Shibaura Machine
View the Future with You

NANOJIN Breakthrough

2021 SUMMER

Optics

REFLEX REFLECTOR

Aspheric

COAXIAL LENS

AIR Spindle

DIAMOND TOOL

Dimand Cutting

Automotive

LED

HEAD LIGHT

Tungstan Carbide

MICRO TEXTURE

Vibration Cutting

FREE-FORM GRINDING

Linear motor

EDITORIAL

Ultra-precision machine tools originated around 1980 were manufactured for specific purposes such as aspheric lenses. Although its market has strongly expanded in the past decade, it is still only focused on optical products, such as camera lenses mounted on smartphones. We also have gained a big presence by offering ultra-precision lathe and machining centers, especially in Asian market. Recently, the situation of machine tools industry is changing because of the transition stage of automotive technologies, for example, EV from petrol, automated operation and so on. Therefore, we set off into new field by integrating with another of our origin. It is a large-sized machine tools manufacturing having a long history over half a century. We are going to expand to machine tools having high versatility to be available to use by users who focus on automotive, medical and various mold products. One of them is a headlight lens mold having a complicated texture on the surface. We of course know we must consider many problems to solve, for example, cutting technology, tool-path generation and evaluation methods. We believe that people who work with machine tools manufacturing, tool making and researching will be needed to some community over the world. In other words, we hope that the leaflet will be supportable for them.

"JIN" stands for the human being in Japanese. Here in the leaflet, we would like to introduce that the NANOJIN implies people who work on the NANO processing industries. Through the leaflet NANOJIN, we would like to have a great community to have active communication opportunities with NANOJIN, who is working for Nano processing industries, about experiences, ideas and information.

We would like to introduce two writers provided with articles in the leaflet. They have been working deeply with ultra-precision machining. One is Prof. Kakinuma from Keio university. He has many achievements regarding precision machining and other categories and always has new viewpoints of manufacturing with different essentials. He gives us some lectures to open new technology in the leaflet. The other one is Tanaka Katsutoshi (Ph.D.) who is one of start-up members of our ultra-precision machining tools at manufacturing division. He has worked with machine tools design and created various type machine tools from beginning stage. He shows our history in the leaflet.

Masahiko Fukuta
Expert / Ph.D. (Eng.)
SHIBAURA MACHINE CO.,LTD.

FIELD #1

BEYOND PRECISION

YASUHIRO KAKINUMA,
PROFESSOR, DEPARTMENT OF SYSTEM DESIGN ENGINEERING,
KEIO UNIVERSITY

Shibaura machine Co. Ltd., located at the foot of Mt. Fuji, cover a wide range of processing machines such as large 5-axis machine tools, glass and injection molding machines, and ultra-precision processing machines. In particular, it is a pioneer company of ultra-precision cutting and grinding machine. Their ultra-precision machines created by the sophisticated machine elemental technologies that cannot be imitated, such as the special V-V rolling bearing and the original linear motor technology, realizes stable nano-precision subtractive processing. Currently, the machine continues to evolve to achieve incredible processing accuracy of 0.1nm beyond the limitation of nano scale precision.

PRESENT AND FUTURE IN ULTRAPRECISION MACHINING

In removal process of hard and brittle materials such as glass and silicon, conventional grinding/ cutting process cannot avoid cracks.

For example, in the case of glass, the machined surface becomes white like turbid frosted glass. However, if the depth of cut is reduced to the nano meter scale, cutting phenomena is remarkably changed and the machined surface becomes transparent without cracks. The former processing state is called brittle mode machining, and the latter is called ductile mode machining. The development of research in ultra-precision machining originated from the discovery of ductile region in machining of brittle material by Bifano et al [1]. They have found that when the depth of cut is less-than critical depth of cut, even hard and brittle materials become in a cutting state where continuous chips are generated like metal cutting. In order to stably realize this ductile mode machining, a machine tool that can operate with nano-precision while maintaining high mechanical rigidity is required, which is impossible with conventional micro-precision machine tools. Ultra-precision machining has given a big impact on not only hard and brittle materials but also mold-and-die materials.

Ultra-precision machining enables us to fabricate complex molds for the production of functional optical components used in various applications such as an overhead display of automobile. Currently, a complex mold with fine texture on the free-form surface can be manufactured by combining the elliptical vibration cutting technique and the ultra-precision processing machine, which are becoming a de facto standard for fabrication of molds for functional optical parts in Japan.
Looking at the academic field, in the direct machining of hard and brittle materials, process modeling, machining path optimization, evaluation of subsurface damage, etc. are initiatively researched. Researchers attempt to systematically understand the phenomenon of ultra-precision machining in various materials.
The current major issues in ultra-precision machining are low machining efficiency and low usability. For the former, the depth of cut must be set as very small as a few nanometers, so productivity must be sacrificed. As will be described later, in glass grinding, we have proposed Reaction-Induced Slurry Assisted (RISA) grinding with the help of chemical reaction to enhance the productivity together with the engineers of Shibaura Machine Co., Ltd. In terms of usability, ultra-precision machining is extremely difficult to handle and requires a very high level of technical skill and sufficient experience. The solution to this issue will be sensing technology that develops against the background of IoT, and adaptive control technology based on the acquired sensor signals.

Reference:
[1] Bifano GT, Dow TA, Scattergood RO. Ductile-regime grinding of brittle materials: Experimental results and the development of a model. 32nd Annual Technical Symposium, International Society for Optics and Photonics 1989:108-15

> "CURRENTLY, THE MACHINE CONTINUES TO EVOLVE TO ACHIEVE INCREDIBLE PROCESSING ACCURACY OF 0.1NM BEYOND THE LIMITATION OF NANO SCALE PRECISION."

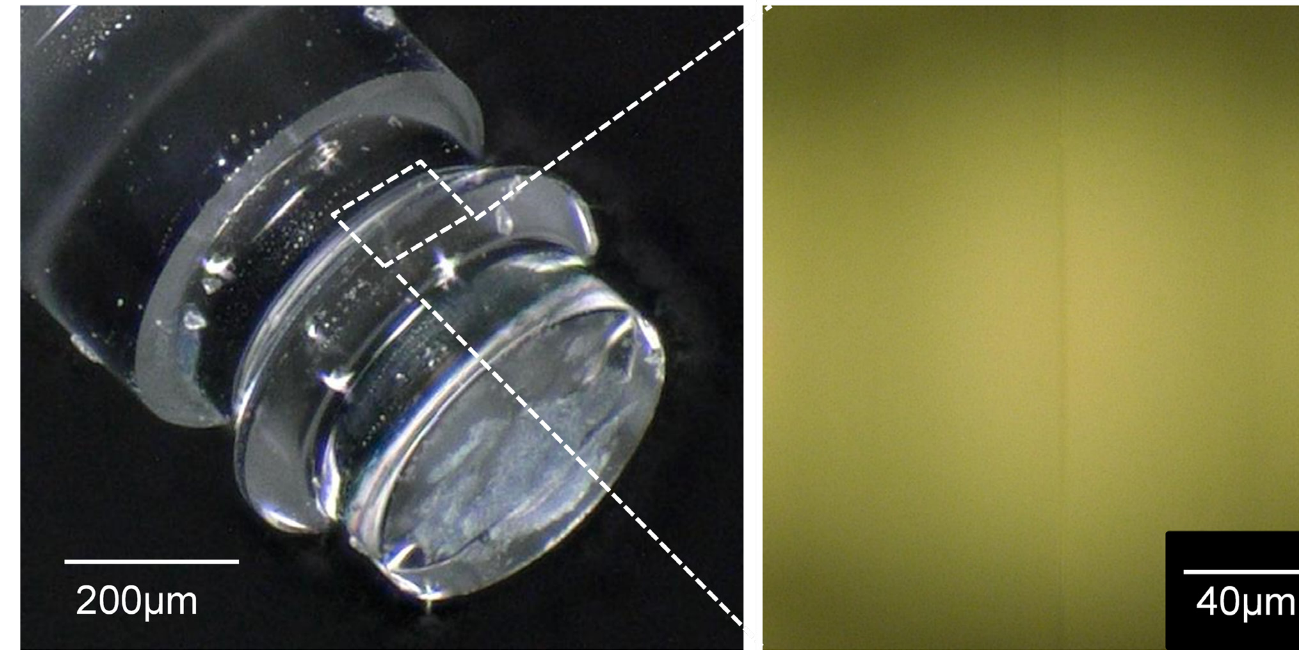


Figure 1. Optical micro resonator of single crystal CaF2 produced by ultra-precision turning process

RESEARCH INTRODUCTION WITH ULTRA-PRECISION PROCESSING MACHINES

Ultra-precision turning for the CaF2 optical micro resonator (machine: ULG-100E)

Optical micro-resonator, storing light having a specific wavelength, is a key part of next-generation optical signal processing. Single-crystal Calcium Fluoride (CaF2) is the most suitable material and ultra-precision turning is a feasible process for the CaF2 optical micro-resonator. However, crystal anisotropy causes big difference of cutting performance on each crystal plane and cutting direction. By applying the crystal model and cutting theory, the most preferable turning methodology is derived and a fine machined surface without cracks is successfully achieved. Furthermore, influence of the subsurface damage on the Q factor of the resonator is investigated. TEM observation shows subsurface area up to several tens of nanometer below changed from single crystal to poly crystal due to ultra-precision turning. Diamond tool with 0 degrees rake angle results in lower damage than the one with negative rake angle and it leads to improvement of the resonator performance.

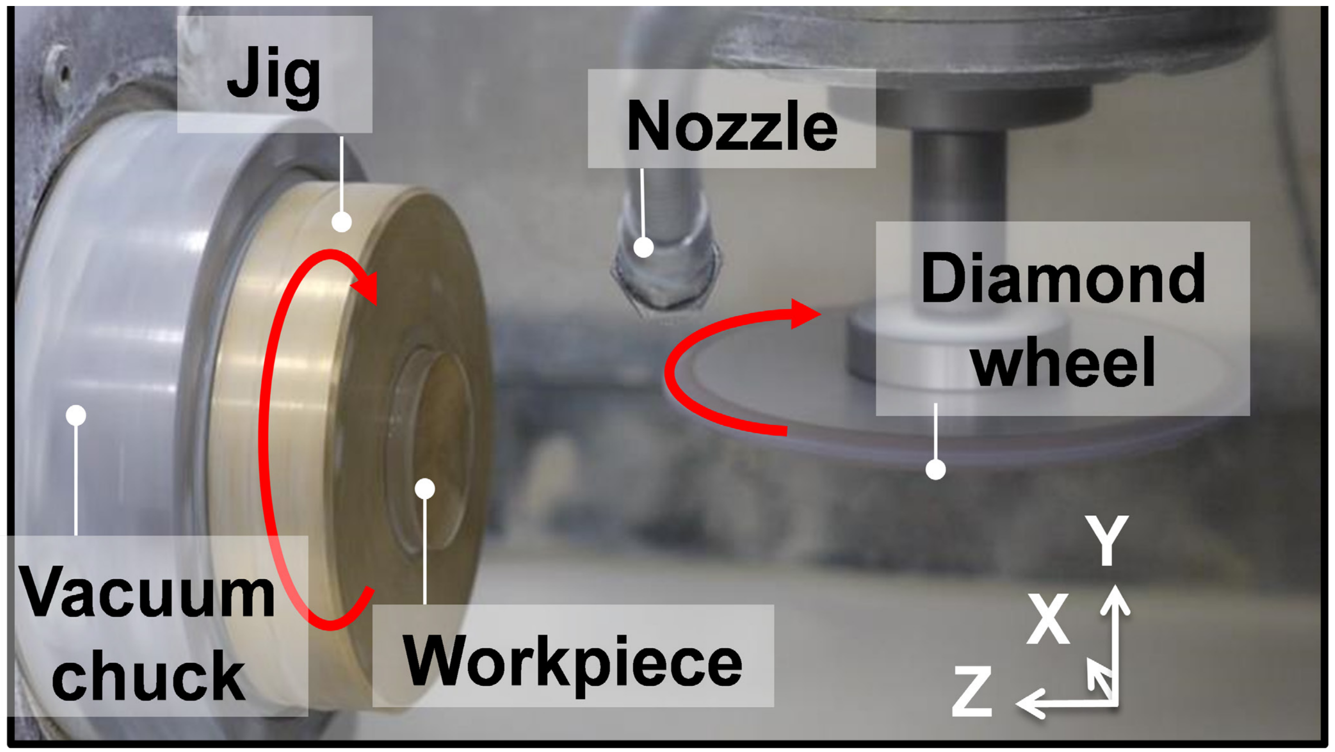


Figure 2. RISA grinding of BK7 glass

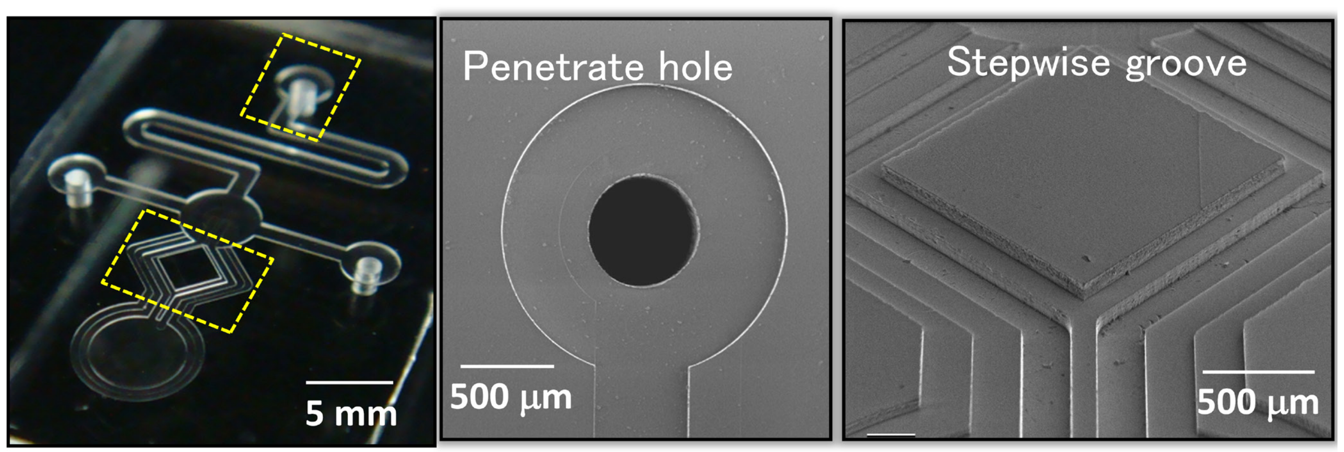


Figure 3. PDMS micro-fluidic chip with 3 dimensional complex channels fabricated by cryogenic micro-milling process

High efficiency optical lens fabrication with Reaction-induced Slurry Assisted (RISA) grinding (machine: ULG-100E)

For a next standard of broadcasting with 8K display resolution, higher accuracy and more efficient production of large aperture glass lenses is increasingly required to produce high-resolution imaging devices. These glass lenses are typically manufactured by both ultra-precision grinding and polishing. However, typical ground surface having cracks results in prolonged polishing and low productivity. In order to reduce the required amount of polishing or even obtain a polish-free fine surface, chemical Reaction-Induced Slurry assisted (RISA) grinding is proposed and its effectiveness is experimentally evaluated. The results show that the proposed grinding method successfully provides a high-quality surface comparable to a polished surface and results in more than 10 times higher productively than conventional grinding.

Direct fabrication of 3D Micro-fluidic chip by cryogenic micro-machining (machine: UVM-450C)

Microfluidic chips with micro channels ranging from submicron to a few millimeters are in high demand. The viscoelastic polymer of PDMS has suitable properties as the substrate material for the chip, i.e. high transparency and chemical stability. However, it is difficult to machine PDMS by milling process because of its softness and adhesion. We have developed cryogenic micromachining technique of PDMS completely immersed in liquid nitrogen as the direct process to precisely fabricate 3D customized chips.

EUSPEN LIFE TIME ACHIEVEMENT

JUNE 2009
SAN SEBASTIAN SPAIN

9TH INTERNATIONAL CONFERENCE OF THE EUROPEAN SOCIETY FOR PRECISION ENGINEERING AND NANOTECHNOLOGY

A WAY OF MASTERY

Tanaka Katsutoshi, technical advisor (Ph.D.) of Shibaura Machine has been working on ultra-precision machine since 1977.

In the meantime, he was awarded with the 'Medal for Distinguished Engineers" Japan Society of Mechanical Engineers, 1996)' and 'Lifetime Achievement Award (Euspen, 2009)' regarding the research of ultra-precision processing.

This is a inside story which has been being involved

"TANAKA HAS CREATED A NEW PRODUCT RANGE OF ULTRA-PRECISION GRINDING AND TURNING MACHINES."

A WAY OF MASTERY

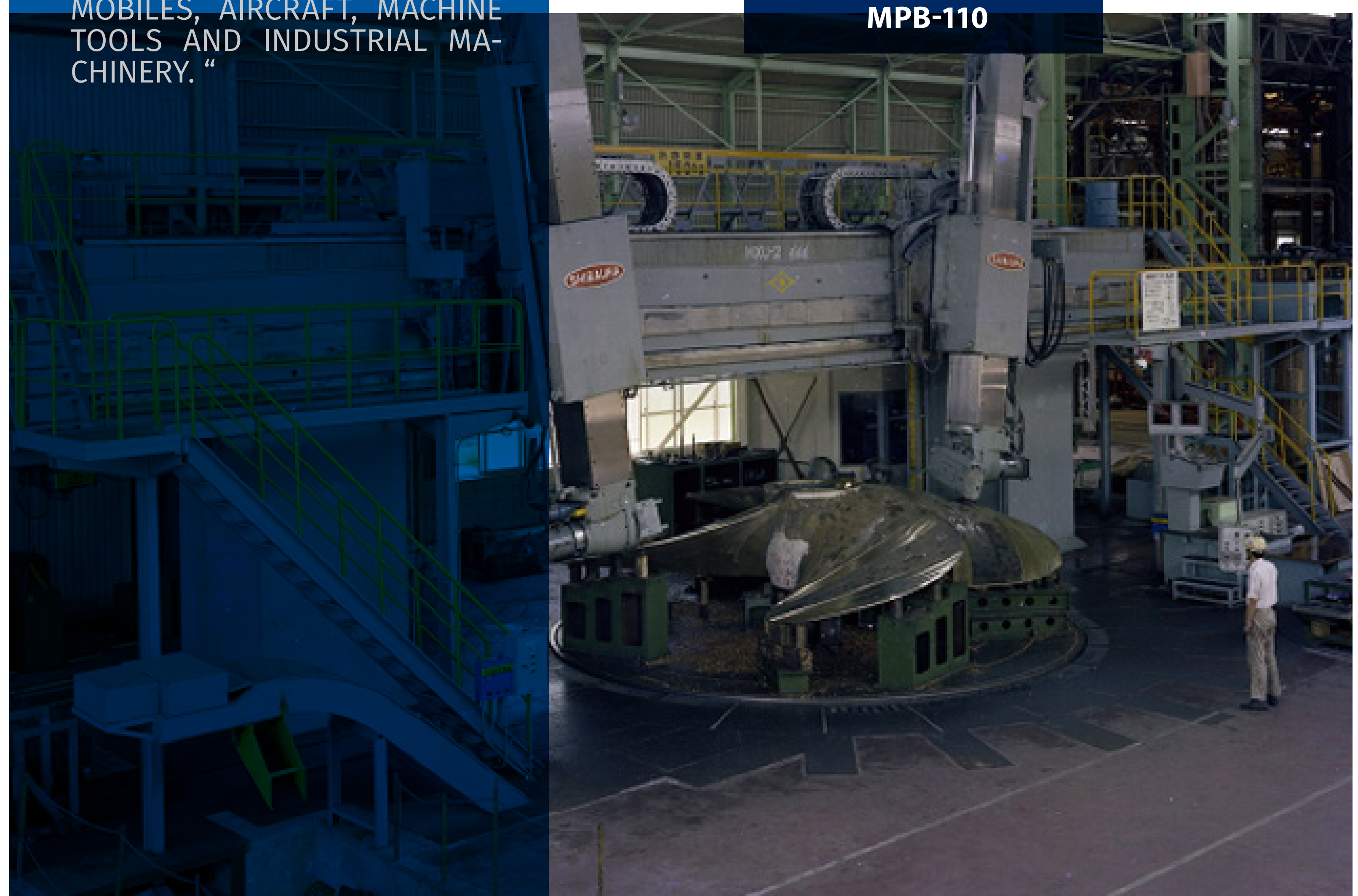
By Tanaka as the key enginner on Shibaura Machine's archives.

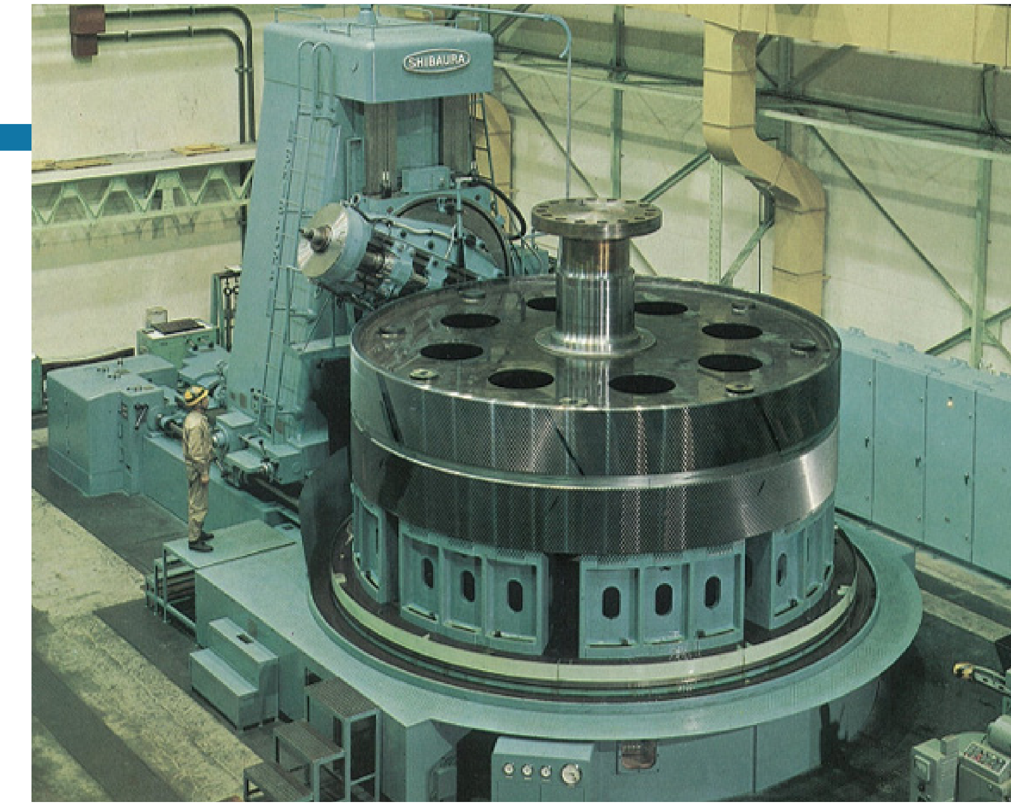
Since Shibaura Machine's establishment in 1949, we have contributed to the supply of various machine tools to process key parts such as heavy electricity, shipbuilding, steel, automobiles, aircraft, machine tools and industrial machinery. Among them, a ultra-large five-sided processing machine that processes the frame of a marine diesel engine, a wing surface processing machine that processes the wing surface of a propeller for propulsion and a slot mirror that processes the groove of a power generation generator have been highly evaluated in the world.

In 1977, Shibaura Machine started working on high precision machining and high precision machine tools as an in-house venture. As of 1977, there were no industries that required high precision machining technology, and we carried out the development of aerostatic bearing spindles and aerostatic bearing guideways, mirror finished surface machining with single crystal diamond using these, and the improvement of environment for high preci-

"SINCE SHIBAURA MACHINE'S ESTABLISHMENT IN 1949, WE HAVE CONTRIBUTED TO THE SUPPLY OF VARIOUS MACHINE TOOLS TO PROCESS KEY PARTS SUCH AS HEAVY ELECTRICITY, SHIPBUILDING, STEEL, AUTOMOBILES, AIRCRAFT, MACHINE TOOLS AND INDUSTRIAL MACHINERY. "

MPB-110





sion machining such as measuring equipment for evaluation and precision constant temperature room. In addition, in order to establish the technique of scraping, which is indispensable for improving the accuracy of guide ways, mounting surfaces, etc., a one-meter square reference plate was manufactured by three-surface rubbing for use as a standard for the flat surface.

We developed a polygon mirror generator in 1981 when the optical mirror finished surface machining (that requires accurate surface roughness and flatness) of aluminum alloy using aerostatic bearings was applied to the polygon mirror machining for scanners of laser printers. Since then, the laser printer market has expanded, and even after 40 years, laser printers still account for 85% of all printer sales (about 5 trillion yen) today.

Since 1980, the demand for magnetic disk devices as a recording medium for computers expanded, and it was expected that

ABS-10

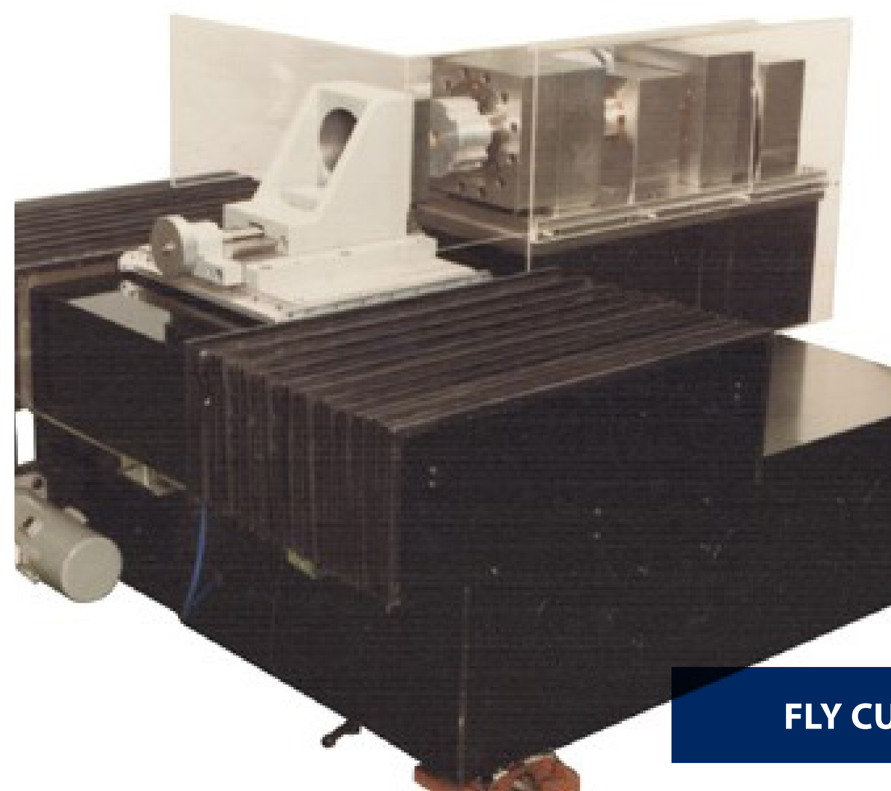
A WAY OF MASTERY

WE DEVELOPPED A POLYGON MIRROR GENERATOR IN 1981.

The demand for a magnetic head, one of the components of the magnetic disk device, would increase. The magnetic head is manufactured from a ferrite block by cutting, grinding, gluing, and polishing. The cutting and grinding required a high precision creep surface grinding machine (high precision slicing machine), so we developed a CNC high precision slicing machine in 1984. The configuration of this machine included a V-V sliding guideway for the X-axis for creep grinding, the motion accuracy of which was 0.3 μm per 400 mm, a linear guide for the Y-axis and Z-axis for positioning, the scale feedback of which was 0.1 μm, a cylindrical aerostatic bearing spindle with a built-in induction motor for the grinding wheel axis, the rotation speed and rotational accuracy of which were 12,000 min^{-1} and 0.3 μm.

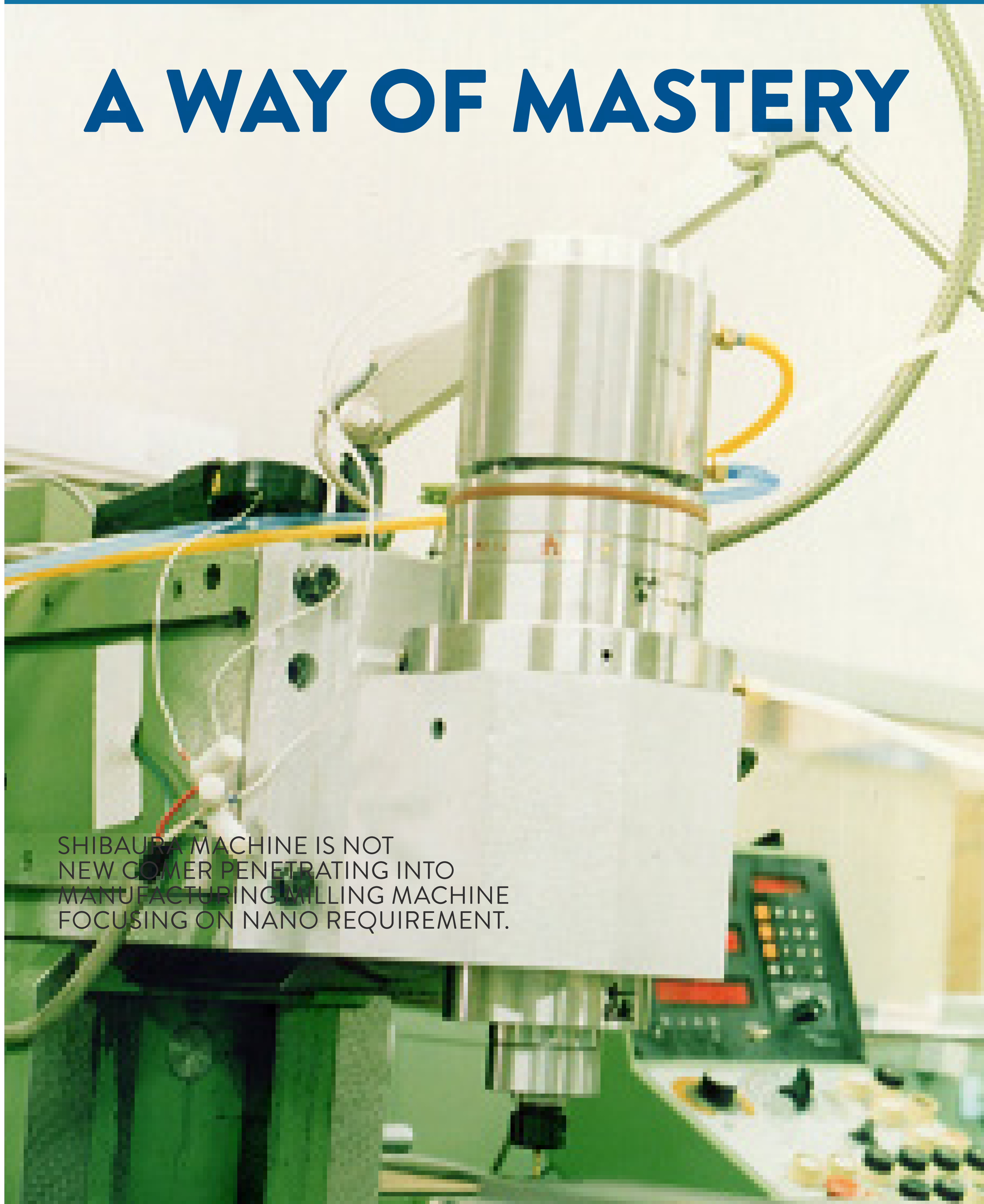
The high precision slicing machine contributed to the production of magnetic heads that became finer and more accurate day by day, and about 1,200 units were delivered in the six years up to 1990. Recently, we have developed a high precision slicing machine that satisfies the accuracy of V-groove substrates required for 5G.

As of 1977, there were no industries that required high precision machining technology, and we carried out the development of aerostatic bearing spindles and aerostatic bearing guideways.



FLY CUTTER

A WAY OF MASTERY



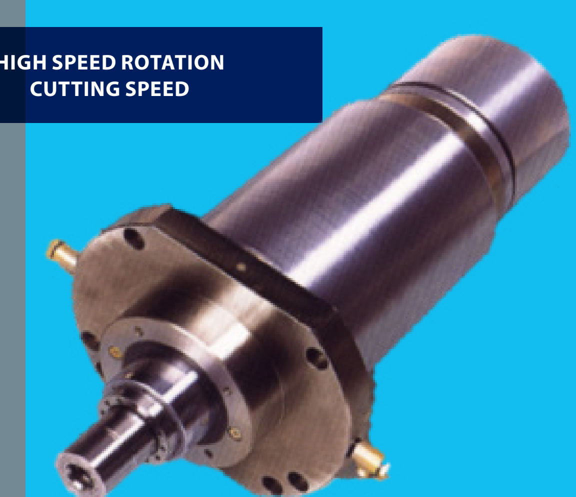
SHIBAURA MACHINE IS NOT NEW COMER PENETRATING INTO MANUFACTURING MILLING MACHINE FOCUSING ON NANO REQUIREMENT.

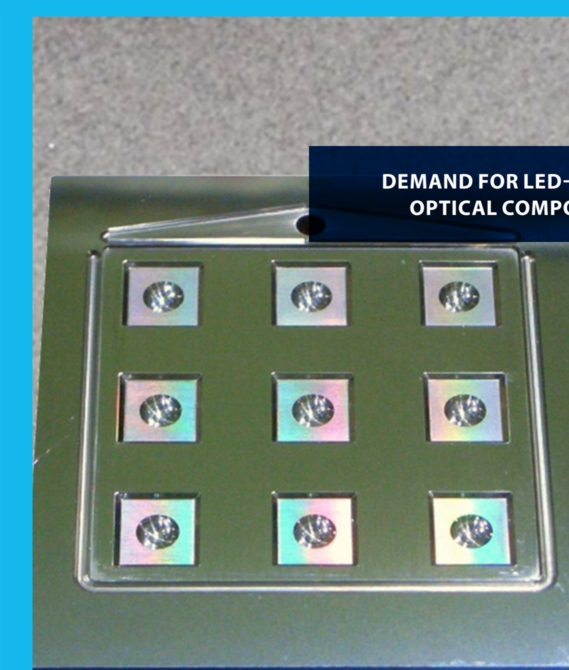
In 1990, we started research on end milling with a cylindrical aerostatic bearing spindle having improved performance (accuracy, stiffness, and high-speed rotation). The use of the aerostatic bearing spindle allowed high-speed rotation, the selection of a cutting speed according to the tool material, and the increase of the feed rate. The high rotational accuracy improved the machined surface roughness. In addition, it was expected that the tool life would be extended due to the stabilized feed rate per blade and that the temperature rise of the workpiece would be reduced due to favorable chip discharge that removes cutting heat.

At that time, in order to reduce costs and shorten lead times, the mold industry sought a direct shape machining method using high-speed cutting (direct milling) as a counterpart of the conventional method centered on electric discharge machining. The end milling with a cylindrical aerostatic bearing spindle was applied to and effective for such a direct shape machining method.

CYLINDRICAL AEROSTATIC BEARING SPINDLE

In 1990, we started research on end milling with a cylindrical aerostatic bearing spindle.





F-MACH 442

UVM-700E (5AD)

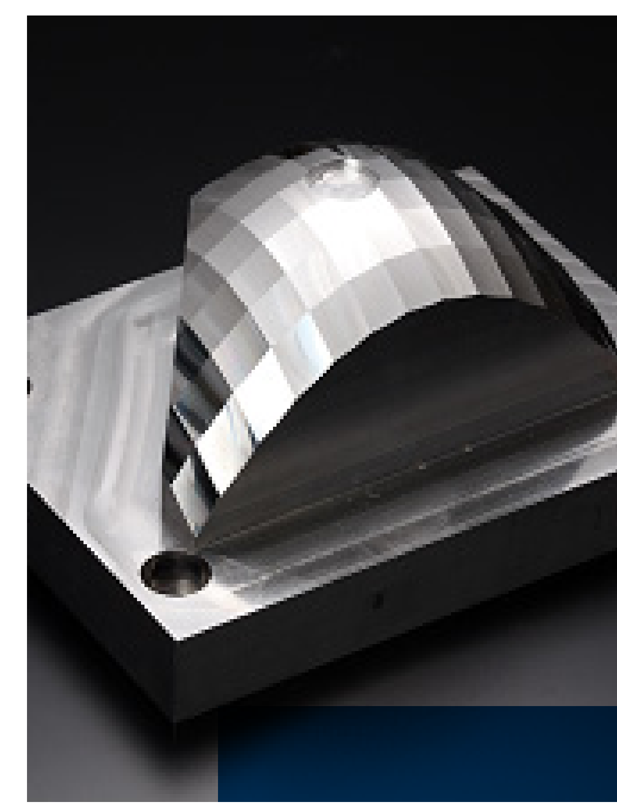
A WAY OF MASTERY

"SINCE THIS NEW MACHINING METHOD WAS PROPOSED, WE PROCEEDED WITH THE COMMERCIALIZATION OF A HIGH-SPEED MACHINE TOOL FOCUSING ON THE AEROSTATIC BEARING SPINDLE."

Although the market of this machine tool did not expand easily due to the limited number of suitable applications, there occurred demand for LED-related optical components. Therefore, we renewed this machine tool as a high precision machining center in 2008, and improved the machining accuracy and mirror finished surface by adopting a linear motor drive system for all linear axes, and diversified the product with ATC and various attachments.

In recent years, as halogen lamps for automobile headlights and other light sources have been replaced with LEDs, the material of the lenses and reflectors has been changed to plastic. For this reason, improved precision (form accuracy and surface roughness), complicated shapes, and larger sizes have been required for the molds, and those that cannot be finished by polishing as before have increased, so we have developed a 5-axis control high precision machining center.

Shibaura Machine contributed to the transition of television displays from cathode ray tubes to flat panel displays by manufacturing a number of dedicated high precision machine tools.



A WAY OF MASTERY

For rear projection displays, we developed a large CNC high precision vertical lathe that manufactures the mold of Fresnel lenses that are used as screens. A machine for 130-inch display used a table having a diameter of 3,400 mm supported by hydrostatic bearings, a ball screw-driven V-V roller guideway for the X-axis, a linear guide for the Z-axis, and a direct-drive aerostatic table with a synchronous motor for the B-axis. Unfortunately, the demand for this machine has disappeared due to the increase in size of liquid crystal displays.

In 1996, we developed a high precision double column machine for manufacturing light guiding plate molds for liquid crystal displays. The latest machine (2005) uses a V-V roller guideway and a with-core linear motor drive system for the X-axis, Y-axis, and Z-axis (vertical axis), and is also capable of cutting curved grooves using the C1-axis on the X axis (capable of indexing and turning) and the A-axis and C2-axis on the Z-axis.

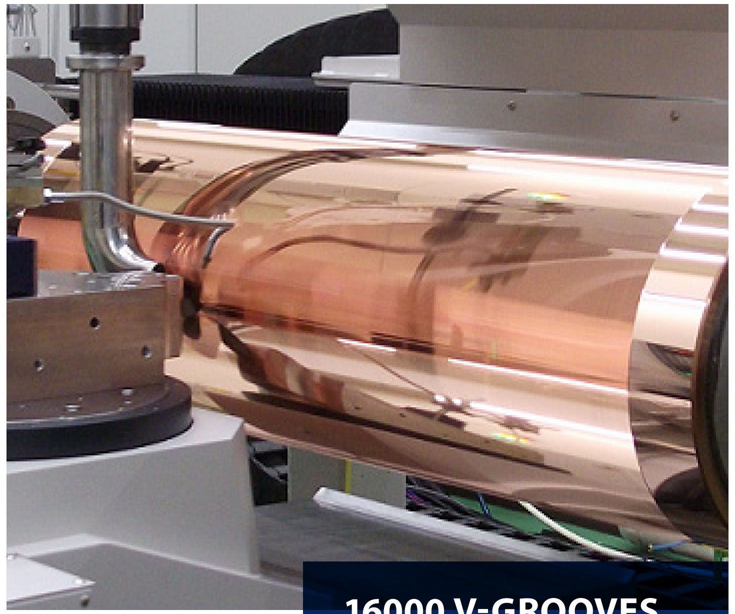
In 2007, we developed a high precision grooving lathe for machining prism sheets used for liquid crystal displays and roll dies for lenticular lenses.

In 2007, we developed a high precision grooving lathe for machining prism sheets used for liquid crystal displays and roll dies for lenticular lenses. The configuration of this machine includes hydrostatic bearings for the

UTD-3400B (H)

UMP-6585D

ULR-628B



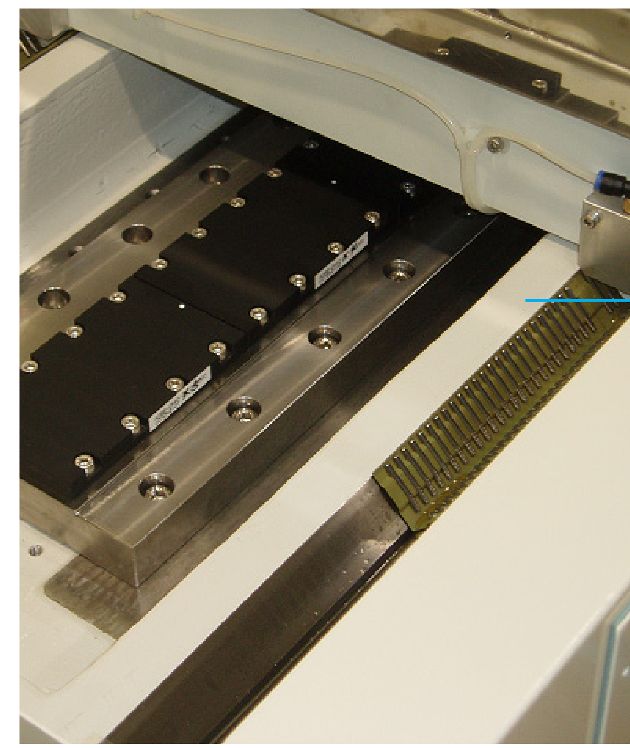
16000 V-GROOVES

A WAY OF MASTERY

ULG-100D(5A)

SHIBAURA MACHINE MADE THE SAME MACHINING POSSIBLE BY DEVELOPING A COMPACT CYLINDRICAL AEROSTATIC BEARING SPINDLE.

Spindle (having the C-axis function) and the tailstock axis, which support heavy rolls, a V-V roller guideway having a with-core linear motor drive system for the Z-axis, which is the feed axis of the turret, a V-V roller guideway having a with-core linear motor drive system also for the X-axis, which is the infeed axis, and an aerostatic bearing for the turret turning axis(B-axis). This machine can make complicated grooving on a roll by using the X-axis, Z-axis, B-axis, and C-axis. The machining of a large roll may take a month. Also this machine has been used for another new use, machining of rolls for anti-counterfeit films.



V-V ROLLER GUIDEWAY HAVING A WITH-CORE LINEAR MOTOR DRIVE SYSTEM ALSO FOR THE X-AXIS, WHICH IS THE INFEED AXIS, AND AN AEROSTATIC BEARING FOR THE TURRET TURNING AXIS(B-AXIS).

In 1975, a high precision CNC lathe having a control resolution of 25nm was developed in the United States, which enabled high precision mirror finished surface machining of axisymmetric spherical surfaces, aspherical surfaces, and paraboloidal surfaces with NC control.

Also Shibaura Machine made the same machining possible by developing a compact cylindrical aerostatic bearing spindle that uses a synchronous motor drive system for the V-V roller guideway and the workpiece spindle, introduced a commercialized control device with a resolution of 10 nm and

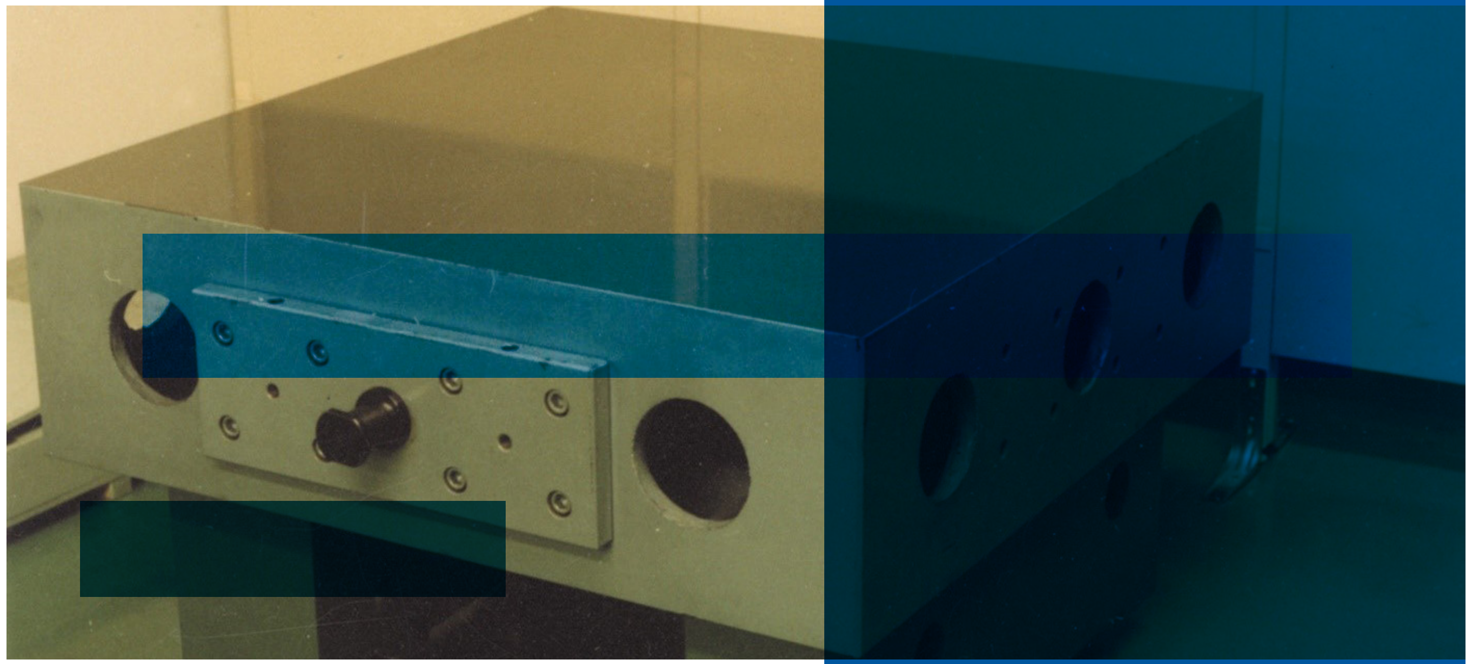
A WAY OF MASTERY

We believe that these products were created due to the fact that high precision machining technology was able to meet their requirements.

Succeeded in developing a 2-axis control high precision aspherical grinding machine in 1991. The market for this machine gradually expanded to include pickup lenses for CDs and DVDs, fθ lenses for laser printers, and aspherical lenses for cameras. Since 2000, there has been a huge demand for new aspherical lenses such as smartphone cameras, security cameras, and dashboard cameras. The required number of control axes of the high precision aspheric generator is 2 to 5 (X, Y, Z, C, and B axes), and the required command unit of the program is 1 nm and 0.1 nm. In addition, the guaranteed value of the form accuracy for aspherical lens molds for smartphones of as accurate as 30 nm is required.

In order to meet the requirements for such multi-functionality, improvement of machining accuracy, and stabilization, we improved the efficiency and machining accuracy by enabling the workpiece spindle with the C-axis function to improve the accuracy and stiffness with use of a porous restrictor and to be controlled at a constant peripheral speed with rotation speed control in 0.01 min^{-1} units. Due to the adoption of a with-core linear motor drive system that has large thrust and low heat generation for the linear axis, the temperature control within ±0.01°C in a machining booth, etc., we have supplied more than 900 units and have contributed to that industry so far.

The products presented above, which are dealt with by the machine tools, such as laser printers, hard disk drives, liquid crystal displays, digital cameras, with-camera mobile phones, smartphones, security cameras, dashboard cameras, etc. could not even be imagined in 1977. It is not clear whether high precision machining technology realized these products or the requirements of these products drove the development of high precision machining technology. However, we believe that these products were created due to the fact that high precision machining technology was able to meet their requirements.



SHIBAURA MACHINE IN EUROPE

SHIBAURA MACHINE EUROPE WAS ESTABLISHED IN 2019 IN ITALY AS A SUBSIDIARY OF SHIBAURA MACHINE JAPAN, IN ORDER TO ENHANCE SALES AND SERVICE SUPPORT FUNCTIONS IN THE EUROPEAN

With excellent access to European countries, we have been enhancing sales and technical support to our sales partners and actively developing new markets, thereby improving our presence.

Shibaura Machine (FKA Toshiba Machine) is a leading global manufacturer of injection molding machines, die casting machines, machine tools, nano processing systems, industrial robots, and extrusion machines. The engineering origins of Shibaura Machine can be traced back more than a century to Shibaura Engineering Works, established in 1875. Through the many subsequent decades, we have continued to grow and evolve, through challenge and adversity, into a premier global manufacturer of a wide variety of innovative, precise, supremely reliable machinery. Shibaura Machine was among the first companies in the world to establish mechatronics-oriented production systems. Continuous research and development – always searching for a better way – has enabled us to take advantage of our own advanced precision technologies and sophisticated electronics experience and use them to improve the machines we build for our customers. It is the continuity we have achieved over generations of accumulated skill and knowledge, our ability to build upon the shoulders of those who preceded, which makes us special. At our state-of-the-art manufacturing facilities in Japan, as well as more recent globally integrated facilities in China, India and Thailand, we produce all of the components to yield the superb precision and impressive infrastructure of our machines – from small factory automation equipment to machinery of truly mammoth proportions. As our company's odyssey continues, as we continue to work with our customers to co-create greater value, we will continue "to strive, to seek, to find, and not to yield".

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