

Core Technologies Ensuring Safety and Security in Community Development and Manufacturing

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Abstract

The KOBELCO Group has been consistently providing materials and key components that support industries in the transportation sector, life sector, and energy-infrastructure sector. These core technologies were acquired by Kobe Steel during its early years when it ventured into diverse areas like materials and machinery. They were developed to address a wide range of needs across various fields and are unique to the Kobelco Group. The Group is committed to further enhancing these core technologies, with the aim of supporting the creation of products that are fundamental to our daily lives. This commitment ensures the safety and security of our communities by providing stable energy supplies to local societies. Additionally, the Kobelco Group will contribute to improved safety and productivity within our manufacturing facilities and at its customers' sites.

Introduction

The KOBELCO Group's corporate philosophy begins with the goal of a world in which people, now and in the future, can fulfill their hopes and dreams while enjoying safe, secure, and prosperous lives. The company has evolved into its current state by building on its original foundation of promoting technology development and by manufacturing subsequent innovations domestically. Said innovations have grown into established technological fields that have become the backbone of Japan's economic fortitude. Going forward, the company must consider major environmental changes on a global scale in conjunction with developing further innovations.

Over the 118 years since the founding of Kobe Steel in 1905, we have collaborated with our customers to create and provide the products they need. The company is structured into three core businesses: the materials business, which comprises steel and aluminum, advanced materials, and welding; the machinery business, which comprises machinery, construction machinery, and engineering; and the electric power business. **Fig. 1** depicts the seven segments into which the structure is organized. The KOBELCO Group's history dates back to the early 1900s. Its timeline is shaped by the development and commercialization of

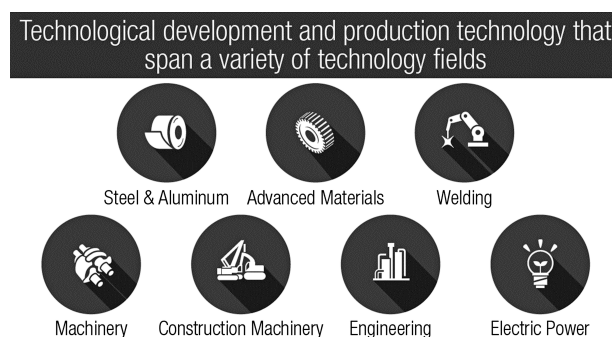


Fig. 1 Business segments of the KOBELCO Group

numerous product lines that were firsts in Japan in business areas centering around the heavy industry (**Fig. 2**). These product lines do not comprise finished products, such as vehicles or engines, but rather parts and components that are essential to the function of the final product. The customers of any given segment are diverse. Accordingly, the KOBELCO Group provides products and services that support a wide range of perspectives by understanding the trends and needs of customers in various fields. We will continue to meet the diverse needs of our customers with the 21 core technologies cultivated over the course of developing these diverse businesses.

Doing so will support the 2021 materiality of ensuring safety and security in community development and manufacturing by fostering safe and productive manufacturing operations as well as a safe, secure, and prosperous life for all people.

The KOBELCO Group's customers can be broadly categorized into three market sectors: mobility (transportation), life (infrastructure for everyday life), and energy & infrastructure. The KOBELCO Group's promise to society is to ensure safety and security in community development and manufacturing by solving various societal challenges through products and services that meet the diverse needs of our customers in these fields. The prerequisites for this goal are to provide our customers with peace of mind when using our products and to maintain manufacturing capabilities that ensure product reliability and productivity.

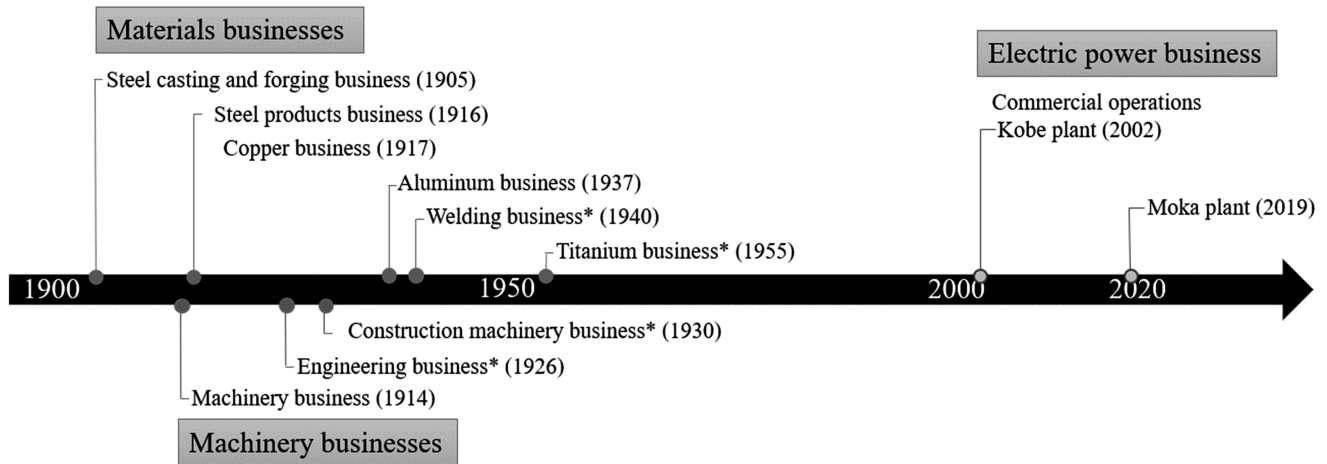


Fig. 2 History of the KOBELCO Group (* indicates the first business in Japan)

This is why manufacturing within the KOBELCO Group makes use of 21 core technologies cultivated through years of technology development in a broad spectrum of businesses. This paper outlines the company's approaches from the perspective of safety and security in every market sector and manufacturing alongside the core technologies that support these approaches.

1. Product portfolio and core technologies supporting our way of life in the transportation sector (vehicles, vessels, rail, and aircraft)

1.1 Vehicles

In the automotive sector, representing the most familiar type of transportation equipment in people's daily lives, there is a need to reduce weight, ensure safety in the event of a collision, and meet increasingly stringent environmental regulations. What society demands of vehicles changes continuously, with new materials fit for purpose being developed in tandem. The KOBELCO Group is a manufacturer of metal materials, specializing in both steel, which features high strength, and aluminum alloys, which are characterized by their lightweight. The company has contributed to safety and weight reduction through multifaceted material technologies. Two example developments occurred in parallel in 2004 in response to the demand for high-tensile strength thin sheet steel that had been growing since the late 1990s. Specifically, the KOBELCO Group developed a 1470-MPa-class cold-rolled high-tensile steel, the world's highest strength at the time, as well as a high-strength aluminum alloy for use in hoods, bumpers, and suspensions. To provide materials that meet customers' needs,

it is important to control the microstructure, which governs the mechanical properties of a material, such as strength and ductility. The core technologies that serve as driving factors here are atomic-level analysis and evaluation technology for analyzing microstructure as well as metallographic structure control technology, which have commonly been applied to different types of materials. Steel and aluminum alloys, which are widely used in industrial applications, are microscopically very different materials in terms of their crystal structures and strengthening mechanisms. However, this does not present a significant challenge for the KOBELCO Group to overcome because our strength lies in our extensive technological knowledge and experience in controlling each material at the atomic level. Furthermore, we are also working intensively on technologies that help customers select the right material for their needs. These technologies support the KOBELCO Group's multi-material car body design. It is extremely important to preclude the fracture of special steel wire rods used for bolts and springs during use. Coarse non-metallic inclusions in the steel can increase the risk of fracture, which is why we have refined our core technology of metal inclusions control technology.

1.2 Vessels

The shipbuilding sector supports the logistics of our everyday lives. The hull, engine, and various equipment must be able to navigate safely at sea and ensure the safety of human lives. The KOBELCO Group contributes to the safety and security of vessels by offering a diverse portfolio of products, including cast and forged steel, steel plate, welding consumables, and machinery. For ship propulsion

parts such as engines, we provide high-fatigue strength crankshafts with high cleanliness steels; for ship hulls, we provide steel plates designed specifically for hulls as well as welding consumables. The development of these materials is supported by core technologies such as metallographic structure control technology, atomic-level analysis and evaluation technology, and inclusions (in metal) control technology. The welding business has its foundations in the shipbuilding sector. We are well versed in the trends and needs of our customers during construction, contributing to improved ship reliability in materials and other areas of technology such as welding systems and welding construction processes. These developments and expertise have been made possible by core technologies such as welding mechanism modeling technology and melting, forging, and welding technology. In the area of machinery products, we offer a microchannel heat exchanger (DCHE) for marine applications, which combines compactness and high reliability based on technology developed across more than 50 years of heat exchanger production. The KOBELCO Group is also one of the world's leading compressor manufacturers, offering three types of compressors: screw, centrifugal, and reciprocating compressors. It supplies the most efficient and reliable compressors for any type of vessel, including BOG compressors that compress boil-off gas for LNG-fueled vessels. The core technologies supporting these innovations are structural deformation and breakdown evaluation technology, which ensures the safety of structures; machine vibration, noise, and dynamics characteristics control technology, which achieves low vibration and low noise of machinery products; and thermal and fluid dynamics control technology, which improves the efficiency and performance of machinery products and processes.

1.3 Rail

The rail sector, representing an essential means of long-distance mass transport in Japan, is seeing increased focus on the use of lightweight materials. This is especially true of high-speed trains such as the Shinkansen. We support this trajectory by providing various types of aluminum alloy components. High-speed rail demands technology that reduces weight and ensures safety. And because noise and vibration increase as weight is reduced, damping innovations are necessary as well.

In response to this need, we have developed vibration-damping elements with improved noise insulation properties by joining vibration-damping resin with an aluminum alloy. We have

also developed porous sound-absorbing panels proven in practical use by introducing numerous micro-perforations in aluminum sheets. The core technology behind the sound-absorption characteristics is machine vibration, noise, and dynamics characteristics control technology. The KOBELCO Group has been a pioneer in the area of novel transportation systems since establishing Japan's first new transportation system¹⁾ at the Okinawa International Marine Exposition. The company has continued this legacy through its involvement in the engineering of unmanned operation systems (systems for signal security, automatic operation, operation management, etc.).

1.4 Aircraft

The aircraft sector, which supports an essential means of international transportation, requires superior safety characteristics for airframes, engines, and equipment. Jet engines in particular, which are subjected to intense vibration, temperature, and pressure, require an exceptional balance between durability and low weight. Titanium alloys constitute one material we provide to meet the demands of this set of applications. As an integrated producer of titanium alloys, managing processes from melting to forging, the KOBELCO Group provides various materials such as titanium forgings and plates. Weight reduction is pursued to the utmost limit in the aircraft sector. As such, assemblies that were once made of many parts are now cast as a single component. Cast products made from lightweight metals such as aluminum alloys and magnesium alloys have been developed and have successfully contributed to weight reduction. These materials, which have also been exploited in the automotive industry, have been based on three core technologies: metallographic structure control technology, atomic-level analysis and evaluation technology, and melting, forging, and welding technology.

2. Product portfolio and core technologies supporting the life infrastructure field

The KOBELCO Group also provides materials essential to people's everyday lives, such as aluminum alloys for beverage cans and titanium alloys for eyeglasses and watches. The company continues responding to changing demands for materials that occur alongside changes within society. Our domain extends beyond structural materials into areas such as materials for electronics.

2.1 Semiconductors

The KOBELCO Group's components and technologies also improve the functionality of common electronics indispensable to our everyday lives such as printers as well as computers, televisions, smartphones, and other products with liquid crystal displays (LCDs). In 1989, the KOBELCO Group launched a target business (Kobelco Research Institute, Inc.), which began with the development of targets for magneto-optical disks. Since 1990, the KOBELCO Group has also helped develop semiconductor devices and manufacturing processes, cultivated its equipment business, and built an infrastructure for evaluation and analysis. Although the company has since withdrawn from the DRAM business, it has continued its ventures in target materials, inspection equipment, and process equipment components necessary for semiconductor processing. The group is currently using the technology to study the functional electronic materials technology by combining it with advanced analytical and inspection technologies. As a result, it is possible to analyze the functions that emerge when semiconductor materials are configured into devices. The company has been making great strides in this business by developing target materials for flat panel displays (FPDs) since 2000.²⁾ The technological foundations acquired here, including more advanced atomic-level analysis and evaluation technology as well as computational science, have become indispensable for differentiating structural materials such as ultra-high tensile strength steel and high-strength aluminum.

2.2 Medical equipment

Using the cryogenic technology refined through the use of gas separation equipment as a foundation, we began marketing metallic superconducting wire rods in 1980. In 1989, we established JASTEC (Japan Superconductor Technology, Inc.) and subsequently developed a proprietary technology for the uniform processing of composite wires using hot isostatic pressing. This technology is combined with superconducting magnet manufacturing technology for application in NMR (nuclear magnetic resonance) and MRI (magnetic resonance imaging), and it is widely used in products in the medical field. Developments in this area occur in tandem with the development of electric control technology and magnetic property control technology.

3. Product portfolio and core technologies supporting everyday life in the energy and infrastructure sectors

3.1 Civil engineering and architecture

Large buildings, bridges, and other civil engineering and architectural structures are the foundation of safe and secure life. As such, these structures must be reliable and long lasting.

In 2002, the KOBELCO Group developed Japan's first 780-MPa steel plate³⁾ for architectural structures to meet the increased demand for earthquake resistance in the wake of the Great Hanshin-Awaji Earthquake. The company has also developed various steel plates and welding consumables with superior weld safety. Controlling the processes of deformation and fracture of steel plates is important for improved safety of steel structures.

In this regard, we have been providing components that ensure reliability through structural deformation and breakdown evaluation technology, such as material damage evaluation technologies and numerical simulations. We are also developing welding robot systems to support welding automation in steel frame assembly operations, ensuring to safety and security in manufacturing.

Likewise in 2002, we developed a highly corrosion-resistant steel plate³⁾ for cladding bridges that reduces lifecycle costs by 30 - 50%. Slowing the progression of rust formation is of key importance. Accordingly, we have developed surface morphology control technology based on information from local analysis technology using high-brilliance synchrotron radiation (SPring-8). One of our core technologies, metal surface control technology, is the key technology that precisely controls rust morphology in this innovation. This technology is designed to improve the service life of steel plates by accounting for both their mechanical properties and their operating environment, greatly contributing to reliability.

We have contributed to the safety and security of our customers in the field of construction machinery with equipment such as hydraulic excavators and crawler cranes. Examples of improved factors include riding comfort, strength, energy conservation, and the control of vibration, noise, and hydraulics. Core technologies that have played an important role in this sector include structural deformation and breakdown evaluation technology as well as machine vibration, noise, and dynamics characteristics control technology. The KOBELCO Group also developed the world's first hybrid excavator, incorporating the hybrid technology of an engine plus an electric motor that has become

commonplace.⁴⁾ The core technology used here is electric control technology and magnetic property control technology.

3.2 Industrial infrastructure

The KOBELCO Group provides compressors that can be considered the central component of various plants, such as power plants and steel mills. The company is also the founder of the machinery industry, with a history of more than 100 years and a total of more than 10,000 units manufactured and sold. We have been refining the technology of high-pressure LNG and BOG compressors that feature stable operation at the liquefaction temperature of methane (-161.5°C) since the early 1990s. Since 1996, we have delivered many of them to LNG import terminals. These compressors have achieved stable operation even in extremely harsh environments, such as offshore oil and gas production facilities. The KOBELCO Group takes the top share of the global market for large resin mixers and pelletizers. The key features of these product lines are their exceptional durability and productivity, which enable 8,000 hours of continuous operation per year. In particular, the company has captured more than half of the world's plant market share for polyethylene.

3.3 Societal infrastructure

The KOBELCO Group possesses a wide range of water treatment technologies, including water and sewage treatment facilities and environmentally friendly waste treatment technologies. These product groups are very important components of societal infrastructure and industrial plants, where extremely high reliability, durability, and performance are critical. We are responding here to the trust of our customers through the support of our core technologies similar to those declared relevant to construction machinery in the previous section. These core technologies include those related to structural deformation and breakdown evaluation technology to ensure reliability and safety; machine vibration, noise, and dynamics characteristics control technology to achieve low vibration and noise in machinery products; and thermal and fluid dynamics control technology to improve efficiency and performance of machinery products and processes.

3.4 Electric power

Diversification of the KOBELCO Group

continued into the 21st century with the construction of the Kobe Power Plant within Kobe Works in 2002. This foray into the electric power supply business got its start by making maximum use of the operational expertise accumulated through coal infrastructure and private power generation in the steelmaking business. The plant has implemented the highest level of environmental measures for an urban power plant located close to an electricity demand area. It can supply clean, highly efficient power with very low transmission loss and contributes to energy self-sufficiency in urban areas. When many power plants near the coast were shut down following the Great East Japan Earthquake in 2011, the KOBELCO Group began considering power supply projects in eastern Japan, opening a large-scale inland thermal power plant in an industrial park by Moka Works in 2019. The Moka Power Plant, which is supplied by city gas, uses a state-of-the-art combined-cycle gas turbine (CCGT) power plant system for the most efficient power generation in Japan. As an initiative that fortifies the electric power infrastructure by decentralizing power source locations, this plant has been deemed an exemplary private-sector initiative for national resilience (Cabinet Secretariat) and energy infrastructure resilience (Ministry of Economy, Trade and Industry).⁵⁾ The core technologies that support these ventures include carbon resource conversion and application technology, thermal and fluid dynamics control technology, adsorption and desorption technology, and metal surface control technology. We will continue enhancing these core technologies and building new technological foundations to contribute to the stable supply of electric power to local communities. We will also take on the challenge of becoming carbon neutral by developing and demonstrating biomass cofiring and by investigating ammonia cofiring and mono-firing.

4. Core technologies supporting safe and secure manufacturing

Improving our manufacturing capabilities is key to ensuring timely delivery and instilling confidence in customers of Kobe Steel's materials and machinery products. The core technologies that support manufacturing within the KOBELCO Group have become more sophisticated and have resulted in synergistic effects through the promotion of multiple businesses, including the materials and machinery businesses.

4.1 Manufacturing of materials

The manufacturing processes of metals in the materials business necessitate high-temperature environments, such as when materials are heated to high temperatures for melting and solidification processes and during hot working. To control these manufacturing processes, we have developed measurement technology under special conditions, which is a core technology to measure temperature and shape, and thermal and fluid dynamics control technology, which is a core technology for combustion control and flow control. The process control technology is an additional supportive core technology, which is intended for the accurate, efficient, and safe operation of equipment under continuous long-term operation, such as blast furnaces in steel mills. We have responded to the diverse needs of society and our customers by applying the technology we have cultivated in the field of materials process control to process automation and to the design of machinery products. Advancing process technology from the perspectives of both materials and mechanical aspects has also served this objective.

4.2 Machinery manufacturing

As a machinery manufacturer, the company's sphere of activity also includes metalworking machinery such as cold rolling mills. The 1980s saw a rapid expansion of the field of materials for electronics in response to the rising popularity of equipment designed to store and share information. The demand for cold rolling mills with high dimensional accuracy increased in conjunction with this trend. Kobe Steel was an early adopter in the development of machinery and equipment to produce sheet metal with high precision. Notably, Kobe Steel is both a material manufacturer for the sheet metal sector and an end user of metal processing equipment. We developed the core technology for controlling the rolling process, that is, metal working process technology, from both perspectives.

Material-cutting processes are an essential part of the manufacture of machine parts. In addition to its machinery business, Kobe Steel previously maintained a tool business. Through these businesses, the company has advanced metal working process technology in a variety of ways for manufacturing in the KOBELCO Group. The manufacturing process of a machine part involves estimating machinability before actually performing machining. This enables the process to be designed

for optimal cutting conditions and tool design. As such, we are refining processing technology for materials with low machinability in house in support of our customers' manufacturing operations.

4.3 Production management

A unique attribute of the KOBELCO Group is that it comprises multiple businesses, each with a diverse product mix. One technology that has been inherently strengthened is operations research (OR) application technology. This technology supports decision-making in large-scale and complex production processes through total optimization of areas such as meeting delivery deadlines and minimizing inventory. It is also an effective technology for reforming the production process. The blast furnace and converter at Kobe Works were shut down and consolidated into operations at Kakogawa Works in 2017, a decision based in large part on this technology. In recent years, efforts to optimize manufacturing processes and logistics in factories have been applied to the development of models for calculation and analysis of CFP (carbon footprint of a product). This value tracks the amount of greenhouse gases emitted in each stage of a product's or service's lifecycle and converts it to CO₂.

The company has widely applied system technology in its materials business to control and manage production processes, such as in the form of process computers and production management systems that control high-temperature, high-speed rolling processes. Advances in telecommunications have enabled the collection of large amounts of data and faster processing. Meanwhile, network and machine learning technologies have also evolved significantly. The data-driven science and AI application technology that reliably incorporates these advances is making it possible to operate various plants efficiently and with a relatively minor environmental burden.

As mentioned at the beginning of this paper, Kobe Steel has provided key components such as industrial machinery and equipment plants that support customers' production plants - elements that must continue running in stable operation for 25 to 50 years. After-sales service, such as maintenance and inspection of equipment and provision of replacement parts, is also important for customer safety and reassurance. As a global company with a diverse product portfolio, product optimization is also one of Kobe Steel's top priorities. We have therefore applied the methods and expertise we have cultivated toward a platform that uses ICT to optimize and enhance our products, thus

creating a servicing technology. Historically, Kobe Steel's technological developments have centered around the sale of goods. Now, however, these core technologies enable us to focus on the value that can be captured in the environments in which our customers use our products. Going forward, we will propose new business models by initiating discussion not only within the KOBELCO Group, but also with our customers and the market.

Conclusions

Since its founding, the KOBELCO Group has continuously provided key components that support industry to enrich people's lives, cultivating 21 core technologies in the process. In continuing to meet the diverse needs of our customers, we will continue

supporting a safe and secure society by combining the core technologies of the deeply rooted the KOBELCO Group in various ways.

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