Technological Innovation Capturing Market Changes

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The environment surrounding manufacturing is changing significantly and JTEKT, which produces mother machines (machine tools) as its flagship products, must respond to this change in order to secure its survival. Particularly significant changes are the shift to electric vehicles and the reduction of the working population. In this paper, we will introduce our production equipment and processing methods enabling us to produce small, lightweight, high precision parts for EVs. We will also provide examples of smart technology for equipment and factories, as well as 3D metal molding technology as responses to the reduction of the working population.

***Key Words**: EV shift, working population, skiving, IoE, additive manufacturing*

1. Introduction

The environment surrounding industry is facing major change. On a global scale, examples of such change are the shift towards electric vehicles in response to global warming and monozukuri responding to a diversification of user needs. Meanwhile, within Japan, a rapid decline in the working population including the retirement of skilled technicians is a matter of urgency. Amidst such a situation, various initiatives are being launched on the monozukuri shop floor, such as introduction of IoT (Internet of Things), utilization of AI and line automation. Moreover, even in regards to machining methods, in line with the practical realization of 3D molding technology, there are increasing expectations on equipment utilizing additive manufacturing as well as the conventional removal technology. At JTEKT, parallel to maintaining and improving the competitiveness of our strength – equipment for engine manufacturing – we are taking on new initiatives responding to various changes, represented by the shift towards EVs of automobiles.

This paper will introduce machining methods and machining technologies contributing to the higher accuracy of parts in response to the EV shift and shift towards compact, lightweight and quiet products.

This paper will also introduce examples of JTEKT's original IoE (Internet of Everything) initiatives tailored to manufacturing shop floors facing a declining working population and additive manufacturing leveraging 3D metal lamination molding technology.

2. Response to the EV Shift of Automobiles

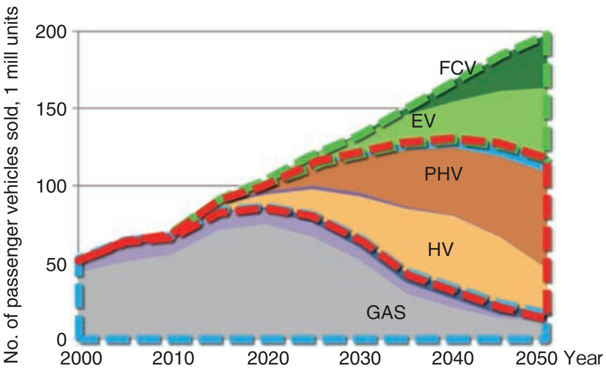
It is expected that the number of automobiles produced will continue increasing in the future, however in terms of the drive unit, there is a shift away from combustion engines alone and towards utilization of electric motors. It is predicted that vehicles such as hybrid vehicles (HV) which use an internal-combustion engine and battery/motor in combination, plug-in hybrid vehicles (PHV), electric vehicles (EV) and fuel cell vehicles (FCV) will increase in number in line with technological advancement (**Fig. 1**).

The parts and production equipment utilized as a result of this EV shift are required to have the below characteristics.

(1) Compact and lightweight for longer battery travel distance
(2) Higher accuracy to support quietness and high-efficiency
(3) Equipment suitable for engine downsizing

For all of the three above-mentioned items, it is important to consider space productivity (productivity indicator in relation to equipment footprint). Automakers must secure sufficient space for engine production, in addition to production of those products related to the EV shift, such as motors and batteries, and can minimize investment cost of increasing plant capacity by using equipment with high space productivity.

In light of this, the following section introduces concrete initiatives involving machine tools to meet the requirements of (1) and (2) above.



Source: IEA_ETP “World Automobile Sales Forecast” 2012

Fig. 1 Prediction of shift to electric vehicles

2. 1 Downsizing of Parts through Skiving

As **Fig. 2** shows, skiving is a gear processing method using the relative speed generated when the tool and workpiece are tilted relative to one another and rotated simultaneously. People have known about this processing method itself since long ago, however the synchronization of high-speed and high-accuracy tools and workpieces required to obtain cutting speed was essentially made possible by advancements in CNC servo technology in recent years. Another factor behind the practical realization of skiving is that appropriate design for tool shape to suit the gear tooth profile has become easy to achieve.

With skiving, it is possible to obtain workpiece shapes not previously possible with conventional processing methods. As **Fig. 3** shows, with the conventional hobbing technology, there was a large incomplete tooth portion and this made downsizing of parts difficult, however with the application of skiving, the incomplete tooth portion is reduced, therefore parts can be made compact and lightweight. In the same way, **Fig. 4** shows how skiving eliminates the need for the undercut, which was necessary with the conventional methods of gear shaping and broaching, which helps to improve part strength and has the additional benefit of reducing part weight.

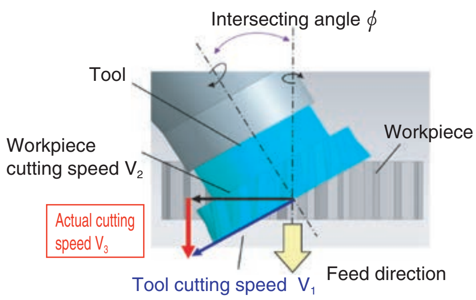


Fig. 2 Principle of skiving

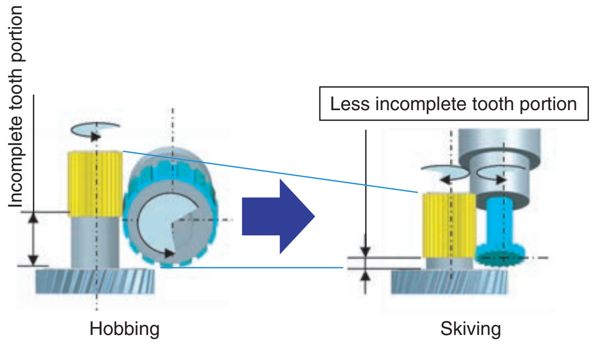


Fig. 3 Characteristics ① of skiving

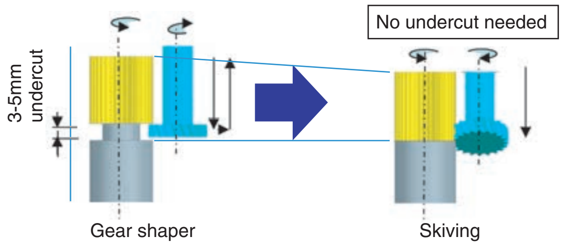


Fig. 4 Characteristics ② of skiving

JTEKT developed and commercialized the Gear Skiving Center as a processing machine that performs skiving.

The Gear Skiving Center also features the functions of a machining center and is capable of automatic tool change. Furthermore, the principle of skiving requires high rigidity, therefore we have increased mechanical rigidity by shortening the stress path from the machining point to the guide.

Due to the Gear Skiving Center’s ability to turn and index the workpiece, as well as to perform automatic tool change, it is possible to integrate six conventional processing methods into just two, as shown in **Fig. 5**. This type of process integration achieves efficient operation of equipment to suit varying-type/varying-volume production as well as higher precision of coaxiality and positioning through single-chuck machining.

As described above, skiving makes it possible to achieve efficient equipment operation through process integration, enabling of compact, lightweight and high-accuracy parts, as well as cost reduction. This makes it an effective method for machining gears used in many EVs, etc.

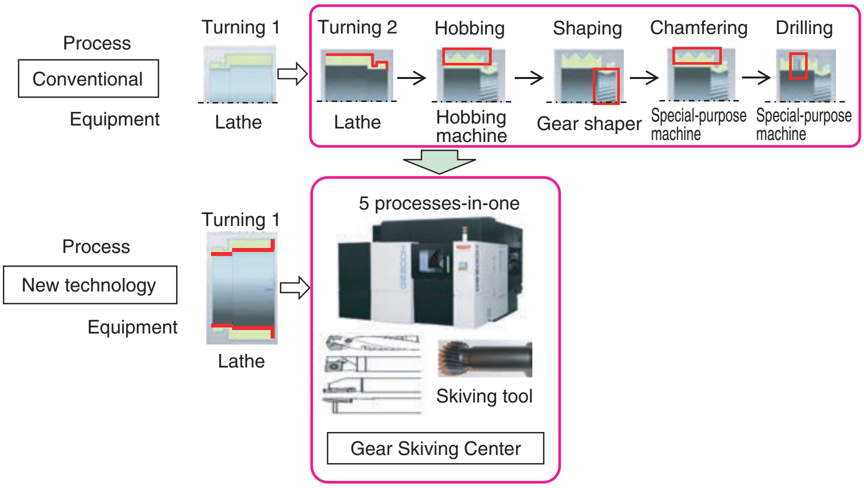


Fig. 5 Example of ring gear process integration

2. 2 Response to High-Accuracy Grinding/ Compact Parts

In line with an increase in EV production, the production of lithium-ion batteries is also increasing. Of the equipment used for lithium-ion battery production, coating machines and presses use many high-accuracy rolls and these rolls must be grinded at a high accuracy in the unit of microns (shape accuracy, mirror finishing). Currently, production depends on skilled workers with advanced grinding skills, however in response to increase production, expectations are growing regarding equipment able to produce high-accuracy rolls without the need to depend on worker skill.

In order to meet shape accuracy needs, JTEKT is developing and launching a cylindrical grinder featuring a thorough low heat displacement design and low-vibration design, as well as functions such as automatic determination of grinding conditions. Furthermore, the various companies of the JTEKT Group are collaborating on initiatives to develop CBN/diamond wheels and grinding technologies (**Fig. 6**) aimed at securing high-quality grinding surfaces, such as mirror finishing. Through these comprehensive development efforts, we aim to offer customers a grinder capable of easily mass producing high-accuracy rolls without relying on skilled workers.

Apart from roll production, higher accuracy grinding technology has a broad application scope, including reduction of noise and vibration generated from vehicle drive parts, as well as improved part accuracy that leads to better fuel economy, therefore JTEKT wishes to constantly evolve it as a fundamental technology through which we can differentiate ourselves from others in the industry.

Meanwhile, from the perspective of our 5-year mid-term management plan and our "Beyond" mid-term plan which considers a further 5 years into the future, the popularization of EVs is predicted leading to a gradual decrease in the demand for grinders used in machining engines, which has been the backbone of JTEKT's grinder business to date, therefore we must develop new markets. JTEKT offers a lineup of compact crankshaft grinders for the robot and compressor markets, for which demand is expected to grow in the future. To date, based on our camshaft grinder for automobiles which possesses a profile grinding function, we have proposed installing tooling for the eccentric portion of the compact crankshaft, however, now there is a need to improve accuracy of surface roughness, dimensions and roundness, as well as to make the equipment more compact in order to suit the dimensions of compact crankshafts. For the compact crankshaft grinder, we have deployed compact, high-accuracy technology such as shown in **Fig. 7**, and succeeded in improving grinding accuracy at the same time as reducing space and improving productivity. This makes it possible to meet requests for space productivity improvement by customers who need to secure space in preparation for increased production.

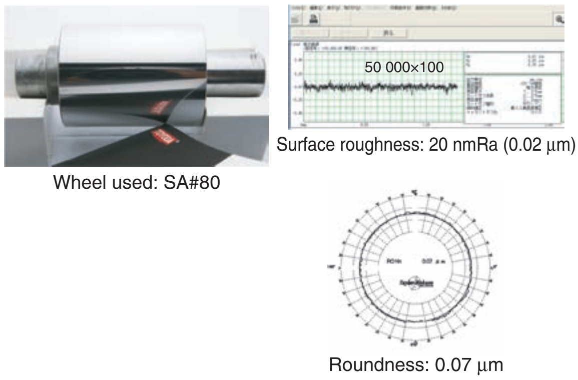


Fig. 6 Example of high-accuracy roll fully-automated mirror finish

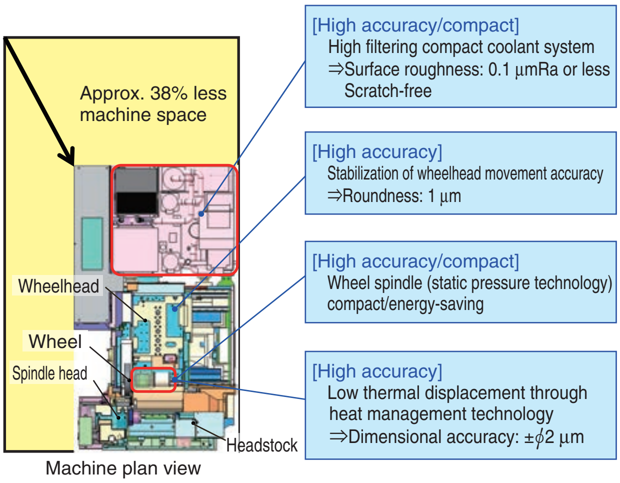


Fig. 7 Deployment of technology achieving both compact/high-accuracy and good productivity

3. Response to Decline in Working Population

In Japan, due to the declining birthrate and aging population, it is predicted that the working population in 2025 will decrease by 17% compared to 1990 (**Fig. 8**), and the issue will arise of personnel shortages on the production shop floor. In Japan, the manufacturing industry has survived due to offering products with high added value, such as high quality and high performance, compared to low cost products imported from overseas. The source of this added value is the existence of skilled workers with abundant experience. The true problem of a decline in working population is the shortage of skilled workers, therefore there is a need to produce results with limited resources.

So that we may thoroughly eradicate the "seven wastes" lurking in production sites which prevent added value creation, and engage in efficient monozukuri with limited resources, JTEKT presents the proposals of "Factory Smartification" and "Machine Smartification" leveraging IoE from the perspective of a manufacturer with both an auto parts business and a machine tools business.

[Proposals in response to a declining working population]

1. Shortage of production personnel
   ⇒Factory smartification, improved productivity, automation
2. Shortage of skilled workers who create high added value
   ⇒Machine smartification: Digitalization, knowledge acquisition

* ①Over-processing waste ②Inventory waste ③Overproduction waste ④Waiting waste ⑤Motion waste ⑥Transport waste ⑦Defect waste

3. 1 "Factory Smartification and Machine Smartification" Leveraging IoE

Firstly, "Factory Smartification" is whereby, even on the monozukuri shop floor, there is a need to "have production lines that are trouble-free" and "have production lines that do not stop" in order to "improve productivity." To achieve this, JTEKT not only considers IoT, which is about connecting "things", it also considers "connection of everything", including people and services, and, calling this as "IoE" or "Internet of Everything", we propose four IoE solutions. In regards to the introduction of IoE, we have defined the four steps shown in **Fig. 9** and offer the optimal solutions for each step.

Step 1, the "Connection" solution, proposes a PLC, TOYOPUC Plus, that connects the various control equipment in a factory, then the "Visualization" solution of Step 2, proposes a PLC, TOYOPUC-Hawkeye, that

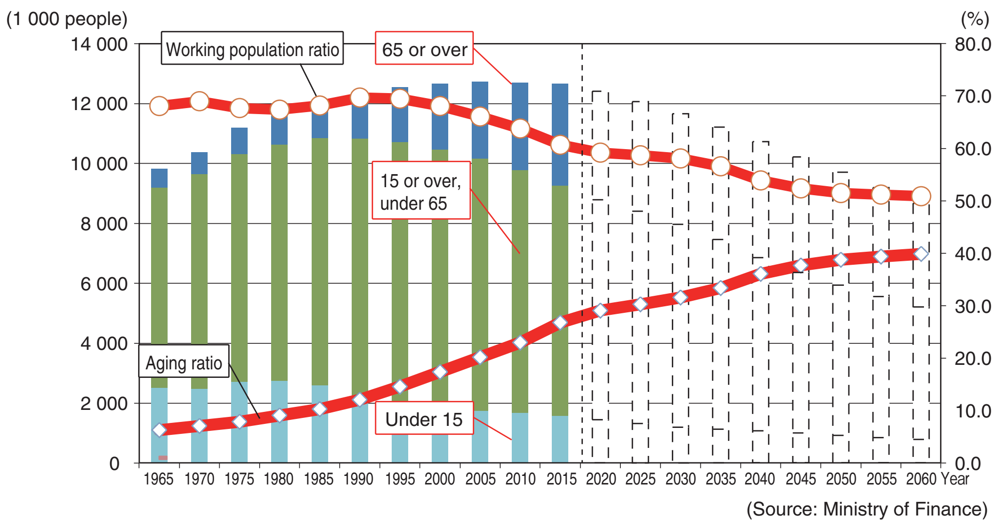


Fig. 8 Predicted decline in working population

finds the weaknesses in a factory based on the collected information in order to make improvements, and for a production management system which primarily uses andons, enables customers the freedom to make any combination of equipment, visualized content and time periods that they wish.

The "Value" solution of Step 3 proposes TOYOPUC-AAA, an edge-type analysis module that analyzes data from various sensors mounted on equipment, so that customers can do something to prevent their equipment breaking down before it is too late. The "Chain" solution of Step 4 proposes data utilization not only within one's company, but with suppliers, group companies and customers, by broadening the scope.

Next, "Machine Smartification" uses the data collection, accumulation, display, analysis and determination functions of the "Value" solution (Step 3) mentioned above, to make a machine capable of autonomously and automatically detecting abnormalities in terms of machine maintenance and machined workpiece quality, as well as the optimization of machining status.

In order to realize machine smartification, model-based analysis technology of the machine and machining statuses and utilization of AI for statuses and conditions that are difficult to analyze using models. The "Smart Cutting" introduced in the next section is a technology that makes it possible for even non-experienced workers to obtain chatter-free machining conditions, which will lead to "Machine Smartification" in the future enabling the significant reduction of time required for trial machining – a process which relies on skilled workers.

3. 2 Smart Cutting

When using long tools for deep boring of metal, etc., there is a high potential for chattering to occur due to tool distortion. To prevent chattering, the conventional approach was to perform trial machining first and select the machining conditions (spindle RPM) where chattering did not occur. However, the scope of optimal machining conditions in which chattering does not occur is extremely narrow, and a significantly high number of man-hours by a skilled worker was required to complete this task. As such, we developed JTEKT Smart Cutting technology, which enables anyone to easily find the

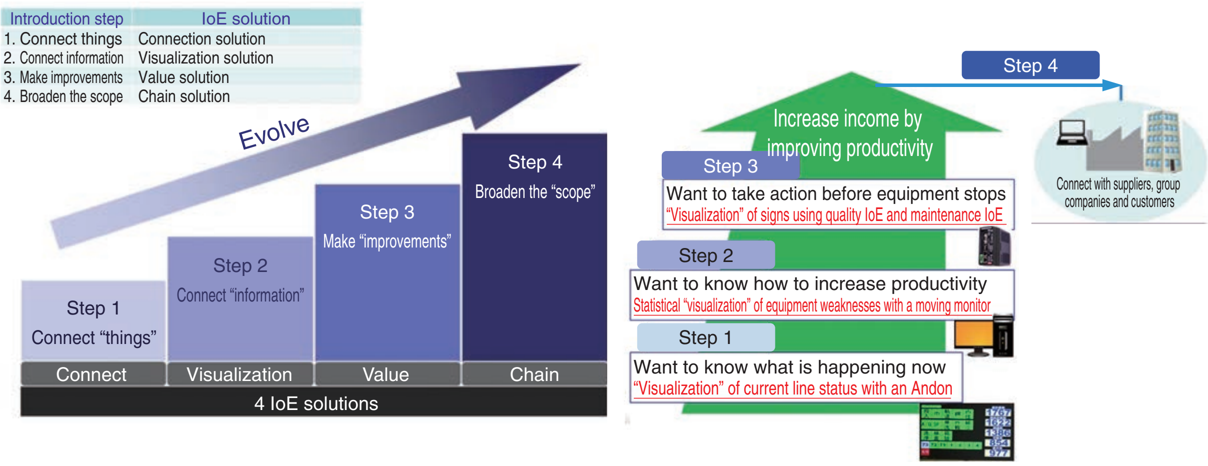


Fig. 9 The four steps

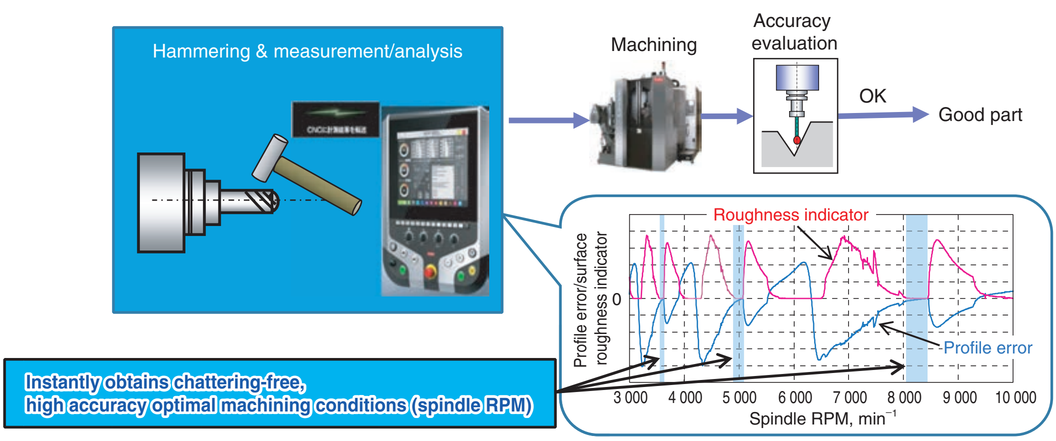


Fig. 10 JTEKT Smart Cutting

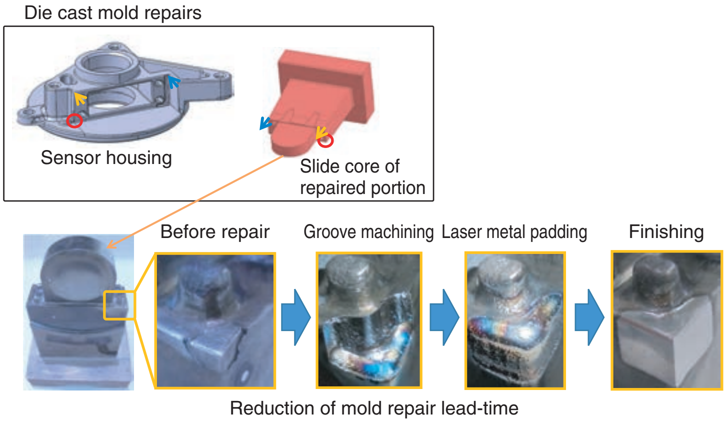


Fig. 11 Mold repairs using laser cladding

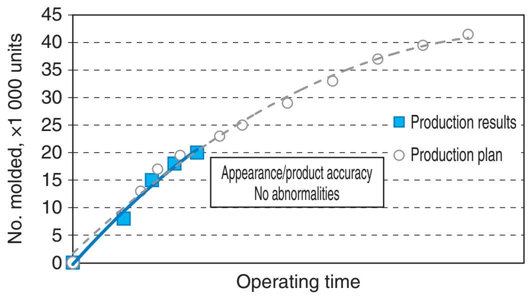


Fig. 12 Aluminum die cast-Repaired mold forming count evaluation

optimal machining conditions by measuring the dynamic characteristics of tools including the spindle through hammering. This technology is expected to reduce man-hours of skilled workers.

4. 3D Metal Molding Technology

Many people associate “3D printer” with 3D metal molding technology. This term was first used to refer to a device that utilized technologies such as a nozzle and head on a printer to create layers of material inexpensively and with low molding accuracy. In contrast, “Additive Manufacturing” (AM) is the term used for high-performance devices such as those which use resin and metal materials to perform molding with good accuracy. In the machine tools field, the 3D metal lamination technology associated with AM is utilized to perform 3D metal lamination molding. Two methods exist; “Selective Laser Melting” (SLM) involves spraying metal powder then using a laser to create solid layers one at a time, and “Laser Metal Deposition” (LMD) involves using a laser to create solid layers from metal powder that has pooled on the layer surface. LMD is also known as laser cladding, and JTEKT is developing this for the purpose of mold maintenance (**Fig. 11**). It is believed that this technology could be used for lamination of metal with functions responding to various needs other than mold maintenance, and that the applications of this technology used in combination with removal technology could expand further in the future.

Mold repairs using laser cladding are performed on molds for manufacturing JTEKT products and 20 000 molds to date have been repaired using this method. With laser cladding mold repairs, there is no abnormal wear, cracks and so forth, and good product accuracy is maintained (**Fig. 12**).

5. Conclusion

This paper has introduced JTEKT’s initiatives in response to the EV shift and declining working population. We must continue our efforts in response to environmental changes. JTEKT wishes to view such changes as business opportunities to achieve advanced technology development and product development that predicts needs. To this end, we will hone our ability to respond nimbly and swiftly to environmental changes from a customer perspective and aggressively engage in initiatives for new technologies to bring about monozukuri innovation.

*1 TOYOPUC is a registered trademark of JTEKT Corporation.

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