AWARDS IN 1992

JSME DISTINGUISHED ENGINEERS AWARD

Satoshi NINOMIYA, Hitachi Ltd.
for the Development and application of Large Steam Turbine Technology for Central Power Station

Noda HIROTAROU, Meidensha Corporation.
for the Introduction and Promotion of Gas Turbine For Emergency Power Generation Application Stipulated by Fire Service Act

Hiroshi SAMI Toyota Motor Corporation.
for the Research and Development for Advanced High Speed Automotive Diesel Engine

JSME MEDAL for the Best Papers

Modeling Time Information in Manufacturing
Masahiko ONOSATO and Kazuaki IWATA, Osaka University and Shuzo NISHIDA, Setsunan University

Thin-Film Formation on a Rotating Disk
Taku OHARA, Tohoku University, Hideo OHASHI, Kogakuin University, and Yoichiro MATSUMOTO, The University of Tokyo

Formation Mechanism of Thermal NOx in pulverized Coal Combustion
Ken OKAZAKI, Tokyo Institute of Technology, Kazuo SUGIYAMA, Suzuki Motor Corporation, and Isao YURI, Central Research Institute of Electric Power Industry

Experimental Study of Turbulent Heat Transfer in a Two-Dimensional Curved Channel (Time-Mean Temperature and Multiple Temperature/Velocity Correlations in the Entrance Section)
Mutsuo KOBAYASHI, Hiroshi MAEKAWA, Tsuyoshi TAKANO and Masato KOBAYASHI, Niigata University.

Mechanism of Surface Cracking of Alumina Ring in a Mechanical Seal
Makoto KOMIYA, Kenji MATSUDA and Motohiro KANETA, Kyushu Institute of Technology

Evaluation of Stress Intensity Factor for a 3-D Surface Crack by Means of A.C. Potential Drop Technique
Masumi SAKA, Tohoku University, Takashi KANEKO, Bridgestone Corporation, and Hiroyuki ABE, Tohoku University

Characteristics of a 36T/D Oxygen-Enriched Air-Blown Cyclone Coal Gasifier
Michihiro SHIRAHA, Kenichi FUJII, Eiichi HARADA, Motoaki, HIRAO, Syunpei NOZOE and Shingo SUZUYA, Kawasaki Heavy Industries, Ltd. and Hideki TAKANO, Kawasaki Steel Corporation

Active Wave Control of a Flexible Beam (Fundamental characteristics of an active sink system and its verification)
Nobuo TANAKA and Yoshihiro KIKUSHUMA, Mechanical Engineering Laboratory, Ministry of International Trade and Industry

A Pore Response Function Method for Quantitative Evaluation of Hydrogen Attack in Steels
Junji TAKATSUBO and Shigeyuki YAMAMOTO, Government Industrial Research Institute, Chugoku

Identification of Viscoelastic Properties of a Left Ventricle
Junji TANI, Tohoku University, Tohru MIYAZAKI, Niigata Engineering Co., Ltd., Kikuo OHTOMO, Tamotsu TAKISHIMA, Yoshiro KOIWA, Tadasu OHYAMA, Yoshio SHIMIZU, Takehiko TAKAGI, Junichi KIKUCHI, Hideyuki HONDA and Nobuo HOSHI, Tohoku University

Numerical Simulation of the Small Vortices in the Intake and Compression Processes of an Engine
Ken NAITOH, Nissan Motor Co., Ltd., Kunio KUWAHARA, Institute of Space and Astronautical Science, Manfred JESCHKE and Egon KRAUSE, Aerodynamisches Institut, RWTH Aachen

Residual Stress Measurement in Silicon Substrate after Thermal Oxydation
Hideo MIURA, Hiroyuki OHTA, Hiroshi SAKATA and Noriaki OKAMOTO, Hitachi, Ltd.

JSME MEDAL for the Development of New Techniques

◆ Development of High Quality and High Productivity Cast-Iron-Die-Casting System Being Friendly with Earth Environment and Operators

Kiyoshi OSAKI, Hisayuki SAKURAI, Masatoshi KAWAGUCHI, Honda Engineering Co., Ltd., Takao NAGATA and Masayoshi YASUDA, Honda Motor Co., Ltd.

1. Introduction

Urgent-technical problem of our cast-iron-production division is to satisfy requirements for protection of Earth environment and saving of resources, that is, our actural target, is to produce thin and lightweight castings, which can be used for highly-functional parts, with reduced quantity of industrial waste (molding sand). Moreover, in the automobile industry which aims at "car production being frendly with the operators", improving of the operators' working conditions has to be considered seriously. Taking of actions against the poor working conditions (hard, dirty and hot) of our cast-iron production was urgent for us, too.

We developed the die-casting system to overcome those issues and mass-production of ductile-cast-iron knuckles and chilled-alloyed-cast-iron camshafts was started. (Photo 1)

2. Outline of the system

Unmanned production, which could not be realized by the traditional sand-mold casting, must have the cooperation of this system for its starting. Our system is based on the die-casting technology using the copper-alloy die. The throughly automated-die-casting system, composed of various sensors and CPU, can control the casting conditions to secure QC of our casting, motion of the MC and die to protect, and transfer motion of the product-conveyor line so as to realize unmanned production.

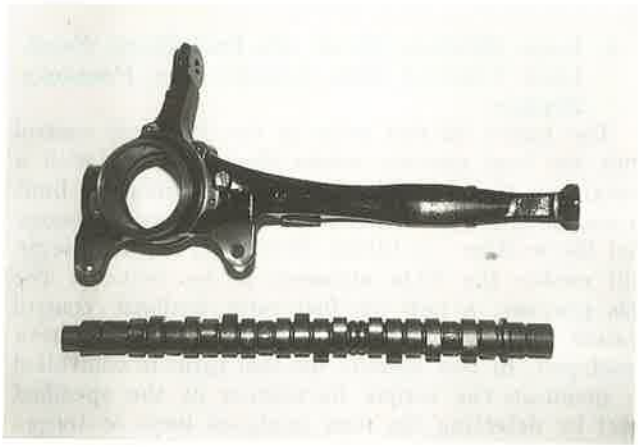


Photo 1

After finishing of one cycle of the die-casting process, consisting of a 44 seconds of casting and a 8 seconds of curing, casting is output from the die and transferred automatically to the succeeding processes as high temperature (900 to 100°C), where the casting is subjected to cutting of its casting gate, correcting of dimensions and heat treatment. The product can be obtained after the casting has been shot-blasted and checked by the supersonic tester.

As we discontinued to use molding sand, we could intensify important point of the traditional casting process and reduce the number of its steps remarkably. At the same time, a big reduction of our industrial waste in quantity and improved operators' working conditions could be achieved.

3. Feature of the technology

To obtain sound casting with complicated shape by the precise-die casting, it is essential to separate the casting from the die under the condition that its skin is solidified and its core is still unsolidified. This is our basic idea. According to it, th esolidified amount of the skin and timing of separation of the casting from the die are very important. This means that coolant sensitivity of die material is the critical-technical factor and we use copper alloy for out die.

This enables us to obtain casting with complicated shape by the die casting. The new technology involved in the temperature control for the die are the prediction control by the CPU along with heating medium and cooling one.

4. Merit achieved

The merits given by the new method are; increased fatigue strength of the casting by 15% casued by finer-solidified structure than ever; reduced weight of the cated knuckle by 13%; improvedworking conditions (dust reduction by 60%); and reduced quantity of industrial waste by 75%. Moreover, the new productivity is 2 times of the former one.

5. Conclusion

The achievement realized by adoption of this system – improvement in product quality, productivity and working environment and reduction of industiral waste – can contribute for solving of future issues of our cast-iron-production division and we might expect the system will bring us more advanced cast-iron technology.

◆ Development of New Lean-Burn Engine

Hiroshi OKANO, Souichi MATSUSHITA, Masahide KOSUGI, Nobuyoshi SUGITANI, Toyota Motor Corporation, and Kouji TSUKADA, Toyota Central Research and Development Incorporation

A lean burn engine has lately received considerable attentions in viewpoint of saving energy and prevention of global warming. In 1992, we introduced a new

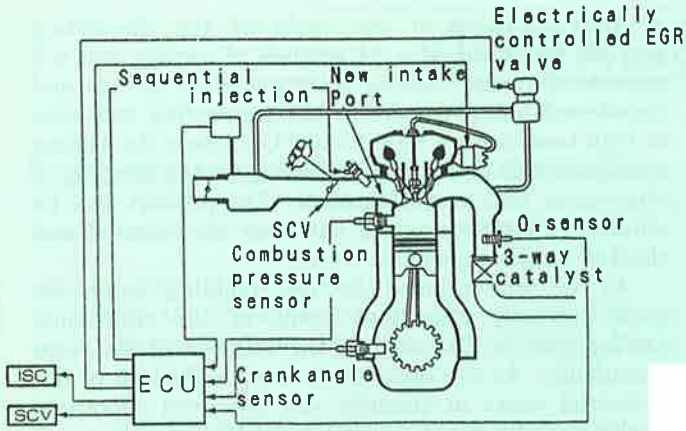


Fig. 1 New System Construction

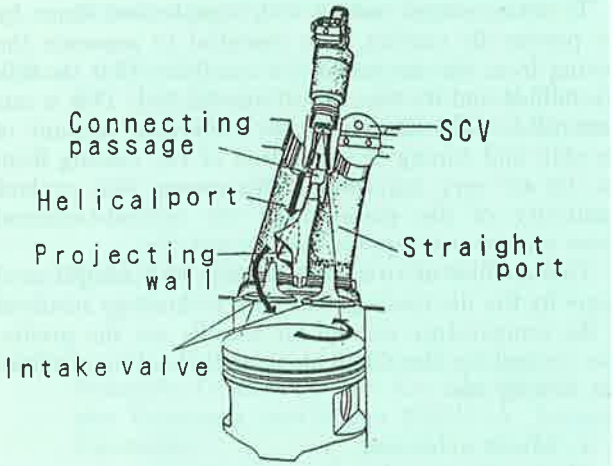


Fig. 2 New Intake Port

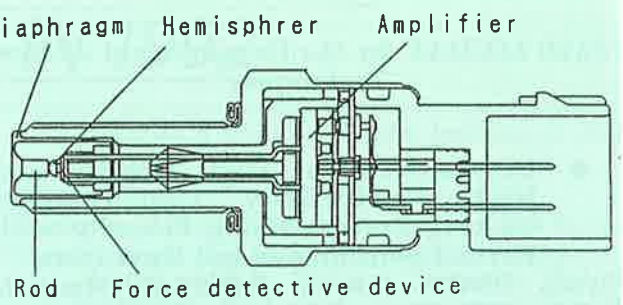


Fig. 3 Structure of Combustion Pressure Sensor

1.61 DOHC 4-valve lean burn engine to Japanese market, which was adaptable to medium class vehicle and vehicle with automatic transmission. In this paper, an outline is given upon system and fuel economy of new lean burn engine, which are achieved through technologies such as a new intake port design and a new lean mixture feedback control system with combustion pressure sensor.

1. Introduction:

Reduction of fuel consumption has been attracting much attention in veiw point of energy saving and prevention of global warming. In such a background, many engines adopt the system in which the air-fuel ratio is controlled in the window gate of 3-way catalyst. This system is very effective in reducing the exhaust emission, but leaves a room for improvement in terms of fuel consumption because the air-fuel ratio is controlled at the stoichiometric air fuel ratio. A lean burn engine is attracting attention as a means to reduce both the exhaust emission and the fuel consumption.

2. System Outline:

The new lean burn engine is planned to be mounted on M/T or A/T vehicle with an eqivalent inertia weight of 1.25 ton while satisfying the domestic emission control standard (in 10–15 mode). Fig. 1 shows the new system composition. The differences from the conventional system are as follows:

(1) A new intake port for enlargement of lean mixuture area
(2) A new air-fuel mixture control system using a combustion pressure sensor for reduction of NOx emission
(3) Electrically controlled EGR system (A/T vehicle) for improvement of fuel consumption in stoichiometric mixture area

3. New Intake Port:

In the lean engine, improvement of combustion was realized by high in-cylinder turbulence such as swirl. To get the turbulence, a new intake port for 4 valves has been developed as shown in Fig. 2. This port consists of a helical port and a straight port which are almost separated. The helical port has a projecting wall for swirl generation. A two-hole type injector is adopted and placed downstream the SCV. With a partial load, the SCV is closed and the intake air flows mainly through the helical port to generate a swirl. A part of the flow is led through the connecting passage between the helical port and straight port and generates a high speed flow for atomization of the fuel on the straight port side, To new intake port adopts the fuel supply system with relatively low swirl ratio to realize lean burn. As a result, the constriction of the intake port can be relaxed to attain high volumetric efficiency when the SCV is closed.

4. Lean Mixture Limit Air-Fuel Ratio Feedback Control with Combustion Pressure Sensor:

The target air-fuel ratio in the feedback control with the lean mixture sensor should be set with a margin on the rich side from the lean mixture limit in consideration of dispersion of the sensor or engine and the weather conditions. Reduction of this margin will enable the NOx emission to be reduced. For this purpose, a new air fuel ratio feedback control system using a combustion pressure sensor has been developed. In this system, air fuel ratio is controlled to maintain the torque fluctuation at the specified level by detecting the lean mixtgure limit or torque fluctuation limit directly from the combustion state. Fig. 3 shows the structure of the combustion pressure

sensor. The combustion pressure is transmitted from the diaphragm to the force detecting device via the ceramic rod and hemisphere. The force detective device converts the pressure into hte voltage by the piezoelectric effect. This signal is out put after amplification by the built-in amplifier.

5. Electrically Controlled EGR System:

The EGR driven by a stepping motor has been adopted for A/T vehicle to improve the fuel consumption in stoichiometric mixture area used in accelaration.

6. Effect of Fuel Consumption Improvement:

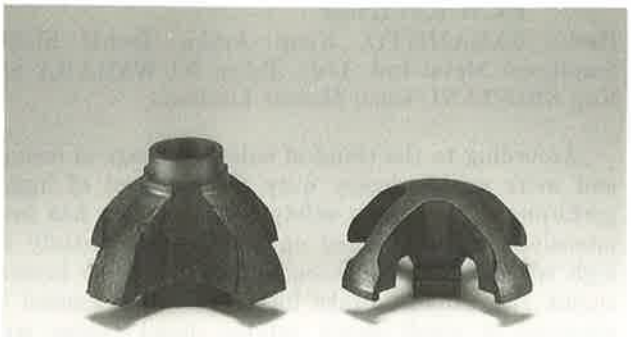
As compared with the convetional 3-way catalyst system engines, the new lean burn engine has been confirmed to bring about improvement of the fuel consumption by 9 to 11%, both in the 10–15 mode and at a constant of 60 km/h while satisfying the NOx regulation standard.

◆ Development of Hemispherical Core Die for Hollow Extruded Shape of Aluminum Alloy by Casting Core Material

Yoshinari OKI, Ryouji TSUNO, Sankyo Aluminium Industries Co., Ltd., Yoshihiro YOSHIDA, Tomokazu YAMASHITA, Toyama Light Metal Industry Co., Ltd., and Yoshiharu KOSAKA, CK Metals, Ltd.

Hollow extruded shape of aluminum alloy, used in building materials, is produced through hot extrusion using a single extrusion press. Among the decisive factors in this production, the die plays a large role. At present primarily a port-hole die is used largely. For small lot production of a wide variety of items, the die has taken on an increased importance. The weight and size of the die has increased and the cost of the die also has increased.

A die which is named hemispherical core die, has been developed for hollow extruded shapes of alminum alloy. The endface of the die is hemispherical on entry side of a billet. The maximum tensile stress appearing around the root of a mandrel of the core is remarkably reduced in comparison with a port-hole die, which results in suppresion of crack initiation. The hemispherical core die is designed by FEM. FEM analysis showed that the core weight and maximum tensile stress around the mandrel of the new type die are respectively lowered to 12% and 26% those of the previous type of die. A hemispherical core, manufactured on the base of the FEM analysis is lightened to 13% and the extrusion pressure is lowered to 96% of the previous type of die.



A near-net shape as cast block.

Machined-finished shape of the hemispherical core die.

The solidification simulation is used for the purpose of predicting the solidification defects and increasing the temperature gradient at the point of tensile stress. The hemispherical cast die with a temperature gradient of more than 3 K/mm has the same high-temperature stress characteristics (according to the tensile test piece, which is cut from the root of a mandrel of the core of the cast die) and demonstrates the same extrusion features as that of forged hemispherical core die.

And adoption of the hemispherical core is found to be effective in reduction of die weight and in moderation of peak tensile stress on the core, which in turn improves the life of the die, in comparison to a conventional port-hole die. The cooling arrangement for unidirectional solidification of nearnet shape cast block is determined through a solidification simulation, which can attain the necessary mechanical properties of cast materials. By machining a hemispherical core die from the nearnet shape cast block, the machining time is shortened by 50%, the machining yield increases 2.6 times and the amount of raw material is reduced by 38% in comparison to a hemispherical core die made from a forged ingot. The displacement during extrusion of the shape of the cast core is less than that of a hemispherical core made from a forged ingot.

◆ A Development of Ultrasonic Motors for Autofocus Lenses

Ichiro OKUMURA, Yutaka MARUYAMA, Jun TAMAI, Takayuki TSUKIMOTO and Akio TSUTA, Canon Inc

1. Abstract

We succeeded in developing two types of ultrasonic motors (A ring-type and a bar-type) for actural use in commercial products. They are incorporated as autofocus drive actuators in SLR (Single Lens Reflex) lenses. This research and development achieved is the world's first application and mass-production of the utrasonic motors.

The ultrasonic motors are new kind of actuators in drive principle and structure, which are completely different from conventional electromagnetic motors. It transforms electric energy into mechanical vibration energy by piezoelectric ceramics and drives its rotor by frictional force.

Main features of the ultrasonic motors are as follows:

(1) Low speed and high torque (So it needs less or no gear trains. Consequently, accurate positioning and silent driving are achieved.)
(2) Good controllability with highly responsive starting and stopping characteristics
(3) Large holding torque without any electric power

2. Ring-type Ultrasonic Motor

The figure shows the structure of ultrasonic motors. The stator of the ring-type motor consists of a metal ring with piezoelectric ceramic ring adhered. The rotor is pressed to one side of the stator. A supporting felt and a cone-shaped disc spring are located on the opposite side of the stator. The rotor is connected to helicoid cylinder with focusing lenses through a rubber plate placed on the rotor.

The electrodes on the piezoelectric ceramic are divided into two groups. All the electrodes, whose length is one half of the vibration wave length, are polarized in alternatively opposite polarity and electrically connected with conductive paint. When a voltage is applied to the electrodes, all of the piezoelectric ceramic strains and deforms the stator ring. Furthermore, large displacement of the stator is obtained by resonance phenomenon when the frequency of the applied voltage is close to the natural frequency of the stator ring. When the two groups of piezoelectric ceramic's electrodes are driven simultaniously with a quarter different phase in space and time, a travelling bending vibration is excited. Elliptic motion, which is obtained by combining normal and tangential vibration, is prouduced at the top of the stator. The tangential vibration is caused by inclination of the neutral plane. It has a difference in phase of a quarter piriod from the normal one.

The rotor pressed to the crest of the travelling vibration, is driven to the opposite direction from the travelling vibration. The velocity of the rotor depends on the tangential velocity of the elliptic motion. Its range is from a few to hundreds milimeters per second. The low velocity and the high frictional froce result in the unique characteristics of the ultrasonic motor, low speed and high torque.

3. Bar-type Ultrasonic Motor

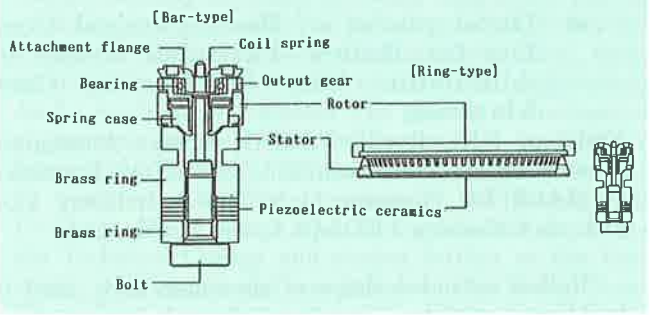
The ring-type ultrasonic motor is adequate as an actuator for lenses because of its hollow shape. Many kinds of motors with different diameter are needed to be designed for various glass lenses. In addition ring shape is disadvantageous in manufacturing and material cost.

The bar-type ultrasonic motor is developed to reduce the production cost. The structure of the motor is shown in the figure. The stator cosists of brass rings, piezoelectric ceramics, and electrode pates. These parts are piled and clamped by a bolt. The bolt has a supporting pin at the top. A rotor, a pressing coil spring, and an output gear are located coaxially. Consequently, it can be assembled completely automaticaly. The cost and weight are reduced to one third of those of the ring-type motor.

	Size/ Weight	No Load Speed (r.p.s)	Maximum Torque (N×m)	Power Consumption (watt)	Maximum Efficiency
Bar-type	ϕ11 × 25 mm/11 gr	16	0.007	1	40%
Ring-type 1	ϕ62 × 10 /26	1.3	0.09	1	35
Ring-typep 2	ϕ77 × 10 /45	0.7	0.16	1	35
Ring-type 3	ϕ73 × 11 /45	0.7	0.13	1	35
DC Motor	ϕ12 × 15 / 5	340	0.0016	4	45

Every ultrasomic motors have low speed and high torque compared with the conventional DC motor. This characteristics contribute to silent and quick response of the autofocus lenses.

Cross Sections of Ultrasonic Motors



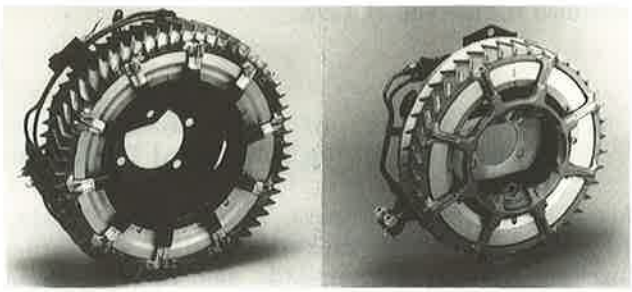
5. Summary

In this article, two types of ultrasomic motors only for autofocus lenses are explained. This case is the start of the ultrasomic motor's application. Other types of ultrasonic motors with different shape and size will be realized and wil be applied to large variety of devices such as compact information devices in the near future.

◆ Permanent Magnet Type Compact ECB Retarder

Haruo SAKAMOTO, Kenji Araki, Toshio SUZU, Sumitomo Metal Ind. Ltd., Tohru KUWAHARA and Kōji SHINTANI, Isuzu Motors Limited

According to the trend of enlarged usage of heavier and more speedy heavy duty trucks, need of higher performance and more safety brake system has been intensively desired. Load on wheel brake mainly for high speed trucks has been increased due to lowered engine and exhaust brake force, which are caused by adoption of small swept volume diesel engine with turbo & cooler coupled with fast ratio final gear for fuel economy of heavy duty trucks. Together with such a circumstance, load on wheel brake is also



(a) 10 tonnage truck retarder (b) 4 tonnage truck retarder

Fig. 1 Permanent Magnet Type Compact ECB Retarder

increased by reduced rolling resistance of tire and aerodynamic drag force.

In the past wheel brake size was increased (mainly width of brake drum was increased) to remedy the situation. However, because of space limitation further increase of width is hard to obtain. As a result, numerous researches have been conducted such as material change of lining, improvement of cooling performance of brake drum, adoption of retarder and so on. Among them retarder was admitted to be the best choice from the preliminal study.

The conventional electro-magnetic or hydrodynamic retarders have had some technical matters to be solved. Heavy weight, expensive, space of installation, and need of reinforcement for car body due to heavy weight are such problems, and, therefore, retarders have not been so popular in Japan.

Under the circumstances mentioned above, Sumitomo Metal Industries, Ltd. and Isuzu Motor Ltd. have worked a joint project of retarder and succeeded for the first time in the world in developing epoch-making eddy-current retarders featuring light weight, compact and easy installation by using the most powerful Nd-Fe-B base permanent magnets.

This new type of retarder gives the improvement of safety at the time of brake application while running at high speed based on test results of excessive way on mountainous area. This retarder can be incorporated to conventional brake system as an integral part, and for improvement of brake safety the retarder is to be used mainly at high speed, while conventional wheel brake is to be used at low speed running or in an emergency.

The sales of this retarder was inaugurated in Jan., 1991 for the type for 10 tonnage trucks and in June, 1992 for the one for 4 tonnage trucks. At this moment the amount of total sales is 2,000 sets, which have received highly good reputation from customers. The examples are very comfort while driving, less weariness, no goods crumble, and less lining wear. One user estimated that the expenditure for buying the retarder compensated by the maintenance cost of linings is only 14 months. Rather than such an economical effect by this retarder the newly developped retarder is expected to raise the safety in trucks and busses service, and improve the circumstance of driver' work.

The figure attached shows the outlook of the ratarders.

◆ Drop Shaft Facility

Sadao TAKAHASHI, Ishikawajima-Harima Heavy Industries Co., Ltd., Mitsuo TAKAHASHI, New Energy and Industrial Technology Development Organization (NEDO), Shozo SHIODA, Japan Microgravity Center (JAMIC), Koji OGAWA, Toshiba Corporation, and Hirosato INDO, Mitsui Engineering & Shipbuilding Co., Ltd.

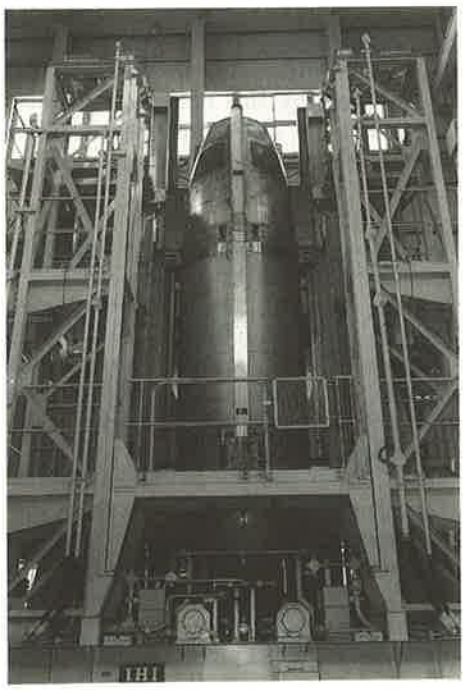
1. Introduction

The world's deepest drop shaft facility for microgravity experiment using the former coal mine shaft of 710m depth (free fall zone of 490m and braking zone of 220m) was constructed at Kamisunagawa, Hokkaido, Japan in 1991. Unlike similar facilities in the U.S. and Europe, which have a vacuum shaft, an atomspheric shaft have been adopted in view of the exceptional depth of the shaft. The rocket shaped sapsule in which experimental devices are loaded is falling through the drop shaft and performs microgravity of 1×10^{-5}G for 10 seconds.

2. Basic performance

Basic performance of this facility is as follows;

(1) Microgravity time : 10 seconds
(2) Microgravity level : approximately 1×10^{-5}G
(3) Deceleration at braking : 8G
(4) Maximum payload weight : 1000 kg
(5) Real time data transmission between falling capsule and control room including colour image.



Outside view of capsule

3. Microgravity production

The rocket shaped capsule (1.8m in diameter, 8m in length and 5.7 ton in max. weight) is a welded structure of aluminum alloy. A double capsule arrangement has been adopted. Microgravity is created by floating the inner capsule in which experimental devices are loaded, in the vacuum space of the outer capsule while falling. The inner capsule is released a moment before the outer capsule. The inner capsule must not come in touch with the outer capsule for 10 seconds. Since the gap between two capsules is very narrow, and since such a contact can occur when the inner capsule is released with an initial velocity, the motion of the inner capsule (except that in the direction of gravity pull) is controlled by five pairs of electromagnetic bearings mounted inside the outer capsule during 0.4 second just after released.

Two vertical steel rails are oppositely installed in the drop shaft. Upon released, the outer capsule is magnetically guided in its fall between rails. The attraction type electromagnetic leviation method has been chosen for this magnetic guide. The motion of the outer capsule is controlled in five axes (excepting downward translation) with six pairs of electromagnets and the outer capsule is falling through the free fall zone of 490m without touching the rails.

The atmospheric drag exerted on the outer capsule while falling is counteracted by the compressed air jet thruster. The vertical distance between two capsules is detected by a sensor mounted on the outer capsule. The thruster jets are controlled by feedback loop using the signal of the sensor, to maintain the inner capsule within a prescribed range of distance, and the free fall condition of the inner capsule is kept.

4. Laser communication

An optical communication system is installed. In this system, laser light is transmitted through the air between the capsule and the bottom of the shaft. The result of experiments in the falling capsule are observed in real time by this optical transmitter. The command data can be also transmitted in real time from the control room to the falling capsule by this system.

5. Braking and recovery of the capsule

After free fall of 10 seconds, the capsule plunges into the braking tube (1.9m in inner-diameter and 200m in length) with the falling speed of 98 m/s. Since the bottom of the braking tube is closed, air inside the tube is compressed and the capsule is softly decelerated. Fourteen sets of mechanical braking shoes are installed at the bottom part of the braking tube and catch the brake fin of the capsule. Capsule recovering equipment is hanged down from the top of the shaft by wire rope and the capsule is recovered to the ground in tens of minutes after released.

6. Concluding remarks

This drop shaft facility is operated by Japan Microgravity Center and more than 300 times of drops for microgravity experiment has been successfully performed till the end of 1992.

◆ Development of Precise Heating Technology Using a Vertical Diffusion Furnace

Shigeki HIRASAWA, Tetsuya TAKAGAKI, Hitachi, Ltd., Masuo SUZUKI, Kokusai Electric Co., Ltd., Shigekazu KIEDA, Hitachi, Ltd., and Takuji TORII, Hitachi Koki Co.

In semiconductor device processing, a row of regularly spaced silicon wafers is placed in a cylindrical electric furnace and heated to 1000°C for several tens of minutes. This is done to cause diffusion of inpurity atoms (arsenic, boron, or phoshorus) in the silicon substrate and oxidation of the substrate. Recent advances in VLSI technology require drastic progress in uniform heating and clean heating of wafers.

We developed a precise wafer heating technology using a vertical diffusion furnace through research using thermal computer simulation, flow visulaization and radiation thermometry. Figure 1 shows an outside view of the new diffusion furnace.

Hitherto, horizontal furnaces have been used, but heating uniformity has been limited. This is because the entrance to these furnaces is in the horizontal side, and the air coming in with the inserted wafers cools the lower part of the furnace. It also carries dust that dirties the interior of the furnace. Based on results of flow visualization experiments, the entrance to the new vertical furnace is placed at the lower end. Also, preheated process gas is supplied to the upper part of the furnace and flows down inside.

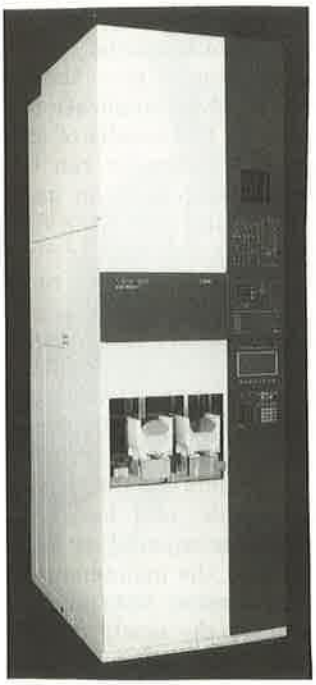


Fig. 1 Outside View of Vertical Diffusion Furnace

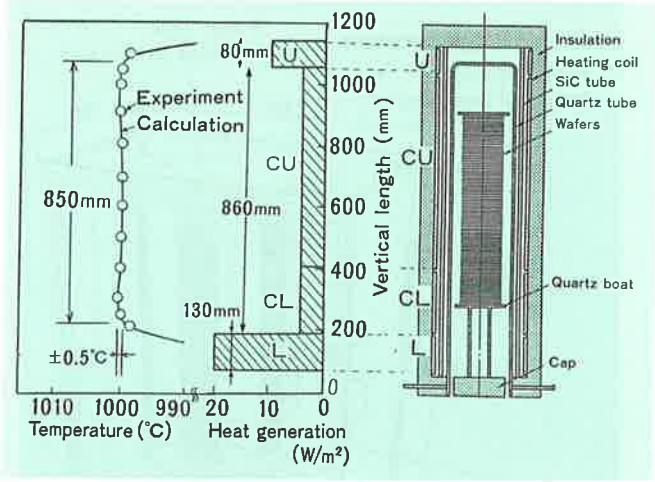


Fig. 2 Steady-State Temperature Distribution in Furnace

Consequently, the concentration of air coming in with inserted wafers is 15 ppm, which is less than 1/1000 of the value for conventional horizontal furnaces. Uniform heating and clean heating are therefore possible.

Figure 2 shows the steady-state axial temperature distribution in the furnace and the heating power generated in each of the four zones of the heater. The temerature distribution in the furnace is uniform to within ± 0.5°C due to the opitimized design of the furnace and optimal heating power control. The range of temperature variation is 1/10 of that with horizontal furnaces. The length of the furnace is 1.4 times the length of the uniform temperature region, which is 60% of that in horizontal furnaces. Miniaturization of the furnace and energy savings have thus been achieved.

When wafers are inserted into the furnace, the heating power is controlled dynamically. Using optimal dynamic control, all wafers reach the target temperature rapidly and there is no overshooting. Consequently, all wafers are heated uniformly.

A new radiation thermometry technique has been developed. Using an optical guide consisting of two quartz prisms, the thermal radiation from a wafer being measured is reflected and brought to the outside of the furnace, where it reaches as pyrometer. A measuring wavelength of 0.9 μm is used because at this wavelength silicon wafers are opaque and their emissivity does not depend on temperature. This technique is accurate to within 2°C. Methods of temperature measurement and heating power control are key technologies in factory automation of semiconductor manufacturing.

The new vertical diffusion furnaces are a great step forward in uniform heating and clean heating of wafers, and are used in semiconductor manufacturing equipment for 4- and 16-Mb DRAM (Dynamic Random Access Memory) chips all over the world. The new technology has promoted integration of IC and minute manufacturing processes.

◆ Development of the Optical Mass Storage System (Optical MSS)

Ichiro YAMADA, Nippon Telegraph and Telephone Corporation, Masateru SASAKI, Fujitsu Limited, Akinori WATABE, Kikuji KATOH and Kazumasa KANEKO, Nippon Telegraph and Telephone Corporation

1. Developmental background

Optical disk drives, with their extremely high recording densities, are promising for the next-generation memory device for image database files and high-speed backup files. However, conventional optical disk drives using 130-mm ISO standard magneto-optical (MO) disks have data transfer rate during recording of only 0.2 to 0.3 MB/s, because they need three disk rotations for erasing, writing, and read-verifying to record data. Furthermore, the disk rotation speed is fixed at 1800–2400 rpm. The second-generation drives must have overwriting, instantaneous read-verifying and faster disk rotation.

NTT and Fujitsu have developed a three-beam optical disk drive with a data transfer rate of 2.1 MB/s, and used it to build a high-speed, large-capacity Optical Mass Storage System (Optical MSS) with a maximum capacity of 1 TB.

2. Drive and library technologies

2.1 Three-beam magneto-optical disk dirve

(1) Two-head three-beam drive configuration

We achieved overwriting and instantaneous read-verification with 130-mm ISO standard MO disks, by using a two-head three-beam drive configuration, as shown in Figure 1. One optical head is for erasing and the other is for writing and reading. The write/read head uses two separate beams with different wavelengths. The 830-nm write beam and the 780-nm read beam are combined at a dichroic mirror, and focused onto the disk. The position of the read

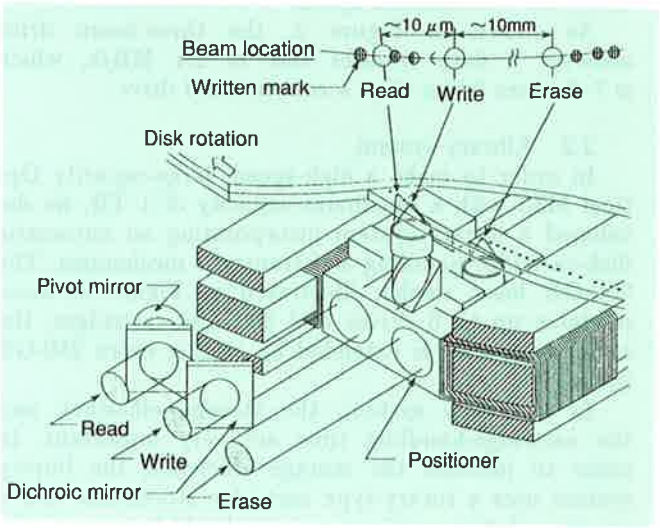


Fig. 1 Two-Head Three-Beam Drive Configuration

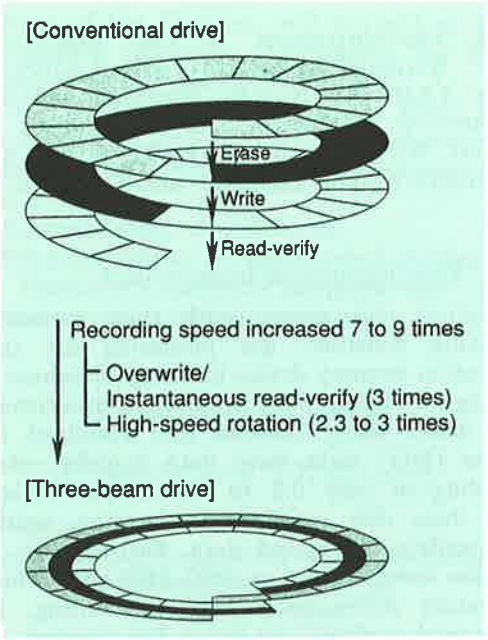


Fig. 2 Three-Beam Recording Sequence

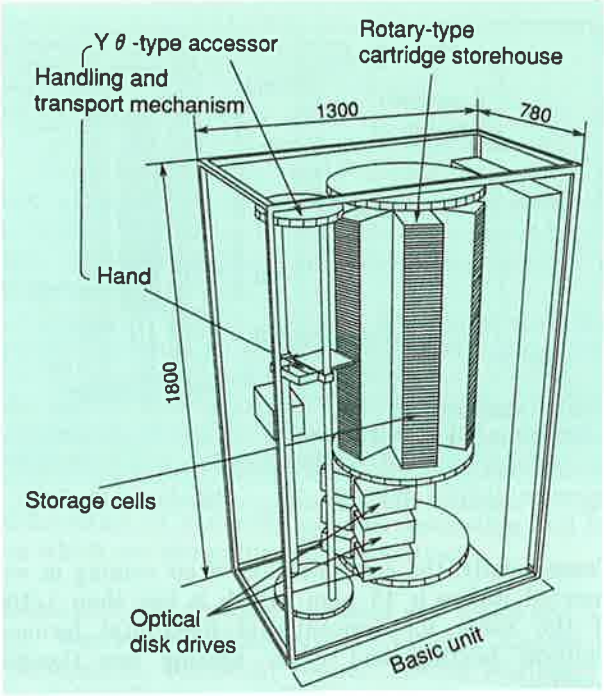


Fig. 3 Library System Configuration of 250-GB Basic Model

beam relative to the write beam is controlled by a pivot mirror.

Erasing, writing, and read-verifying for recording are carried out simultaneously after the three beams have been positioned onto the same track by lens actuators.

(2) High-speed lens actuator

The disk rotation speed was increased by improving the stiffness and power consumption of the lens actuator by using an aspherical plastic objective lens and redesigning the moving aprts, and increasing the higher-order mechanical resonances to 35 kHz in focusing, and 45 kHz in tracking. As a result, the gain-crossover frequency for focusing was increased to more than 5 kHz, and for tracking to more than 6 kHz, so the focusing and tracking capabilities are good enough to handle a commercial 130-mm standard MO disk rotating at 5400 rpm, which is 2.3–3 times the conventional speed.

As shown in Figure 2, the three-beam drive achieves a data transfer rate of 2.1 MB/s, which is 7–9 times faster than a conventional drive.

2.2 Library system

In order to make a high-speed, large-capacity Optical MSS with a maximum capacity of 1 TB, we developed a library system incorporating an automatic disk-cartridge handling and transport mechanism. The 250-GB basic model, illustrated in Figure 3, accomodates up to 6 drives and 390 disk-cartridges; the storage capacity is extended by adding extra 250-GB modules.

In a library system, the storage efficiency and the cartridge-handling time are very important. In order to increase the storage efficiency, the library system uses a rotary-type cartridge storehouse and a precise relative-positioning control which corrects the two-dimensional hand position relative to the required storage cell or drive. As a result, the storage efficiency of 250 GB/m^2 was achieved, which is more than 4 times that of a magnetic tape MSS. The 250-GB basic model occupies a floor-space of only 1m^2.

An average cartridge-handling time of 5 seconds was achieved by introducing a disturbance observer to estimate the solid friction as well as the velocity of the accessor or the cartridge storehouse.

3. Conclusion

The Optical MSS meets the demands of a multimedia database file. The system should be particularly useful for newspaper and other publishing companies for storing, referencing and processing very large documents and color negatives. Construction companies could use the system to store blueprints and hospitals to store X-rays. The Optical MSS is also suitable for high-speed backup instead of a magnetic tape MSS, in large computer systems.

Table 1 Optical MSS Specifications

Storage capacity		250–1000 GB
Number of drives		2–11
Average cartridge-handling time		5s
Storage efficiency		250 GB/m^2
Drive	Data transfer rate	2.1 MB/s
	Average access time	45 ms
Medium	Class	130-mm ISO standard MO cartridge
	Storage capacity	650 MB (Total for both sides)

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