KOBELCO Group's Core Technologies: Providing Solutions for Future Society

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Abstract

Kobelco Group is dedicated to providing solutions for current and future societal challenges. In pursuit of achieving carbon neutrality, the Group is advancing proposals for materials and solutions that contribute to weight reduction and electrification in the automotive sector. Additionally, to address concerns about maintaining and strengthening Monozukuri (manufacturing) capabilities in the face of Japan's declining labor force in the future, the Group is also developing welding systems and digitization to complement the skills of workers. These activities are based on a diverse range of core technologies that Kobe Steel has cultivated in its material and machinery businesses and their combination over the years.

Introduction

Although it is always difficult to predict the future, gaining insight into the prognoses of various areas and responding to changes are two actions that are necessary for sustained growth. The problems projected to plague society in the future have already begun, notably including frequent disasters caused by extreme abnormal weather events due to the effects of global warming, food crises due to droughts, and the loss of habitable areas due to rising sea levels. In response, there has been a rapid push toward becoming carbon neutral - an effort to reduce the greenhouse gases that are the main cause of these calamities. Changes in population and the workforce are also exerting effects on markets, society, and the economy at the most fundamental level. Much of the world is grappling with issues such as water and food shortages due to population growth. Conversely, in Japan, a rapid workforce reduction due to a shrinking population and a markedly increasing national average age have raised concerns about the sustainability of businesses in all industrial sectors. The resulting erosion of the financial basis of social security and economic slowdown are societal problems that have already begun. However, beginning to emerge in a variety of sectors are "exponential technologies." This term refers to innovations that develop exponentially and whose trajectory cannot be determined by the extrapolation of conventional technologies. Artificial intelligence, VR, quantum computing, machine learning, self-driving cars, and materials science are examples of areas where active technology development and implementation in society are underway. It is important to envision what society will be like when these innovative technologies are integrated and put to practical everyday use.

To respond to these major changes and unpredictable forthcoming societal challenges, Kobe Steel's products will have added functionality to respond to changes in the way our customers and the manufacturing sector use materials. Moreover, the KOBELCO Group is working to provide solutions that help customers fully exploit these new functionalities to transform their products and manufacturing processes. Part of the foundation of these upcoming developments is the company's diverse set of core technologies, which have been incorporated into the business profile over many years in the materials and machinery businesses. Combinations of these core technologies represent the remainder of the foundation of the upcoming developments. The portfolio of technologies includes material-related technologies such as steel, aluminum, titanium, copper, and welding consumables; machinery technologies such as industrial machinery, compressors, and construction machinery; and manufacturing technologies that support various manufacturing operations. In addition, we have been providing solutions to practical issues from the exploration stage to design, manufacturing, and service so our customers can use these materials and machinery products effectively. This paper presents examples of past activities toward solutions development and their prospects for the future (**Fig. 1**).

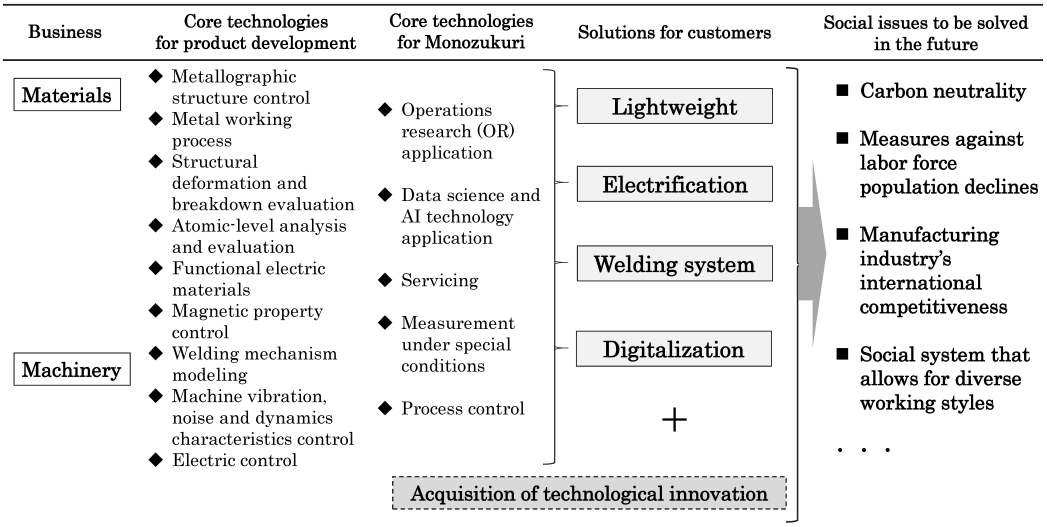

Fig. 1 Providing solutions for the future society by Kobelco Group's core technologies

1. Core technologies supporting lightweight solutions

Kobe Steel has spent many years developing the materials necessary for vehicle weight reduction and electrification to help reduce greenhouse gas emissions. Reducing vehicle weight plays an important role in extending the range of electric vehicles and improving the fuel efficiency of both conventional combustion engine vehicles and hybrid vehicles. Kobe Steel's unique lightweight solutions make use of traditional materials such as steel and aluminum and exploit the characteristics of steel, aluminum, and other materials (e.g., resin) in a highly targeted manner in the development of new structural designs. Some structural designs even feature combinations of dissimilar materials. The company is also involved in developing forged aluminum suspensions and extruded aluminum bumpers. In this way, the KOBELCO Group is promoting a customer-focused, multi-material strategy to provide optimal materials and lightweight solutions that combine improved safety and reduced weight and cost according to vehicle type.[1)]

To strengthen these multi-material strategies, the Technical Development Group established the Multi-Material Structures and Joining Laboratory within the Mechanical Engineering Research Laboratory in 2014. It was initially staffed by several researchers from areas such as the steel and aluminum business units. In 2017, the division was converted into a cross-divisional initiative as the Automotive Solution Center to validate its ability to create unprecedented technologies and products as well as to foster full-scale activities to develop multi-material technologies and products. 2020 saw a renaming to the Application Technology Center in conjunction with a reorganization, with the mindset that the division will contribute to areas of society beyond the automotive sector.

Two main core technologies support weight reduction solutions. One is metallographic structure control technology to support the development of lightweight materials. The other is structural deformation and breakdown evaluation technology to meet the requirements for the design and performance (e.g., crashworthiness) of lightweight components. The use of aluminum products, wire rod, and plate in structures in the civil engineering and architecture sectors have set the foundation in structural performance evaluation technology through experimentation and numerical simulation. Structural optimization technology is effective for the structural design of construction machinery and machinery products such as compressors. It is similarly effective in the design of lightweight automotive parts, as is machine vibration, noise, and dynamics characteristics control technology, which has long been a focus of technology development for vibration and noise control. Metal working process technology, which has been refined in the manufacturing sector, has also been applied to challenges in forming, cutting, and joining processes in parts manufacturing and assembly.

To solve future societal challenges, the automotive industry is accelerating its shift toward carbon neutrality in support of a decarbonized society. Accordingly, the entire manufacturing process must comply with regulations related to greenhouse gas emissions. The KOBELCO Group is advancing technology development efforts involving lightweight solutions that use steel and recycled aluminum for many parts. The group intends to

reduce greenhouse gas emissions in the materials manufacturing process in conjunction with these developments. Aluminum and other lightweight materials tend to have higher CO_2 emissions factors during manufacturing compared with steel; however, lightweight contributes to lower CO_2 emissions during driving. As such, in the process of material selection and optimal structural design of automotive parts intended to reduce environmental burden, it is essential to consider each material's characteristics when evaluating the environmental burden over the entire lifecycle. When using lightweight materials, it is necessary to evaluate the total environmental burden via a lifecycle assessment (LCA), which evaluates greenhouse gas emissions over the entire lifecycle of a vehicle. As a result, the material perfectly fit for purpose can be proposed.[2)]

2. Core technologies supporting electrification solutions

The automotive and machinery products sectors are also accelerating the shift toward electrification, with a relatively fast pace of technology development leading into early implementation. In response, we are promoting the development and provision of magnetic materials that optimize electrified components. Various products contribute to the electrification of vehicles, including wire products such as pure iron-based soft magnetic materials for DC components (solenoids, electric switches, etc.) in electric vehicles; magnetic iron powder for motors and transformers for high-speed, high-torque applications; and titanium for fuel cell stacks. In proposing magnetic materials, it is important not only to provide materials but also to develop magnetic solution technology to predict performance (efficiency, loss evaluation, etc.) when magnetic materials are used in electric components. This can be accomplished via simulation and enables customers to use the materials effectively.

To accelerate marketing and solutions development activities for magnetic materials, the KOBELCO Group established the Magnetic Materials Marketing and Development Office in 2021, bringing together the Steel & Aluminum Business Unit, Advanced Materials Business Unit, and Technical Development Group. This restructuring brought together the aforementioned independent business units (wire rods and bars, steel powder) and the Technical Development Group to begin providing proposals to customers. Furthermore, our mission is not limited to existing materials products, but rather also includes uncovering potential needs that our customers themselves have not yet detected. For example, we are capitalizing on the features of thin magnetic wires made of pure iron-based soft magnetic material to design motor cores without electromagnetic steel plates to develop low-profile, high-performance (low speed and high torque) axial gap motors.

The core technologies that support electrification solutions include atomic-level analysis and evaluation technology and functional electronic materials technology, which are indispensable as the foundation of the metal materials business and technology development. Electrical control technology and magnetic property control technology are also necessary for guiding optimization of electric components that use magnetic materials. These core technologies related to electrical and magnetic control have been cultivated in Kobe Steel's machinery business, such as through the development of compressors and construction machinery. However, we have also acquired expertise from applications involving motors and other electric components in machinery products.[3)]

The company has also begun developing its own electric components. We have recently developed electric actuator technology that uses a 3D magnetic pole structure and can generate more than three times the electromagnetic force of conventional electric actuators. This technology will enable the development of compact, high-torque motors anticipated to prove useful where conventional motors fail to perform sufficiently. For example, we aspire to develop a forming process that enables finely tuned movements via the electrification of hydraulic or pneumatic presses used in manufacturing. Our intention is to contribute to carbon neutrality through the electrification of vehicles, transport equipment, and industrial machinery by collaborating with our customers in a three-pronged approach involving magnetic materials, solutions, and devices.

3. Core technologies supporting welding solutions

The welding business of the KOBELCO Group began in 1930 with the production of coated welding rods. Since then, the group has worked with industries and fabricators in Japan and abroad to develop and disseminate new welding technologies, contributing greatly to the advancement of society. The group has also maintained the number-one position in Japan in the fields of welding consumables and robot welding systems for medium-to-thick plate. Automation and the use

of robots in factory welding have been promoted in the domestic architectural steel frame sector. Additionally, the labor shortage of recent years has led to support for automation of on-site welding. Furthermore, the need for a variety of automated welding technologies is increasing outside Japan. To meet these needs, Kobe Steel's Welding Business Unit is developing a welding solutions business that solves customers' challenges through the integration of welding technologies such as welding robots, power sources, equipment, consumables, and processes.[4)]

The core technology supporting welding solutions is based on the optimization of welding consumables. Optimal welding consumables have a chemical composition that forms weld metal with good mechanical properties, bead shape and appearance, and stable formation and transfer of molten droplets in response to digital power source control, enabling stable welding for a long time. Digital power sources are also available as welding mechanism modeling technology. Controlling the current waveform and wire feed speed optimizes the formation and transfer of molten droplets, supporting stable penetration and bead shape, high-speed welding, and low spatter and fumes.

Welding robots are also becoming increasingly important for worker safety and for productivity improvement. One of the main components of the automated welding system developed is the arc tracking function. This function detects minute changes in current resulting from changes in the distance to the target workpiece caused by the weaving operation during welding. It detects and corrects deviations in the weld line for stable, high-quality welding that cannot be achieved with other robots. In addition, the welding robot uses touch sensing with the welding wire to detect the position of the workpiece before welding. If the robot is operated at high speed during this process, vibration as well as wire deformation from overtravel occur when the robot stops suddenly, reducing the accuracy of welding position detection. To combat this issue, the system instantaneously plans a trajectory that moves the wire in the opposite direction while suppressing vibration at the time of detection. This achieves sudden-stop-vibration suppression at the time of touch sensing with a stop time of 0 seconds. The system is also equipped with a sensor-based position detection function. Complex weld lines, such as saddle welds, preclude arc tracking. The cross-section of such welds is measured using a laser light curtain combined with tip misalignment compensation technology to enable the highly accurate detection that is difficult to achieve with a single tracking compensation method.

The labor shortage is expected to further intensify due to the unprecedented decline in the birthrate. The decline in the number of skilled welding technicians is a driving factor in the need for robotic solutions as well as automation. Moreover, such developments are needed quickly to ensure that the related skills are passed on effectively, which is challenging. Also notable is that whether a vehicle is powered by a reciprocating engine or an electric motor, the characteristics required of suspension components (e.g., salt corrosion and fatigue resistance, lightweight) remain unchanged. As such, we will be adding new value to current welding consumables by enhancing electrodeposition coating capacity and developing welding consumables for high-strength steels as well as welding solutions for the automotive sector.

4. Core technologies supporting digitalization solutions

Digitalizing manufacturing operations is essential not only for efficient production, but also to create new value added. In 2021, the KOBELCO Group established the Digital Innovation Technology Center (DITec) within the Technical Development Group to promote and accelerate DX (digital transformation). The mission of the Center is to lead transformation through the development and application in business of advanced technologies as part of the KOBELCO Group's DX strategy, which aims to promote business innovation and value creation through digital technology. Within these mission and objective statements, a key point is that the needs of customers and society are the starting point. DITec has cross-functional responsibility within the group. As such, it fosters the development of infrastructure and human resources in support of data utilization. This Center also incorporates the latest technologies related to DX and is responsible for technology assurance.

The core technologies supporting digitalization solutions are based on production management technology, control technology, and measurement technology developed in practical manufacturing applications from the perspective of a materials and machinery manufacturer. These specialized groups of technology are the starting point for promoting the development of new digitalization and AI technologies including their application.[5)] Operations research (OR) application technology originally arose out of efforts to use computers in production control operations and to automate and optimize the operations of large, complex

steel mills. Data-driven science and AI application technology is also a fundamental technology, with roots in the development of computational science in the 1980s. Foundational here is the application of atomic-level models to control materials and plant and machinery product operation. As a result, AI technology efforts have advanced in conjunction with the development of machine learning. Materials informatics (MI), a method of informatics that uses research techniques such as statistical analysis, has recently been introduced in materials development. The KOBELCO Group is rapidly optimizing component design and manufacturing conditions to achieve the desired material properties by using machine learning and analyzing large amounts of data. We are applying our findings to develop steel, aluminum, copper, and other materials as well as in the investigation of new materials.

Our developments in servicing technology include a platform that ties data to the entire value chain (including sales, marketing, development, design, manufacturing, and service) for the purpose of communicating with customers. One example of our efforts to strengthen contact with customers is our stepwise improvement of production management at plants with a highly varying product mix by linking order and delivery information, production management, and operational status across the entire plant and supply chain.

The KOBELCO Group aspires to provide new value by transforming business operations through the linking of data to customers, development, and manufacturing, such as by using AI and ICT to optimize planning. Moreover, the group is working to support safety, high quality, and efficiency in manufacturing by enhancing processes involving multiple products. Key factors are the use of digital technology and the promotion of automation and optimization by connecting the entire factory.

One of our core technologies supporting manufacturing is that of measurement technology under special conditions. This group of technologies includes non-destructive testing to verify the surface and internal quality of various materials and large structures, process measurement technology in harsh environments such as blast furnaces with high temperatures and dust, and surface profilometry technology to evaluate the flatness of sub-nm silicon wafers based on the dynamic behavior of rolling mills several dozen meters in size. These unique measurement technologies for special applications and environmental conditions are the core technologies necessary to promote digitalization in manufacturing.

Thus, digitalization solutions can effectively solve challenges in all sectors. Data is rapidly advancing throughout society; it goes without saying that making the best use of data as a management resource is an essential factor in solving future societal challenges. We regard societal change as an opportunity to transform our operations and support value creation through digital technology.

Conclusions

To solve future societal challenges, the KOBELCO Group will extend the "point" core technologies refined over many years to create the "plane" technologies that are useful for products, technologies, and services in the practical world. Combining point and plane technologies will yield three-dimensional solutions that can further contribute to our customers' businesses.

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