Kawasaki Heavy Industries
Quarterly Newsletter

Scope

Autumn 2016
No. 109

Contents

120th Anniversary Logo

Kawasaki marked its 120th anniversary on October 15 this year. With this logo, we wish to express a symbol of trust backed by 120 years of history and tradition as well as our continued commitment to meeting the needs of society and further improving corporate value —a task we take on through products and services employing advanced technologies.

About the Cover

Crystallization of technological synergies —Ninja H2R—
See Special Feature for further details.

【Special Feature】

A Heritage for the Future: Tracing Back 120 Years of Manufacturing

—Ground-breaking Kawasaki Products through the Ages

This year marked the 120th anniversary of the founding of Kawasaki Dockyard. In this special feature, we look back on the role Kawasaki played in supporting the development of Japan's modern industry and discuss landmark products of each age. We also introduce some of our most recent efforts toward the future.

Interview

Kawasaki and the Rise of Modern Japanese Industry

Aiming to become a one-of-a-kind, all-around manufacturer

When James Watt invented the steam engine in the late 17th century, the world entered a new era of engineering in which science was wedded to technology. And just as engineering became a major trend that defined the times, the Meiji Restoration ushered in a new era in Japan.

One notable aspect of the history of Japan's modern industry is that both the government and the private sector were fully aware that the era of engineering had arrived, and everyone knew what would be needed in the times ahead.

At the top of the list were iron and shipbuilding. Shipbuilding is an integrated industry that combines material dealing with iron, peripheral technologies including molding technology, the design and manufacturing of engines, the manufacturing of jigs, and ship maneuvering systems. If it were not for shipbuilding in those days, Japan would not have acquired integrated industrial capabilities. A solid source of capital was also considered a prerequisite in pursuing an integrated industry.

Kawasaki, Mitsubishi Heavy Industries, and IHI each founded their own shipbuilding businesses on the basis of operations acquired from the ironworks and shipyards of the Shogunate and former clans. It is surprising that there were as many as three companies that already understood the importance of having integrated industrial capabilities and tried to establish them during the tumultuous years of the early Meiji period.

Among the three companies, Kawasaki in particular focused on channeling its accumulated industrial capabilities into business domains that "depended on Kawasaki for their existence". Kawasaki was apparently not just interested in increasing market share; it always aspired to become a unique manufacturer.

Transportation underlies product development in heavy industry. Business domains expanded from shipbuilding to rolling stock, aircraft, and automobiles. Throughout this process and in every domain, Kawasaki always stayed attuned to the demands of the times and focused on areas in which it excelled. In addition, Kawasaki did not confine the technologies it developed within narrow domains. Rather, it fed them back to its entire operations, further enhancing its integrated industrial capabilities.

These accumulated capabilities eventually led to the creation of unique products such as Unimate, the first industrial robot produced in Japan, and small gas turbines. While at Western companies, product developers and people on the front line of manufacturing tend to work independently, without interfering with each other, Japanese companies take a more cooperative approach in which front line people and developers work together to achieve new technologies and products. This exemplifies the confidence Japanese companies have in their manufacturing departments, and Unimate is proof that such a manufacturing culture can result in innovative robots.

In gas turbines as well, Kawasaki created a market for standby power generators and expanded its lineup. If Kawasaki had been aiming for top market share, it probably would have pursued large products, but instead, it steadily secured a foothold as a one-of-a-kind manufacturer. Kawasaki's integrated industrial capabilities allowed it to pursue a wide range of operations.

"Aiming to become a one-of-a-kind, all-around manufacturer" — this has remained the stance of Kawasaki's technology and product development throughout its 120-year history. And this, I believe, characterizes the heritage of Kawasaki's manufacturing.

Kazuyoshi Suzuki

Deputy Director, Center of the History of Japanese Industrial Technology, National Museum of Nature and Science. Investigates and studies the development of science and technology from the Edo period to the modern era from an empirical point of view.

Kawasaki History **Starts!**

1897

Kawasaki Dockyard's first vessel *Iyomaru* was launched.

The Meiji Government issued the Shipbuilding Encouragement Act in 1896 with the aim of modernizing and expanding the Japanese shipbuilding industry. *Iyomaru*, the first vessel to be built under the new Act and also Kawasaki Dockyard's first vessel, was launched in 1897. A cargo-passenger vessel with 727 gross tonnage, 877 horsepower, and a flank speed of 11 knots, *Iyomaru* operated between Tokyo and Kagoshima.

1969

Unimate, the first Japanese-made industrial robot, heralded an era of manufacturing by robots.

In 1968, Kawasaki entered into a technical agreement with the U.S. venture Unimation Inc., with the aim of producing industrial robots in Japan. The next year, Kawasaki developed Kawasaki-Unimate 2000, the first industrial robot manufactured in Japan. Unimate was later designated as a *Nihon Monozukuri Isan* (Japanese Manufacturing Heritage Item) by the National Museum of Nature and Science as an industrial robot that had been developed in the U.S. and further improved in Japan.

1878 Shozo Kawasaki, founder, opens Kawasaki Tsukiji Shipyard (Tokyo)

1896 Kawasaki Dockyard Co., Ltd. is incorporated (Starting point of the 120-year history. First president, Kojiro Matsukata)

1897 Launches cargo-passenger vessel *Iyomaru* (727 GT) (First vessel after becoming a publicly traded company)

1914 World War I

1924 Starts manufacturing Hele-Shaw electro-hydraulic steering gears

1929 New York stock market crash, the Great Depression

1939 World War II

Adopts new Japanese company name Kawasaki Jukogyo Kabushikigaisha (i.e., Kawasaki Heavy Industries)

1942 Develops the first mass-produced Type 3 Fighter Hien

1950 Steelmaking division is spun off and Kawasaki Steel Corporation (currently JFE group) is incorporated

1964 Tokaido Shinkansen opens

1969 Develops Kawasaki-Unimate 2000, the first Japanese-made industrial robot

1973 First oil crisis

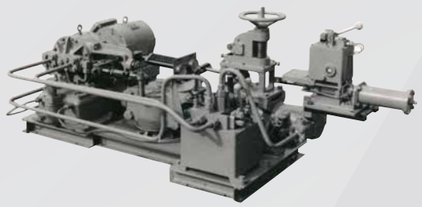
1974 Develops a prototype of the proprietary S1A-01 gas turbine

1977 Delivers the first PU200 gas turbine generator

1924

Manufacturing of Hele-Shaw electro-hydraulic steering gears starts. Hydraulics business launched.

Kawasaki entered into a technical agreement with the British company Hele-Shaw in 1916, and started manufacturing Hele-Shaw pumps in Japan in 1924. A Hele-Shaw pump is a hydraulic pump that is driven by an electric motor and is capable of changing the discharge rate and flow direction of oil. It was long used as a hydraulic power source for steering gears before its technology was adopted for other applications after the war, such as hydraulic equipment for excavators, laying the foundation for Kawasaki's hydraulics business.



1942

Manufacturing of Type 3 Fighter Hien starts. A high-performance aircraft that overwhelmed the world.

Developed for the army, the Hien was equipped with the Ha-40 liquid-cooled supercharged engine, which boasted the world's top performance for a fighter during the Second World War. The Ha-40 was a Japanese-made engine based on the Daimler-Benz DB601A. The first prototype of the aircraft was completed in 1941, and it recorded a maximum of the aircraft speed of 591 km/h in a test flight. This exceeded the performance of Germany's Messerschmitt fighters, which were regarded as the best in the world at the time. The technologies and passion that went into developing the liquid-cooled supercharged engine also led to the Ninja H2R/H2.

1977

Overwhelming share achieved in small and medium-sized markets.

In 1983, Kawasaki sold a gas turbine cogeneration system to its first customer. Total sales of gas turbines passed the 10,000 mark in 2011. This was followed in 2012 by the delivery of the L30A, which featured the world's highest power generating efficiency in its class (over 40%).

Development **Path**

Aiming to become No. 1 in the world with Kawasaki technology.

Kawasaki set its target on commercial facilities and developed Japan's first standby power generator using a gas turbine, creating a new market. Currently, Kawasaki enjoys a 70% share of gas turbines for standby power generators. Armed with a wide variety of products, Kawasaki has also entered the market for continuous power generation. There is a world of difference between standby power generation and continuous power generation in features such as startup properties, durability, and economic efficiency. However, I believe there is still much room for technological development in both applications. For instance, by incorporating the latest results of aerodynamic analysis technology in aircraft, we can develop turbine blades with a shape that achieves a level of efficiency previously unimaginable. To live up to the standard set by our first developer, who said we must not be satisfied with anything less than No. 1, we always aim to stay one step ahead in our development efforts.

Koji Tatsumi
Senior Manager
Industrial Gas Turbine
Engineering Department
Engineering Center
Gas Turbine Division
Gas Turbine & Machinery Company

1991

Work on the Channel Tunnel is completed. Kawasaki's TBMs stun the world with their outstanding performance.

Kawasaki's two tunnel boring machines (TBMs) drilled through a distance of 20 km and 19 km, respectively, 100 m below the sea level in the English Channel. The work went so smoothly that the two rail tunnels were completed eight months ahead of schedule in May and June 1991. This was achieved despite the fact that the tunneling distance was extended from the original distance in the contract. The feat was publicized around the world by the media, which praised the outstanding technology of Kawasaki's TBMs.

2007

Kawasaki Green Gas Engine, with the world's highest performance, is developed.

In 2007, Kawasaki completed the development of a 7.8 MW gas engine featuring the world's highest power generating efficiency and world-class environmental performance. The Green Gas Engine was developed by leveraging Kawasaki's technologies and know-how in reciprocating engines cultivated since it started manufacturing marine diesel engines in 1919. The outstanding performance of the Green Gas Engine received high evaluation from the market, and it continues to attract a steady flow of orders to this day.

1983 Yonkers Plant in New York starts operation
1983 Delivers first order of R62 New York City subway cars
1991 Tunnel boring machines successfully complete work on the Channel Tunnel
1994 The Channel Tunnel opens
1995 Great Hanshin-Awaji Earthquake
1996 100th anniversary
2007 Develops the Kawasaki Green Gas Engine, boasting the world's highest performance
2011 Great East Japan Earthquake
2015 Launches the Ninja H2R/H2, the world's first supercharged motorcycle
2016 120th anniversary

1983

Delivery of New York City Subway trains begins. Local production launched 3 years later.

More than 30 years have passed since Kawasaki delivered the first subway car in 1983, and the company still continues to receive a steady flow of orders from the North American market. The total number of orders amounts to 2,151 cars for the New York City Transit Authority (NYCT) alone, and 4,421 cars for the entire North American market. In 1986, Kawasaki opened a plant in Yonkers, New York, and in 2001 another plant in Lincoln, Nebraska. These two plants manufacture Kawasaki's latest rolling stock for NYCT and other railway operators.

Project Path — Applying Kawasaki's integrated capabilities to continue creating new value.

The specifications required by NYCT were extremely challenging. Nevertheless, we tackled our first project, the R62, with the entire company working as one. The stainless steel body of the R62 made paint come off more easily, and this helped reduce graffiti. As a result, the image of the subway as being dangerous was largely dispelled. The citizens were amazed at the totally different image of the new subway cars: the number of subway users dramatically increased, creating a huge impact on the City of New York at the time. Kawasaki continues to earn high marks by constantly proposing new technology in each project, and by offering expert support throughout the entire process from design and manufacturing to delivery and product assurance. We will continue to pursue the development of safe and comfortable train cars that help increase the safety and efficiency of the entire railway system.

Motoki Nagano
Senior Manager
Overseas Engineering Department 1
Engineering Division
Rolling Stock Company

2015

Truly unique performance achieved by the Ninja H2R/H2.

The Ninja H2R/H2 is equipped with the first Kawasaki custom-designed supercharger, giving this motorcycle the power to deliver the fastest-ever acceleration, while ensuring excellent driving stability. Kawasaki used its gas turbine expertise in pioneering the new supercharger. It also deployed aerodynamic control technologies that it perfected for aircraft to redesign the body, thus enhancing stability at high speeds. Knocking was prevented using gas engine technologies.

Satoaki Ichi
Senior Staff Officer
First Design Department
Research & Development Division
Motorcycle & Engine Company

Development Path — Motorcycle development is a challenge to the unknown.

The Ninja H2R/H2 is touted as a motorcycle with ultimate performance. Ever since Kawasaki released the H2 in 1971 and the Z1 in 1972, its development philosophy of creating the world's fastest, highest-performing motorcycle has remained unchanged. To achieve our development objectives, we must steadfastly work to resolve every new challenge we face. Even when faced with a difficult problem, our development environment and tradition encourage us to positively embrace challenges. I believe we were able to come up with the idea of incorporating the technologies of areas other than motorcycles thanks to such an environment. The supercharger mounted on the H2R incorporates gas turbine technology, which not only helped boost performance but also made the product more environmentally friendly. The process of applying cutting-edge technologies across business segments enables their essence to be passed down to future generations.

2020

Challenge for the Future

Supplying Hydrogen Infrastructure

Creating a New Energy Society and Supporting the Hydrogen Supply Chain

Aiming for technological innovation in the production, transportation, storage, and utilization of hydrogen

To realize a society in which hydrogen plays a larger role in our lives, Kawasaki is developing technologies as a companywide effort to help quickly establish a supply chain that encompasses the production, transportation, storage, and utilization of hydrogen. Kawasaki has already moved from the component development stage to the pilot-scale development and demonstration stage ahead of the rest of the world. It is aiming to conduct technological demonstrations of a liquefied hydrogen carrier and a hydrogen loading terminal in fiscal 2020.

Kawasaki is planning to move forward to the commercialization phase by accelerating the productization of hydrogen liquefaction systems, hydrogen gas turbines, and other hydrogen-related equipment and systems that are highly compatible with Kawasaki technology and whose needs are growing in the market.

(1) Hydrogen production

Kawasaki is aiming to produce hydrogen from lignite, an unused resource, and use it as a future energy source. A stable supply of large quantities of hydrogen is indispensable for full-scale use as an energy source. When liquefied at –253°C, hydrogen is shrunk to about 1/800 in volume, enabling efficient transportation and storage. Kawasaki has already developed Japan's first industrial hydrogen liquefaction system by applying the cryogenic technology it has cultivated over the years.

(2) Hydrogen transportation

To transport a large quantity of hydrogen produced from unused resources overseas safely and efficiently to Japan, Kawasaki is currently developing the world's first liquefied hydrogen carrier based on the design and construction technology of LNG carriers. A demonstration ship is scheduled to be built by 2020, and there is also a plan to build larger ships for commercialization.

(3) Hydrogen storage

Liquefied hydrogen storage tanks and transportation containers are necessary in order to use hydrogen within Japan. Kawasaki is currently developing a 1,000 m^3-class liquefied hydrogen storage facility with a vacuum insulation structure. To do this, it is using technologies accumulated through the development, manufacture, and long-term operation of liquefied hydrogen storage tanks installed at the rocket launch complexes of JAXA's Tanegashima Space Center.

(4) Hydrogen utilization

Since 2015, Kawasaki has been conducting demonstration operations of a gas turbine power generator that achieves mixed combustion of natural gas and hydrogen by a proprietary combustion method and reduces the environmental burden. In preparation for full-scale deployment of hydrogen power generation, which is anticipated in the future, Kawasaki is developing a gas turbine combustor that can suppress NOx generation while accommodating the fast-burning properties of hydrogen, in order to generate power using 100% hydrogen.

Creating Technological Synergies through Matrix Management

The Corporate Technology Division is Kawasaki's R&D department. Its research and development efforts are conducted in a well-balanced manner along three time axes: development of new products and new businesses with each business division in the near future, creation of new products and new businesses in the future, and development of technologies 10 to 20 years in the future.

With a view to cooperating with each business division and working as a team toward common goals, the Corporate Technology Division always shares issues with the business divisions and engages in joint development efforts. To this end, it utilizes numerous mechanisms such as technological networking events and working groups with business divisions.

The other pillar is matrix management. For example, researchers and developers who deal with structures do not just think about structures; they share issues with experts in other fields such as fluid and heat, always working to achieve total optimization.

Further, the Corporate Technology Division serves as an intermediary that enables the technologies held by the seven internal companies to be used in other products, facilitating multi-faceted deployment of technologies for dramatic synergy effects. For example, our knowledge about superchargers was accumulated through developing not only marine engines but also motorcycles and gas turbines, and the composite material technology for aircraft went into the development of rolling stock bogies.

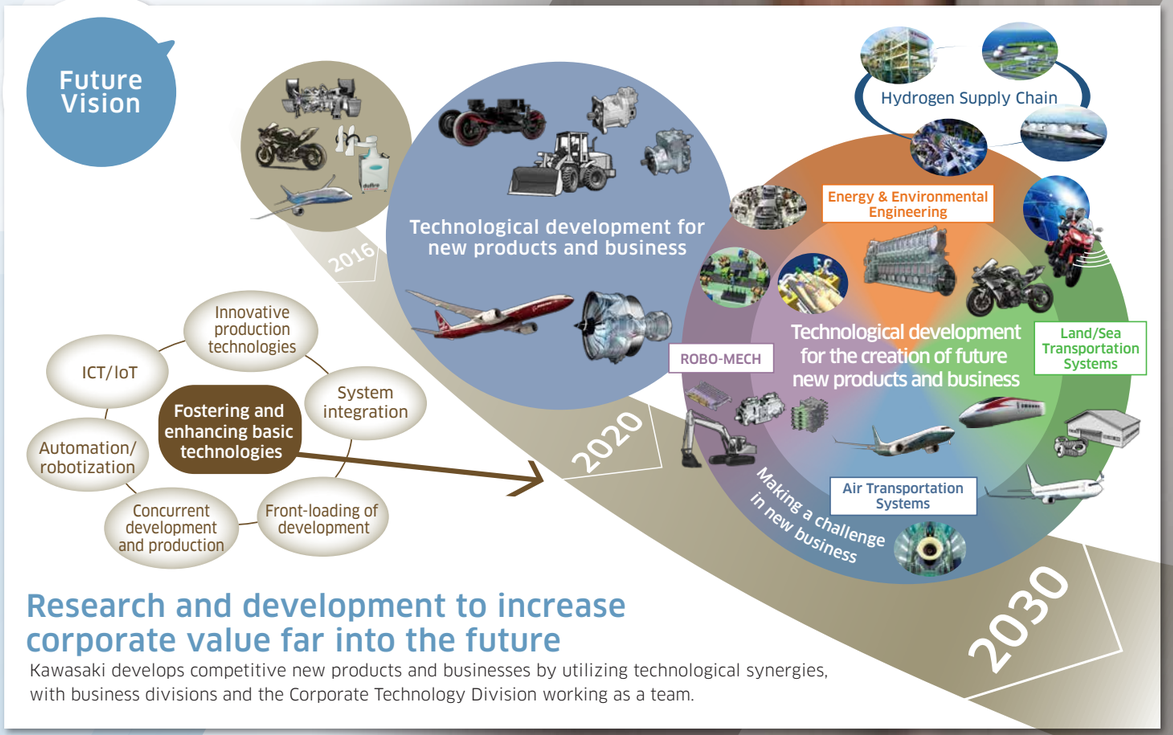
In activities to create future businesses, we envision the kind of corporation we would like to be in the future based on market trends and other factors, and we thoroughly discuss the technologies needed to achieve that before starting research and development. As for the hydrogen project, we are working closely with all the divisions of Kawasaki to establish a supply chain encompassing the production, transportation, storage, and utilization of hydrogen to help build a hydrogen society.

Further, we are currently working on innovation in manufacturing and the enhancement of service businesses by putting priority on the use of ICT and IoT.

From the Project Team

By Koji Kadota, Dr. Eng.

Professional Engineer, Japan (Mech. Eng.)
Managing Executive Officer
General Manger, Corporate Technology Division



Research and development to increase corporate value far into the future

Kawasaki develops competitive new products and businesses by utilizing technological synergies, with business divisions and the Corporate Technology Division working as a team.