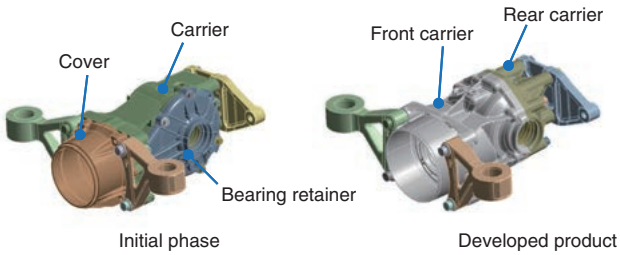


Fig. 11 JTEKT's initiatives for torque control device development



Details of change	Compact/lightweight	High efficiency	High responsiveness
Optimization of carrier die separation direction	✓		
Weld the ring gear onto the differential	✓		
Revise the dust seal lip to reduce sliding resistance		✓	
Reduce sliding resistance of all tapered roller bearings and change to partial ball bearings		✓	
Change the casting method of the front housing to improve process time and yield	✓		
Revise system configuration (e.g. cam, main clutch) and make high responsiveness (response time: 80→45 ms)			✓

Fig. 12 TCD integrated differential

4. 2. 2 ITCC + TORSEN + EPS System

By combining an EPS (electric power steering) torque steer compensation control on the ITCC (electronically-controlled AWD coupling) and TORSEN (equipped as a front differential), we have achieved ITCC torque control that maximizes the TORSEN's torque bias, as well as improves traceability at initial turning and stable cornering/traction performance through rear torque control (**Fig. 13**).

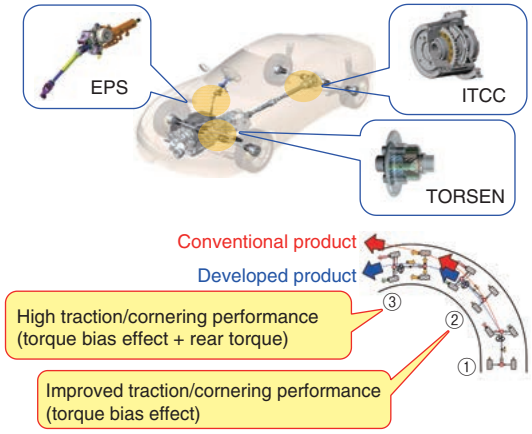


Fig. 13 ITCC & TORSEN & EPS system

4. 3 JTEKT's Vision of Driveline System Supplier

Moving forward, as a driveline system supplier, JTEKT would like to present proposals for vehicle optimization, such as driving force, dynamic performance, and vibration reduction, from the perspective of the vehicle system. In particular, we are working on vehicle performance planning proposals and AWD system proposals as areas that require strengthening, and rolling out activities to feed back into unit development with our conventional core technology as the foundation (**Fig. 14**).

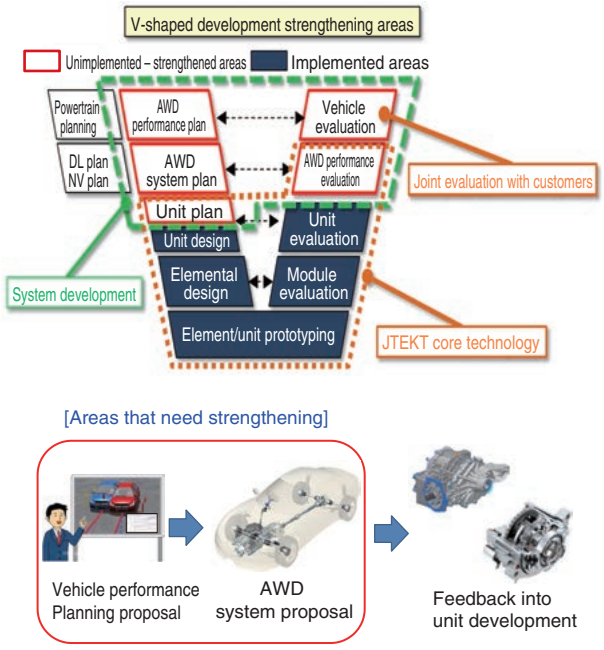


Fig. 14 Vision of a driveline system supplier

5. Other Product Development Supporting Electrification

5. 1 Electric Oil Pump (EOP)

The electric oil pump (EOP) was developed with the aim of supplying hydraulic pressure to the transmission during vehicle idling stop. We successfully reduced the size and increased the efficiency of our EOP through motor integration, innovative bearing arrangement, etc. Also, by leveraging our in-house manufacturing technology, we developed a high-flow EOP able to support cooling applications of HEV/EV motors.

Moving forward, in order to respond to multi-function applications such as reduction gear units, we'd like to increase output further, combine fundamental element technology (internal/ external gears, vane type) with the high-flow/high-output type EOP, and offer a wide product lineup. Through such efforts, we will correspond with global market needs (**Fig. 15**).

5. 2 High-pressure Hydrogen Gas Valve and Pressure Reduction Valve for FCVs

For the high-pressure hydrogen gas valve and pressure reduction valve for the fuel cell vehicle (FCV), "MIRAI" released in 2014 as the activities to promote hydrogen society (**Fig. 16**), there was a need to achieve a high-pressure operating condition of 70 MPa that had not previously been experienced with the conventional

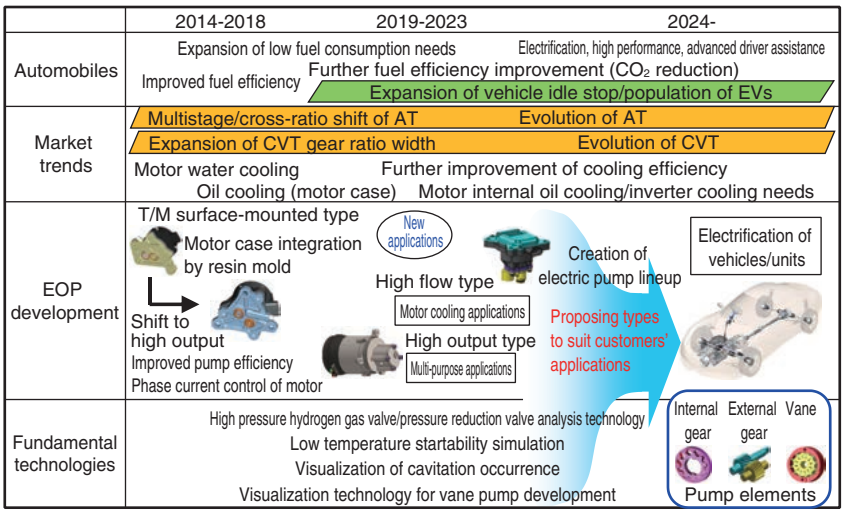
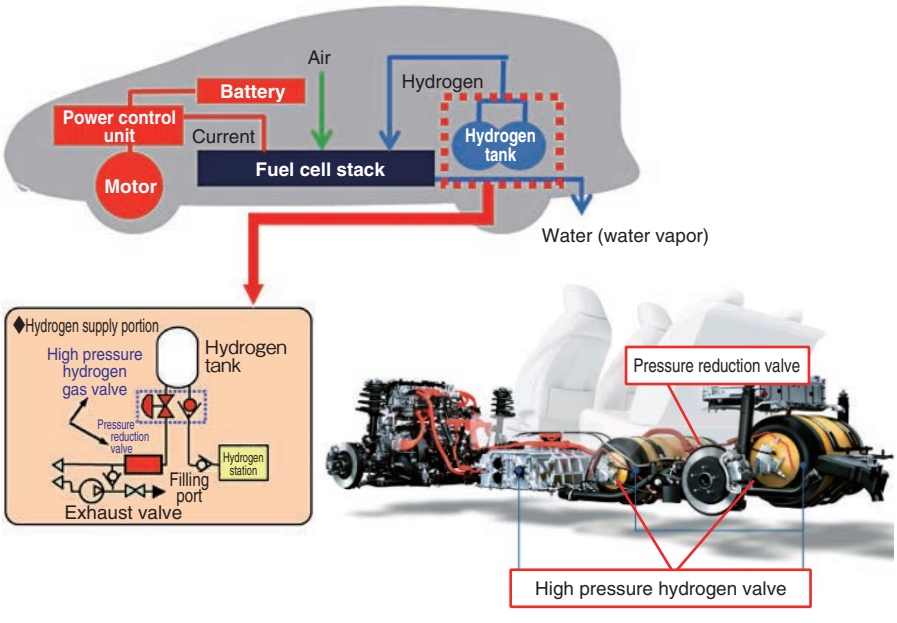


Fig. 15 Initiatives for EOP development



Source: https://toyota.jp/request/webcatalog/mirai/

Fig. 16 High-pressure hydrogen valve and pressure reducing valve

steering system, etc. This made finding solutions to manufacturing challenges, particularly precision machining accuracy and surface conditions concerning sealed surfaces, crucial to success. JTEKT handles this by adopting smart machining methods, such as the minimization of machining allowance by using the MIM (Metal Injection Molding) method for complex-shaped stainless steel (SUS) and low-frequency vibration cutting of difficult-to-cut material (SUS, resin) (**Fig. 17**).

As preparation for future full-scale volume production, JTEKT is endeavoring to achieve size and weight reduction (shorten pressure reduction valve cover and reduce piston sliding portion layers from 3 to 2). When performing stress analysis for this, by switching from the conventional elasticity analysis using maximum principal stress as an indicator, to elasto-plastic analysis using Tresca stress (which is suited to ductile material) as an indicator, we achieved high accuracy analysis of stress fluctuation in a high-pressure state up to 70 MPa. Furthermore, by utilizing technology to visualize the high-speed flow portion, we elucidated the occurrence mechanism for the noise and vibration that occurs due to the turbulence flow of high-pressure hydrogen, and improved quietness.

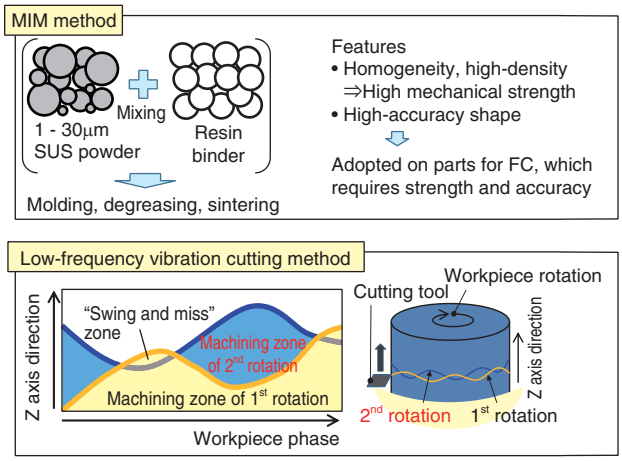


Fig. 17 Smart techniques

6. Initiatives for Next-Generation Technologies

Amidst advancing electrification and self-driving shift of vehicles, as well as an aging society, users' needs are constantly changing and evolving, and industry players have the urgent mission of engaging in initiatives for the next-generation, such as wheel suspension enabling a wide steer angle, vehicle control allowing even the elderly to drive safely and securely, realization of a comfortable driving environment (space), improvement of electricity bill, etc. To respond to future needs such as these, JTEKT will also gather the technologies of our entire group, including integrated control linking steering and drive, bearing/gear loss reduction, and human model analysis, so that we may help create vehicles of the future (**Fig. 18**).

7. Conclusion

This paper has introduced JTEKT's driveline products and technologies for automobiles as well as related future trends and initiatives. Moving forward, amidst the rapid electrification and self-driving shift impacting automobiles, we will draw upon our unit technology for drivelines and transmissions and advance "No. 1 & Only One" products we can be proud of as we aim to leap forward and become the world's leading supplier.

To this end, we will gather the strengths of JTEKT Group, identify trends of the major transformation advancing constantly in the auto industry, strengthen our technological and development frameworks anticipating the future, and contribute to conservation of our planet's environment, as well as help to improve safety.

* ITCC and TORSEN are registered trademarks of JTEKT Corporation.

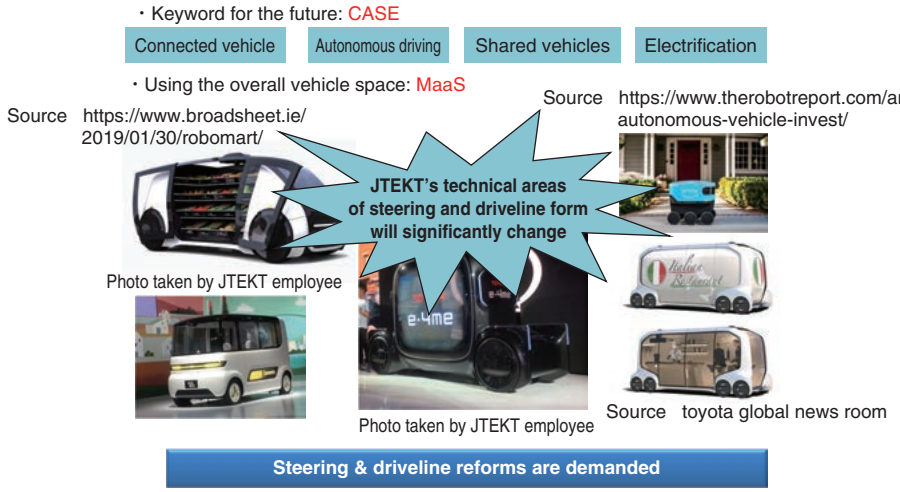


Fig. 18 Initiatives for next-generation technologies

References

1) T. SAKAI: Trends and Outlook of Drive Units for Automobiles, JTEKT ENGINEERING JOURNAL, No. 1013E (2016) 14.
2) JTEKT CORPORATION: JTEKT 10th anniversary history (2016) (in Japanese).

Y. NAKAOKA*

* *Executive Managing Officer*