# JSME AWARDS IN 1996

## JSME Medal for Distinguished Engineers

Katsutoshi Tanaka, Toshiba Machine Co., Ltd.
for Technical Development of Ultra-Precision Components and the Applied Research

Masahiko Nakada, Toyota Motor Corporation
for Study on Reliability Improvement of Exhaust Emission Controlled Engines

## JSME Medal for Outstanding Paper

Analysis of Neural Network Recognition Characteristics of 6 Basic Facial Expressions
Hiroshi Kobayashi, University of Zurich and Fumio Hara, Science University of Tokyo

Effects of Shock Waves on Living Tissue Cell (Red Blood Cell) (Damage of Red Blood Cell and Mathematical Analysis of Deformation Model Using Spherical Shell Filled with Liquid
Masaaki Tamagawa, Kyoto University, Keiichiroh Yoshida, Denso Co., Ltd. and Teruaki Akamatsu, Kyoto University

Solution to Domain Optimization Problems
Hideyuki Azegami, Toyohashi University of Technology

Development of System Resolving All Stress Components in Thermoelastic Stress Analysis
Yukitaka Murakami, Kyushu University, Masaaki Yoshimura, JOEL CREATIVE Co., Ltd.

Pulmonary Blood Flow Model Coupled with Breathing Dynamics
Shigeo Wada, Hokkaido University, Masao Tanaka, Osaka University, Takeshi Horikawa, Hiroshi Nakamura, Ryukoku University, Kazushi Tanaka, Ministry of Construction and Hajime Togari, Nagoya City University Medical School

Group Combustion Behavior of Premixed Spray Streams and Group Combustion Number
Fumiteru Akamatsu, Masashi Katsuki, Yukio Mizutani, Shohji Tsushima and Yong-Dae Cho, Osaka University

Molecular Study of Evaporation and Condensation of an Associating Liquid
(Shock-Tube Experiment and Molecular Dynamics Simulation)
Shigeo Fujikawa, Toyama Prefectural University, Mitsuhiro Matsumoto, Nagoya University, Masanao Kotani, Toyama Prefectural University, and Hiroshi Sato, PS Co., Ltd.

Advanced Thermal Insulation Layers with Row of Heat Pipes
(2nd Report, Experimental Results)
Takashi Masuoka, Hirofumi Tanigawa, Takaharu Tsuruta, Kyushu Institute of Technology and Hiroshi Izaki, Nippon Steel Corporation

Small-Amplitude Oscillations of Encapsulated Liquid Drop Interfaces
Satoyuki Kawano, Tohoku University, Hiroyuki Hashimoto, Ebara Research Co., Ltd., Akio Ihara, Yamaguchi University and Takahiro Azima, Ebara Research Co., Ltd.

Bursting Phenomena in a Turbulent Square-Duct Flow
(Generation Mechanisms of Turbulent Wall Skiw Friction)
Genta Kawahara, Kyozo Ayukawa, Junji Ochi, Ehime University and Fumihiro Ono, Ministry of Transport

Research for Identification of Modal Parameters in Frequency Domain
(2nd Report, Introduction of Nonlinear Least Squares Method and Optimization Method)
Mitsuo Iwahara, Isuzu Advanced Engineering Center, Ltd. and Akio Nagamatsu, Tokyo Institute of Technology

Three-Dimensional Sloshing Analysis in a Rectangular Tank Subjected to Pitching Excitation
Koji Kimura, Hiroki Takahara and Hideo Ogura, Tokyo Institute of Technology

Discrete Time Sliding Mode Control of Zero Power Magnetic Bearing System
Kenzo Nonami, Chiba University Ken'ichi Nishina, Olympus Optical Co., Ltd. and Mitsuru Saito, Nichio Jiden Institute

Periodic Thermal Deformation of Large Seal Ring
Norio Oishi, Kanazawa Institute of Technology and Masato Tanaka, The University of Tokyo

Precision Injection Molding Process Assisted by Infrared Radiation
(Quality Improvement of Polymer Products by $CO_2$ Laser-Assisted Injection Molding Process)
Yasuo Kurosaki, Isao Satoh, Takushi Saito, Tokyo Institute of Technology

*JSME MEDAL for New Technology*

## ◆ DEVELOPMENT AND IMPLEMENTATION OF NUCLEAR POWER STATION WITH ADVANCED BOILING WATER REACTOR (ABWR)

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Toshiki Miyamoto, Toshiba Corporation, Tsutomu Hayashi, Hitachi Ltd. and Steven A. Hucik, GE Nuclrar Energy

### 1. Abstract

The ABWR (Advanced Boiling Water Reactor), the world's most advanced light water reactor and generating electric power output at the level of 1300MWe, was selected for the joint development efforts of the government and industry as part of the third phase of the MITI Improvement and Standardization Program. The world's first ABWR, Kashiwazaki Kariwa Nuclear Power Generation Station Unit No. 6, entered commercial service in 1996.

### 2. Content of Technology

The technical features of the ABWR, as illustrated in Figure 1, include its large power generation capacity, increased plant efficiency, improved core internals, reactor internal pump, fine motion control rod drive, three complete divisions of Emergency Core Cooling Systems (ECCS), reinforced concrete containment vessel, and advanced control and instrument systems. Details regarding some of these key features are provided as follows:

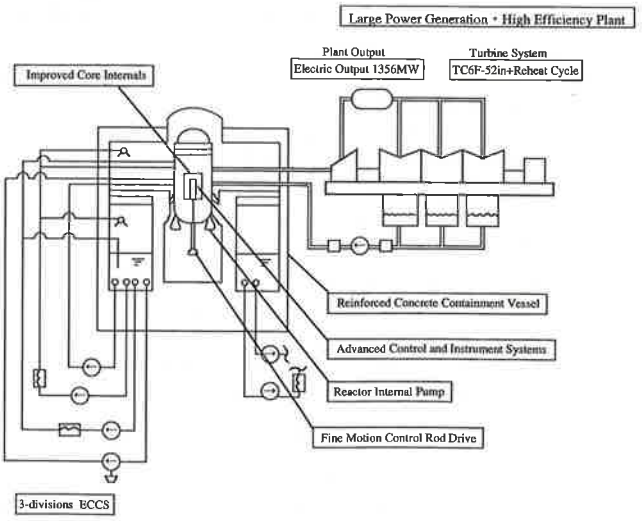


**Fig. 1** Technical Features of ABWR

1) Reactor Internal Pump (RIP)

To replace the external loop reactor recirculation system, which uses large bore piping and conventional large capacity pumps, an internal pump system has been adopted in which smaller capacity pumps are internally installed at the bottom of reactor pressure vessel (RPV). As a result, the following merits are achieved.

- All large pipe nozzles connected to the RPV below the top level of active core region have been eliminated. Therefore, the consequences of postulated Loss of Coolant Accident pipe breaks has been significantly improved and increased safety margin is achieved with smaller capacity ECCS.
- Elimination of the external loop piping reduces the number of welds which must be periodically subjected to In-Service Inspection (ISI) and reduces the levels of personnel radiation exposure.
- Elimination of the external loop piping allows for a more compact reactor containment vessel and reactor building configuration which has a lower overall center of gravity and improved seismic capability.

2) Fine Motion Control Rod Drive (FMCRD)

The ABWR adopted the FMCRD, replacing the traditional hydraulic control rod drive mechanism. The FMCRD utilizes an electric motor for normal control rod positioning with fine pitch control and hydraulic pressure for emergency (scram) insertion.

3) Reinforced Concrete Containment Vessel (RCCV)

In conventional BWR plants, a self-standing steel fabricated structure has been used as the primary containment vessel. However, the ABWR has adopted the RCCV in which the concrete walls of the primary containment structure are integrated with the reactor building so that a shorter construction schedule and compact building size are achieved.

4) Advanced Control and Instrument Systems and Man-Machine Interface

In previous BWR plants, digital systems have been adopted for process monitoring and control systems such as feedwater control, reactor recirculation control and turbine control systems and radiation monitoring systems. For ABWR, in addition to those digitalized process monitoring and control systems, the application of digital systems has been expanded to include safety systems as well. Furthermore, optical multiplex data transmission systems are adopted to inter-connect the digital signals so that centralized monitoring and control system is achieved with the introduction of an advanced control room panel configuration.

The ABWR control room man-machine interface includes a main control console and a large display panel which provides an overall summary of the status of plant systems and equipment. Fixed mimic displays and variable large screen displays on the large display panel are able to supply the overall plant status information to the entire control room staff so that good communication of key plant parameters and equipment status may be assured.

### 3. Summary

The ABWR has achieved improved safety, improved plant operability, reduction of occupational radiation exposure, improved construction schedule and economy through application of the technology and designs as reported above.

## ◆ DEVELOPMENT AND CONSTRUCTION OF A LARGE-CAPACITY LNG INGROUND STORAGE TANK

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Takao Mikoshiba, Ishikawajima-Harima Heavy Industries Co., Ltd., Kiyokazu Kawai, Mitsubishi Heavy Industries, Ltd., Motoo Yamaga, NKK Corporation and Yukihiro Hirata, Kawasaki Heavy Industries, Ltd.

### 1. Overview

The growing consumption of Liquefied Natural Gas (LNG) as a fundamental energy source in Japan has raised demands for increasingly larger tanks which would meet the requirements of effective utilization of land and reduced construction costs.

In order to assure the safe storage of LNG, which is a flammable liquid at a very low temperature (−162°C), efforts toward technological development were expended in various aspects of mechanical structures, involving membrane structures, insulation, etc. and civil engineering factors corresponding to the increasing depth of liquid storage and in increasing the capacity of inground LNG storage tanks were also researched.

Our efforts resulted in the successful 1982 development and construction of a 130,000 kl storage tank, the largest of its kind in the world at that time, and in 1995 of a 200,000 kl storage tank (Fig. 1), currently the largest in the world.

### 2. Technology

As shown in Fig. 1, the inground storage tank consists of membranes made of 2 mm thick SUS304 stainless steel for a liquid and gas impermeable structure; insulation of rigid polyurethane foam (PUF) to be subject to liquid pressure, and a concrete wall serving as a pressure-resistant member. The maximum storage liquid level is below the surrounding ground level. The main technical aspects of our development efforts expended for increasing storage tank capacity are described in the following.

(1) A Membrane Structure Adapted to Increased Capacity Liquid Level
A larger storage tank is subject to greater liquid pressure than its conventional counterpart. The membranes, and particularly the corrugations, are subject to greater stress. To deal with this problem, a design system based mainly on low-cyclic fatigue design (a corrugation form resistant to unstable collapse) and a partition behavior type of membrane were developed.

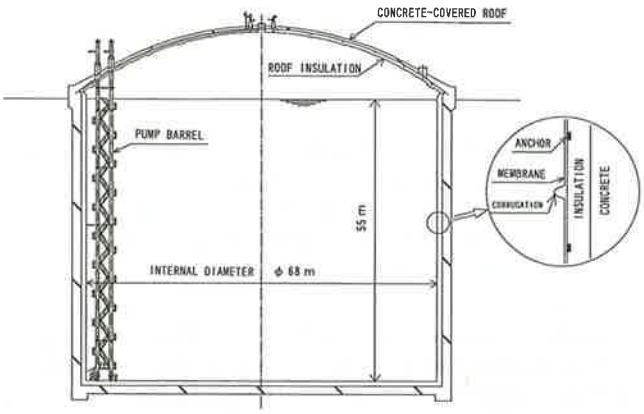


**Fig. 1** 200,000 kl LNG Inground Tank Structure

(2) An Insulation Material Adapted to Increased Capacity Liquid Level
A CFC gas foaming agent was previously used in making rigid polyurethane foam for insulation. In view of the restrictions on the use of CFC, we used a foaming agent of HCFC141b instead and also developed a high-performance type of PUF having greater compression resistance and creep strength to meet the increasing pressure of the liquid. A design procedure involving creep strength evaluation was established.

(3) A High Performance Auto-Sensing Welding Machine for Membranes Speed was an important factor for automatic welding that had to be met in welding membranes, which consist of many thin sheets which have corrugated and other complex surfaces. We developed a new rotary TIG automatic welding machine to be used in place of the conventional pulse TIG welding process. The new welding machine employs a unique groove tracing mechanism using the arcs themselves as sensors, thereby meeting the requirements of high-speed welding, machine weight reduction, and downsizing.

(4) A High Performance Instrument for Measuring Insulation Panel Unevenness
We developed a laser displacement device, equipped with an automatic instrument, aimed at measuring accurately and efficiently the surface level difference between the neighboring insulation panels, which has a negative influence on the membrane's resistance to fatigue.

(5) Development of a New Roof Structure
a. Inner Roof Insulation Structure
An internal roof insulation structure involving multi-layer insulation to be built inside the roof was developed to ensure increased safety against sloshing during earthquakes. For developing this system, we did refrigeration examination with an actual size model, as well as examining insulation performance with an infrared camera
b. Concrete-Covered Roof Design
A concrete-covered roof design was also developed to provide protection against external

impact load, etc. in case the tanks are located relatively close to urban areas.

### 3. Conclusions

As we have successfully achieved the development of large-capacity tanks, it is now possible to store larger volumes of LNG in a limited storage space. Construction costs have been reduced, along with improvement in the safety of the tanks as a result of various technical developments.

LNG inground storage technology, originally developed in Japan, has been so highly evaluated both domestically and abroad that it has become increasingly applied to construction sites overseas, for example in Korea and Taiwan. Thus this technology has also been contributing to the overseas energy industry as well.

## ◆ DEVELOPMENT OF GASOLINE DIRECT INJECTION (GDI) ENGINE

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The major problems of the various mixture formation concepts for direct injection gasoline engines that have been proposed up to the present were caused by the difficulties of preparing the mixture with adequate strength at spark plug in wide range of engine operating conditions. Novel combustion control technologies proposed by Mitsubishi is one of the solution for these problems.

This concept is referred to as wide spacing, that is, the distance between the fuel spray and the spark plug was wide spread. Fuel spray is directed to the piston surface and it is reflected toward the spark plug after impinging on the spherical piston cavity. By adopting this concept, the interval between the end of injection and the spark ignition is long enough for promoting the fuel vaporization and the mixing with the surrounding air can be realized. Consequently, problems of the previous narrow spacing concepts caused by the liquid fuel or the over-rich mixture around the spark plug can be solved. The principal factor controlling the mixing is the fuel spray or gaseous mixture reflection on the cavity wall which is subject to the fuel spray momentum. Unlike the methods controlling the mixing by swirl, it is hardly affected by the engine speed. This guarantees the adequate mixing in wide speed range.

Fundamental technologies developed to realize the adequate mixing control by wide spacing concept are illustrated in Figure 1. The following new technologies are employed ;

(1) upright straight intake ports generating an intense reverse tumble, that is, a tumble with a rotational direction opposite to that of the tumble generated by conventional horizontal intake ports,
(2) a spherical compact piston cavity,
(3) an electromagnetic swirl injector.

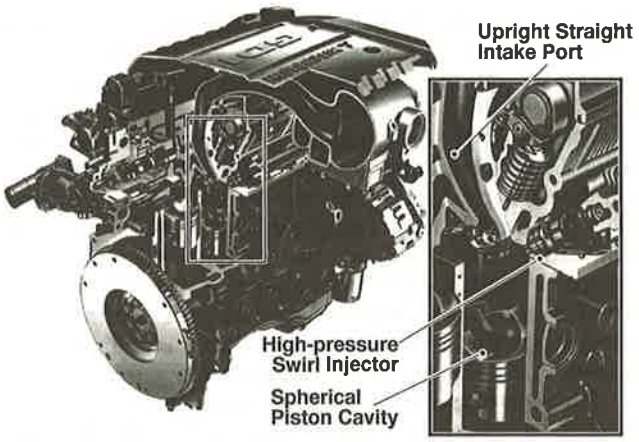


**Fig. 1** Technologies adopted for Mitsubishi GDI engine

Mitsubishi Motors Corporation has proposed the concept of the premixed lean burn engine known as Barrel-Stratification. In that concept, tumble with the direction flowing the piston surface from the exhaust to the intake side was adopted. In order to intensify the tumble in this direction, intake port flow passing through the upper area of the intake port and the flow directed to the cylinder liner at the exhaust side was enhanced. In the case of the direct injection engine, the authors considered that the fuel injectors should not be located at the high temperature exhaust side and that it would be preferable to locate the spark plug at the center of the cylinder in order to realize improved combustion with lower heat loss. As a result, the location chosen for the injector was the intake side. Since the fuel spray is injected on the intake side, the piston cavity should also be located on the intake side. This cavity attenuates the tumble in the conventional direction. Therefore, the authors adopted a tumble having a reverse direction. Reverse tumble was also effective in moving the gaseous fuel toward the spark plug after the impingement on the piston cavity. To realize the reverse tumble, upright straight intake ports were selected. Because the upright straight intake port had the inherent characteristics of the higher flow coefficient, the engine performance at the highest engine speed range was improved. This configuration was also effective in preparing the space in the cylinder head to locate the injector. If the conventional horizontal intake port configuration was selected, it would be difficult to direct the fuel spray towards the piston cavity because the angle between the injector and the piston surface would be determined by availability of space under the horizontal intake port.

A spherical combustion chamber was designed so as to capture the fuel spray and the gaseous fuel and to direct the reflected gaseous mixture to the spark plug. Spark plug was located at the periphery of the combustion chamber. The air-fuel mixture and

the flame should propagate to the center of spherical chamber where the large amount of air exists. This was realized by the intense squish flow generated by the squish area on the exhaust side. During the later stage of combustion, reverse squish flow propagates the flame to the exhaust side. The wall of the spherical bowl at the exhaust side changes the downward liner side air flow to an upward flow after impinging on the piston. Therefore this design is appropriate for enhancing reverse tumble. Furthermore, the shape of the bowl is suitable for preserving the rotational momentum of the reverse tumble until the end of the compression stroke.

An electromagnetic swirl injector realized the atomization, controlled penetration and controlled dispersion of the fuel spray.

Adopting these technologies, GDI (Gasoline Direct Injection) engine is developed. At partial loads, fuel economy improvement exceeding 30% is realized. At higher loads, since air cooling by the latent heat of vaporization increases volumetric efficiency and reduces the octane number requirement, a high compression ratio of 12 to 1 can be adopted. As a result, 10% increase in performance is realized. NOx emission had been considered as one of the most significant issues of lean burn engines. This problem is solved by using the inherent characteristics of stratified combustion of high EGR tolerance and by the newly developed lean-NOx catalyst.

After introducing this engine into market, world wide automotive industry recognized the potential and the feasibility of the gasoline direct injection engines as a future power plant, and accelerated the development work for the practical application of this promising technology.

## ◆ DEVELOPMENT OF 4, 5, 6-CYLINDER DIESEL ENGINES WITH THE SAME CYLINDER BORE AND STROKE

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### 1. Introduction

Diesel engines are widely used in commercial vehicles due to their good fuel economy and durability. Recent growing interest in urban air pollution and spreading expressway require reduced exhaust emission and improved performance and fuel economy.

### 2. Technical Details

To meet the above requirements, the new J-series diesel engines have been developed. This series of engines consists of eight models with the same bore and stroke, which include 4, 5 and 6-cylinder, naturally aspirated (NA) and turbo charged and inter-cooled (TI) models as shown in Table 1. They use many common components machined and assembled in the same production line, resulting in efficient production and cost reduction.

**Table 1.** Specification of the J-series Engines

| Type | J08C | | | | | J07C | J05C | |
|---|---|---|---|---|---|---|---|---|
| | JT-Ⅱ | JT-Ⅰ | J-Ⅱ | J-Ⅰ | J-ⅠA | | | |
| Cylinder No. | 6 | | | | | 5 | 4 | |
| Aspiration | TI | | NA | | | | TI | NA |
| Bore × Stroke (mm) | 114 × 130 | | | | | | | |
| Displacement (cc) | 7961 | | | | | 6634 | 5307 | |
| Max. Output (kW/rpm) | 191 /2700 | 173 /2700 | 158 /2900 | 147 /2900 | 147 /2900 | 125 /2900 | 129 /2700 | 107 /2900 |
| Max. Torque (Nm/rpm) | 745 /1600 | 706 /1600 | 559 /1700 | 530 /1700 | 530 /1700 | 451 /1700 | 490 /1600 | 373 /1700 |
| B.S.F.C. (g/kWh/rpm) | 192 /1400 | 190 /1400 | 205 /1300 | 205 /1300 | 211 /1000 | 207 /1300 | 196 /1400 | 208 /1300 |
| Fuel Injection System | Pump-Line-Nozzle | | | | Common -Rail | Pump-Line-Nozzle | | |

The engines have 4 valve per cylinder with two intake ports and an over head camshaft (OHC). The port shapes are optimized for the best air flow. The 4-valve system enabled centered nozzles and combustion chambers resulting in uniform fuel sprays and combustion. These have reduced the maximum combustion temperature and hence NOx, smoke, and PM emissions. Among the six cylinder models, one is equipped with a fully-electronically controlled Common-Rail fuel injection system. This enables reduced engine idling noise and vibration as well as NOx emissions, by optimally controlling fuel injection characteristics including pilot injection according to engine speeds and loading conditions. This model has been classified as the Official Low Emission Vehicle of Tokyo. In addition, with the applications of a 4-valve system, a newly designed turbo charger and roller rocker arms, engine pumping and friction losses are reduced which results in improved fuel economy and power output.

By the thorough use of a computer database and taking the advantages of being the same bore and stroke, the eight models have been developed in about three years while conventionally two years would be necessary for just one model. The new management of design reduced the development cost by 40 to 50% and the number of components by 35%. Using common components not only increased production, but also reduced development and costs.

The main components of all models are machined and assembled in the common production facilities without machine rearrangements, regardless of the number of cylinders. This has resulted in 15 to 20% reduction in plant and equipment investment and 15 to 20% improvement in assemble time. Also, production quality can be easily maintained due to reduced machine rearrangements. Future design modification in specific models can easily be extended to all models.

### 3. Conclusion

Hino has developed new J-series medium-duty diesel engines for trucks and buses. Power, torque and fuel economy have been enhanced, the exhaust emissions and cost have been reduced. This series of engines has a high potential to meet various future demands from markets.

## ◆ DEVELOPMENT OF A VENTILATED SOUND INSULATING PANEL STRUCTURE

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### 1. Introduction

When the motor vehicles are being accelerated, there is a significant increase in the level of exterior noise. This is largely due to the increased level of noise produced by the high revolution speed of the engine. For the case of a vehicle with a diesel-engine which has high noise level in itself, an under-cover is attached at the bottom of the engine compartment to enclose the engine for noise reduction. However, the under-cover is imposed restriction in its area, because of the heat generated by the engine must escape from the engine compartment. A trade-off between the under-cover's capacity for allowing heat to escape and its sound-insulating capability is the key design factor. Similar contradictory problems exist in other industrial fields as well.

As a means of addressing this problem, we have developed a new panel structure. It makes use of the acoustic anti-resonance of transmitted sounds to provide sound insulation while simultaneously allowing heat to escape through ventilation holes.

### 2. Structure and Sound Insulation Principle

With the aim of developing an engine under-cover which can effectively insulate sound while also allowing heat to escape, we constructed the panel structure shown in Fig. 1a. The panel structure comprises two parallel plates connected to each other, and has two different types of holes with different vibration characteristics. One type, ventilation hole A, is shaped as a pierced hole and forms air mass in it. The other, ventilation hole B, forms an air vibration system of two degrees of freedom based on air mass in the ports of plates and an air spring in the space between two plates.

With this type of panel structure, transmitted sound passing through the air vibration system of two degrees of freedom has opposite phase from the transmitted sound passing through the pierced hole above the resonance frequncy of the air vibration system. The interference, the effect of the acoustic anti-resonance for transmitted sounds through two types of holes, generates the sound reduction. Moreover, the inertia of the air mass helps to maintain the sound insulation at higher frequency.

### 3. Simulation

A one-dimensional wave equation was employed to analytically calculate the effectiveness of the new panel structure. A series of continuity equations of air-particle velocity and equations of sound pressure equilibrium were formed at every boundary in the panel. The transmission loss was calculated by solving the series of the equations.

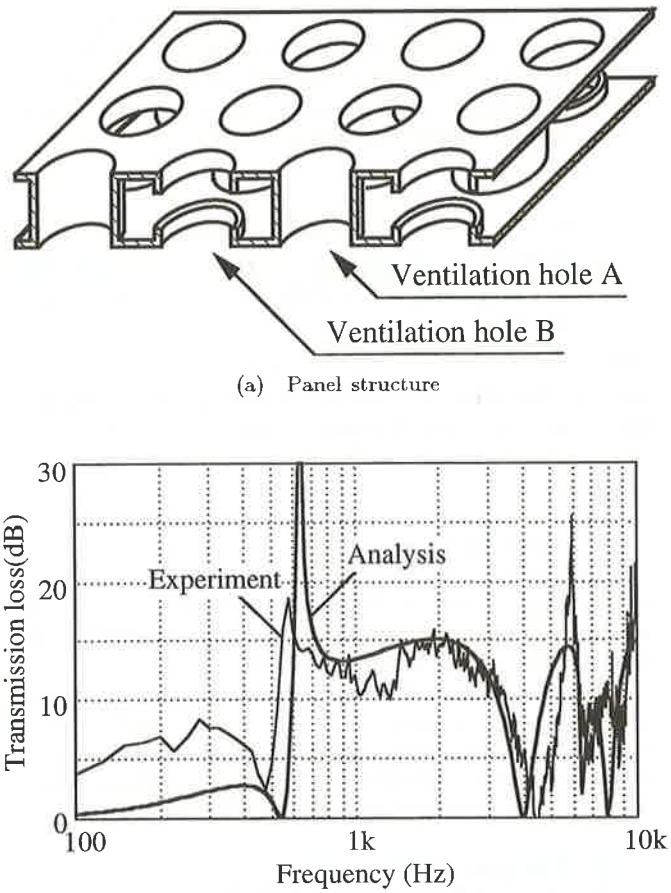


**Fig. 1** Ventilated sound insulating panel

Experiment was conducted using a resin test piece in practical thickness less than 30mm. It was designed to obtain the insulation effect over 10dB between 630 Hz and 3.15 KHz (see Fig. 1b), the range at which engine noise is highest.

These results confirmed that an accurate simulation is possible.

### 4. Technology Characteristics

The frequency characteristic of the new panel can be freely modified by changing the panel's structural parameters, including the opening area ratio, panel thickness, and the allotted ratio of the two different types of holes. Moreover, the airflow through the panel can be controlled easily since the ventilation holes are built vertical to the surface of the panel, and this makes it possible to achieve a maximum reduction of ventilaion resistance.

### 5. Conclusion

A new technology for an engine under-cover structure has been developed to obtain both ventilability and sound insulation simultaneously. We are currently in the process of developing technologies which will enable the new panel structure to be applied to the under-covers for vehicles with very rigid engine compartment layout specifications.

With this technology's high potential for widespread usage in industrial fields, it is already being developed as a means of achieving reduced levels of noise in such applications as manufacturing plants and air-conditioning equipment.

## ◆ DEVELOPMENT OF VEHICLE STABILITY CONTROL SYSTEM (VSC)

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### 1. Introduction

The number of victim in fatal automobile accidents is still high in Japan. It shows the limitation of the method of reducing accidents to depend mainly on driver's care or attention.

We have searched a way to reduce such accidents by improving vehicle dynamic characteristics and found that the most important and effective way is to increase vehicle stability in extreme condition where driver-vehicle combination tends to lose control.

### 2. Purpose of the system

We have collected and studied data of serious accidents, and realized that about one quarter of the cases is related to vehicle dynamic behavior in critical conditions, such as excessive vehicle side slip.

The critical conditions of vehicles were due to drivers' misjudgment of road conditions or unexpected traffic behavior, leading to abrupt maneuver of the drivers.

With blind test in critical condition for average skilled drivers, we have reached the conclusion that it is very difficult for them to cope with excessive vehicle side slip.

The safety devices already introduced to the market, i.e. ABS or TRC (traction control system), are purposed to establish guards for braking or acceleration for longitudinal direction. And our target is to establish guards for lateral direction in vehicle dynamic behavior.

### 3. VSC system

This system consists of the following parts.

(1) Brake actuator that can apply active braking force to each wheel independently.
(2) Throttle actuator with a throttle sensor to control the driving force.
(3) Sensors for wheel speed shared with ABS system.
(4) Gyro rate sensor for yaw rate
(5) Sensors for lateral/longitudinal accelerations
(6) Sensor for steer angle
(7) Sensor for pressure of master cylinder
(8) ECU (electronic control unit) for program computation

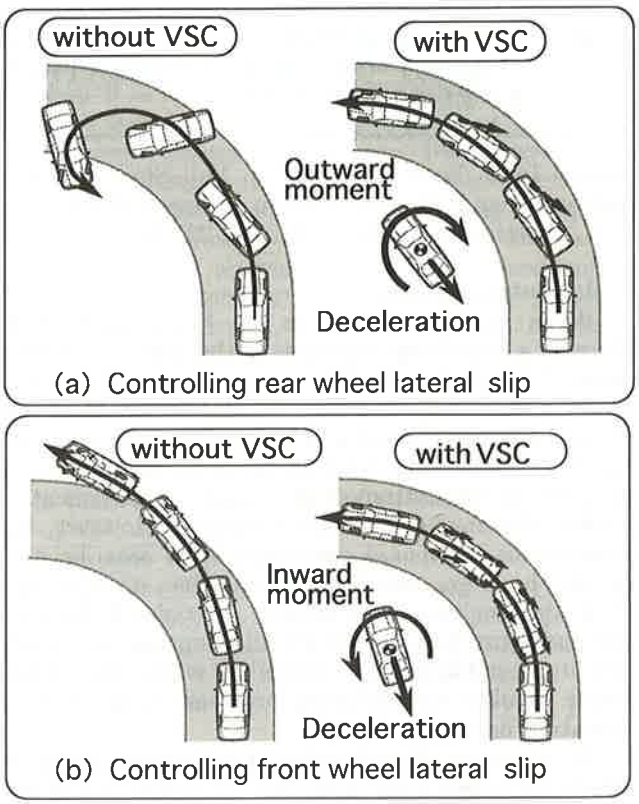


**Fig. 1** Function of VSC

### 4. Operation

VSC calculates vehicle slip angle ($\beta$) and $d\beta/dt$ by using yaw rate, lateral acceleration and vehicle velocity of wheel speed sensors. VSC estimates instability by relation of $\beta$ and $d\beta/dt$ in a phase plane.

Fig. 1 (a) shows the function when vehicle tends to spin. VSC activates outer front wheel brake automatically to induce anti-spin moment and to reduce vehicle velocity.

Fig. 1 (b) shows the function when vehicle tends to drift out. VSC activates each wheel brake individually to induce more yaw moment and to reduce vehicle velocity. VSC controls the yaw moment using the difference between actual yaw rate and target yaw rate calculated from vehicle velocity and steer angle.

Before VSC activates brakes, since warning area is defined, driver is noticed that vehicle is approaching to the limit, by warning lamp and buzzer.

### 5. Effect

By a series of tests, it has been confirmed that the vehicle stability control by VSC is fully effective as aimed for. The test condition includes various steering maneuvering case such as sinusoidal steering which simulates quick lane change. Test condition also includes various surfaces from high $\mu$ to low $\mu$ and running conditions of acceleration and deceleration. Good results have also been obtained in various evaluation tests by average skilled drivers.

The usefulness of the warning lamp and buzzer has also been confirmed.

### 6. Conclusion

Toyota has developed the VSC based on accident survey data. A vehicle equipped with VSC proved to avoid excessive vehicle side slip. VSC has been introduced to the market in Toyota Crown and Toyota Mk II. Through the development, new technologies have been established, such as estimating vehicle dynamic condition and stability control method by phase plane.

The hardware and sensors of the VSC system are based on ABS and TRC, however the aim of the main development was the software. So, VSC has a good cost performance and thus has a great potential for the market.

## ◆ DEVELOPMENT OF HIGH-PRECISION MASTERING MACHINE FOR OPTICAL DISCS

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### 1. Introduction

DVD which was put on the market in November of 1996 is capable of storing 4.7-Gbytes of memory on one side of the disc (7 times the capacity of a CD), and can play about 130 minutes of moving picture application. In order to realize this capacity with a 120 mm diameter disc, the track pitch and minimum pit length must be reduced to 0.74±0.03 $\mu$m and 0.4 $\mu$m respectively. (Figures for a CD are 1.6±0.1 $\mu$m and 0.83 $\mu$m). Therefore, the new mastering machine which precisely records these minute pits on a glass master is the key technology for manufacturing DVD discs.

### 2. Technical Description

#### 2.1 Composition of Equipment

The composition of the equipment is shown in Fig. 1. An exposure laser beam which is modulated into recording pulses of various lengths by an optical modulator is focused on a glass master through an objective lens. Since the glass master is rotated at the designed speed by a spindle, and an objective lens is moved across the glass master at a programmed velocity by an air bearing slider, pits of various lengths are spirally formed on the glass master.

#### 2.2 Exposure Laser Beam Spot

It is necessary for the beam spot diameter to be sufficiently small to form these minute pits. By using a krypton ion laser with a wavelength of 351 nm (CD: 458 nm) as the light source and an objective lens with the NA (Numerical Aperture) of 0.9, the diameter of the beam spot becomes 0.21 $\mu$m at full width at half maximum so that the pit length of 0.4 $\mu$m can be easily recorded. Moreover, by using the exposure beam as the detection light, precise focus detection

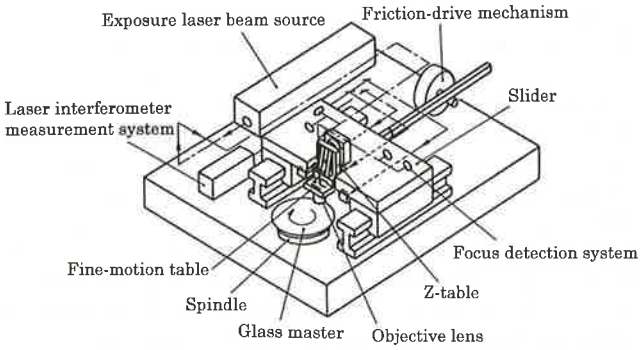


**Fig. 1** Schematic overview of the mastering machine

is possible because the chromatic aberration of the objective lens does not affect the detection. Thus, focusing accuracy better than 0.05 $\mu$m was obtained.

#### 2.3 High-Precision Positioning Slider

In order to maintain the track pitch error within ±0.03 $\mu$m, it is important to reduce the traveling error of the slider. Therefore, the friction drive mechanism in which non-linearity characteristics such as backlash is small is adopted for the drive of the slider. Furthermore, the fine-motion table which carries the objective lens is mounted on the slider. By measuring and controlling the positions of the slider and objective lens using laser interferometers, the fine motion table successfully compensates the traveling error of the slider and the vibration caused by disturbance. As a result, a traveling error less than ±0.01 $\mu$m has been achieved for the objective lens.

### 3. Conclusion

This machine has contributed to standardization of the DVD disc, and now it is working for mass-production of DVD discs in Gotenba factory of Toshiba EMI Ltd.

## ◆ FULLY AUTOMATICAL VERTICAL HIGH-PRECISION SURFACE GRINDER

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### 1. Introduction

The diameters of silicon wafers are increasing, and the current target for investigation is 12 inches size rather than 8 inches. In the past, lapping process was adopted both to flatten a bare wafer before manufacturing a device and to remove the backside of the wafer after manufacturing the device. Back in these days when a wafer diameter size of 2 inches was the mainstream, Okamoto Machine Tool

Works, Ltd. started investigation on the possibility of replacing this lapping process with a grinding method which can cope with graduated wafer sizes and since then it has been buckling down to the work of developing a down-feed-type grinding method. As fully automatic grinding would be indispensable, a highly efficient, fully automatic, vertical-type surface grinder has been developed on the basis of targets set to its each performance. As a result, the processing of back lapping previously applied has been superseded thoroughly by back incorporation in the flattening for 300 mm bare wafers which require a high processing accuracy.

## 2. Contents of the grinding technology

Fig. 1 shows the composition of the present apparatus.

Fig. 1 Fully automatic grinding system
(1) rough grinding, (2) finishing,
(3) wafer cleaning, (4) chuck cleaning,
(5) wafer loading

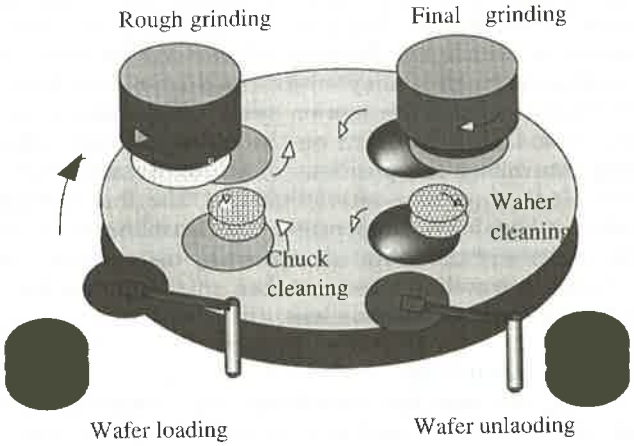


**Fig. 1** Automatical Grinding System

1) Down-feed grinding

Since the wafer has a circular shape, the application of down-feed grinding has made it possible to process the wafer with higher accurately and fewer local fluctuations, and this, in turn, makes it possible to cope with increase in the wafer diameter. Further, since the surface of the wafer is exposed in the case of the down-feed grinding, in-situ measurement of the wafer thickness can be carried out to facilitate in-process control of the thickness, thus making it possible to reduce the film thickness to as thin as 100 $\mu$m.

2) Two-stage grinding method

By applying a newly developed grinding method which divides the grinding process into two stages of rough grinding and finishing, approximately 10,000 wafers can be processed without any dressing throughout the expected life span of the grinder. Although this method is a brittle-mode grinding method[(1),(2),(3)], the disuse of dressing results in a great advantage.

3) Index transferring method

By absorbing the wafer once to the index table, it has been made possible to stably carry out automatic processing of the wafer without taking it off during the processes of initial cleaning, rough grinding, finishing, and final wafer cleaning, and this, in turn, makes it possible to cope with increases in the wafer diameter.

## 3. Conclusion

In addition to reducing the number of processes and improving the processing accuracy and productivity, compared to the traditional lapping method, the present surface grinder also makes it possible to increase the wafer diameter and reduce its thickness. The present grinder is now being adopted by wafer material manufacturers, and the process it employs to grind the wafer is therefore superseding the lapping method. Its contribution to higher-accuracy processing and higher productivity is eagerly anticipated.

## References

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for Study on Cranial Fractures in Head Injury

Noriyasu Kawamura, Toshiba Corporation
for A Study on Structural Integrity Evaluation for Resin Encapsulated Semiconductor Package during the Soldering Process

Atsushi Sakuma, Yamaguchi University
for Studies on Thermo-Mechanical Representation of Phase Transformation Covering Melting/Solidification and Application to Simulation of Welding Process

Min-Cheol Chu, Pukyong National University
for Strengthening and toughening of mullite by dispersion of carbide ceramics particle

Masato Mochizuki, Hitachi Co., Ltd.
for Study on Residual Stress Analysis of Welded Structures

Toshiaki Kitagawa, Kyushu University
for Study on Direct Injection Stratified Change Combustion

Osamu Nakabeppu, The University of Tokyo
for Microscale Thermal Measurement by the Atomic Force Microscope

Eiji Matsushima, Osaka Institute of Technology
for Study of method to measure thermal diffusivity of solid materials by electromagnetic ultrasonic technique

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for Research on Fluidelastic Vibration of Cylinder Arrays by Computational Fluid Dynamics

Shu Takagi, Tokyo Institute of Technology
for Development of a numerical method to solve a free boundary flow with high accuracy (Analysis of a rising bubble behavior)

Jun Matsui, Yokohama National University
for Numerical Analysis of Gas-Surface Interaction by Molecular Dynamics Method

Kosei Kitagaki Electrotechnical Laboratory
for Pseudo Contact Point Monitoring for Skillful Tasks by Robot Manipulator

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Koichi Honke, Kobe Steel Ltd.
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