Manufacturing Innovation with Digital Transformation

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Introduction

It has been said that around 2010, we entered the new era of VUCA (Volatility, Uncertainty, Complexity, and Ambiguity), in which the future is uncertain and cannot be forecast. In the energy and environmental field, for example, the shift toward decarbonization is accelerating more quickly than anticipated. In addition, the COVID-19 pandemic, war, and other disasters have resulted in shortages of fuel, raw materials, and semiconductors and disruptions in logistics, and global supply chains are rapidly becoming unstable.

In such a situation, in order to offer customers valuable products and services, we are required to realize digital transformation (DX) with digital technologies in the field of manufacturing and accelerate our efforts to improve our ability to respond to rabidly changing markets, develop a strong quality assurance system, drastically enhance productivity, and establish a system to ensure compliance with delivery times with combination of the Kawasaki Production System (KPS) and digital technologies.

At the same time, we must develop a working environment befitting of this new era to address challenges, including labor shortages due to the aging population and the transfer of skills to the next generation, and realize innovation through research and development, including provision of new solutions with our manufacturing know-how for solving customers' problems in this complex era.

1 Our efforts toward DX (digital transformation)

We formulated our Group Vision 2030 and announced that we would work valiantly to solve social issues. This Vision aims to offer innovative solutions to social issues, such as global warming and the declining workforce, in a timely manner and to realize a more affluent society. To this end, the Vision refers to our intention to speedily provide social value beyond various borders from a "market-in" perspective.

This requires that we dramatically change our business style and the processes that support it. Kawasaki DX is one of our activities to do so. With the power of digitization, we are working hard on Kawasaki DX in order to shift our business model to focus more on market-in and speed as well as to realize process innovation.

By focusing on three areas, namely "DX for customers," "DX for business," and "DX for employees," Kawasaki DX aims to create new customer value, to shift our business model from offering products and services to offering experiences and value, to strengthen our business foundation's agility, and to change the way our employees work. Also, we are making efforts to strengthen our cybersecurity system and to safeguard privacy so as to promote safe and secure use of digital technology.

2 Our efforts thus far in manufacturing

Our production improvement activities on the shop floor began in the late 1970s when we introduced a new production system based on the TPS (Toyota Production System) into our manufacturing departments for mass-production products, including motorcycles and hydraulic equipment. We subsequently improved this system so that it can be applied to build-to-order products, such as aircraft and ships, and expanded its application to every product, regardless of production volume, lead time, and order type. This production system, called KPS, is our company's standard and embodies our manufacturing principles.

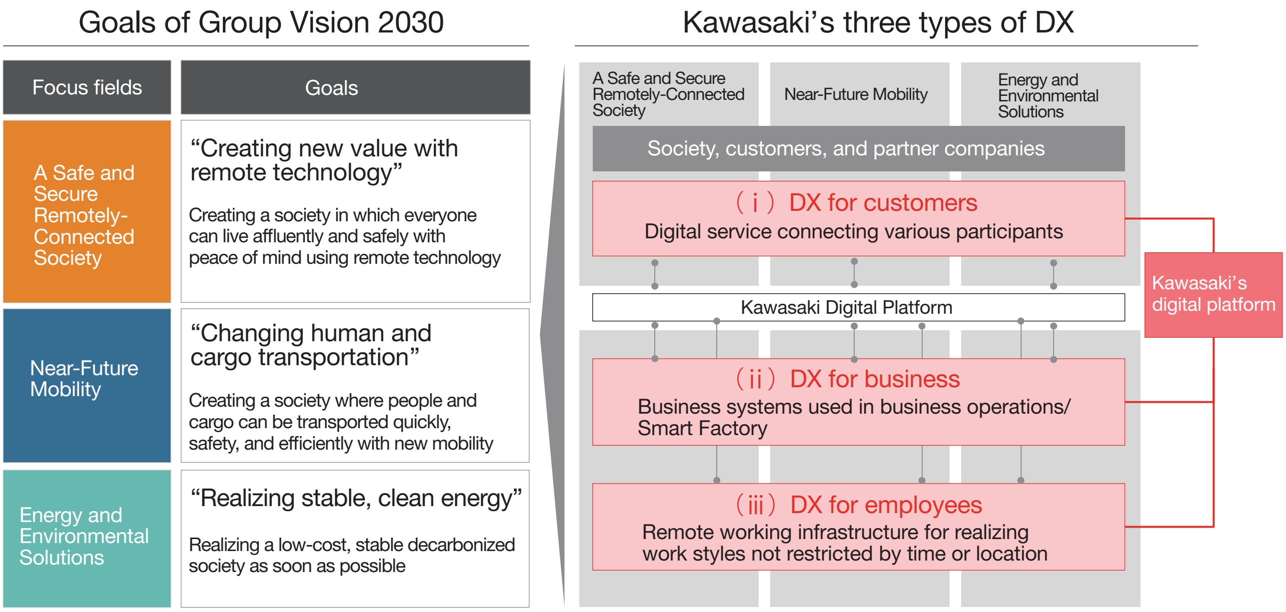

Fig. 1 Overall image of Kawasaki's DX strategy

In KPS, one important point regarding shop floor management is to visualize the actual situation and to iterate the improvement cycle. Here, visualizing refers to standardizing work and assessing differences between the plan and actual results. This clarifies which points should be improved. An important thing in KPS's shop floor management is to implement the PDCA improvement cycle, starting at the identified improvement point, in order to evolve our factories day by day.

In line with the progress of digital technology, since around 2000, we have been actively adopting new technologies to iterate the PDCA improvement cycle more accurately, speedily, and visibly within KPS. For example, we use a visual work instruction system that features monitors to prevent operational errors and transfer work skills to the next generation. In addition, we use a work result collection system that employs barcodes to assess the shop floor concisely and accurately in real-time and to analyze differences between the plan and actual results. However, thus far our utilization of digital technology has focused on streamlining improvement activities on the shop floor, the results of which have often been merely partial optimization of individual workplaces.

3 Manufacturing innovation with DX (digital transformation)

"DX for business," one of the Kawasaki DX activities, aims to reform engineering, manufacturing, and other work processes in the value chain with digital technology as well as to streamline and sophisticate them to maximize customer value and then to utilize the collected digital data to provide experiences and value. As part of such efforts, we are promoting "cross-divisional digitalization," which is intended to rectify connections between work processes in order to optimize the entire value chain, and "divisional digitalization," which is intended to sophisticate operations in individual work processes in order to create new value.

(1) Cross-divisional digitalization

"Cross-sectional" refers to digitalizing information throughout the entire value chain, across different work processes from sales and order acceptance to development and design, procurement and manufacturing, and maintenance and servicing. This enables information to be shared without human intervention and is aimed at eliminating communication of unnecessary information and information stagnation while facilitating prompt, accurate, efficient collaboration towards the rectification and overall optimization of the value chain.

As an initiative to improve development and design processes with advanced digital technology, we have launched the K-DPX (Kawasaki Design Process Transformation) activity. With K-DPX and KPS, all stages can be connected seamlessly, from the engineering chain, including product development, production preparations, and production, to the supply chain.

In an effort to build a foundation for promoting DX, we are improving manufacturing-related work processes throughout the entire group, enhancing work quality, and promoting streamlining of work by viewing the entire value chain, including the engineering chain and supply chain, in

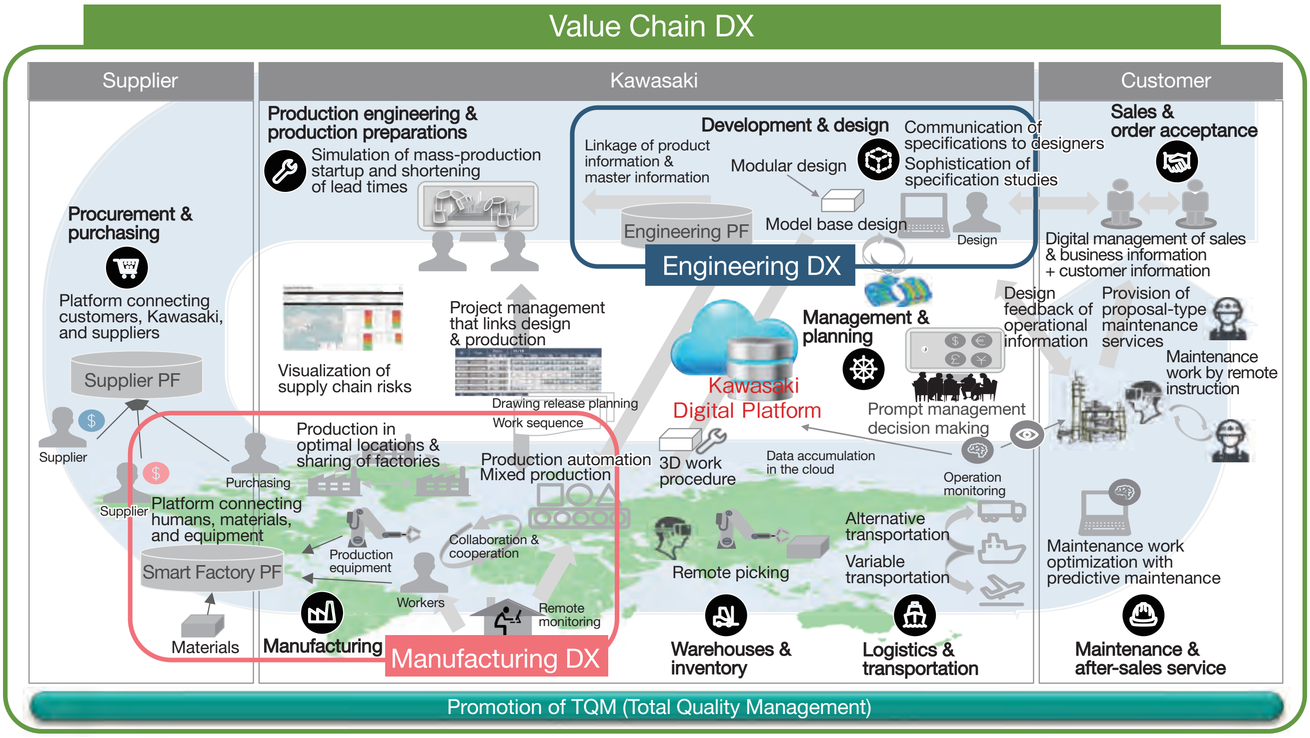

Fig. 2 DX for business

a cross-divisional manner through TQM (Total Quality Management) activities, thereby developing a strong corporate culture through which we can respond to the changing business environment.

Toward manufacturing DX, with the aim of optimizing the operation of entire factories using AI (artificial intelligence) and data analysis techniques, we are working to digitalize the information in each process, including design, process design, and production planning.

(2) Divisional digitalization

"Divisional digitalization" refers to using digital technologies to deepen individual work processes in the value chain. In the development and design process, we precisely verify design models in virtual spaces with high-precision simulation technology to shorten development time and to develop high quality products. In the maintenance and servicing process, we remotely monitor the operation of delivered products to prevent failures and to support optimal operation.

As an effort toward manufacturing DX, we are developing new ways of manufacturing and working. With respect to new ways of manufacturing, we are working to improve assembly times and quality using XR (Extended Reality) technology, which renders digital information into something that can actually be seen. Also, we are using AI technology for analyzing camera images and robot technology to automate and/or mechanize visual inspections in inspection processes, which are currently done by people.

As for new ways of working, we are using XR technology and robot remote control technology to develop an environment in which diverse people can work without being constrained by time or location.

Also, with regard to manufacturing going forward, we are making use of data science, including machine learning, in development and designing. We are actively working on materials informatics to efficiently predict and discover new materials and devices, process informatics to efficiently create the materials and devices, and generative design to generate optimal product designs.

4 Optimization of factory operations (Smart Factory)

Many of our factories are of the high-mix, low-volume production type, being job-shop factories where the production volume of each product is low and where parts of various types are machined and assembled in a limited amount of space. These factories play host to an enormous number of processes in which materials, parts, and products move in a complex way. The automation rate is still low, and production machines and people work side by side. In addition, when trouble or design changes occur, they have been addressed on-site, relying on communication between people.

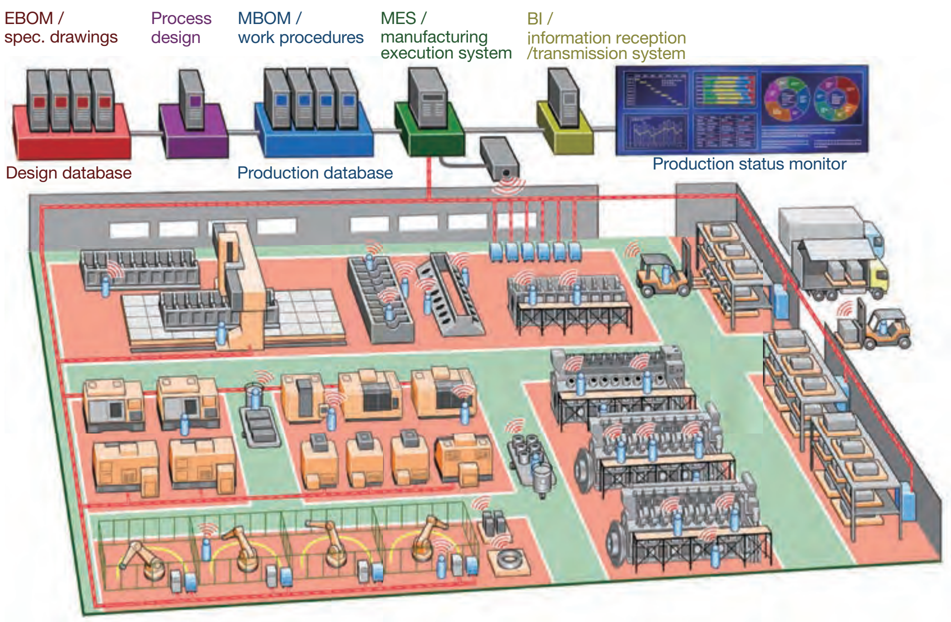

Fig. 3 Smart Factory

In such job-shop factories, our goal is to digitalize and link every piece of data and to operate the factory based on the principles of KPS's shop floor management with the minimum resources and the shortest cycle. To this end, we will set up a core system ERP (Enterprise Resource Planning) for making production plans and operating the entire factory, and based on such production plans, issue work instructions from the MES (Manufacturing Execution System) to each process. We will then collect the work results and indicate these results as KPIs (Key Performance Indicators).

In addition, we are working to create measures to improve the PDCA (Plan-Do-Check-Act) cycle through optimization computation methods, including genetic algorithms, and AI, such as deep learning and machine learning. For example, we are developing a system that determines the order in which products are fed into the final assembly line with optimization computation using genetic algorithms and AI. Moreover, we are developing a system that uses AI for analyzing camera images to monitor whether work is being done safely and whether work standards are being observed.

To realize Smart Factories, we thus aim to accurately, speedily, and visibly carry out all of KPS's PDCA improvement cycle activities, including everything from planning to instruction and recording, analysis, and improvement, with digital technology.

5 New ways of manufacturing

As for new ways of manufacturing, we are using XR technology to improve assembly times and quality. XR technology is a generic term for technologies to realize "Extended Reality," which include VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality) technologies.

VR technology enables people to work virtually without an actual product or workspace, and is used, for example, to train inexperienced workers or workers who are to engage in dangerous work prior to that work. AR technology enables workers to check work procedures and drawings during work without looking away or changing their body positions. MR technology, as typified by Microsoft's HoloLens, provides concrete visual representations of work procedures, including work positions, tools, and actions, which empowers even inexperienced workers to ensure a certain level of quality while observing work standards.

In addition to the use of these technologies, we are utilizing technology for analyzing camera images with AI and robot technology to automate and/or mechanize visual inspections in inspection processes, which are currently done by people.

6 New ways of working

As for new ways of working, with the aim of realizing a society in which everyone can work productively under humane conditions, we are working to promote remote manufacturing with remote control in order to develop an environment in which diverse people can work without being constrained by time or location.

To this end, in addition to developing remote-controlled

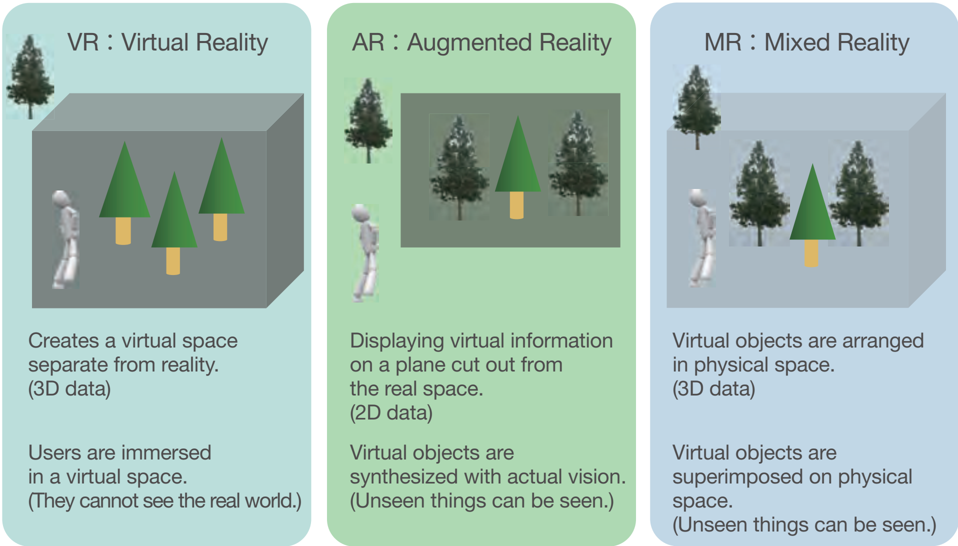

Fig. 4 XR (VR/AR/MR) technologies

robots, we are evaluating high-speed wireless communication technologies, particularly private 5G technology, as key digital technologies. Private 5G enables us to flexibly and efficiently build networks in factories.

Private 5G has three basic performance characteristics: high speeds with high capacity, ultra-low latency, and massive connected devices. These features can be customized to meet the user's needs, and effective use of private 5G on the shop floor is expected to improve productivity.

We will proactively adopt private 5G in factories. This will enable us to carry out various tasks with wireless remote control, which is effective for addressing labor shortages due to the declining population; for improving the working environment, and for transferring experienced workers' skills to the next generation. In addition, we will promote "Remote Factory" by implementing remote working, which has become a common practice during the COVID-19 pandemic, on the shop floor.

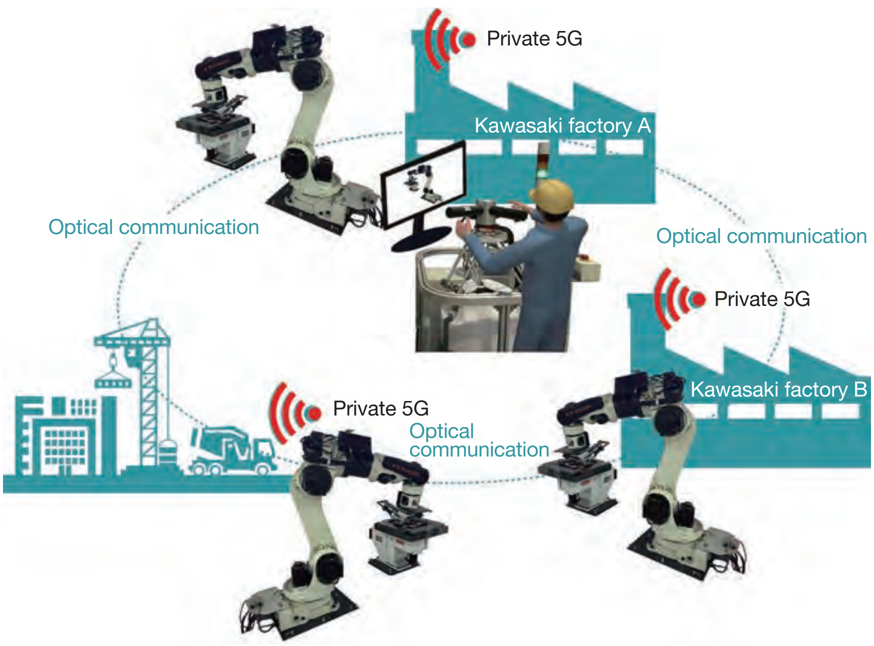

Fig. 5 Utilization of private 5G for remote control

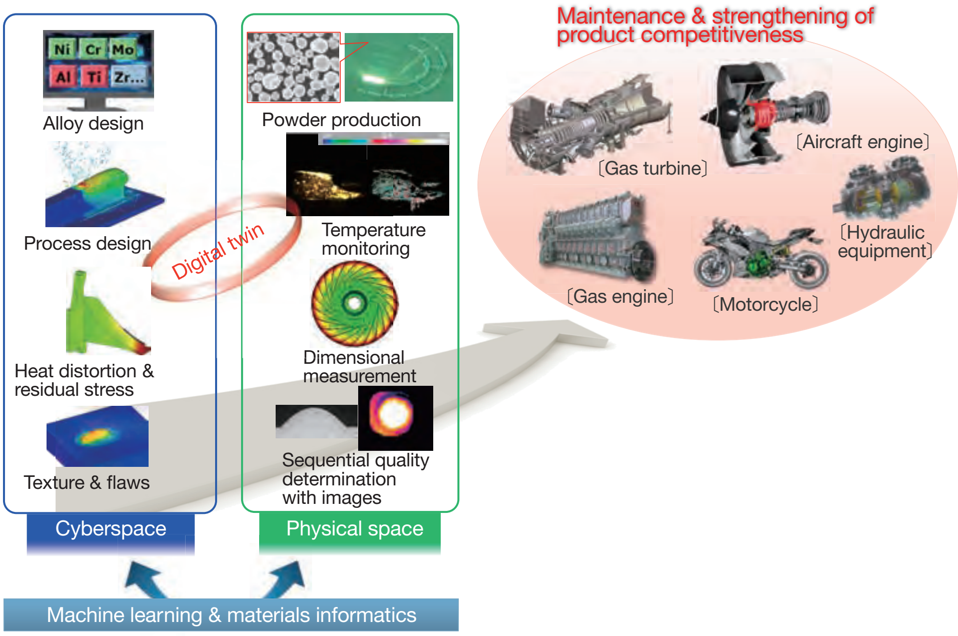

Fig. 6 Enhancement of products' added value

7 The future of manufacturing

We aim to develop a new manufacturing workflow that incorporates information science to optimize performance and manufacturing in the initial stage of development by applying digital twin technology, which will enable reproducing a series of verifications from design to manufacturing in cyberspace.

AM (Additive Manufacturing) technology, which is a manufacturing method by which a material is stacked in layers (as typified by 3D printers) to form a shape, has advanced remarkably, and efforts are underway to put this technology to practical use mainly in Europe and the USA. AM technology allows for more flexible design than conventional manufacturing methods, and in addition, has high affinity with today's digitalization, suggesting high potential for significantly streamlining design and manufacturing processes (in terms of cost, lead times, and energy use). Thus, we believe that developing "Design for AM," a design methodology for additive manufacturing, and promoting materials informatics, including new alloy design and material development, will lead to enhancing our products' added value.

Through these efforts, we will sophisticate our production engineering development and develop new materials, reform our design and manufacturing processes, and enhance our products' added value, thereby contributing to maintaining and strengthening our competitiveness in the global market.

Conclusion

Thus far, we have engaged in manufacturing based on KPS, our unique production system. We are now promoting Kawasaki DX to actively utilize digital technologies throughout the company.

In the field of manufacturing, we will combine the techniques and innovations of KPS that we have accumulated over our long history with the power of digital technologies of DX, including AI, in order to deepen KPS in a revolutionary way and to develop a corporate culture that has diverse values and a sense of speed, thereby giving shape to our slogan "Changing forward."