

## Simulation Technologies for Mechanical Systems

### Aiming for Compatibility between Performance and Reliability

KUBOTA Yuji

#### Trends in Mechanical Simulation Technology

YOSHIDA Yuichiro / OZAWA Kaoru

Computer-aided engineering (CAE) is an essential information technology, supporting engineers in tasks such as research, development, and design of products and contributing to the shortening of development periods. With CAE now being widely used in the business sphere, the quality assurance of CAE and efforts to strengthen appropriate CAE processes are also required. Britain's National Agency for Finite Element Methods and Standards (NAFEMS) is taking the initiative in the quality assurance of CAE, and the American Society of Mechanical Engineers (ASME) and the Japan Society of Mechanical Engineers (JSME) have also started work in this area.

With this as a background, Toshiba has been promoting the quality assurance of CAE processes based on ISO 9001, and is making strong efforts to utilize the appropriate CAE processes for product development.

#### Structural Design of Mobile Electronic Products Using Large-Scale Stress Simulation

KAWAKAMI Takashi / YOSHIMURA Shinobu / AKIBA Hiroshi

Structural integrity design is of great importance to ensure the reliability of hardware products, and a large-scale stress simulation technology has recently become available for this purpose.

We have performed drop impact analysis of a fully assembled model of a cellular phone using ADVCTM, which is a commercial parallel structural analysis code based on the ADVENTURE system, and verified very good performance. In addition to improving the accuracy of structural integrity design, this large-scale stress simulation is expected to save labor and shorten the process of stress analysis for the structural design of hardware products.

#### Visualization of Turbine Blade Pressure Loss Characteristics by 3D Unsteady Flow Analysis

YOKONO Yasuyuki / BISWAS Debasish / NIIZEKI Yoshiki

Toshiba has performed numerical studies of three-dimensional (3D) incompressible viscous flow within a turbine cascade based on a high-order large eddy simulation (LES) approach, to visualize 3D unsteady flow for investigation of the pressure loss process.

Analysis was carried out for a wide range of inlet flow angles in the design and off-design conditions. The numerical simulation was able to reproduce and obtain good coincidence with the experimentally measured results of the occurrence of a sharp increase in pressure loss in the center of a turbine blade as the inlet flow angle shifted from the design flow angle. It was found that a leg of the horseshoe vortex produced in the leading-edge region was stretched toward the blade suction surface, and that the formation of a secondary vortex core in the trailing-edge wake region was the main cause of the pressure loss. By the reproduction of flows in off-design conditions, this numerical method is applicable to simulations of a wide range of design conditions.

#### Captured Image Simulation Technology for 198.5 nm Photomask Defect Inspection Tools

SHIRATSUCHI Masataka / HONGUH Yoshinori / HIRANO Ryoichi

Semiconductor manufacturing process technologies have been making progress in terms of nanofabrication in recent years. In particular, argon fluoride (ArF) excimer laser exposure tools and alternating phase shifting masks (alt-PSMs) are expected to be utilized in actual production. A feature of the alt-PSM is its three-dimensional (3D) structure to control the wavefront phase as well as amplitude of transmitted light. It is therefore essential to develop a highly precise photomask inspection method to check such newly developed photomasks.

In the development of optical setups suitable for inspecting these new types of photomasks, Toshiba has developed a captured image simulator with a vector model diffraction solver, which is able to appropriately support such 3D photomask structures and high-numerical-aperture (high-NA) magnifying optical systems.

#### Simulation Technology for Optimizing Component Design and Manufacturing Processes

NAKAGAWA Yasutada

Maintenance of quality and shortening of processing times are required in various component manufacturing processes such as resin molding, press processing, removal processing, adhesion, crystal growth, and so on. To meet these requirements, Toshiba has introduced a simulation technology for optimizing component design and manufacturing processes.

In the manufacturing process, for example, the optimization of double-sided polishing conditions to enhance the flatness of silicon (Si) wafers, and of the heating temperature profile of adhesive for connecting Si chips to printed circuit boards (PCBs) in flip-chip surface mounting technology, were realized using the newly developed simulation technology. In the design of components, not only functions and performance but also manufacturability must be taken into consideration. As an example of the application of our simulation technology, the design of PCBs was optimized in order to minimize PCB deformation in the reflow process by making use of the difference in thermal expansion between copper and PCB resin.

#### Crack Progress Simulation Analysis in Residual Stress Fields

ENDO Tetsuya / OHASHI Toshiki / OKUDA Yukihiko

In recent years, the need for assessment of the structural integrity of core shrouds with cracks due to stress corrosion cracking (SCC) on welded joints of core shrouds in boiling water reactor (BWR) plants is increasing.

The direction of crack propagation due to welding residual stress is known to change in a multiaxial stress field. In response to the demand for prediction of the propagation of cracks due to SCC, Toshiba has developed a multipurpose two-dimensional crack propagation analysis method that allows rapid evaluation, and a three-dimensional crack propagation analysis method for detailed evaluation of cracks having a complex shape.

#### Coupled Thermal-Stress Simulation Technology for Electronics Package Structures

HIROHATA Kenji / AOKI Hideo / NINOMIYA Ryoji

New high-density assembly technologies such as thinner printed circuit boards (PCBs) and narrow-pitch soldering are being applied to the production of compact digital equipment with high functionality. High reliability and ease of assembly are also required for these products in addition to high functionality. As a result of this trend, technologies for the analysis and evaluation of product failure phenomena due to complex problems related to heat and stress have become increasingly important.

Toshiba has developed a coupled thermal-stress simulation technology to predict the mechanisms of failure phenomena and improve the design and production processes. This technology realizes high-quality design by considering both manufacturability and reliability at the first stage of development.

#### Numerical Simulation of Mixed Lubrication for Air-Conditioner Rotary Compressor Mechanisms

ITO Yasutaka / HATTORI Hitoshi / MIURA Kazuhiko

Reducing the friction loss of the compression mechanism is of key importance in improving the efficiency of air-conditioner compressors.

Toshiba has developed a technology for the numerical analysis of mixed lubrication. This technology is useful for reducing the friction loss and improving the efficiency of rotary compressors in air conditioners. In this analysis, the modified Reynolds equation and the elastic contact equation, taking the effect of surface roughness into consideration, are solved as a coupled problem. The breakdown of a lubrication oil film and occurrence of solid contact can be predicted by this analysis. In addition, a mechanical design that minimizes friction loss can be realized. We have applied this analysis to the vane sliding surface, which is one of the main sliding parts in rotary compressor mechanisms. The effects of the design parameters on the friction loss were clarified by simulation.

#### Simulation Technology for Virtual Control Firmware Testing

YOSHIDA Mitsunobu / KONDO Koichi / MOTOHASHI Shoichi

With the scale of firmware in electromechanical products continuing to increase year by year, the shortening of overall development times with quality assurance is one of the highest priorities of firmware development.

Toshiba is promoting "virtual firmware testing" using a mechanical simulator in the upstream development process. The key feature of this mechanical simulator for control firmware is both simplicity and reusability of the simulation model, rather than precision of the simulation model. To meet these requirements, in cooperation with InterDesign Technologies, Inc. we have developed a dynamics simulation modeling language, DCML-<sub>TM</sub>(Dynamics Constraint Modeling Language), and have been applying it to the Vmech<sub>TM</sub> virtual mechatronics simulator.

#### Completion of Steam Turbine Development Facility

SASAKI Takashi / OKUNO Kenichi / NIIZEKI Yoshiki

There is an ongoing need for both higher performance and higher reliability in the field of steam turbines for power generation. It is therefore essential to further speed up development so that the latest technologies can be applied as soon as possible. The development of steam turbine technologies has been carried out utilizing a variety of computational analyses and tests. However, final verification of key technologies is performed by application to an actual machine, requiring a long time for the verification and feedback processes. Shortening the duration of this step is thus important in order to accelerate steam turbine development.

In response to this situation, Toshiba has constructed a test facility as well as an actual-size steam turbine, and commenced their operation.

#### Static Var Compensator for Long-Distance AC Cable Transmission System

TAMURA Yuuji / MIYAZAKI Yasuyuki

Toshiba has developed a static var compensator (SVC) and delivered it to the Oku-Ura Switching Substation of Kyushu Electric Power Co., Inc. for a 54 km, 66 kV AC submarine cable transmission system, the longest such system in Japan.

For the development of the SVC control system, we utilized our accumulated experience in power system analysis technology in order to solve problems such as voltage fluctuations and harmonic resonance of the power system due to the long distance of the AC cable transmission system from the Kyushu mainland to the Goto Islands. In addition, we adopted a thyristor-controlled transformer (TCT) and harmonic filters to realize a compact SVC configuration, and installed the thyristor valves and control/protection cubicles in a package house at the factory to shorten the construction period.

The newly developed SVC is expected to offer a technical solution for the interconnection of long-distance cables between mainland locations and remote islands.

#### TOSPECTRON<sub>TM</sub>-I Inner Surface Defect Inspection System for Steel Strip Manufacturing Process

WATANABE Keisuke

Defect inspection systems are essential to the quality assurance of the steel strip manufacturing process. Demand is increasing for the inspection of not only defects on steel surfaces, but inner surface defects as well. Furthermore, the detection of inner surface microdefects has become necessary for high-quality steel products in recent years, and high-speed detection is also required due to the speeding up of production lines.

To meet these requirements, Toshiba has developed the TOSPECTRON<sub>TM</sub>-I inner surface defect inspection system, which enables real-time detection of inner surface microdefects in steel strip moving at high speed. This system achieves a 10 mm position resolution by the use of a highsensitivity Hall sensor, as well as both high-speed and stable detection at 100-1,200 m/min by the adoption of a universal filter integrated circuit (IC).

#### Vehicle License Plate Recognition System with Improved Robustness against External Conditions

TAKETA Kosuke / SAKURAI Yusuke / AOKI Yasuhiro

There is an increasing need for correct vehicle license plate recognition for the Electronic Toll Collection (ETC) system, due to the relaxation of vehicle type restrictions and rising number of nonpaying drivers. However, license plate recognition is subject to disturbance under varying illumination environments such as the sunlight condition, shadows on the plate cast by parts of the vehicle itself, and so on.

To overcome these problems, Toshiba has developed a license plate recognition technology for both four-wheeled vehicles and motorcycles that offers increased robustness against factors creating environmental disturbances. This system consists of an image sensing module and an image processing module, with countermeasures against the shadow problem. An algorithm for optimization of the camera parameters based on the intensity of the plate image and an algorithm for estimation of the plate location prior to recognition are incorporated in the system, both of which improve the robustness of the system's performance.

#### FE100T Industrial Computer Equipped with Dual-Core Processor

HARUYAMA Hitoshi

The application of industrial computers has expanded into various industrial fields, including not only factory automation (FA) but also social infrastructure systems such as broadcasting and communication systems, transportation management systems, water supply and sewerage monitoring systems, electric power generation and supply systems, and building management systems, as well as automated equipment, inspection and analysis equipment, and so on. In monitoring and control systems as well as equipment with embedded computers, there is an accelerating trend toward open systems and an increasing number of systems using PCs and PC servers. The demands of industrial computer users have therefore expanded and diversified according to the purpose of use and scale of application.

In response to these circumstances, Toshiba has developed and commercialized a new industrial computer, the FE100T, equipped with a dual-core processor.

#### 8000 Series Digital Transmitters for Overseas Markets

SASACHIKA Hideki / YOKOMOTO Hiroaki / TAKAHASHI Kiyokazu

Digital terrestrial television broadcasting was launched in Japan in December 2006, and deployment of the digital transmitters has already been completed in key stations (the main transmitting stations of the broadcasting stations) throughout the country. The digitization of broadcasting is also progressing rapidly in global markets, especially in China and Brazil, and is expected to further expand on a large scale from now on.

In response to the needs of the market, Toshiba has developed the 8000 series transmitters for digital terrestrial television broadcasting. The features of the 8000 series include higher power, the capability to handle various modulation methods, coverage of all ultrahigh-frequency (UHF) bands, and space-saving design.

#### Improvement of Light Extraction Efficiency of OLEDs Using Subwavelength Grating