Mitsubishi Materials Craftsmanship Magazine

BM005E

YOUR GLOBAL CRAFTSMAN STUDIO

REACH FOR THE SKY

Supporting the Aerospace Industry

Vol. 5 Stories

MESSAGE

Fumio Tsurumaki
Managing Executive Officer, Mitsubishi Materials Corporation
President, Advanced Materials & Tools Company

Tool manufacturers strive to scale a tall mountain towering before us, this metaphorical mountain is made of ever evolving new materials. Lighter and stronger materials are constantly evolving and are used in ever broader applications. Aerospace frames and engines are examples where the most advanced materials can be found. It is our mission to cooperate with customers in the aerospace industry as we aim to reach the peak of this extremely challenging mountain that stands before us, the pinnacle of new machining technology. This requires that we have the willpower, strength and the ability to make quick and accurate judgments and take effective action to overcome the obstacles we face along the way. This also means having the necessary resources such as products, machining technology and the manufacturing capability, while sufficient strength means providing funding and human resources. After we have all these things in place, we can plan our route. It is then and only then that both manufacturer and customer can embark on the challenging climb toward the summit.

I am confident that Mitsubishi Materials Craftsman Studio will continue to be a place to transit knowledge, take temporary shelter and share the joy of having reached the summit.

Being the Best Partner for Our Customers' Success

Thank you for reading the fifth issue of Your Global Craftsman Studio.

Technical innovation has advanced rapidly in areas across the economy and the aerospace industry featured in this issue is no exception. Keeping pace with innovation requires tool manufacturers to establish machining technologies for new materials such as aluminium-lithium alloys and ceramic matrix composites (CMC).

Responding to requests from customers that use cutting-edge materials requires that we anticipate their needs and prioritize the commercialization of products that not only meet, but exceed them. Looking beyond the limits of products and services to realize ideal products and services to satisfy customer needs, leads to the creation of phenomena beyond our imagination. Therefore, tool manufacturers must select their targets and concentrate on development that effectively serves the specialized fields handled by customers. Mitsubishi Materials has reinforced its approaches to each of the industries it serves, and the Aerospace Department featured in this issue is an outstanding example.

Becoming a real business partner for individual customers means sharing a deeper mutual understanding and product realization through face-to-face interactions. To ensure this close contact, we have established five technical centres worldwide to provide detailed technical support to our customers. We have also added the Central Japan Technical Center, in Gifu, Japan, to this support network. The establishment of this centre enables us to provide broader services to western Japan as well as the aerospace and automobile industries located in central Japan; and we are committed to further expanding and improving our network of technical centres to ensure global coverage.

In May 2017, we introduced DIAEDGE, a new brand based on the desire to provide even more attractive corporate value to our customers in the cemented carbide business. We are committed to the continuing development of high-quality products like "DIA" and "EDGE" to provide sophisticated performance that embodies our excitement and enthusiasm for excellence. We are confident that "Your Global Craftsman Studio" will continue to serve as an innovative environment in which we can work closely together to further improve this new product line as one of the world's top cemented carbide brands.

Mitsubishi Materials continues leveraging the unified efforts of employees throughout the company to ensure the speedy provision of services that provide effective solutions to customers. The mission is to provide the best technology, products and human resources to support the success of customers.

Shinichi Nakamura
Executive Officer,
Mitsubishi Materials Corporation
Vice President,
Advanced Materials & Tools Company

YOUR GLOBAL CRAFTSMAN STUDIO

EYE on MARKET AEROSPACE INDUSTRY

AIRBUS A320neo has been in service since 2016.

BOEING 737MAX was first put into service in 2017.

New models are environmentally friendly.

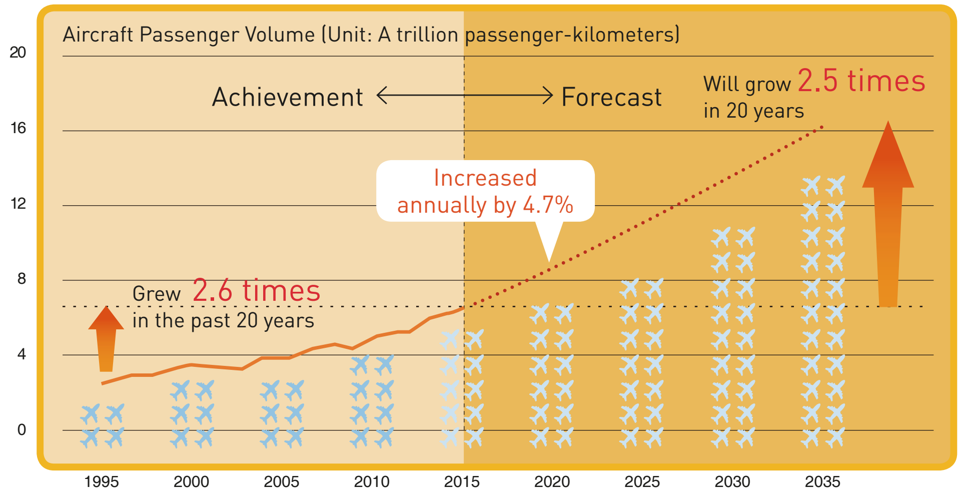
Competing in the Global Aerospace Industry

Huge demand promotes expansion of the industry.

With a big push from emerging economies, the number of global aircraft passengers (Aircraft Passenger Volume) is expected to remain at a high annual growth rate of 5%. The total share estimated from the remaining confirmed orders submitted by two major companies, AIRBUS (Europe) and BOEING (U.S.), was 85% at the end of 2016. Small single-aisle aircraft with around 150 seats are highly popular in the short and medium-haul markets in highly-populated countries such as China and India. AIRBUS and BOEING deliver approximately 1,000 small aircraft per year. Regional passenger jets with around 100 seats have been produced by two major companies, EMBRAER (Brazil) and BOMBARDIER (Canada); however, SUKOHI (Russia), COMAC (China), and Mitsubishi Aircraft (JAPAN) are scheduled to enter the market, which will escalate competition.

In addition, the engines mounted on passenger aircraft developed in the 21st century are more environmentally friendly, featuring low noise emissions and high fuel efficiency. The aircraft industry's anticipated growth will drive development and change in the machining industry, opening new opportunities and creating exciting challenges.

Demand for Global Passenger Aircraft Continues Growing at 5% Annually



Source:
Japan Aircraft Development Corporation

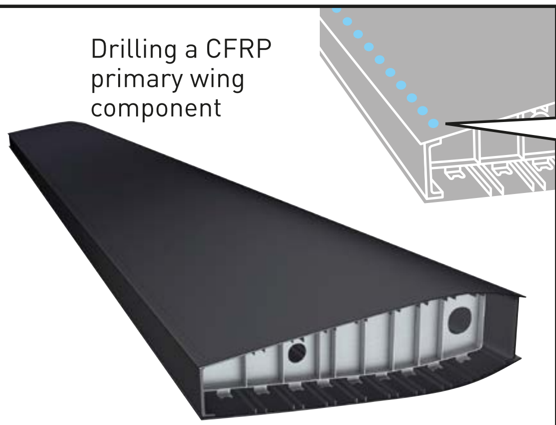
Cutting Tool Manufacturer Making Strides in New Material Development for Ever-evolving Aircraft

Increased market demand for passenger jets is keeping companies that manufacture related parts busier than ever, pushing them to increase productivity.
A passenger jet has more than 3 million parts. To achieve the highest possible fuel efficiency, lighter, stronger, corrosion-resistant materials have been developed for airframes and landing gear, and materials that can withstand high temperature are employed for engines.

The materials employed in the manufacture of aircraft have advanced remarkably in recent years. The use of increasingly strong, high heat-resistant alloys, titanium alloys, aluminium alloys as well as compound materials such as CFRP has become the norm. Because these new materials are all hard to machine, cutting tool developers are working with aircraft and machine manufacturers to conduct research and development with the goal of realising high-efficiency, high quality, and high-accuracy processing methods.

Airframe

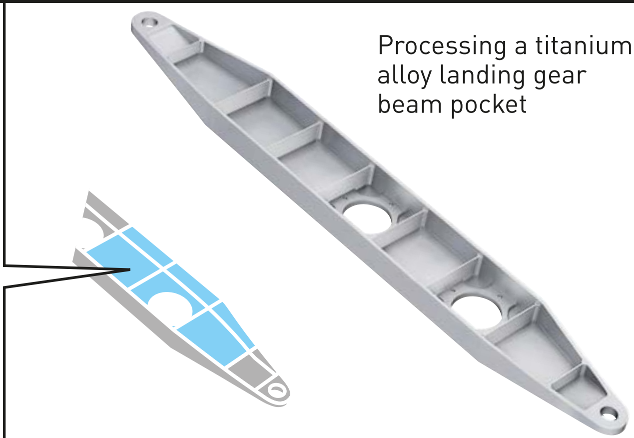
Drilling a CFRP primary wing component



Diamond coated drill

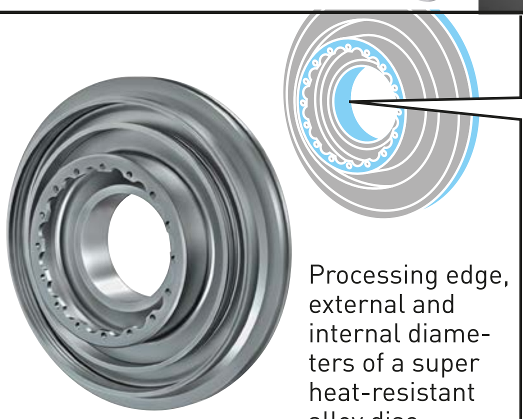
End mill with exchangeable head

Processing a titanium alloy landing gear beam pocket



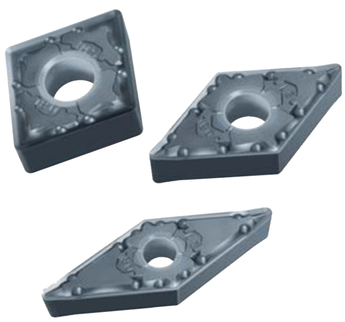
Landing Gear

Jet Engine



Processing edge, external and internal diameters of a super heat-resistant alloy disc

Inserts for turning of difficult-to-cut materials



EYE on MARKET **AEROSPACE INDUSTRY**

Flying to the Global Stage with the Aerospace Industry

Mitsubishi Materials Global Network

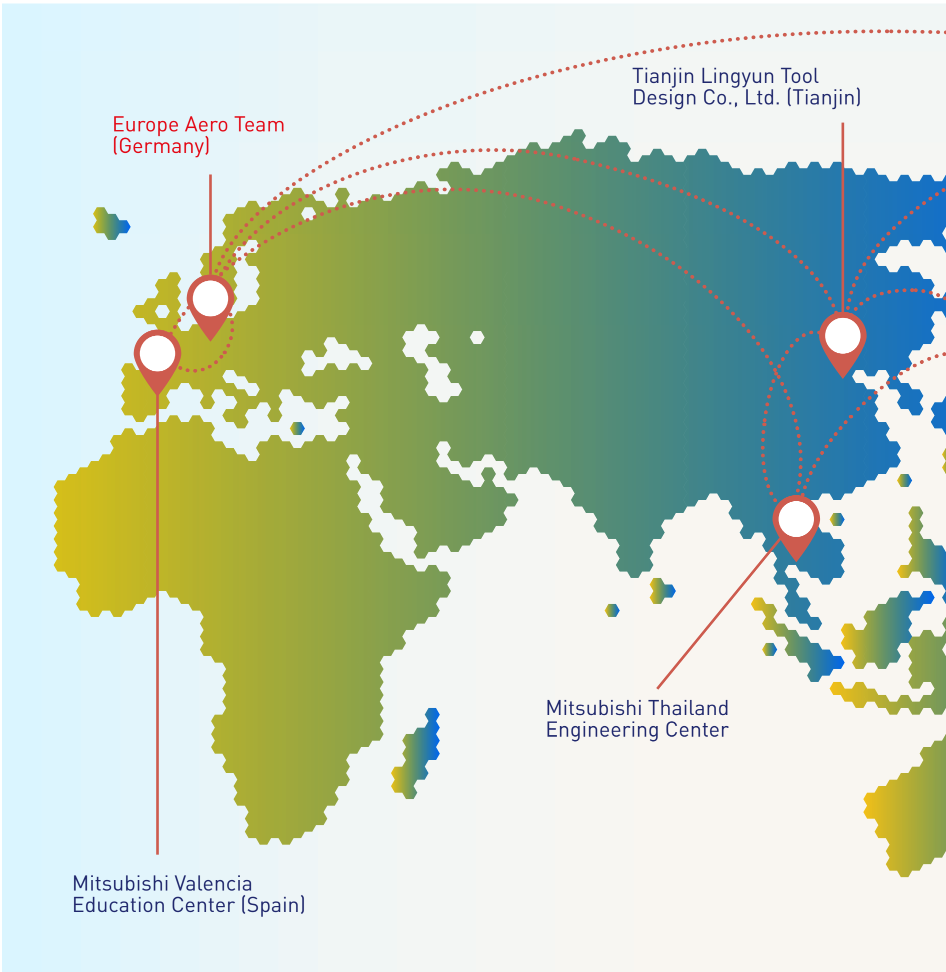
The large number of orders coming from around the globe has spurred the growth of the commercial aerospace industry. Mitsubishi Materials established its Aerospace Department in autumn 2016 to ensure that its customers receive the highest quality products and services. As an extension of this new department in Japan, staff have also been assigned to Europe and the U.S. to provide prompt and complete responses to customers. Furthermore, a close relationship was established with six technical centres in Japan, Europe, and the U.S., as well as with universities and research institutions both at home and abroad to develop innovative machining technologies.

EUROPE

Teamwork that reaches beyond national boundaries

Mitsubishi Materials' sales offices in Europe, Russia, and Turkey, and its technical centre (M-VEC) in Spain serve as manufacturing bases for cutting tools. The European Aero Team originated at MMC HARTMETALL GmbH (Germany) cooperates with technical staff assigned in England, France, Italy, Spain and many other countries on an ongoing basis to provide the most advanced solutions to aerospace-related manufacturers.

In 2014, Mitsubishi Materials joined the Advanced Manufacturing Research Center (AMRC). Many aerospace industry manufacturers from around the globe have joined the AMRC to participate in research, development and tests of new-generation manufacturing technologies, and Mitsubishi Materials' role in a wide range of AMRC projects has been highly regarded. Furthermore, Mitsubishi Materials actively exhibits in world-class aerospace trade shows, including the Paris Air Show (France) and the Farnborough International Airshow (England), both of which are held biennially.



Akira Osada, PhD
General Manager, Aerospace Dept.,
Advanced Materials & Tools Company,
Mitsubishi Materials Corporation

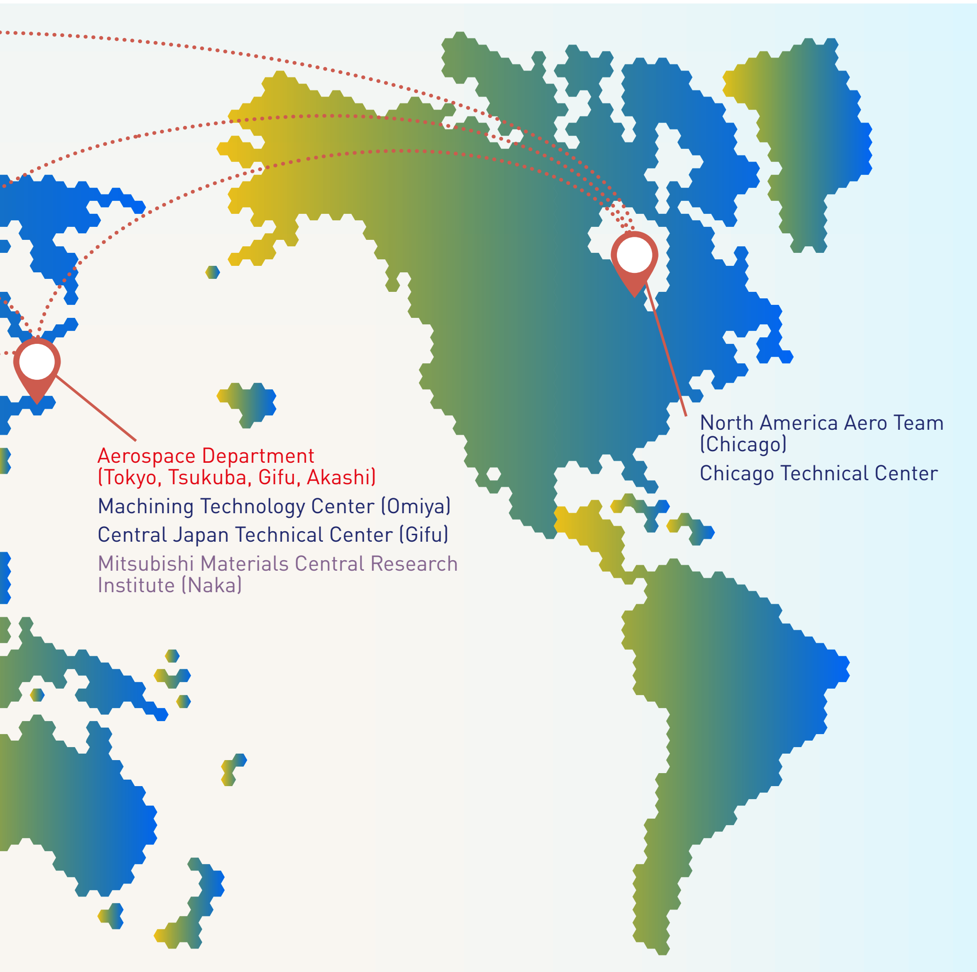
Mitsubishi Materials Solutions

To ensure prompt and complete solutions (products and services) to its individual aerospace industry customers, Mitsubishi Materials has established the Aerospace Department. Half a year has passed since the department began operations and it is committed to providing the highest level of specialization, technology and quality to customers. Striving to advance development, Mitsubishi Materials is confident that by continuing to work from the customer's viewpoint will maintain its place as "Your Global Craftsman Studio", and provide solutions that contribute to the development of the aerospace industry.

JAPAN

Elite Machining Professionals Playing an Active Role on the Global Stage

The Aerospace Department features a wide range of functions that are essential for success. These include marketing development, design and the creation of prototypes at domestic bases under the initiative of the head office (Tokyo) to provide prompt and thorough responses to requests from customers not only in Japan, Europe and the U.S., but also in the rapidly growing Asian markets.
Opened in June 2017, the Machining Technology Center (Omiya) and Central Japan Technical Center (Gifu) boast the most advanced machine tools, including 5-axis machining tools and multi-task machines, and other measurement and analysis devices to handle a wide range of machining tests. Staff at these two centres cooperate with technical centre staff throughout the world, improving their specialised techniques on a daily basis.
Since its foundation in 2013, staff have actively interacted with university researchers. Additionally they have participated in the Collaborative Research Centre for Manufacturing Innovation (CMI) project at University of Tokyo's Institute of Industrial Science, a project supported by the Ministry of Economy, Trade and Industry. This pursuit of technology in cooperation with research institutions, machine tool manufacturers and the Mitsubishi Material Central Research Institute (Naka) continues to further the development of unique, high-performance cutting tools.
The Aerospace Department continues flying to the world with the aerospace industry as an essential partner for the improvement of customer productivity.



U.S.A.

A High Degree of Specialisation in a Major Industry

Aerospace is a major industry in the United States. A wide variety of manufacturers, both large and small, form this gigantic market.
Mitsubishi Materials U.S.A. has its head office in Los Angeles, its Marketing Department and Technical Center in Chicago, and two cutting tool manufacturing sites in neighboring states to satisfy customer needs.

Recently, the need for high-performance processing for large structural parts made of titanium and aluminium alloys has been increasing. The North America Aero Team provides attractive and effective solutions utilising high-quality specialised knowledge. Using its broad global network, Mitsubishi Materials is capable of providing prompt service to aerospace manufacturing bases worldwide. The team also cooperates with research institutions specialising in next-generation machining technologies.

Discussions with Customers → Tool Design → Creating Prototype → Machining Test → Delivery of Prototype Tools


Providing estimates and proposing solutions


Determining specifications and target performance

Special Feature

Competing in the Global Aerospace Industry

EYE on MARKET **AEROSPACE INDUSTRY**

New Technical Center has been Established in Central Japan to serve the Aerospace and Automobile Industries.

The Central Japan Technical Center is a 15-billion-yen facility located at Mitsubishi Materials Gifu Plant. The new facility provides attractive solutions such as CAD/CAM/CAE responses, tests utilising a wide range of machinery and effective technical support. It also features a high-profile Machining Academy operated under the motto, "Your Global Craftsman Studio, for You and the World."

In addition to the Machining Technology Center in Saitama servicing eastern Japan, Mitsubishi Materials has technical centres in the U.S., Spain, China and Thailand. The newly established Central Japan Technical Center serves as a second base in Japan to provide broader services to western Japan and the aerospace and automobile industries located in the geographical centre of the country.

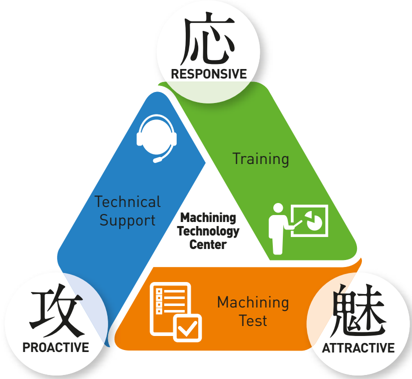
The Machining Technology Center in Saitama utilises the most advanced equipment and innovative materials in its active development of new-generation machining technology in collaboration with customers. Meanwhile, the expanded range of equipment at the newly established Central Japan Technical Center ensures its capability to fulfill its mission as a base to provide technical services to a wider spectrum of customers utilising a wealth of accumulated knowledge and know-how.

Central Japan Technical Center has more than 10 machines installed, including high-accuracy machining centres, multi-task machine tools and automatic lathes, to conduct CAE analysis and CAM simulation under conditions similar to those at customer sites. In addition to proposals for ideal cutting methods for finished products, machining conditions are simulated that anticipate the needs of individual customers, and examine them under realistic conditions. Test results are also simulated for customers. Furthermore, it is also possible for us to handle materials that are difficult to machine with standard tools, to develop special tools that satisfy more specific customer needs, and provide support to ensure the most effective tool use.

Mitsubishi Materials' Machining Technology Center and Central Japan Technical Center cooperate with several technical centres both at home and abroad to provide prompt and effective customer-oriented solutions anywhere, anytime. Open innovation with universities and other institutions is also encouraged to advance research and development of machining technology for the future. Furthermore, a Machining Academy program has been operated at the Machining Technology Center from June 2016 to pass on technology in a wide range of areas, including basic and advanced machining theories, tool damage improvement, trouble shooting and production line improvement utilising a number of measurement and analytical devices. It is also planned to offer the same services at the Central Japan Technical Center to provide opportunities to systematically cultivate human resources capable of passing on the most advanced machining technologies and know-how to engineers employed by Mitsubishi's customers.

Solutions are considered, created and shared with customers. The mission is to provide the best solutions and services for individual customer needs, and support their business to facilitate success. In its role as a manufacturing professional, Mitsubishi Materials continues to be the "Global Craftsman Studio" chosen by more customers.

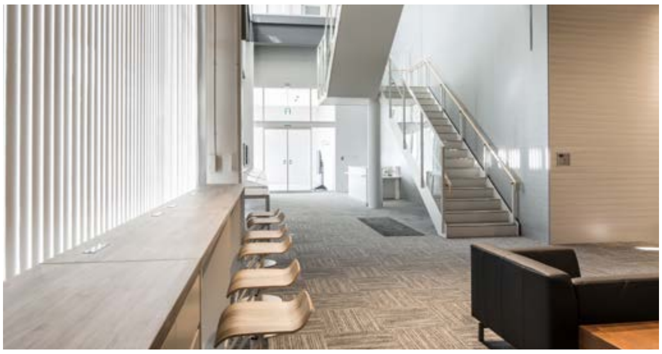
■ Technical Center Functions



MACHINE ROOM

SEMINAR ROOMS

ENTRANCE / RECEPTION ROOM



FOCUS on PERFORMANCE

IHI Corporation Soma No.2 Aero-Engine Works

Striving to Establish New Manufacturing Technology to Prepare for Increased Aerospace Engine Production

IHI Corporation Soma No.2 Aero-Engine Works manufactures more than 3,500 aerospace engine parts such as disks, blisks and gears. Equipped with more than 700 machine units and utilising more than 100,000 manufacturing processes, this plant handles the small-lot manufacture of a wide range of products. In this feature, the focus is on this cutting-edge machining site that supports the global aerospace industry.

As a Leading Company in Aerospace Engine Manufacturing in Japan

IHI Corporation is engaged in four major business areas: "Resources, Energy and Environment," "Social Infrastructure, Offshore Facilities," "Industrial Systems, General-Purpose Machinery," and "Aero Engine, Space and Defense." Our aerospace engine business accounts for 60 to 70% of our total production in Japan. IHI is also the major contractor involved in the manufacture of most of the aircraft employed by the Japanese Ministry of Defense. We have also participated in international joint development projects for a wide range of commercial aircraft engines through the development, manufacture and supply of modules and parts. Furthermore, the engine development and manufacturing know-how we have accumulated is utilised in maintenance and repair work, which has been highly regarded by many customers, including overseas airlines that outsource maintenance to IHI.

IHI Soma No.2 Aero-Engine Works Boasts the Most Advanced Equipment

IHI handles the production, assembly and maintenance of aircraft engines at four plants: the Kure Aero-Engine & Turbo Machinery Works (Kure City in Hiroshima), the Mizuho Aero-Engine Works (Mizuho-cho, Tokyo), the Soma No.1 & No.2 Aero-Engine Works (Soma City in Fukushima). The IHI Soma Works, the largest IHI plant, is located in Onodai, 10 km inland from the Pacific Coast in Fukushima Prefecture.

The Soma No.1 Works was established as the fourth manufacturing base of the Aero-Engine, Space & Defense Business Area in 1998 with the partial transfer of Tanashi Aero-Engine Plant functions to handle the manufacture of aerospace engine parts. In 2006, the remainder of the Tanashi Plant functions were transferred to the Soma No.2 Works. The Works has electric wiring and compressed air piping along the beams of the building to supply each piece of equipment. This allows the free layout of equipment to facilitate flexibility in responding to changes in demand. The Works are clean and free from the odor of the machining oil, which allows employees to work in comfort.

(Left to right) Ryoji Takahashi: General Manager; Masayoshi Ando: Engineer; Hatsuo Okada: Manager
Production Engineering Department, Soma No.2 Aero-Engine Works, Aero-Engine, Space & Defense Business Area

Depth of Aerospace Engine Parts Manufacturing
Tenacity in Establishing New Machining Technology

With demand in the aerospace industry expected to rise, the need for eco-friendly aerospace engines will increase. There is an interest about manufacturing at the Soma No.2 Aero-Engine Works, where low-pressure turbine parts are manufactured. In this feature, Ryoji Takahashi, General Manager, Masayoshi Ando, Engineer, and Hatsuo Okada, Manager were interviewed at the Production Engineering Department, Soma No.2 Aero-Engine Works.

How do the Works' strengths contribute to the high market share of IHI?

Takahashi: "IHI has long experience and extensive know-how in the manufacture and assembly of aerospace engine parts. Shaft and low-pressure turbine parts are our specialty, and they are highly regarded by our customers. Our company has grown through contracts for the Ministry of Defense; however, the sales ratio of commercial aerospace engines has increased. In addition, IHI is one of the few companies that boasts the wide range of skills and technology required to handle the entire engine manufacturing process."

Could you tell us about the depth of aerospace engine part manufacturing?

Takahashi: "Many of the parts that go into aerospace engines are made of light, but extremely strong materials, which are difficult to cut; and the required machining accuracy of most of these parts must be within 0.01mm. Our thoroughly managed manufacturing processes ensure the production of high-quality parts. Engine development requires tool machining tests and performance evaluations normally conducted over an extended period of time to determine the final manufacturing processes. Once registered, tools employed in the manufacturing processes cannot be easily changed. Of course, if productivity can be significantly improved, it is well worth the effort to consider changes not only in the tools, but also in the manufacturing processes. Any changes, however, must adhere to strictly determined procedures. Because we need to follow the procedures for changes in tools and processes, undergo strict screening, and obtain approval, we need to plan with great care to avoid costly delays. This principle is fundamental to our mission to design manufacturing processes that achieve high accuracy machining and high productivity before mass production."

What is the current state of aerospace engine part manufacturing?

Okada: "In an effort to extend flight range, development of next-generation aircraft with high-performance and high fuel efficiency has been actively pursued. The engines installed in such aircraft require new materials that feature higher temperature durability and lighter weight."

Takahashi: "Therefore, composite materials have often been employed in engine manufacturing over the past 10 years. To reduce CO_2 emissions and lower the cost of transportation, improved fuel efficiency is essential. This is why the use of light, strong CFRP and CMC has been increasing. Meanwhile, convention metals are still required and metal alloy development has been

(Left) Koshiro Terashima, Mitsubishi Materials Corporation, Advanced Materials & Tools Company, Sales Division, Sendai Sales Office

pursued to increase strength. Increasing the strength of the material makes it thinner and lighter, which increases fuel efficiency. However, machining has become very difficult with the development of composite materials and highly strong alloys. Expanding aircraft demand means heavier air traffic, and that means increasingly severe standards regulating environmental load."

What is the relationship between material improvement and machining technology development?

Takahashi: "Weight reduction is very effective. For example, reducing the weight of rotating parts leads to a reduction in the weight of bearing and stationary components. Reducing the overall weight of the engine achieves a significant improvement in fuel efficiency, which has a dramatic effect on operating costs. At the same time, this reduces environmental load. However, as material strength increases, machining becomes more difficult. Expanding the industry requires the further development of machining technology. It is very important to have both high-quality cutting tools and machining technology to reduce material weight."

Ando: "Recent components employed in aerospace manufacturing are made of extremely expensive and difficult-to-cut materials. Therefore, it is important to design processing methods that prevent damage to products even when tools break during machining. In addition to manufacturing high-quality products while reducing machining costs, which is our primary mission, we also strive as much as possible to prevent damage to products."

Okada: "As materials continue to improve, current machining methods may not be capable of processing them. Even if current machining is retained, materials may be processed using other methods, methods such as laser and electric discharge machining. Cutting tools may be completely different from what they are now."

Okada: "Let me give you a recent example. We needed to significantly improve disk productivity in response to the increased production of aerospace engines due to expanding demand. We traditionally applied broaching to process dovetails, the joint used to install the blade on the disc; however, the broaching machine is extremely expensive and tool manufacture requires a relatively long period of time. In addition, broaching is a machining method with low cutting levels, which made it difficult to significantly improve productivity. Therefore, we sought a completely new machining method. First, we applied milling to the rough machining of the dovetail. It has been two years since we began development, and we are almost ready to institute the method. The merit of milling is stable tool availability, and the forms and materials are easily improved. Productivity is also significantly higher than broaching. However, there are also some drawbacks. Tools per machining volume in broaching are less expensive than those used in milling. For milling, we needed to reduce the total cost of tools, a goal we realized by minimizing the number of tools employed utilizing appropriate tool path and maximizing tool life. Although we faced many challenges during the shift from broaching to milling because of our lack of experience, young staff worked persistently to overcome each challenge. At the beginning of the shift, when tools were frequently damaged during machining tests, I sometimes felt that we would have to give up. However, support from Mitsubishi Materials staff helped us to continue moving forward in designing machining methods, creating prototypes and evaluating the product. The efforts and enthusiasm of the engineers at both companies led to this success."



Producing the World's Top Machining Technology and Becoming the World's Top Plant

The development of excellent engines means achieving the highest precision and lightest weight possible. Improvement of precision leads to the reduction of energy loss, and weight reduction increases output per weight. This also leads to the improvement of environmental performance through the reduction of fuel consumption, noise and gas emission. The key to such improvement is progress in the development of materials such as high heat-resistance and lighter weight, plus machining technology must keep pace with that progress. The mission of the Soma No.2 Aero-Engine Works is to continue developing new products based on such high machining technology.

At the end of the interview, Ryoji Takahashi, General Manager of the Production Engineering Department, said, "There is a particular business model for the development of commercial aerospace engines, whose IHI sales ratio has been gradually increasing. It is a development program, the international partnership. Commercial aerospace engine development requires an extremely high investment of time and money. This program, therefore, offers international joint development through a partnership among the best players in a wide range of areas. To disperse risk, each partner's costs of development are proportional to its ratio of investment. Furthermore, partners establish long-term strategic relationships for each part they take charge of, handling such responsibilities as manufacturing, technical development, product support, after market services (spares, engine maintenance services). IHI's strength is its know-how in integrated manufacturing for most aerospace engine parts, and its ability to discuss individual strengths, such as shafts, compressor parts and fan parts, etc. with partners to expand the services it can offer to the market. Expanding the range of parts in its specialty business, IHI competes confidently with global competitors. In order to achieve its goal of becoming the world's top plant, IHI strives continuously to achieve and maintain global-level manufacturing, quality management and machining technology to ensure the highest level of manufacturing capability. We are very excited about the possibility of installing engines that IHI has developed into commercial aircraft, engines that feature parts made in Japan. This is a common dream among those of us engaged in the development and manufacture of aircraft in Japan." From Soma to the world, we continue working hard to improve our technology at the IHI Soma No.2 Aero-Engine Works.


HISTORY OF MITSUBISHI

Vol. 5

The Heart of Manufacturing in the Centre of Tokyo

Tokyo Plant

Mitsubishi Materials Advanced Materials & Tool Company began with the manufacture of the TRIDIA carbide tool in 1931, and the Tokyo Plant played a central role in the history of the tool. It was not so common to have such a plant in the middle of Tokyo and the Mitsubishi Materials Tokyo Plant witnessed the pre- and post-war periods, the high growth period and the bubble economy as it grew into a base for the manufacture of carbide tools.


The Mining Research Institute at the time of foundation
Research on carbide alloys started in this building.


The Tokyo Plant in the strong economic growth period (around 1960)

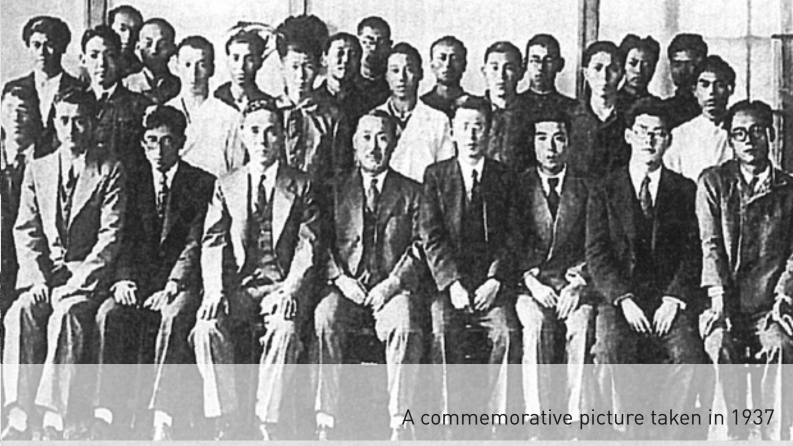

The Tokyo Plant before the shift to the Tsukuba Plant (around 1986)

Beginning of Carbide Alloy Processing

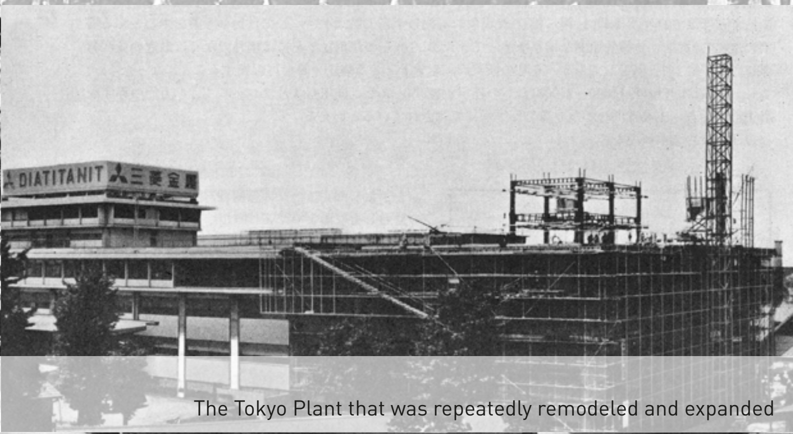
The Tokyo Plant was located where Shinagawa Chuo Park now stands. At the centre of Tokyo just a few minutes on foot from the Shimo-shimmei Station on the Tokyu Oimachi Line, the Tokyo Plant operated from 1916 until about 25 years ago. Mitsubishi Materials' carbide tool business started 100 years ago in 1916, back when the Mitsubishi Goshi Kaisha Mining Research Institute (Central Research Institute) was established as a private company research institution, which was based on a proposal by Koyata Iwasaki. The institute engaged in research on tungsten ahead of other companies. In 1923, it began research on carbide alloys. In 1926, the German company, Krupp, launched WIDIA, the world's first carbide tool. The surprising cutting performance prompted companies around the world to also accelerate their research on carbide alloys. A member of the staff at the Central Research Institute that was in England at the time, was awestruck when he witnessed the performance of WIDIA's product. Mitsubishi Materials immediately realised the potential of carbide alloys and pushed development. Overcoming obstacles proved to be a prodigious challenge, forcing the company to toil eight long years before the launch of its first carbide product, TRIDIA, in 1931. When Mitsubishi Materials relocated the Mining Research Institute to Omiya, the carbide alloy development business remained and continued operating as the Oi Branch.

Severe business conditions during the war

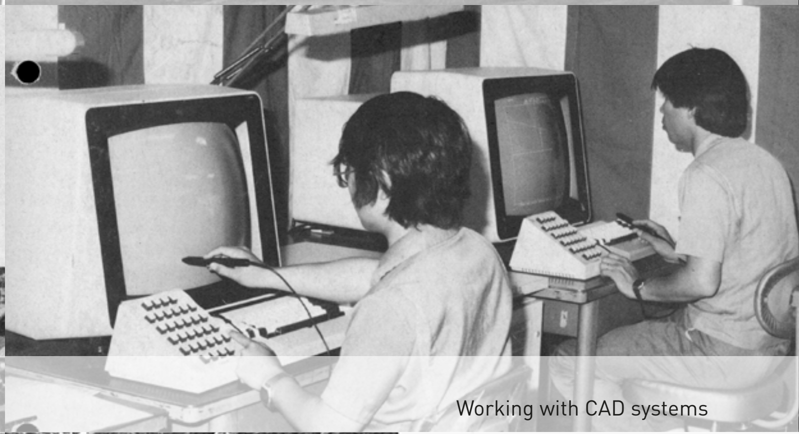
The start of World War II in 1939 had an immediate impact on the industry. The demand for war supplies such as cemented carbide and stellite increased whilst employees were sent to the war front. By 1943, monthly production of cemented carbide had exceeded 1 ton and stellite production exceeded 3 tons. It was at this time that the plant became independent from the Mining Research Institute. Continuing operations as the Tokyo Metals Plant, it was soon designated as Important National Plant. The plant was damaged in 1944 when allied air raids hit the city; and after the war, it was listed as a possible asset to be included in post-war reparations and faced the risk of confiscation. The plant avoided that fate however and employees worked hard to restart production. The carbide tool business had been on track for success, but the war derailed it; conditions after the war meant that no other companies could consider buying it or even investing in it, which worsened Mitsubishi Materials' situation considerably. The top management was forced to consider reducing production and laying off employees; but the labour union resisted this plan, insisting that if cutting production forced the layoff of even one employee, the plants should be closed. In the end, on October 31, 1948, Mitsubishi Materials had no choice but to lay off most of its employees, retaining only the minimum number required to


A commemorative picture taken in 1937


New 6-story building responding to mass production



The Tokyo Plant that was repeatedly remodeled and expanded


Working with CAD systems


Designing tools

The site is currently occupied by Shinagawa Chuo Park.

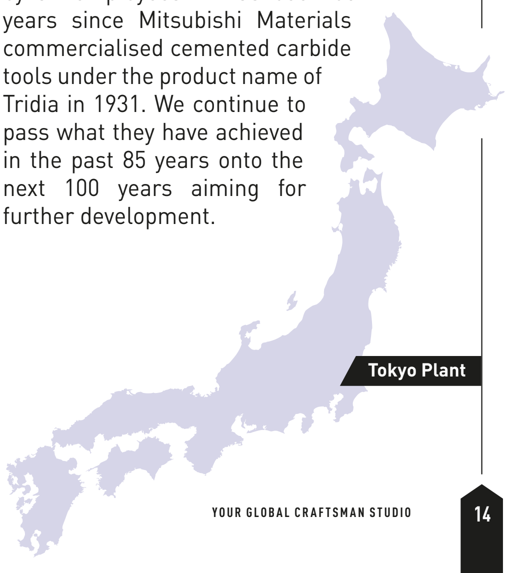
maintain the plants and their technology, but hoping that they would be able to re-instate them soon. The company continued developing mining tool bits for Europe and the U.S. and strived to return the company to its pre-war status. In December of the same year, 1948, the plants reopened and the laid-off employees were immediately called back.

Economic growth and the bubble economy

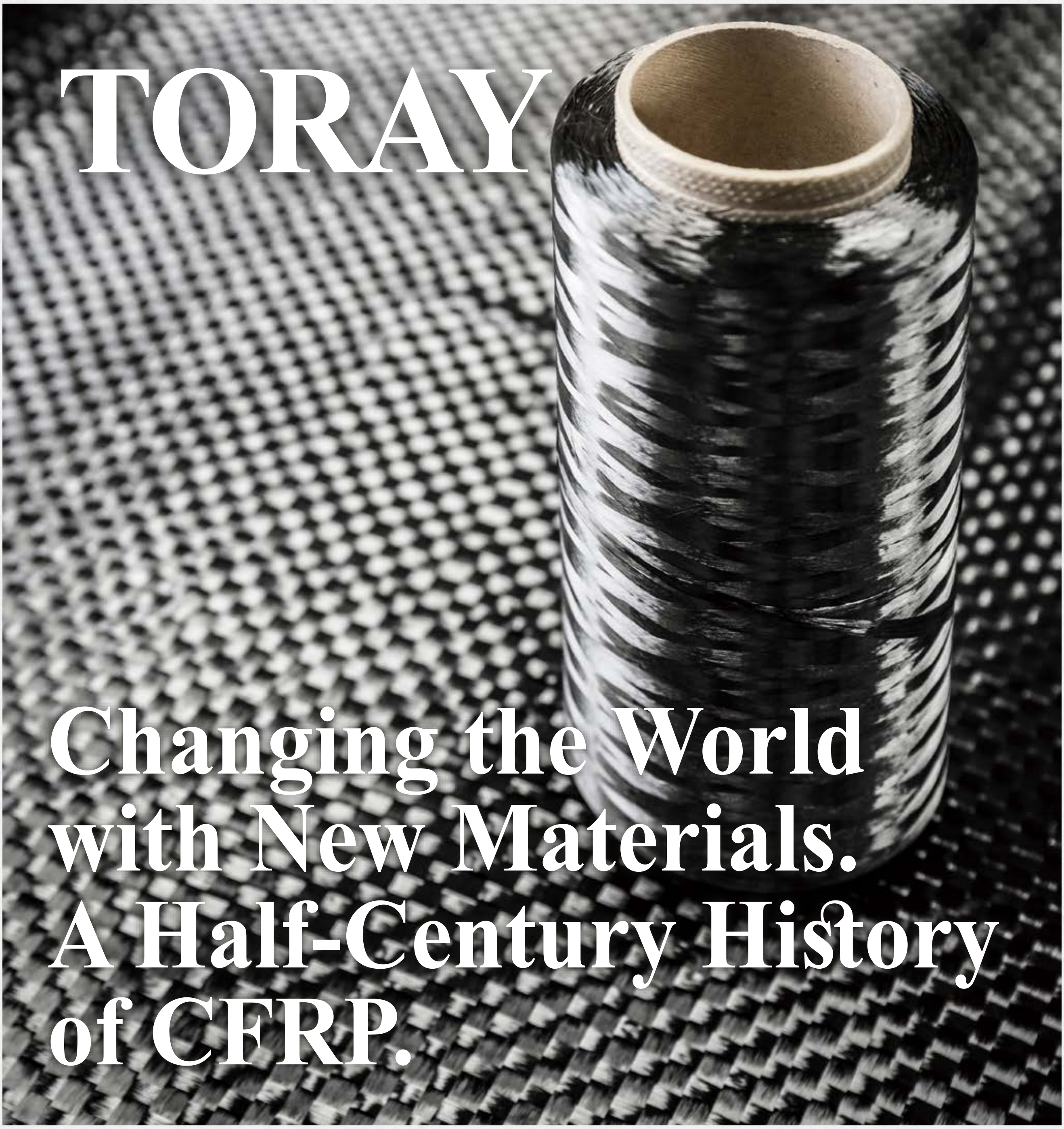
In 1952, the Tokyo Metals Plant was renamed the Mitsubishi Metal Mining Company Ltd. Oi Plant. After a period of robust economic growth, the company moved into the black for the first time after the war in 1955. Following this, it increased production gradually, achieving record profits for three consecutive terms from the first half of 1967 through to the first half of 1968. The plant grew into a major business that supported the entire company. In 1969, the company built its Gifu Plant, realising that although they could become the top company in Japan with the Oi Plant, the Oi Plant alone would not allow it to become the world's No. 1 company. In 1970 the Oi Plant was renamed into Mitsubishi Metal Corporation Tokyo Plant. It was 35 years since the launch of TRIDIA and a turning point at which the company decided to introduce its carbide business to the global market.

The spirit of the past handed down to the present

Through the shift from the Mitsubishi Metal Mining Company Ltd. Oi Plant to the Mitsubishi Metal Corporation Tokyo Plant, the carbide tool business continued to grow. Facing the challenge of a significant expansion in demand over such a short period of time affected customer services and product development capability. Because of its location in urban areas, it was hard to expand facilities, which impacted the company's ability to expand business, including employee service and benefit programs. To address this situation, management discussed relocating the Tokyo Plant to Ishigemachi in Yuki County (present day Joso City) near Tsukuba Scientific City in Ibaraki Prefecture. The Tokyo Plant was relocated to the Tsukuba Plant site in March, 1992. The spirit of independence and striving ever forward helped the Tokyo Plant to survive hardship. This spirit has been carried on by all employees. It has been 85 years since Mitsubishi Materials commercialised cemented carbide tools under the product name of Tridia in 1931. We continue to pass what they have achieved in the past 85 years onto the next 100 years aiming for further development.



TECHNOLOGY ARCHIVE



TORAY

Changing the World with New Materials. A Half-Century History of CFRP.

Dreaming about a Black Aircraft Flying through the Air

Lighter than aluminium and stronger than iron, carbon fibre reinforced plastic (CFRP) is a revolutionary material that has changed new-generation manufacturing by finding its way into applications such as major structural parts for commercial passenger jets. It was in the early 1960s that research on carbon fibre started in Japan. We interviewed Shunsaku Noda, General Manager, and Hiroshi Taiko, Deputy General Manager of the Aerospace Technology Section, ACM Technology Department, TORAY, about the fifty-year history of carbon fibre and CFRP development.

TECHNOLOGY ARCHIVE

CLOSE UP

What is CFRP?

CFRP is a composite of carbon fibre and resin. Composite materials contain several ingredients to create reinforced properties that cannot be realised with a single ingredient. TORAYCA® Prepreg is used for aircraft parts. It is made by shaping a bundle of 24,000, 5 µm thick carbon fibres into a sheet and impregnating it with thermoset resin such as epoxy. Layering and hardening this sheet creates high strength and a modulus of carbon fibre elasticity.

CFRP performance tends to change significantly according to the volume and layout of the carbon fibres (direction of the fibres, structure of the prepreg layers). Therefore, it is possible to realise a wide range of features by designing for individual purposes.

CFRP Features

- It is light and has a specific gravity of 1.7, just one-quarter that of iron.
- The tensile strength of CFRP is as high as 7 Gpa.
- Tensile elasticity of high-intensity CFRP is as high as 630 Gpa
- It also features excellent dimensional stability, vibration damping, high thermal conductivity, non-magnetic, corrosion resistance and high fatigue strength.

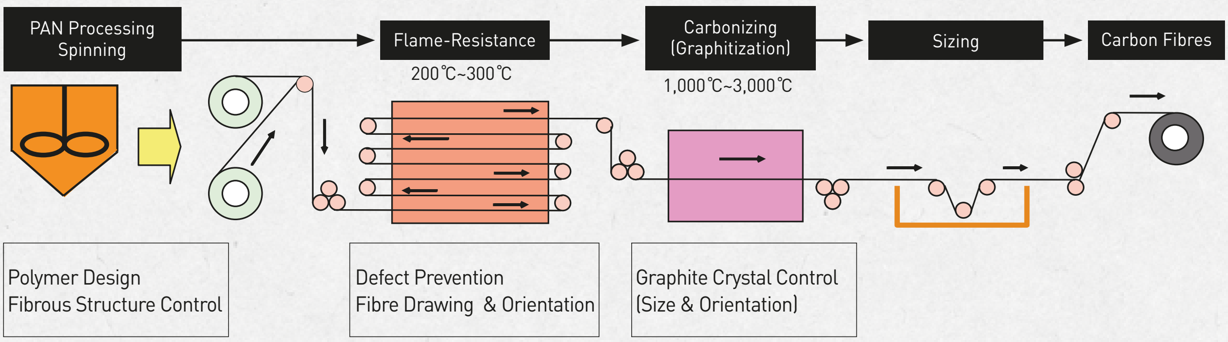
Carbon Fiber Manufacturing Processes

PAN (polyacrylonitrile)-based carbon fibre manufacturing comprises four processes:

1) Polyacrylonitrile plastic is processed and pumped through a spinning machine to be made into fibres.
2) The fibres are heat treated to enhance flame resistance (oxidation).
3) The fibres are heated again to carbonize them.
4) The surface is treated to complete the process.

Diameter: 7 µm

Manufacturing Processes & Component Technology to See the Limits



Part 1 1950 ~

Emergence of Carbon Fibre & Research and Development

Going back to the roots of carbon fibre development, we find the light bulb invented by Thomas Edison and Joseph Swan at the end of the 19th century. The filament used for this light bulb was made of carbonized bamboo fibre. This was the world's first carbon fibre. As tungsten became popular as material for the filament, carbon fibre was gradually forgotten. In the 1950s, carbon fibre attracted renewed attention when the United States accelerated research and development for injector tips for rockets, engines that require high heat-resistance. Meanwhile, in 1959, Dr. Akio Shindo at the Osaka Engineering and Technology Institute invented a method of carbon-fibre manufacturing through the carbonization of polyacrylonitrile (PAN). Since then, carbon-fibre research and development and commercialisation accelerated. Carbon fibre has great strength, making it ideal as a highly-functional ingredient for composite materials. In 1967, Rolls-Royce, one of the world's top aerospace engine manufacturers, announced the application of CFRP to jet engines. Almost simultaneously TORAY started full-scale development of carbon fibre utilising an acrylic fibre, TORAYLONTM. In 1970, TORAY acquired a patent license from Dr. Shindo. Companies manage business based on forecasts of the future marketability and sales potential of their own products. TORAY believed in the potential of CFRP and prioritised the setting up of a manufacturing system with a bold investment that would nowadays be an unthinkable amount.

TECHNOLOGY ARCHIVE

2 1971 ~ Manufacturing Carbon Fibre even before fully Understanding its Potential

The following year, 1971, TORAY started the manufacture and sales of TORAYCA®300, PAN-based high-intensity carbon fibre. Although carbon fibre attracted attention as a new-generation material, its main uses had not yet been clarified. TORAY, however, decided to build a new plant with a 12-ton manufacturing capacity, the largest in the world at the time. This resolute decision was based on the belief among TORAY employees that high-strength materials would someday be in great demand. Top management also had a dream of a black aircraft flying through the air, aircraft made mostly of CFRP. It was around the time that Rolls-Royce was experiencing great difficulty in its development of a jet engine using some CFRP.

Meanwhile, TORAY's first commercialised product made of carbon fibre was fishing poles, a product launched in 1972. The weight of the fishing poles was about a half that of existing types; and while relatively expensive, their performance was highly regarded in the market. In the same year, golf pro Gay Brewer Jr. used black shaft clubs made of CFRP to win the Taiheiyo Masters tournament. The recognition of the black shaft golf clubs quickly spread, and golfers rushed to purchase them. After that, CFRP was also used in the manufacture of tennis rackets, further increasing its popularity. However, CFRP was mainly finding application in entertainment and sports. Considering the industrial potential of CFRP, distribution was low at best.
A turning point came in 1975. The oil crisis that hit in 1973 forced aircraft manufacturers to prioritise the reduction of airframe weight to help realise lower fuel consumption. This turned their attention to CFRP for secondary structural material, parts that have no direct influence on flight safety. It was then that TORAY's dream of seeing CFRP applied to aircraft manufacturing was realised. Along with the application of CFRP to aircraft parts by Boeing and Airbus, the cumulative production of TORAYCA® carbon fibre had exceeded 10,000 tons by 1988. Many overseas manufacturers in countries such as England and the United States determined to withdraw from CFRP business due to low profitability; however, Japanese companies that had passed down their technology from a long-term perspective, including TORAY, continued working on the development and manufacture of CFRP utilising high-performance carbon fibres. In 2010, Japanese carbon fibre manufacturers finally accounted for approximately 70% of the global share.

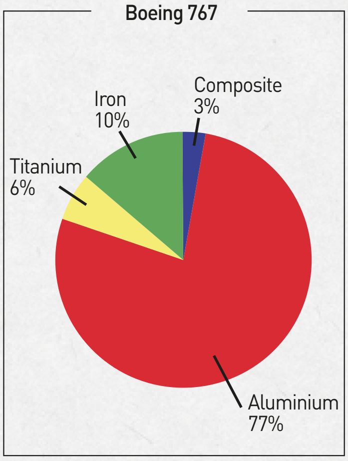
3 1990 ~ Expanding the Application of CFRP as Aircraft Structural Material

In 1990, TORAYCA® Prepreg (sheet-type CFRP) was adopted by Boeing as primary airframe structural material (important parts that directly impact safety), which served as approval for CFRP as a highly-reliable, highly-functional material. CFRP tensile strength is more than 10 times greater than iron while its weight is just one quarter. CFRP can also be formed into a wide range of shapes.

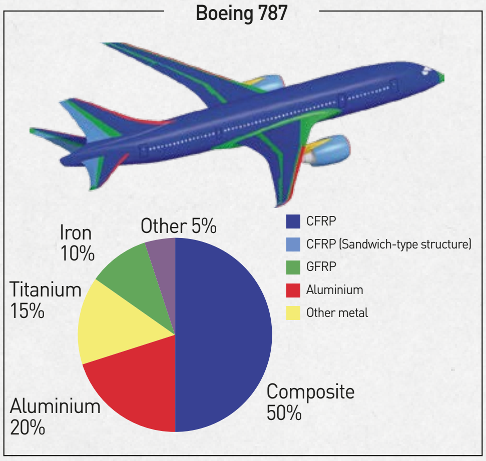
In the Boeing 787 project launched in 2003, CFRP accounts for about 50% of the total weight of the aircraft, including the frame and wings. In 2006, TORAY and Boeing entered into a long-term comprehensive agreement on CFRP supply, which specified the provision of the primary structural material by TORAY.

	Boeing 767	Boeing 787
Airframe	Aluminium	CFRP
Main Wing	Aluminium	CFRP
Tail Wing	Aluminium	CFRP
Flap	CFRP	CFRP

Boeing 767



Boeing 787



4 2010 ~

Industrial Use Accelerates Demand for CFRP

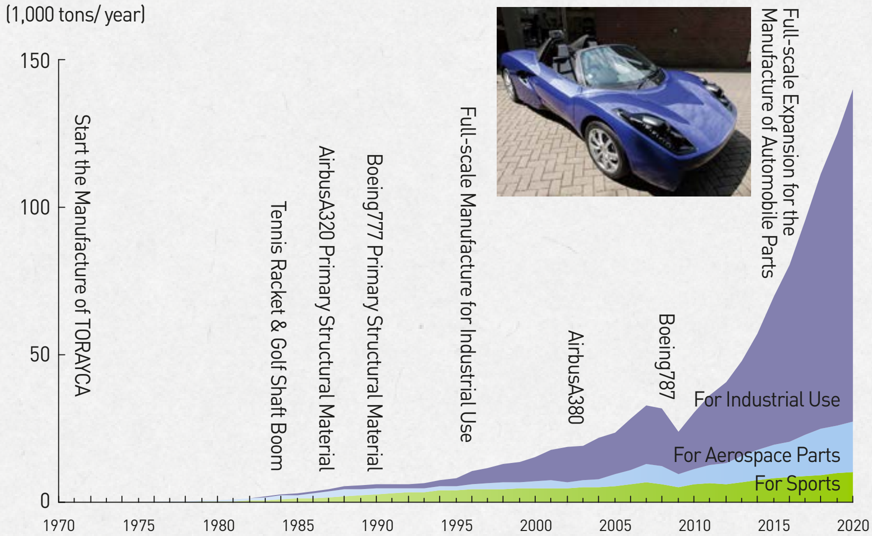
Entering into the 2010, the global demand for CFRP rapidly expanded to cover a wide range of purposes. In addition to use in sports and aircraft products, application includes wind-power generator blades, roofs, automobile parts such as drive shafts, tanks for natural gas and fuel-cell vehicles, high-speed train components, computer bodies and much more.

The carbon fibre composite material business is included in the basic TORAY expansion strategy. TORAY has invested management resources into new areas of growth such as the automobile and aircraft industries, and into other new areas to expand demand. In 2020, TORAY is planning to increase investment into North America to expand its business there.

The strength of carbon fibre at this point is still one tenth of its theoretical value, which leaves sufficient room for continuing improvement. The cost of carbon fibre remains a barrier to popularity in the market; however, along with increasing applications in the automobile parts industry, mass production may reduce costs significantly and increase demand rapidly in the near future.

Nearly half a century has passed since TORAY started the world's first commercial production of carbon fibre. It took persistent effort over a long period of time to find stable markets. What motivated them? That was TORAY's corporate philosophy, long-term continuity, backed by the strong desire among top management to see an aircraft made using CFRP in the air. CFRP will continue to improve as the most advanced, highly-functional material available to global industries.

Carbon Fibre Material Demand



Looking Back Over the History of CFRP

Noda: We are very happy when the products we develop change the world for the better, changes such as reduced fuel consumption in the aerospace industry. TORAY's CFRP has become a strategically expanding business and our mission is to further expand CFRP into a fundamental pillar of TORAY business. Compared with the maturity of metallic materials, the types, amount and applications of carbon fibre composite materials remains unknown. We believe, however, that CFRP has unlimited possibilities and we will continue to explore these possibilities to change the world for the better.

Taiko: My boyhood love of aviation led me to a career related to aircraft and rockets. My dream as someone engaged in research and development is to someday board an airplane made of materials that I designed. The CFRP used in the manufacture of the Boeing787 was developed by senior R&D staff, and I was only involved indirectly. I hope to realise my dream some day.

TORAY Industries, Inc.,
Aerospace ACM Technology Dept.
(Left) Shunsaku Noda, General Manager
(Right) Hiroshi Taiko, Deputy General Manager

Craftsman Story

Vol.6

Kazuya Yanagida:
Gifu Aero Group, Aerospace Dept.
(Joined the company in 1997)

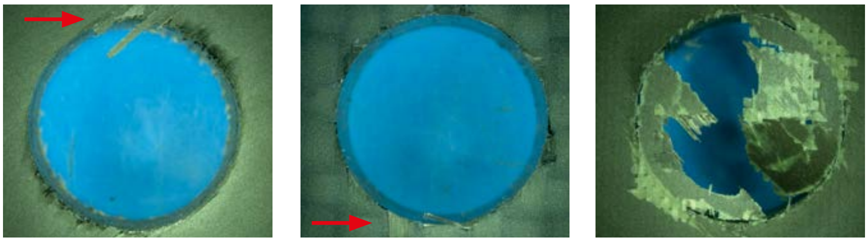
Tadashi Yamamoto:
Gifu Aero Group, Aerospace Dept.
(Joined the company in 2008)

CFRP Machining Drill: MC Series
New Material Development

Since the launch of the Boeing 787 aircraft in 2011, the application of CFRP has gradually increased as a new material for airframes, main wings and other aerospace components. Different from metals, CFRP is made of carbon fibre and resin; and the machining of this new material requires new techniques. We interviewed Gifu Aero Group staff who were engaged in the development of machining techniques for this important material.

Examples of CFRP hole machining defects

Entrance: Uncut fiber | Exit: Delamination | Fibre breakout



What are the peculiar phenomena encountered when drilling CFRP?

– What is the background of the development?

Yanagida: Mitsubishi Materials has delivered drills to customers for machining CFRP for more than 10 years. Utilising the know-how we accumulated over the years we have improved drill functionality to provide a broader range of solutions that are applicable over a wide variety of CFRP materials.
CFRP has layers of carbon fibre and resin that are heat treated. Compared with steel, CFRP is around a quarter of the weight but 10 times as strong. It also features corrosion-resistance, heat-resistance and high rigidity. While the carbon fibre layer is hard but brittle, the resin layer is soft but more plyable.

Yamamoto: This is why CFRP machining produces phenomena that are fundamentally different from machining metals. The major defects encountered in CFRP drilling are the generation of uncut fibres, delamination due to the layered structure and back countering of stacked CFRP and metal (back countering is caused by the metal chips wearing the sides of the hole in the carbon section of the stack as they travel up the flutes of the drill). In this project, we started by checking these phenomena to thoroughly explore the technical mechanisms that generate the defects.

Yanagida: There are two types of CFRP material used for aircraft parts. One contains resins with thermosetting properties and the other is stack material made by layering aluminium and titanium into CFRP. There are also two major machining methods, one is automated machining utilising for example a machining centre, and the other is to drill using hand tools. Due to these different materials and machining methods, it is extremely difficult to create one type of drill suitable for all processes. Therefore in this project, we developed the MC series of seven different drills for a wide range of CFRP materials and they were introduced to the market in April 2017.

MCA Groove Structure for Reducing Stack Materials Back Countering

– Would you please introduce some of the seven products?

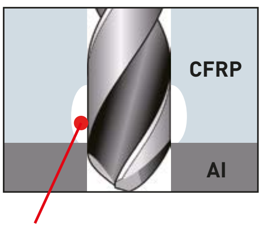
Yanagida: I will show you two types, the MCA and MCC. The MCA is a drill for CFRP and aluminum stack materials. We sought to significantly improve the performance of the CFRP drills that have been available as special products for the past 10 years. We usually drill stack materials composed of carbon fibre and aluminium; whose machinability is completely different, with the same drill. The main problem is a phenomenon called back countering. As the drill penetrates the CFRP and machines the aluminium layer, the expelled aluminium chips can cut the CFRP surface. As a result, the hole diameters in the CFRP and aluminium layers differ. To prevent this, we changed the flute design of the MCA drill.

Yamamoto: We focused on the width of the flutes. The flute width is usually the same along the whole length of the drill; however, the flutes of the MCA gradually widen from the cutting edge to the top. First, we designed narrow flutes to generate compact chips, and then to widened them to help the chips flow along the flutes without interfering with the surface of the hole.

Yanagida: We applied Mitsubishi Materials MWS deep hole drill technology to provide the smooth discharge of chips. This was required to provide an increase in the surface quality of the hole, which was a common problem in the machining of both stack materials and deep holes. For the MCA drill development, we also utilized the technology of MHE drills that are used to machine automobile hubs. MHE drills are used to create holes for bolts on the hubs that connect automobile axles and wheels. The size of the hole diameter in each hub must be very precise, and the surface quality of the holes needs to be extremely high. Preventing the chips from damaging the surface of the hub requires the MHE to have narrower flutes than regular drills.

Yamamoto: As a result, MCA used the features and know-how of the MWS and MHE drills. This means that overall, the drill initially generates small chips that flow through the narrow part of the flute. The chips are then channeled through the broadened upper part of the flute and discharged without damaging the wall of the hole.

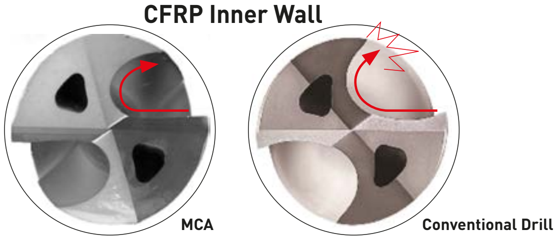
■ **Back Counter**



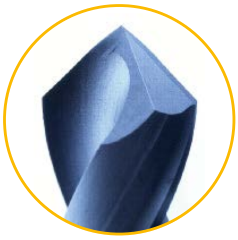
The increase in the hole diameter generated by machining stack materials comprising CFRP and metal

■ **New Flute Form**

The flute was designed to reduce contact between chips and the wall of the hole in the CFRP layer, and allow the chips to be discharged smoothly. This system prevents back countering.



Chips made contact with the inner CFRP wall, which caused back countering!



■ **90-degree point angle**

The sharp point angle reduces thrust from the beginning of machining and restrains delamination.

Positive Edge Prioritizes Cutting Quality

– Please tell us about the background of the developmant of the MCC drill?

Yamamoto: While MCC is designed specifically for the machining of CFRP, aerospace components also use stack materials. The automobile and wind generation industries also use CFRP materials. The customers that machine CFRP materials often need to drill holes in thin plates.

Yanagida: Reducing delamination at the end of the hole was the biggest issue when drilling CFRP. CFRP doesn't have a layer of metal at the exit of the hole that stack materials have and doesn't suffer from back countering. However, the exit of the hole can fragment, which prevents support for the cutting resistance generated when the drill penetrates into the CFRP layer and causes burring at the exit of the hole.

Yamamoto: We prioritised the sharpness of the MCC drills for smoother CFRP machining and reduced cutting resistance to prevent delamination. The most important aspect of the MCC drill is the sharp edge. Drills traditionally feature a negative rake angle to prioritise deflection resistance and prolong tool life. However, a negative rake angle is not capable of cutting hard carbon fiber layers smoothly and this meant that the MCC drill benefitted from a sharper geometry. While cutting CFRP smoothly, it also restricts delamination and the generation of uncut fibres at the exit of the hole. In addition, the 90-degree edge angle reduces the thrust at the beginning of the drilling process, which also helps to reduce delamination.

– What are the characteristics of the coating?

Yamamoto: CFRP has mechanical characteristics that cause abrasion immediately after the start of drilling with uncoated cemented carbide drills. To address this we applied CVD diamond coating to the MCA and MCC drills to increase wear resistance.

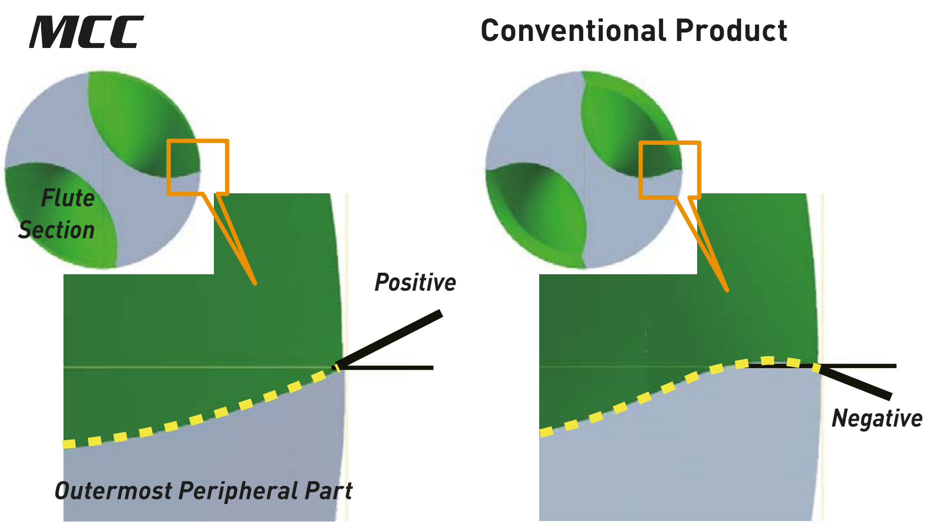
Yanagida: To maximise the sharpness of the drill edge, we needed to consider both the form of the edge and the size of the diamond coating particles. Mitsubishi Materials new CVD diamond coating particles are extremely fine, which significantly increases adhesion and we were able to increase tool life by approximately 10 times compared with conventional coatings.

– What have you done to improve sharpness?

Yamamoto: In order to increase sharpness, which was our priority, we sought the best method of processing the edge and maximising the helix, rake and clearance angles, which are all basic elements of all drills. We examined individual combinations of angles to identify the best match for preventing damage to the drill. In general, the greater these angles are, the better the sharpness becomes. However, cemented carbide is a brittle material and has limited deflection resistance. In addition, the combination of the drill elements and materials determine the final performance, which meant that we had to test the drills repeatedly to gauge effectiveness.
To increase the sharpness, the edge processing I mentioned earlier is also important. The conventional drills produced by Mitsubishi Materials have tiny imperfections on their edges due to pre-coating process. However, for the MCC drill the edge processing is completely different from conventional drills, which made it possible to create a really smooth, even edge. Utilising this new edge processing method enabled us to realize both sharpness and strength, which led to the prolongation of tool life and improvement of hole quality.

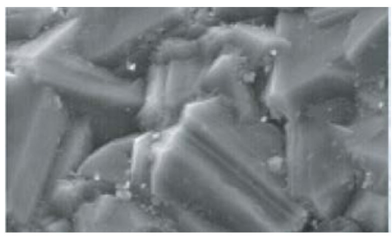
■ **Groove with Deep Rake Angle**

Improved vertical rake angle against the rotation axis produces a sharper edge, which effectively reduces uncut fiber and delamination.

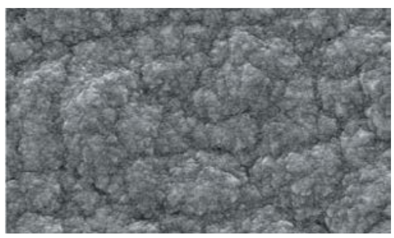


■ **Comparison of CVC Diamond Coating Membrane Surface**

The unique CVD diamond coating realises both wear resistance and smoothness.

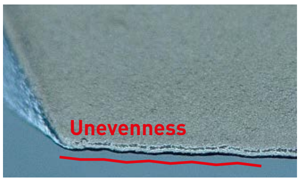


Conventional Product

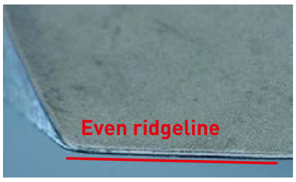


New Coating

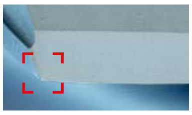
■ **Form Optimisation (Comparison of Ridges)**



Conventional edge processing



New edge processing for CFRP



■ **Reduction of R size**
- Improving sharpness

■ **Even edge**
- Prolonging tool life

Yanagida: To help development of the MC series, we conducted joint research with the Vienna University of Technology (TU Wien) in Austria. When we needed to conduct machining tests for the prototypes with different thicknesses of coatings on the drills, edge forms and rake angles, we asked TU Wien for cooperation and acquired a lot of data from them, which we believe contributed significantly to the success of this major innovation.

Difficulties and Achievements in the Development of New Materials

– What were the difficulties you encountered during the MCC drill development?

Yamamoto: Along with the challenges we faced, we also enjoyed learning about the challenges of CFRP machining. I was transferred to the Gifu Aero Group, Aerospace Dept. when it was established in October 2016 to begin working on the MCC drill development. I had experience in developing drills for metals, but this was the first time for me to work on drills for CFRP.

Yanagida: The developers in this department, including Yamamoto, created prototypes. We operate the tool grinding machines ourselves, considered the best conditions, including cutting angles, speed and types of grindstone and continue creating prototypes as we cultivate our sense as engineers.

Yamamoto: We repeatedly reviewed grinding conditions with a priority on ensuring sharpness. During those processes, we selected promising prototypes for futher testing and asked customers to check their quality and performance. When we heard the words, "This is much better than the drill we are using now," we were naturally very pleased.

Yanagida: Since we design, manufacture and test prototypes by ourselves, we immediately detect even the slightest difference in performance. Yamamoto created the MMC prototypes and because of this he had a few ideas that he applied to product development. This enhanced our ability to deliver an outstanding product.

– Would you please tell us your plans for future drill development for CFRP materials?

Yanagida: The critical requirement in the manufacture of aircraft parts is safety. Prolonging tool life is also an important goal, but the quality of the hole is the priority and we strive to realize both. We predict that CFRP strength will improve and that the appearance of new stack materials combined with stainless steel will mean that overall, materials will become increasingly harder to machine. Mitsubishi Materials continues to conduct joint research with carbon fibre manufacturers and work with universities engaged in cutting-edge research to deepen our understanding of CFRP machining and out ability to respond to ever-changing market needs.

– As we conclude our interview, do you have anything to say to your customers?

Yanagida: JIS and ISO have not yet classified CFRP structures. There are many different types of carbon fibre resins, thicknesses and weaving methods. Therefore it is necessary to tailor drills to the material being used to ensure the highest quality of holes. We are ready to satisfy customer needs, so please feel free to contact us.

Yamamoto: The MC series is listed in the catalogue as standard products. However, I believe that the MC series should be tailored to fit individual customers. We strive to quickly and effectively satisfy the needs of customers, so please feel free to consult with us.

■ **MC Series Product Line-up**

Work Material \ Machine Tool	CNC Machine		Hand Tool
CFRP / CFRTP	For Simple CFRP MCC DD2105	For CFPR/CFRTP & CFRP/Al Stack Material High-Precision Hole Processing MCW DD2110	For Simple CFRP Hand Tool Processing MCCH DT2030
CFRP / Al	For CFRP/Al Stack Material MCA DD2110		For CFRP/Al Stack Material Hand Tool Processing MCAH DT2030
CFRP / Ti	For CFRP/Ti Stack Material MCT TF15	CFRP/Ti Stack Material High-Precision hole Processing MCW HTi10	

*CFRTP=Carbon fibre reinforced thermoplastic resin

ABOUT US

Central Research Institute
Thin Films and Coatings Department

The Research Base that Supports the Aircraft Industry with the Development of Materials and Coatings

Mitsubishi Materials Corporation Central Research Institute Thin Films and Coatings Department conducts research and development on materials and coatings to achieve drastically improved cutting tool performance. In this feature, we report on this highly advanced site and its research and development.

Ask the Manager!

Takatoshi Oshika
Manager, Thin Films and Coatings Department, Central Research Institute

Providing added value through new processes and technology in order to create unique materials.

Pioneering research and development with state-of-the-art analysis and evaluation technology

Mitsubishi Materials Corporation Mining Research Institute was established in Shinagawa in 1917 as Japan's first private research institute. Following relocation to Omiya City (currently Saitama City) in Saitama Prefecture, it embarked on a new path as the Central Research Institute. In 2007, they expanded to Naka City, Ibaraki Prefecture with three branch locations in Omiya, Onahama, and Kitamoto. This year, the institute celebrates its 100th anniversary. The Thin Films and Coatings Department has the largest number of research fellows at the institute. The department focuses on controlling composition, texture, and the interface of hard sintering materials and functional coatings at the nano-level to develop new materials with completely new functions. Department Manager Takatoshi Oshika talked about the strength of the Institute. "We have implemented the most advanced equipment and devices that few other institutes in Japan have and also employ many outstanding researchers with highly-advanced skill levels. The Institute has nine other departments working on a wide range of research themes, including material analysis and electronic materials. These departments are able to quickly apply various technologies in cooperation with one another, which is I believe, a major strength of Mitsubishi Materials. In fact, we have released one new product after another through the integration of technologies developed through different projects. One of these is the world's thinnest flexible thermistor sensor."

The Thin Films and Coatings Department has developed elemental technologies that are applied to the manufacture of innovative products such as the UC5105/UC5115 grades. The CVD coating developed for the UC grades has significantly improved service life and increased its wear-resistant by utilising Al2O3 coating technology. "Currently, we are researching element technology for PCD drills used in CFRP machining, for which the basic material design has already been completed. We are also researching CVD diamond coating materials for CFRP processing with the hope of applying the technology to the new products in the near future." He continued, "We are also working on innovative technological development. For example, when we find that the strength of a coating material doubles by making material particles smaller, we need to redesign the device that makes the particles. For our efforts we end up with the only device in the world. Through such development and use of high value-added equipment, I believe we can

create innovative materials. It is like a magic ball in a baseball comic. Rather than trying to improve our pitching, we strive to create a magic ball that no one can hit. Innovative product development is our mission."

Development of CVD diamond coating materials for CFRP machining

Kazutaka Fujiwara joined Mitsubishi Materials 20 years ago and was assigned to the Central Research Institute 10 years ago. He has been in research and development of CVD diamond coating materials for cutting tools for the past five years. Fujiwara said, "Compared with the development divisions at manufacturing plants, this Institute is more remote from our customers. Therefore, I always keep in mind the need to maintain a close working relationship with the development staff at the manufacturing plants because these are the ones that have frequent contact with customers and so best understand their needs. Understanding customer needs, I seek to identify fundamental principles that lead to new hypotheses. The results lead to the drastic improvement of product performance. I am very happy when I hear that products made with the new technology we developed are recognized by the market." Fujiwara is currently engaged in the research and development of CVD diamond coating materials for CFRP cutting tools used on airframes. "Mitsubishi Materials has already released drills and end mills coated with materials we have developed. We are now working on new coating materials whose performance is even better."

Striving to develop unique technology that can be applied to the manufacture of new products

In addition to single CFRP, composite materials such as CFRP and aluminium or CFRP and titanium are also used for aircraft parts. Processing different materials with a single tool requires a significant increase in performance. The quality of CVD diamond coating materials required to machine such composite materials is necessarily high. Fujiwara said, "For the processing of CFRP only, the higher the ratio of the diamond is, means the harder the material is, the better the performance of the coating material becomes. On the other hand, if we increase the ratio of diamond to process metals such as aluminium and titanium, the coating materials tend to react to the work materials, which can cause adhesion, lower the precision of the machining and shorten tool life. We need to solve these conflicting problems at the same time, achieve outstanding performance over a wide range of work materials with a single coating material that can significantly elongate tool life while we develop the CVD diamond coating materials." Fujiwara is working on the development of CVD diamond coating materials that triple tool life when compared with existing materials. Setting the goal of releasing products in FY 2018, everyone on the team is working hard on research and development. "The mission of the Central Research Institute is to create the most advanced technology. We are excited about producing the kind of technologies that only Mitsubishi Materials is capable of so that we can make our customers happy with products they manufacture using our tools."

Ask the researcher!

Kazutaka Fujiwara
Principal Researcher, Thin Films and Coatings Department, Central Research Institute

Working on the development of CVD diamond coating materials that triples tools life compared with the existing products

Features of the Central Research Institute

1 **The most advanced analytical devices**

2 **Active information sharing among researchers using a comfortable space for these interactions**

3 **Library with many technical books and literature useful for research and development**

CUTTING EDGE

Vol. 5

Development of Next Generation Rotary Tools

In aircraft manufacturing difficult-to-cut-materials are used with much greater frequency. Unfortunately, these difficult-to-cut-materials significantly shorten tool life. Responding to market demand for more innovative machining methods that drastically prolong tool life when working with these special materials, Mitsubishi Materials kept its focus on the development of next-generation rotary cutting tools. In this feature, we focus on two of these, driven rotary cutting tools employed in multi-task machines and passive rotary cutting tools used on general machining centres

PROJECT 1 Making the tool itself rotate

Development of passive rotary cutting tools utilising the merits of multi-task machines

It was about 20 years ago that Mitsubishi Materials first developed rotary cutting tools for lathes that rotated the inserts during machining. At the time, an innovative mechanism was applied that drove the rotation by using the cutting resistance. This significantly reduced boundary wear, a major cause of reduced tool life during the machining of difficult-to-cut materials. While this first-generation rotary cutting tool was highly regarded, the complicated mechanism limited rigidity; and they were relatively expensive compared with standard tool holders. Some customers continued to use them, but demand gradually dropped.

However during that time, new rotary cutting tools were under development. This new development leveraged the know-how accumulated through the company's experience with its first tools. In the design of the new rotation mechanism, the appearance of multi-task machines provided a big hint. The first rotary turning tools rotated inserts by utilising resistance generated during the cutting process, which, depending on cutting conditions, caused unevenness in the rotating force and made it difficult to realize stable performance. It was thought that if a stable, predetermined rotating force could be generated regardless of cutting conditions, there could be successful way to develop a new type of rotary tool. It was around 10 years ago that thoughts started about new rotary cutting tools.

About that time a study on driven rotary cutting tools was conducted by Professor Sasahara at Tokyo University of Agriculture and Technology. A consultation period was undertaken with them for a while; and then three years ago, a full-scale joint research was started. Using multi-task machines made it possible to realise voluntary control of tool rotation, which paved the way to achieving driven rotary cutting tools.

The multi-task machines not only allowed control of the tool rotation, but it also allowed contact angles to be freely set. This prompted research for the best combination of cutting conditions and tool contact angles.

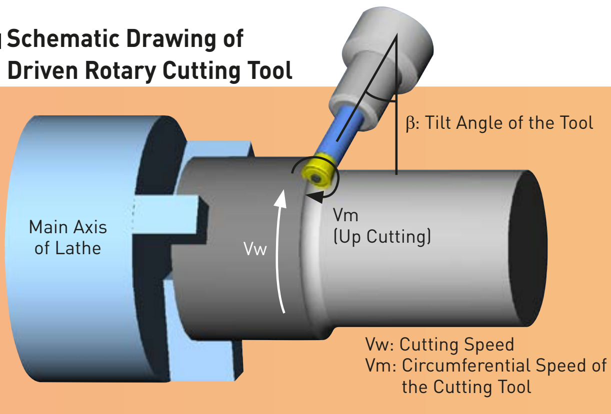
In addition to rotational frequency (rotation speed of tools), it is important to identify the best contact angle. Chip thickness, which has a significant influence on tool life and flow direction, varies depending on basic conditions such as speed, feed and cut. Along with these considerations, the new design employed different tilt angles, which created the potential for difficulty in finding the best combination of cutting conditions. To address this, Professor Sasahara was asked for help in looking at the figures from a theoretical viewpoint to investigate the best conditions.

Meanwhile, the greatest challenge in the development of tool forms is minimising the misalignment of the centres when fixing the insert to the tool. Larger misalignments cause eccentric rotation against the rotation axis of the tool, which changes the amount of cut and causes a mismatch between the predetermined and actual size of the part being machined. In addition, changes in amount of cut causes instability in cutting resistance, which generates chattering and damages the inserts.

After repeated trials, it was possible to reduce the degree of concentricity between the insert and cutting tool to 0.01 mm or less.

Another major feature of the new cutting tool is found in the internal coolant. The tool was designed to supply coolant from the space between the insertion hole and clamp screw. This mechanism tends to lower clamp force when the insert is installed onto the cutting tool; however, this unique design maintains the necessary clamping force. The tool itself rotates consistently, which evenly disperses the heat generated during the cutting process over the entire circumference of the cutter. Supplying the coolant from inside the cutting tool makes it possible to effectively cool the entire insert and to discharge chips smoothly.

■ Schematic Drawing of Driven Rotary Cutting Tool



During Processing

Mechanisms Under Development

Realising tool life that is approximately ten times greater than general insert-type cutting tools

The newly developed driven rotary cutting tools offer the following features:

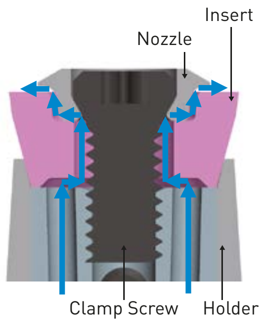
1. Use of the entire circumference of the insert evenly disperses tool abrasion to promote longer tool life.

2. Stable rotation of the tool itself effectively disperses cutting heat; and the internal coolant design significantly reduces insert abrasion.

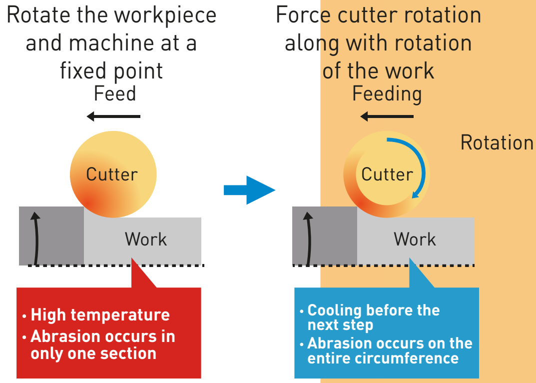
3. The uniquely developed high-precision and high-rigidity clamp mechanism realises stable, high-performance machining.

These features have drastically prolonged tool life during the machining of Inconel718 compared with standard cutting tools. In addition, driven rotary cutting tools are suitable not only for machining difficult-to-cut materials such as heat-resistant alloys, but also for the machining of composite materials such as aluminium and iron. These are especially effective in significantly reducing total running costs by prolonging tool life to reduce the frequency of insert replacement during unmanned machining or during the operation of multiple machines by a small number of employees.

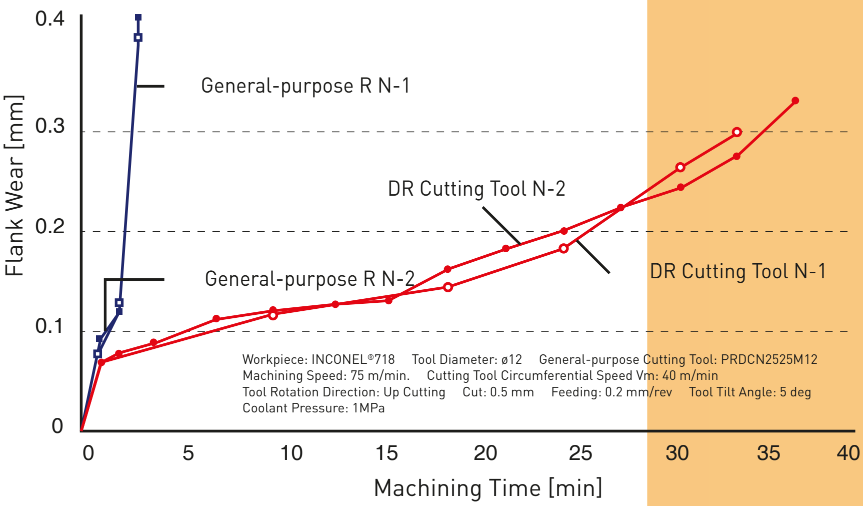
■ Internal Structure of the Coolant



■ Driven Cutting Tool Mechanism



■ Tool Life Curve for INCONEL®718



Was it possible to address the issues that arose during development of the first rotary cutting tools?

Looking at the general compression ratio (CR) of chips, it was thought that approximately one-third of the machining speed, which is equivalent to the chip discharge speed, may be ideal as the rotation speed of the inserts to reduce the flank wear that is often a problem in machining difficult-to-cut materials. The first rotary cutting tools were rotated by cutting resistance, which did not allow control of the rotation speed. Therefore, a detailed examination of this hypothesis was not done at that time.

The new rotary cutting tools have several parameters, which makes it difficult to identify the optimal cutting conditions. Although recommended conditions have been identified for general use, it is very interesting to know that the optimal rotation speed of the tool against the machining speed of the workpiece is now one-third of the speed assumed for the first rotary cutting tools. Driven rotary cutting tools are now under development with a view to market introduction in 2017.

CUTTING EDGE

(Left): Yuji Takada, Tsukuba Aero Group, Aerospace Dept. who was involved in the development of passive rotary cutting tools
(Right): Wataru Takahashi, Advanced R&D Group, Machining Technology Center, Research & Development Division who was involved in the development of driven rotary cutting tools

PROJECT 2

Passive rotary cutter with insert that rotates by itself during machining

Calculating the theoretical rotational force of the insert

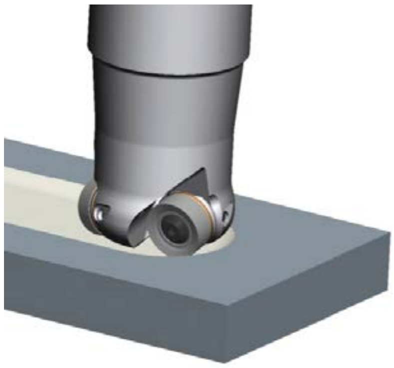
The new passive rotary cutter was developed as a milling tool utilising know-how gained through experience with the first rotary cutting tool.

Since the launch of the first rotary cutting tool, Mitsubishi Materials has applied a mechanism which rotates the insert with cutting resistance to end mills and face milling cutters. However, it was very difficult to install the rotational mechanism of the first rotary cutting tool to the milling tool due to its size, making it seem an impossible goal.

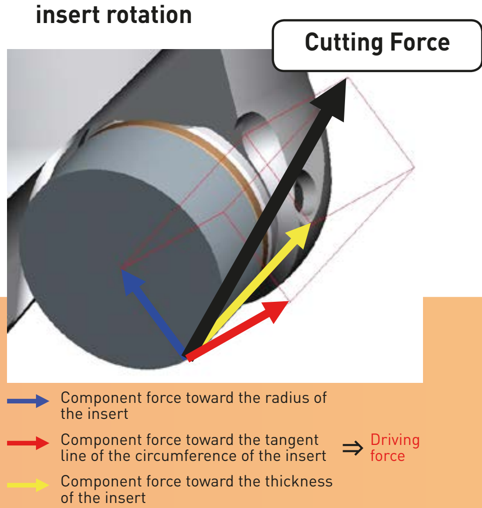
However, advancement of difficult-to-cut materials over a wide range of industries required further improvement of machining efficiency as well as prolongation of tool life. About 10 years ago, realizing the potential of inserts that rotated during milling, Mitsubishi Materials started joint development of rotary cutters with Nagoya University and Mitsubishi Heavy Industries, Ltd.

The first challenge was to identify the ideal angle to drive insert rotation utilising cutting resistance and to ensure an optimal rotating force. If the cutting resistance is too low, it won't generate sufficient drive to rotate the insert. If it is too high, it causes chattering during machining and leads to tool or insert damage. We needed to identify the angle that would generate enough cutting resistance to rotate the insert reliably to allow a broader range of cutting conditions.

Nagoya University overcame this difficult challenge. Applying complex formulas, the engineers successfully identified the optimal angle for insert placement for effective rotation. Compared with the trial-and-error method employed in the development of the first rotary cutting tools, being able to calculate the optimal values theoretically, significantly reduced the time needed for development.



■ **Mechanism of driving force for insert rotation**



Machining

The first rotary cutting tool

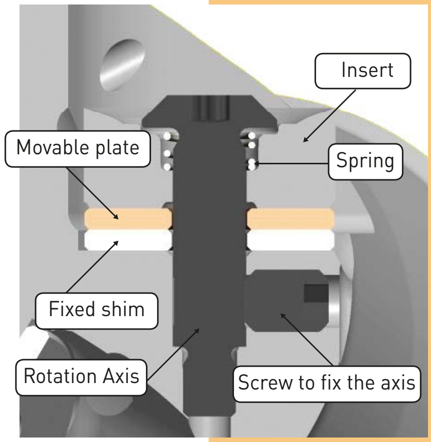
Realised tool life extending 8 to 10 times greater than Mitsubishi Materials' existing tool

The next challenge was fitting the insert into an extremely narrow space, a particularly difficult challenge. It was necessary to design a rotational mechanism that could be installed in such a narrow space. This required optimisation of the clearance of the insert hole and clamp screw to allow smooth rotation of the insert during machining. If the clearance is too small, it will stick; too large and it causes chattering. In addition, to achieve sufficient rigidity it is important to have the best clamp screw thickness for the size of the insert. After repeated examination and analysis, several prototypes and lots of experimentation, a spring above the clamp screw was successfully installed, which made it possible to develop a rotational mechanism that had both the ideal clearance and strength required. Just as the end of the development was in sight with the rotational mechanism, another challenge needed to be faced. The bottom of the insert came into contact with the cemented carbide shim on the tool body during rotation, which caused uneven wear. The rotation of the insert could even out cutter wear; but the cemented carbide shim that received the cutting resistance faced an uneven load, plus the load on the section below the cutter was intense. Because the insert and shim were both cemented carbide, contact and continued rotation under a local load would definitely create uneven wear. To address this problem, a movable metal plate was placed between the insert and cemented carbide shim as a buffer.

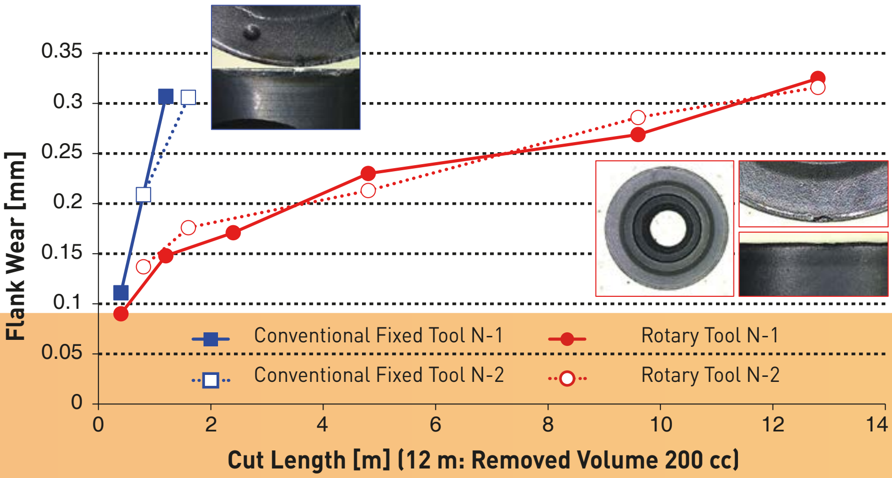
The biggest merit of rotary tools is long-time unmanned machining that does not require corner change; and as the graph below shows, we were able to achieve tool life that extended eight to ten times longer than our existing cutters.

This passive rotary cutter is scheduled to be on the market in 2017. It is planned to expand this success to the development of cutters for end mills, face milling and turning. Along with the expansion of the sizes of the insert, it is also planned to develop cutters for ramping.

■ Rotary Cutter Mechanism



■ Heat-resistant Alloy Machining Test Results <End mill Rotating Machining>



Cutting Conditions: vc = 30 m/min. fz = 0.1 mm/t ap = 1.0 mm ae = 18 mm Single Point/ Wet Processing Machining Workpiece: INCONEL®718

和 Japanese *Shuriken*

Enshi Goju Yocho by Utagawa Kunisada
The fight of a *ninja* who sneaked into a house.

What are *shuriken*?

Shuriken, which literally means a sword hidden in the hand, is a special weapon traditionally used by ninja. Samurai also learned to use them along with their use of spears, training in archery and fencing. Tokugawa Yoshinobu, the *Edo Period's* last Shogun, is known to have been an expert in the use of *shuriken*. When and how *shuriken* were developed remains unclear. Some argue that forged weapons used in the *Sengoku Period* (1467-1568) evolved into *shuriken*, others claim that they evolved from throwing weapons received from China in ancient times. *Shuriken* are effective to a range of up to 15 meters. Small and black in color, they are hard to see, which makes them hard for the enemy to dodge. Because they need to hit the target in a certain way to be fatal, *shuriken* were traditionally used to distract the opponent so that the warrior could dispatch him with his sword or escape; but they could also by coated with poison and thrown with the intention of nicking the enemy. There are two types of *shuriken*, bo *shuriken* (stick type) and *kurumaken* (wheel type) and different schools of martial arts used different shapes. The colour, however, was invariably black. The black color was produced by placing cotton on heated *shuriken* as they hardened. The cotton burns and adheres to the metal. This made the shuriken not only less visible, but also rustproof, easy to handle, and the rough surface created by this process retained the poison that was applied.

What were *ninja*?

Some say that *ninja* emerged in the *Asuka Period*, about 1,400 years ago. They were originally thought to have been men in the service of Prince Shotoku. Known as *shinobi*, they collected information from the Imperial Court. Historical documents mention shinobi in and after the *Nambokucho* Period (1336-1392). The term *ninja* became popular around 1955.

The role of and attitude toward *ninja* changed along with the times. The major role was not fighting in battles. *Shinobi* in the *Sengoku Period* served as spies for feudal lords, tasked with infiltrating enemy territory and collecting information. Therefore, their most important mission was to return alive, which motivated *ninja* to practice a wide variety of skills, including *shuriken*. The popular image of a *ninja* is of the silent spy hiding in an attic eavesdropping on the conversation taking place below. In fact, they most commonly blended in to the local population and picked up information from conversations. In the peaceful Edo Period (1602-1868), the major role of *ninja* was to gain as much information about the political situation of neighboring territories to protect their own domain and lord. As *shinobi* gradually disappeared in the late *Edo Period*, factually inaccurate images of *ninja* appeared in novels and other entertainment. *Ninja* were often portrayed utilizing their mysterious skills to commit theft. In *Kabuki* (Classical Japanese drama) and *Ukiyoe* (pictures of everyday life in the Edo Period), *ninja* were often dressed in black and held *shuriken* in their hands, a portrayal that influenced the current image of *ninja*. *Ninja* remain cloaked in mystery and we'll have to wait for future studies to tell us more about these interesting figures.

Type of *Shuriken*

Top right is a *bo shuriken*, and others are *kurumaken* in different shapes.

There are two major types of *shuriken*, bo *shuriken* (stick type) and *kurumaken* (wheel type). *Bo shuriken* are easier to make and more powerful than *kurumaken*. *Kurumaken*, on the other hand come in a wide variety of shapes. *Kurumaken* are more popular than *bo shuriken* because they have many blades, each of which can hurt enemies.

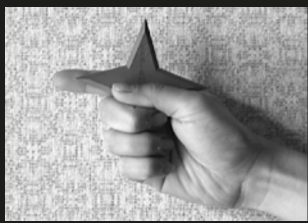
How to hold and use *shuriken*

How to hold:

There are different ways of holding *shuriken* for different occasions. There were no specified ways of use them. They were made to hit a target no matter how they were thrown.

[Bo Shuriken]

[Kurumaken]



Example 1

Example 2

Example 3

How to use *shuriken*

[*Hon-uchi* (Orthodox Throw)]

The orthodox way of use *kurumaken*. Swing your arm down from above.

Throwing stance

Throw the *shuriken* directly at the target

[*Yoko-uchi* (Sideway Throw)]

Slide it sideways. This technique is often shown in manga; however, it is almost impossible. It is necessary to hold the *shuriken* firmly to make a powerful throw.

[How to carry *shuriken*]

Shuriken were carried in a deerskin pouch and hung on the hip. A few *Shuriken* were also placed in a hidden breast pocket for protection and easy access when attacked by enemies

Tip of the *Shuriken*

1. Weapon of *Ninja.*

Ninja carried many weapons other than *shuriken*. One of these was a sickle and chain. It was made compact so it could be held easily in one hand. It was hidden in a pocket for easy access.

2. Did historical figures serve as *ninja*?

Quite a few historical figures were rumored to have been *ninja*. For example, some believe that Matsuo Basho; the author of *Oku no Hosomichi*, who wandered throughout Japan, and Ishikawa Goemon; a Robin Hood figure who stole from the rich to give to the poor, were *ninja*. This is certainly possible, and many more people may have been *ninja* as well.

3. *Ninja* did not wear black.

We picture ninja clothed in black, but in *Shoninki*, one of three books covering the secrets of the *ninja* arts, describes *ninja* as wearing dark brown or dark blue. Before electricity, clothing didn't have to be black to be hard to see at night.

Cooperation: Ninja MUSEUM of Igaryu

Editorial Note

The publication of MMC Magazine Vol. 5 was made possible through the cooperation of many talented and dedicated people, and I would like to express my deep appreciation to those who accepted our requests for interviews.

This issue focuses on the aerospace industry as a continuation of Vol. 1. Aircraft manufacturing takes full advantage of cutting-edge materials and processing technology and we share interviews with people actually engaged in machining parts used for aircraft. Through these interviews I hope you feel the excitement, depth and pleasure of manufacturing. This issue also includes a special report on a new material, CFRP. CFRP is common now, but it had a long history of development supported by the enthusiasm of Japanese manufacturers.

I also hope this issue helps to share the potential and value of working in the aerospace industry and promote its advancement in Japan and in the world as it continues to grow.

Yutaka Nada
Chief Editor

Your Global Craftsman Studio Vol. 5
By Business Strategy Dept.
Advanced Materials & Tools Company
Mitsubishi Materials Corporation

YOUR GLOBAL CRAFTSMAN STUDIO 005

Mitsubishi Materials is not just a tool manufacturer

We are committed to responding promptly to customers' challenges and to actively contribute to their success with the dedication of a professional craftsman.

We will strive to become the only tool manufacturer globally offering "your personal craftsman studio", a unique service for our customers.

It is the place where you can:
Find state-of-the-art technologies and products.
Find solutions, anytime, from anywhere in the world.
Share our excitement about the latest technology trends and product innovation.

It is the studio where we think, share, create and develop together with our customers, exciting solutions to meet their specific needs.

YOUR GLOBAL CRAFTSMAN STUDIO
MITSUBISHI MATERIALS

YOUR GLOBAL CRAFTSMAN STUDIO

The meaning of our logo
Our logo shows people, standing on a circle, holding hands. The circle represents the earth. Holding hands reflect our commitment to grow and succeed "hand in hand" with our customers and closely work with them to improve performance across the globe.
The shape of the logo embodies a variety of ideas. It captures the image of "cutting tools" combined with the dominant letter "M" of the Mitsubishi Materials brand name. It also depicts a flame that symbolises our passion for craftsmanship.

MITSUBISHI MATERIALS CORPORATION

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