Development and changes in NC created by a machine tool manufacturer

Celebrating 50 years of the development of "OSP" control systems

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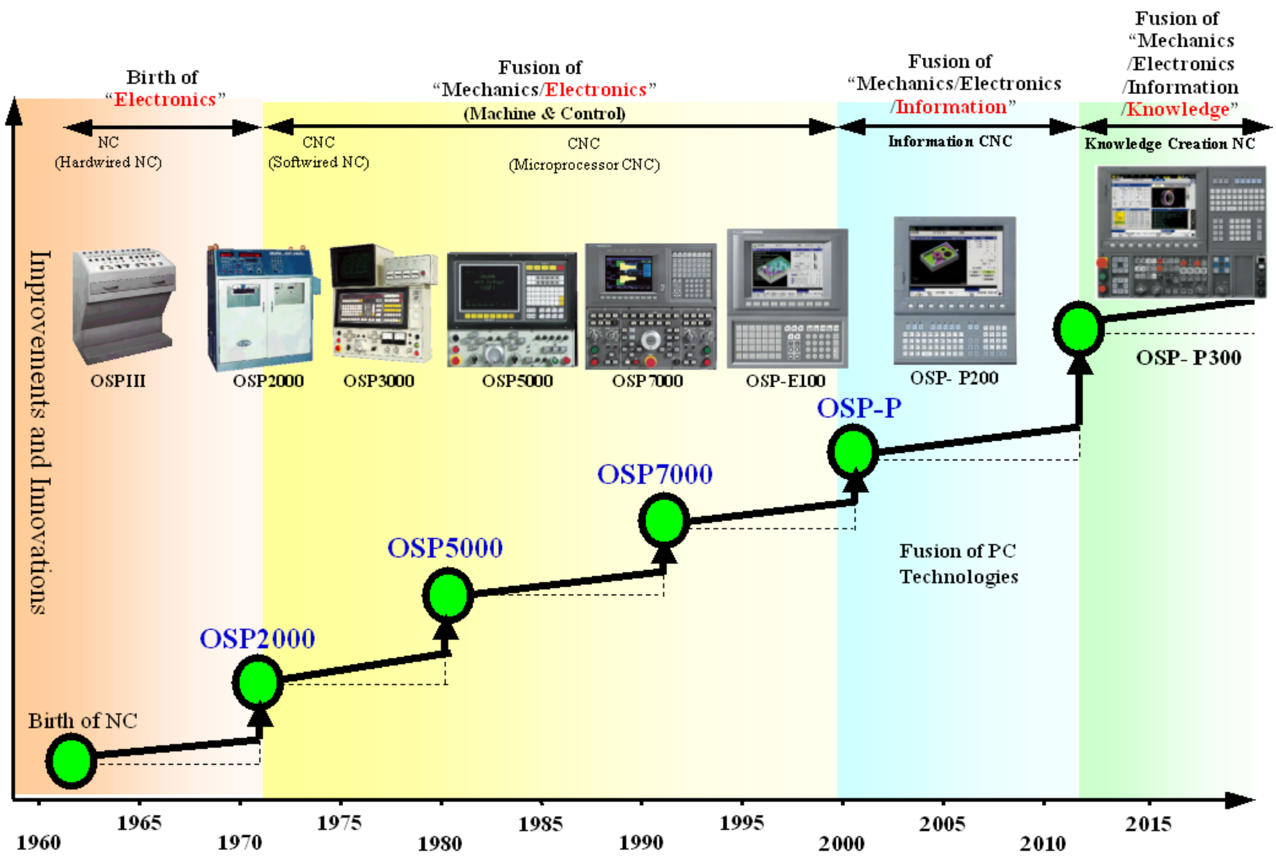

Figure 1 "OSP" control model developments

Our company was founded in 1898 as a machine tool manufacturer and advanced ahead of other companies thereafter to begin developing NC technologies, then in 1963 released the "OSP series" NC controls. We would like to express our wholehearted gratitude to the many people who have supported us over the years, allowing us to celebrate this 50th anniversary this year.

Our company maintains a corporate philosophy of "total responsibility" as a machine tool manufacturer which has expanded its business domain to include NC controls. We take our responsibility seriously, and work as a "manufacturing service", carrying out development of NC controls based on our passion to provide a superior service not available anywhere else in the world.

Our company also maintains an "absolute value philosophy" according to which we allow no compromises. We do not allow for relative assessments, believing measures must be absolute, and continually work to create NC controls that improve upon current controls and cannot be found from any other company.

Looking back on the past 50 years we see the developments detailed below, also shown in **Figure 1**.

In 1963, we succeeded in developing NC controls, which at the time were mainly hardwired circuit, positioning NC controls.

Starting from around 1980, the progress of computer technologies began to make possible more advanced and complex control. Our company has intensified its development of technologies which integrate machinery design and electrical control, and has created a wide variety of machinery and electrical fusion technologies including high precision digital servo motor systems, high speed NC control technologies that allow for die machining at high speed and high accuracy and thermal displacement compensation technologies on higher rigidity machinery.

Starting from around 1990, networking through intranets became more prevalent. Our company intensified the development of technologies which combined information with machinery and electrical fusion technologies, establishing machinery, electrical and information fusion technologies which manage information throughout an entire plant such as downloading programs through a network, linking with production management systems and monitoring the status of various machinery.

Photo 1 "OSP2000" minicomputer utilizing NC control

From 2000 onwards, handling of PC based CNC allowed for use of applications which operate on Windows, greatly increasing the scalability of users. Further, intelligent technologies were added to the machinery, electrical, information fusion technologies, functions to prevent mechanical collisions, functions to determine optimal processing conditions, and other functions were developed, and the 4 existing intelligence technologies were commercialized.

Each of the machinery design, electrical control, information and intelligence technologies evolved with time, and technologies which fused these individual technologies were created. Among all of this, our company was proud to introduce several our own "only one" technologies.

Photo 2 "OSP5000" NC control with "IGF" interactive programming function

<Introduction of "only one" technologies>

① Absolute position feedback (1963-)

At the time of the development of the original "OSP" unit, the "incremental method" which was used by the industry was a method where a specific position is set as the "home position", and a pulse signal is provided from this home position to the motor while simultaneously counting the pulses to detect the positions of moving parts. Of course there were issues such as when the NC power is turned off, the pulse count is lost, so when the power is turned on again, a "return to home position" operation is necessary where the moving parts are moved back to the specified position, and if the pulse count is mistaken, control will be carried out with the incorrect detection position.

Meanwhile, the "absolute position detection method" developed scrupulously from the first of our company's "OSP" units, can identify and detect any position within the entire moving part range immediately after power is turned on by detecting the gear train mechanical condition. As such, no "return to home position" is necessary when turning on power, and absolute position detection means that control won't be carried out while the position is incorrect, making this a highly reliable control method.

② Software variation (1972-)

Machine tools are used for 10 or more years after being installed. Because NC at the time were all "hardwired NC" where numerical control logic was all carried out by hardware, it was not possible to update the features from the time of installation.

Based on a concept of "software variation", our company made a practically usable "softwired NC", which has numerical control software loaded in a NC specialized high speed minicomputer, ahead of other companies (**Photo 1**). Shifting numerical control logic to software made possible arc interpolation, tool diameter/nose R compensation, various automatic cycles and other advanced control, progressing advanced functionality, leading to the full-scale introduction of NC machine tools to plants and greatly contributing to increased productivity.

③ Interactive programming function (1981-)

Entering the 1980's, as the introduction of NC machine tools progressed, the number of NC operators became insufficient, or the operators did not keep pace with the advanced functions, leading to demand for an NC where those advanced functions could be more easily utilized.

Photo 3 "Advanced One-Touch IGF" interactive programming

Our company developed the "IGF" interactive programming function that allows for easy creation of NC programs by simply sequentially inputting machining methods, shape, tools, and cutting conditions while looking at machining diagrams without using G/M code to create NC programs (**Photo 2**).

Thereafter, these functions could all be easily carried out using the "Advanced One-Touch IGF" function which allowed for all machining processes to be automatically determined just by inputting the machining shape, and even machining of complex shapes in keeping with the increasing complexity of machine tools and the evolution of machining methods (**Photo 3**).

④ High precision digital servos (1982-)

The direct current servo motors that were mainstream at the time, were controlled by an analog speed signal output by a tachogenerator, which resulted in issues such as temperature drift caused positioning errors and vibration caused by tachogenerator ripple voltage.

This prompted our company to develop a high precision digital servo system that uses a microprocessor. This system uses 160,000 division high resolution position detectors to carry out servo control through software processing based on digitally detected absolute positions, which allows for stable, high precision control. In addition, shifting control to software served as the basis for the subsequent construction of a variety of high precision servo technologies.

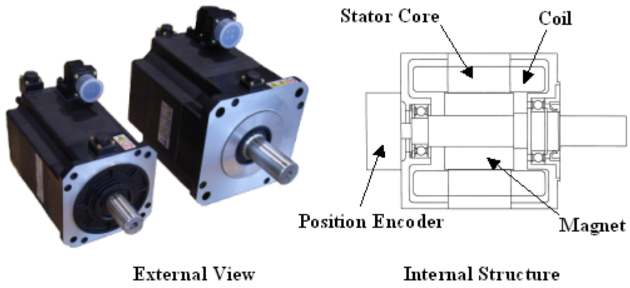

Figure 2　Brushless servo motor

In addition, direct current servo motors were limited in terms of what degree that could be sped up due to flashovers caused by sparks from the brushes, and also suffered from design constraints in the mechanical structure in order to allow for brushes to be replaced. Our company then developed the world's first brushless servo motor as a part of a high precision digital servo. The motor is a simple structure with no brushes, allowing for high speed rotation (**Figure 2**). A major feature of our company's brushless motors is a small cogging torque ripple (motor torque ripple) of 0.5% or less, realizing fine machined surfaces through smooth feed.

⑤ ***High speed contour machining control function "Super-NURBS" (1987-)***

At the end of the 1980's, multiple high performance microprocessors were used, taking advantage of the digital servo technologies noted earlier, to develop high speed contour machining control which allows for high speed and high precision machining of the free form surfaces that are characteristic of shapes in automotive press dies and plastic dies.

This control is a machining technology which allows for continued compensation for machining accuracy while machining curved surface shapes at high speed by quickly reading mass quantities of the enormous amounts of micro straight line commands that make up NC programs for machining free form surfaces and internally generating the machining curves, then controlling acceleration and deceleration automatically based on curvature. In recent years, progress has been made in high speed contour machining control of a simultaneous 5 axes consisting of the basic 3 XYZ axes with 2 additional axes of rotation (**Photo 4 and Figure 3**).

Photo 4　Machining using "Super-NURBS" high speed contouring

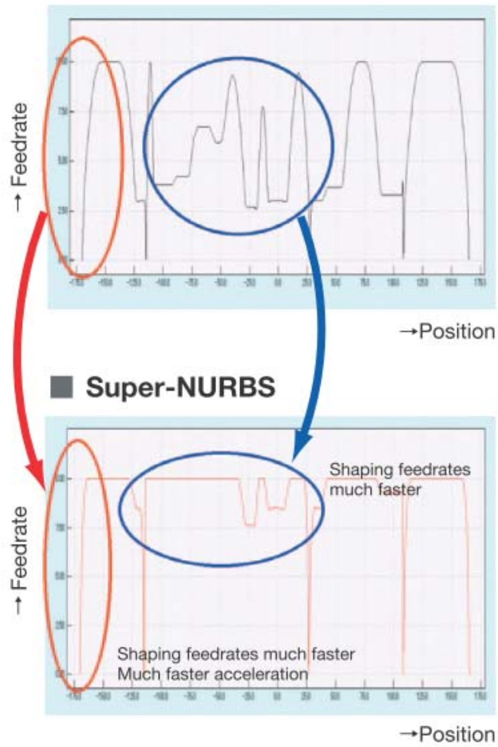

Figure 3　"Super-NURBS" high speed speed control

⑥ "AbsoScale" absolute positioning linear encoder (1988-)

In general, ball screws suffer from thermal expansion during operation, decreasing machining accuracy. Direct detection of the positions of moving parts is carried out by linear position detectors as a countermeasure against this. In general, induction and linear encoders were used, however the former involved complex and difficult assembly and signal adjustment work, and the latter used the incremental method, and so had reliability issues due to noise and other factors.

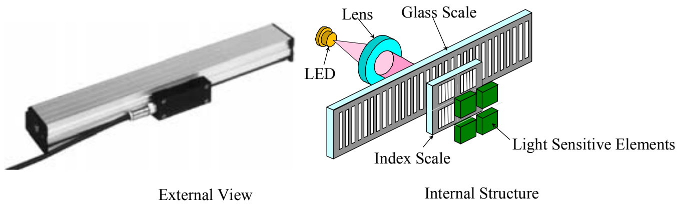

Figure 4 "AbsoScale" absolute positioning linear encoder

Our company thus developed "AbsoScale" (**Figure 4**) to overcome these shortcomings of induction and linear encoders. Specifically, this is an optical encoder which combines 2 tracks consisting of a high resolution track that detects accurate positions and an absolute position track. This 2 track detection method later evolved into an absolute value irregular cycle code, and is today used in products by all encoder manufacturers as absolute position linear encoders.

⑦ Machining management (1993-)

In order to improve the productivity of machining, it is necessary to reduce job change time and increase the percentage of time actually spent on machining. In 1993, our "MacMan function" was developed to automatically collected machined processing results (what type of parts were processed when and in what quantity), operation results (amount of time powered on, cutting time, job change time, etc.), and displayed the information in graphs and also reported the information to a management computer in real-time via a network.

⑧ "PREX" Motor (1997-)

In general, the turret (cutting tool holder) for lathes is equipped with 2 motors, a servo motor which rotates the turret and carries out positioning, and an induction motor which drives the rotating tool at high rotation speeds. Our company developed a synchronous reluctance motor which allows for both servo functions for positioning and high speed rotation, allowing for a structure with only one motor installed on the turret (**Figure 5**). This motor does not use a permanent magnet, instead using an excitation current to control a field magnet, which allows for unrestricted control even up to high rotation speeds.

⑨ High precision servo technologies (2000-)

・Projection Flatten Control

In curved surface convex peaks and other quadrant reverse rotation sections, servo motor follow error creates projections, and in die machining these projections become projections that appear on the machined surface (**Figure 6**). Previously, these were corrected in a manual process called polishing, however in recent years there has been a desire to make polishing unnecessary, leading to the development of reverse torque compensation which suppresses quadrant reversal projections based on acceleration.

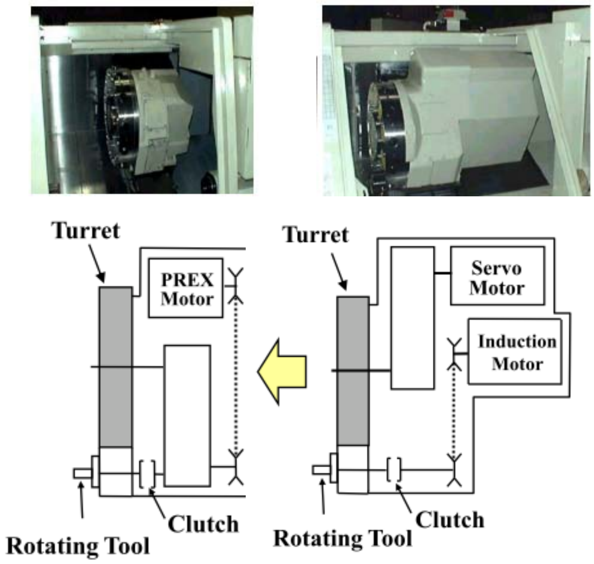

Figure 5 Conversion of turret to single motor structure using "PREX" synchronous reluctance motor

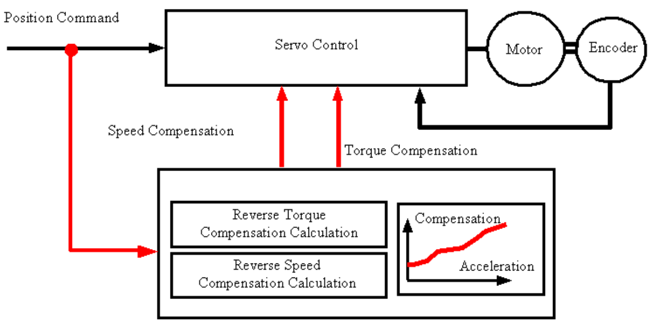

Figure 7 Projection flatten control block diagram

The cause of follow error during reverse rotation is nonlinear friction, and precision compensation control is carried out for motor torque during reverse rotation based on thorough analysis of friction models. **Figure 7** shows a block diagram of reverse torque compensation based on acceleration.

・*Ball screw bending compensation*

In large machines which machine automobile chassis dies, ball screw bending due to acceleration and deceleration is approximately 50 µm, and in bi-directional die machining bending error appears as projections as shown in **Photo 5**.

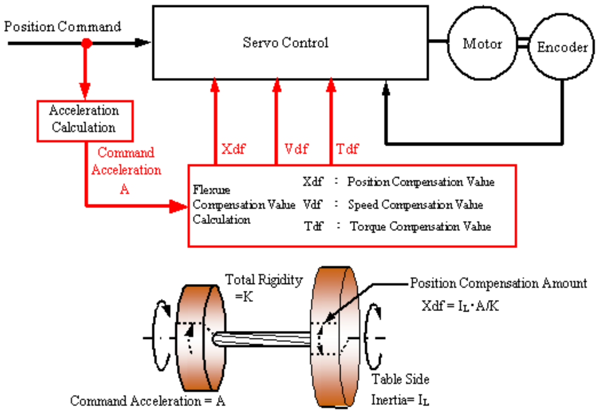

Figure 8 Ball screw bending compensation block diagram

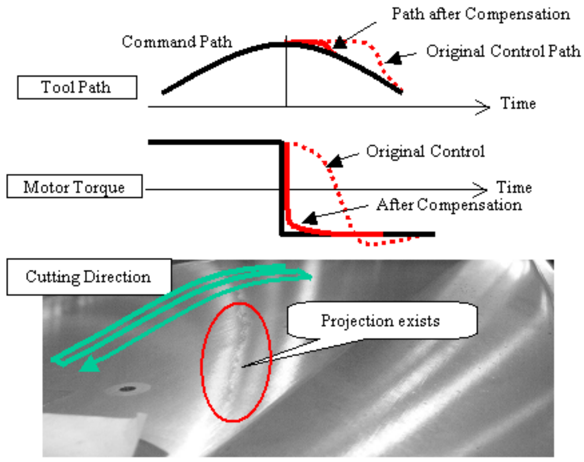

Figure 6 Quadrant reverse projection example

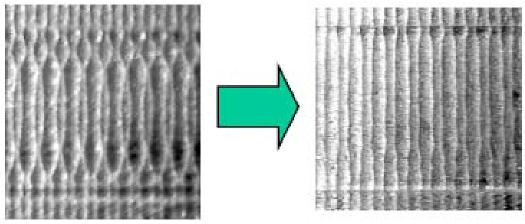

Photo 5 Die machining surface projections

As a countermeasure against these projections, the ball screw bending amount is predictively calculated based on the command acceleration, and the position, speed and torque are compensated. A block diagram of this ball screw bending compensation is shown in **Figure 8**.

⑩ "IT plaza" (2000-)

As a result of the IT revolution of the late 1990's, primarily represented by the internet, in order to build new production processes in the manufacturing industry, a variety of IT tools were introduced, and in 2000, our company proposed the "IT plaza" production system which was a fusion of machinery, machining and control technologies. The "IT plaza" concept model shown in **Figure 9** shows the process innovation aimed for in the production processes for "quickly and inexpensively creating high value added products" from the 3 basic axes of design/production technology processes, production management processes and knowledge management, as well as the orientation for each thereafter.

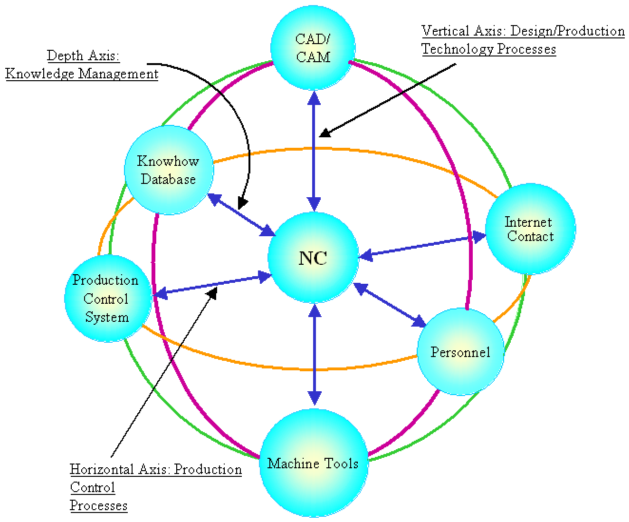

Figure 9 "IT plaza" concept model

Photo 6 The latest "OSP-P300" control

<Introduction of the latest technologies>

Here we would like to introduce our latest "OSP-P300" control (**Photo 6**) which fuses the latest PC technologies, our companies control technologies and "intelligent technologies" which can take the place of skilled operators, to allow for "easy operation" so that complex machinery can be operated by anyone from veteran operators to beginners.

◆*Intelligent functions*

・*Thermal deformation compensation "thermo friendly concept"*

This function realizes an original concept of (1) making thermal deformation manageable, (2) creating a machine structure which evenly distributes temperature and behaves predictably and (3) adds highly precise thermal deformation compensation control, which allows for stable, machining of precise dimensions without the need to worry about thermal deformation in standard plant environments.

・*Collision prevention "Collision Avoidance System"*

This function uses 3 dimensional data of machinery, materials and tools to simulate actual operations slightly ahead of time, allowing it to stop the machine just before a collision actually occurs, allowing for safe operation even in complex multitasking/5 axis machining.

・*Machining condition search function "Machining Navi"*

"Machining Navi" visualizes the cutting conditions, allowing for even non-expert users to utilize machinery and tools to their full potential. For example, when chatter occurs in milling, the function analyzes it and displays the optimum spindle speed so that the operator can follow the on-screen guidance to change the rotation speed and verify the results.

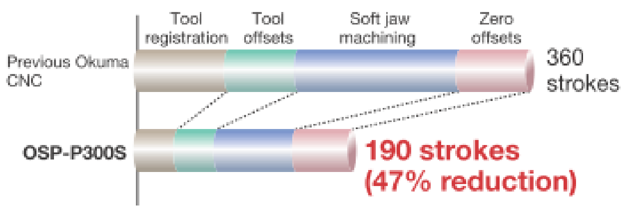

Figure 10 Comparison of number of operations with previous NC controls

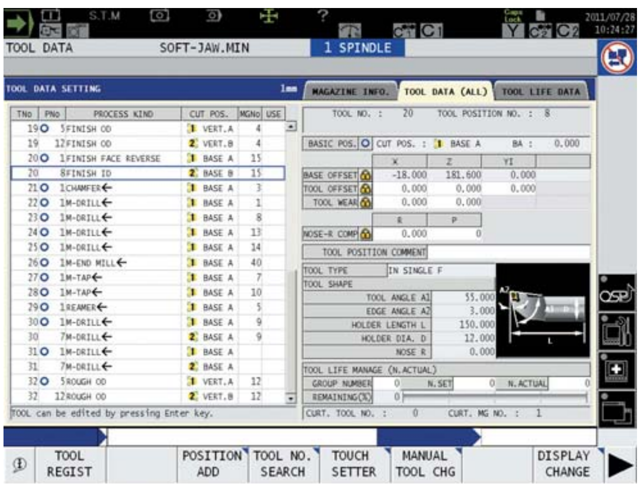

Photo 7 "Single mode operation" for tool registration

◆*Easy operation function of the latest "OSP-P300" NC device*

The "easy operation" function analyzes operator work procedures and helps to realize smooth operation in accordance with operator intent.

For example, for complex machines which use a wide variety of tools, the preparation of the tools is a major burden. Specifically, (1) the various tools have to be equipped and offset, (2) the reference tools have to be registered using the interactive programming function "Advanced One-Touch IGF" and (3) the tools being used have to be registered in the "Collision Avoidance System" collision prevention function.

This function has realized "single mode operation" which allows for smooth processing without having to switch between the operation screens in a complicated manner (**Photo 7**). **Figure 10** shows a comparison of the number of key operations between a previous type of our company's NC mounted on a multitasking machine and the "OSP-P300" which provides a smoothness of operation that cannot be expressed by statistics alone, as well as a significant reduction in the number of key operations.

<*Conclusion*>

Innovation is "new combinations" and "new directions". The "OSP" series has created a new technology trend based on concepts of being "Your Single Source for Machine & Control" and "the fusion of mechanics, electronics and information" since 1963 and we will continue to strive to create new innovations in the "fusion of mechanics, electronics and information and knowledge" in the future in order to provide better added value to customers and contribute to improving customer productivity.