Technical Improvements and Front-Loading of Cellular Phone Mechanism Evaluation

● Masayuki Satou ● Yutaka Nozaki ● Taketsugu Kawamichi
● Sigeo Ishikawa

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Fujitsu has ensured the sufficient mechanical strength of cellular phones by carefully considering the expected conditions of their use and by repeatedly improving the design based on the results of various evaluations. Currently in Japan, more than 96 million people, or about 76% of the population, have a cellular phone contract, and it is very difficult to cultivate new customers in this market. To win in the market, it is important to rapidly develop and offer attractive devices that meet the market needs ahead of competitors. This paper describes the technical improvements and front-loading of the mechanism evaluation that Fujitsu has implemented to help achieve rapid development of cellular phones. This paper then describes the results of making these changes.

1. Introduction

A recent trend for cellular phones is software service diversification and slimmer, lighter designs. Also, customers are requesting cellular phones that are more robust. On the other hand, a large variety of cellular phone models must be developed and put to the market in a short period. However, the conventional development process and evaluation method are insufficient to flexibly satisfy growing customers' needs. To solve this problem, we developed a simulation technology based on a three-dimensional model from early stages of development, and developed a front-loading technology for providing short-term development. The above "Front-loading" means to solve problems in an early part of the design stage and to improve quality in the early parts of the development stage. This improves both quality and productivity at the same time. This paper describes the conventional mechanism evaluation system, the new mechanism evaluation technology and front-loading, and their results.

2. Conventional mechanism evaluation system

In the conventional evaluation system, robustness of a sample product was evaluated, and structural problems were extracted and fed back to the design stage several times to improve the finished status of the product. In this case, a long time and a high cost were required to grasp structural problems because the product had to be actually produced and sampled for evaluation. In addition, if a serious defect was detected in the product structure, the design sometimes had to be modified on a large scale, which might require additional modifications to a large extent. Therefore, when the process advanced to later stages, the degree of freedom of structural changing decreased and finding the improvement method to satisfy all of the conditions of quality, cost, and delivery (QCD) became difficult.

The following describes the tests for conventional robustness evaluation, and their weak points:

1) Drop and impact test: For detecting faults

that are caused by drops and impact

This tests a product's durability when it is dropped onto a floor or concrete. A cellular phone is dropped repeatedly by controlling its drop posture, and problems (e.g., separation of parts from substrate) are extracted and improved.

2) Pressure test: For detecting faults that are caused by applying pressure load

This tests a product's durability when it is stepped on or bent forcibly. A cellular phone is mounted on a jig, various types of loads are applied, and problems (e.g., crack in LCD) are extracted and improved.

3) Weak points of these tests

Because dispersion of the related parts cannot be considered, the problems that were already solved in the trial production stage may recur in the mass production stage. Otherwise, the problems that did not occur in the trial production stage may occur in the stage immediately before mass production. Thus, the real evaluation results may be acquired after the product approaches to the completion status.

3. New mechanism evaluation technology and front-loading

The following describes the new mechanism evaluation technology:

3.1 Cooperation with upper processes

A verification technique with a virtual process is introduced to reduce the number of products to be sampled for evaluation. Fujitsu uses the high-quality finished product development method using a virtual product simulator (VPS) from the upper parts of the development stage.

In the conventional system, the Mechanism Division produced trial products, improved product quality by executing the evaluation test process (drop test, impact test, etc.), and assured the product robustness before starting the mass production stage. But, development expenses and time were insufficient at present because we had to develop and produce multiple models in a year. This limited product quality and development efficiency. In addition, such the non-trivial problem solving in the trial production stage greatly delayed the later processes.

To solve these problems, we have advanced the virtual process using the VPS model, that is, the examination of the virtual technology. First, we introduced a virtual design review (VDR) as a verification technique. When the VPS model creation by the Mechanism Division is finished, the structure clearance, strength, mold validation, and analysis results consistency are previously reviewed in virtual environment. Then, various problems are detected and solved in early stages, and the problem information is fed back before the evaluation model is created. Thus, robustness problems can be previously solved.

Recently, also PCB data designed in the electrical CAD environment "EMAGINE" can be used for VPS processing. Therefore, radio characteristics (including antenna characteristics), substrate parts separation, substrate warp, and heating in the assembled product as well as mechanism parts status can be reviewed at the same time. Thus, the range of preliminary verification has been widened. As our product development sites are widely dispersed, remote collaboration is performed frequently using the DirectShare so that all the persons who are engaged in the development can have the same consciousness and knowledge without considering distance and time.

Figure 1 shows the cooperation with upper processes.

3.2 Front-loading of simulation

Next, we introduced the structural simulation of the performance evaluation test by using the finite element method (FEM) to grasp problems in earlier stages before creating a trial product. As structural problems can be solved before creating a trial model, additional modifications in later processes can be prevent-

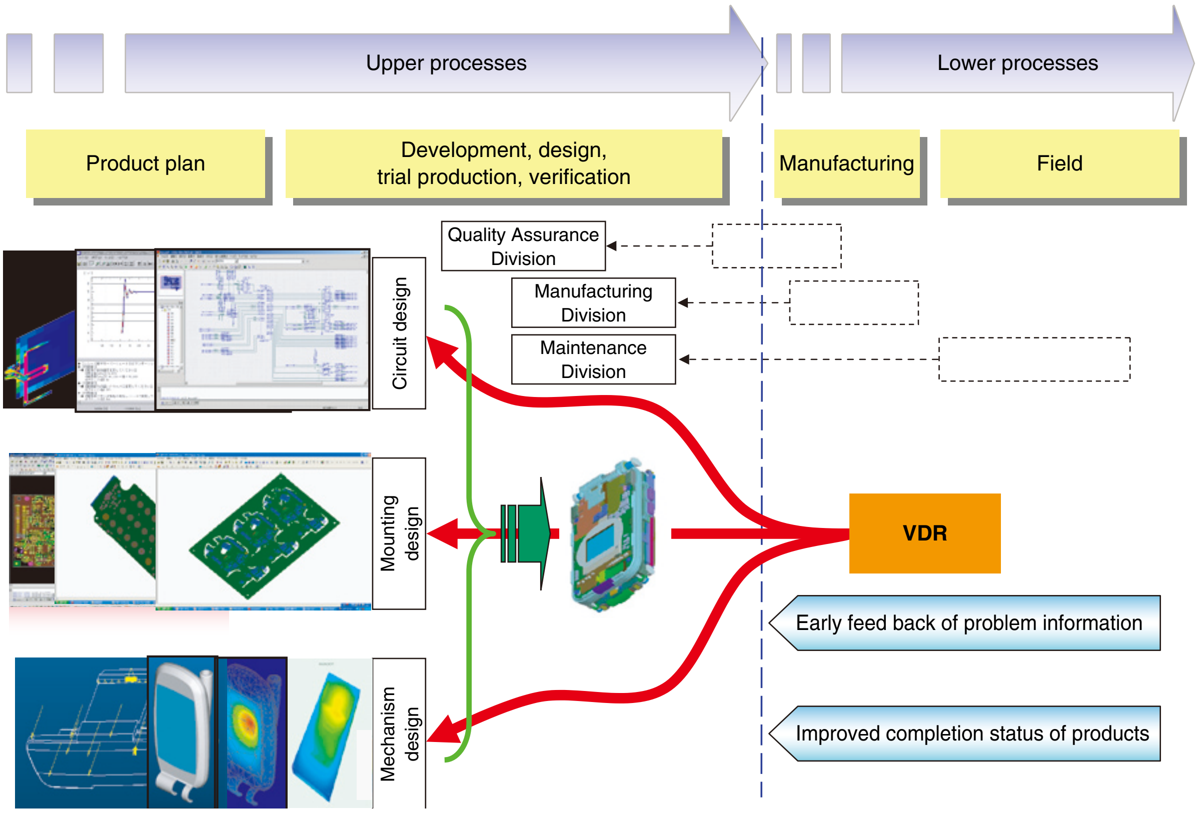


Figure 1
Cooperation with upper processes.

ed. Especially, as the FEM model of the device assembly status can be made and precise simulation can be done in the same conditions as those for the actual product, the earlier design quality is remarkably improved.

Device development requires product plan, basic design (structure analysis), detail design, trail product evaluation, and mass production evaluation. Simulation has higher effects when it is applied to earlier development stages that have higher degree of freedom. Larger structure change can be easily made in earlier stages of development. If problems are detected in earlier stages, effective countermeasures can be made easier. It is important to consider what should be done in each stage of development and to apply the determined activities according to the scheduled processes. In the product plan stage, simpler models are examined in various ways in order to check the possibility of the new structure. Therefore, those dimensions of parts which are required to assure sufficient strength can be checked and the strength of various models can be examined in the design stage. In the conventional system, as strength examination was difficult in the design stage, structure problems to determine the design could not be easily grasped. Next, in the basic design stage, parts to be mounted are actually placed in the models having the selected design, and preliminary simulation based on the product simulation is performed to check faults in more detail. For example, a surface mount model substrate based on the earlier mount plan is mounted in the product body, and simulation is executed. If there is a problem that may be solved by changing the parts layout, mount layout changing is examined. Next, in the detail design stage, an FEM model is created based on the detail 3DCAD model determined for the metal mold, and the simulation equivalent to the simulation of a sampled product is performed to improve the detail product design. However, even if optimal simulation is performed, not all of the structural problems can be grasped and additional faults may be detected later in the trial production evaluation stage: trial product evaluation stage. In such a case, the fault information must be fed back to the design stage as quickly as possible. For efficient processing, the existing FEM model was remodeled. More steady countermeasures can be made by simulating some of the proposed correction plans.

The following introduces some examples of main robustness simulation performed by Fujitsu:

3.3 Strength evaluation by static structural simulation

Simulation is performed on an FEM model by regenerating the pressure test conditions used in the robustness evaluation test. In this simulation, the strength that is equal to or higher than that specified in the standard must be confirmed. For example, a pressure load is applied as shown in **Figure 2 (a)**, the maximum strain of the LCD glass at this time is simulated, and it is checked that the product can stand at least the specified pressure load.

Parts separation from a surface mount substrate by a test load can be checked by comparing the substrate strain near the mounted part with the evaluated limit strain of the sample substrate.

3.4 Drop and impact strength evaluation by dynamic structural simulation

The basic robustness of a product can be grasped by the above static structural simulation. However, when a product is dropped or has an impact, the own weight of the product acts as a load. Such product damage cannot be correctly checked by static structural simulation. For example, when the outer case is strong and has a wide internal clearance, the case may not be damaged by an external force, but the internal parts may warp largely inside the case by their own weight and may be broken. Such breakage is liable to occur in a surface mount model shown in **Figure 2 (b)**. Surface mount models must be precisely evaluated by drop and impact simulation.

The possibility of LCD glass breakage can be evaluated by calculating the LCD glass strain in the same way as in the above pressure simulation.

Basically, simulation is performed based on the reliability evaluation list of the product. As simulation does not require sample production cost, more detail evaluation can be performed in many conditions as compared with the evaluation of a sampled product.

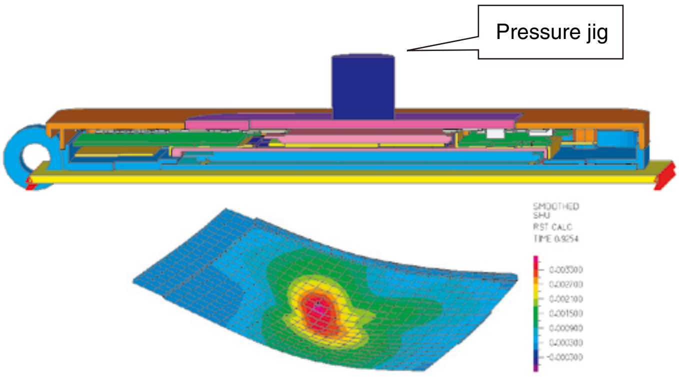
3.5 Evaluation of flexible cable in opening and closing test

Cellular phones that are mainly used at present are of the flip type. As users repeatedly open and close the LCD panel of the phone, the durability of the hinge cable during opening and closing must be sufficiently high. Generally, a flexible cable is used in the hinge part. As a product using a large LCD panel requires many signal lines, multiple cables must be mounted and their durability is liable to be shorter.

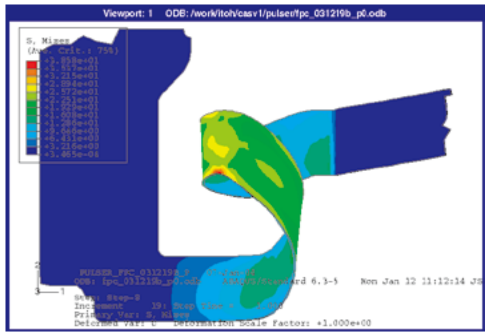
Figure 2 (c) shows the results of a cable unit durability test. The relationship between strain amplitude and repetition count at breakage occurrence is shown. The durability of a flexible cable during opening and closing can be predicted by evaluating the strain amplitude of the cable in the opening/closing cable bending simulation.

3.6 Evaluation of welded parts in mold-flow analysis

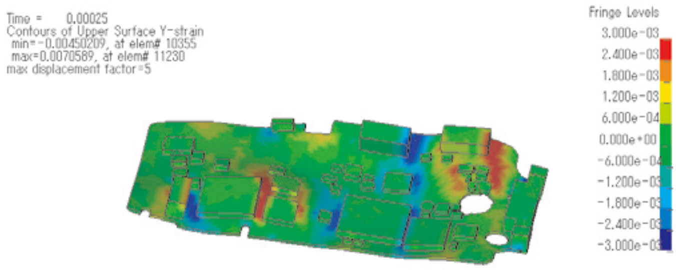
A weld line is created on resin parts such as a case during injection molding when multiple



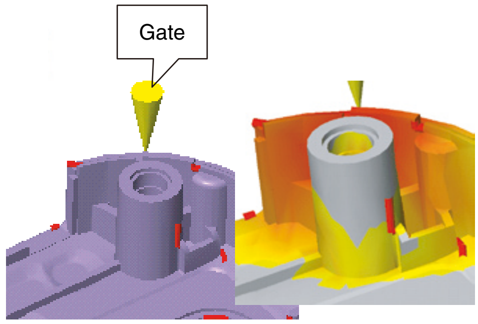
(a) Evaluation of LCD crack in pressure test



(c) Evaluation of flexible cable in opening and closing test



(b) Evaluation of parts separation in drop and impact test



(d) Evaluation of weld lines in mold-flow analysis

Figure 2
Examples of structural simulation.

resin streams flow via key holes, etc. and encounter each other again. Weld lines are low in strength. If stress concentrates to a weld line by pressure or drop during normal use, the weld line is liable to be broken. Recently, high-strength materials including glass, etc. have been frequently used. But, such reinforced materials are liable to be damaged especially at the positions of weld lines. Checking the strength of weld lines must not be omitted. **Figure 2 (d)** shows an example of evaluation of weld lines around a boss of a case.

3.7 Evaluation of dispersion in quality engineering

Even if the strength that satisfies the robustness standard is confirmed in the structural simulation, the strength is actually assured only when the product is produced correctly according to the design nominal values. However, when cellular phones are mass-produced, some manufacturing dispersion usually occurs based on the productivity and production lots, and the necessary strength may not be acquired. To solve this problem, Fujitsu uses an allowance design method in structural simulations. This method is based on the allowable design techniques of quality engineering, and handles parts dimensions as error factors. Influences of dimensional dispersion are checked before the manufacturing stage begins. **Figure 3** shows an example of dispersion influence evaluation in quality engineering. In this example, the influence, on the board strain, of dimension dispersion of case

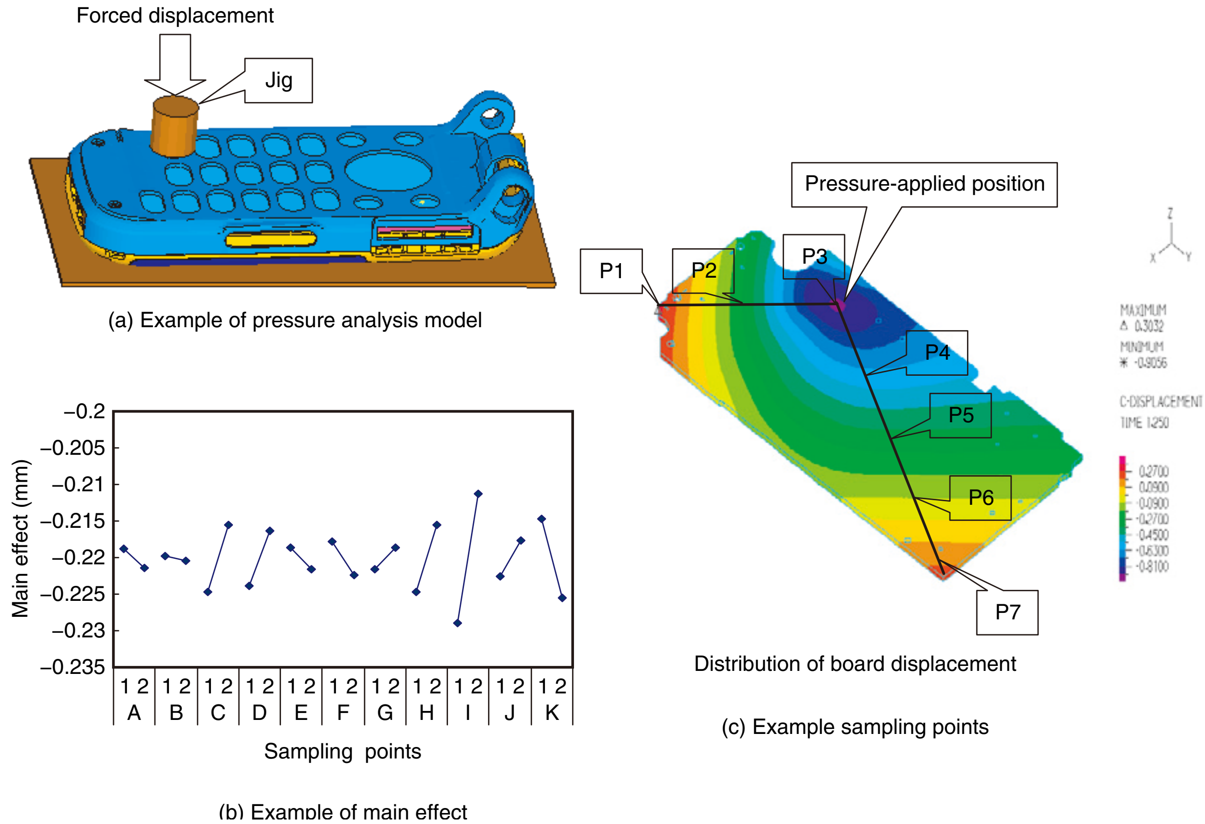


Figure 3
Example of dispersion influence evaluation in quality engineering.

parts at key pressing is analyzed. The manufacturing yield percentage can be increased by selecting and managing the largely influencing dimensions. If the necessary precision exceeds the manufacturing limits, the structure must be reviewed and productivity must be improved.

4. Results of new activities

The following introduces our activities made for the new evaluation technology and front-loading:

4.1 Results by cooperation with upper processes

The aim of this technical innovation is to improve the ease of product development in virtual environment. It has been established to preliminarily confirm and evaluate the productivity, workability, and maintainability by using a VPS model with higher quality before making a trial product.

In the conventional system, we manufactured products according to instructions written on paper such as manufacturing drawings and work orders. But, in the new system, assembly instructions and disassembly procedures using animation video are used. This remarkably improved work quality, that is, provided the reduction of work mistakes, minimization of work variations between workers, and parts order mistake reduction by visualization. In addition, starting manufacturing and maintenance could be made earlier. Reducing paper documents enabled manufacturing jig production and checking mounting conditions to be made in earlier stages.

Thus, product quality could be improved in virtual processes, robustness could be improved

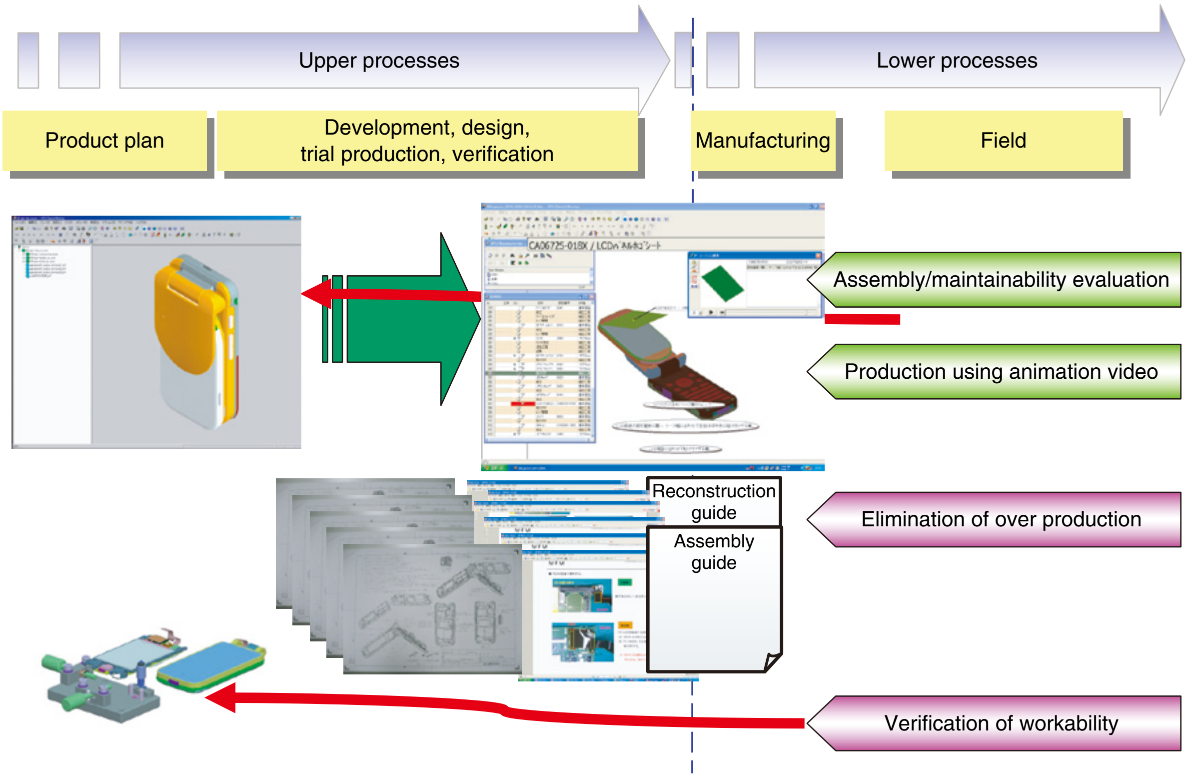


Figure 4
Pursuing ease of production in virtual environment.

by performing also manufacturing verification, and the number of products to be sampled for evaluation could be reduced. **Figure 4** shows our activities made for pursuing ease of production in virtual environment.

4.2 Results of high-level analysis and front-loading

The design quality at the mass production start has been improved by high-level analysis of robustness in the early stages of development.

The percentage of remolding for robustness improvement was reduced to about 1/3 as compared with our conventional system. Thus, the development expenses were remarkably reduced. **Figure 5** shows the comparison of the remolding percentage between the conventional models and present models.

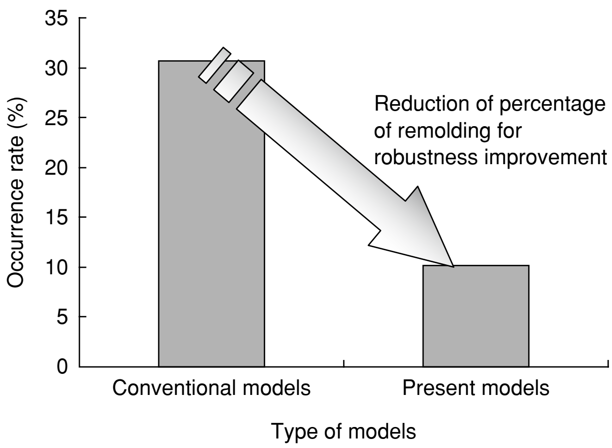


Figure 5
Comparison of remolding percentage between conventional models and present models.

5. Conclusions

This paper described production in virtual environment and the results of analysis technology and front-loading by introducing an example of cellular phone development.

Resin parts of a cellular phone have slight differences due to molding conditions. These differences influence the parts strength, and some development conditions cannot be theoretically represented. Therefore, there are some differences between the simulation results and sampled-product evaluation results.

However, if trial products are repeatedly evaluated in the development like the conventional system, it is difficult to assure miniaturization (thinning), weight saving, and higher-level functions according to the current environment changing and customers' requests. In addition, it is difficult to complete the development exactly according to the plan. In the simulation technology that we introduced, robustness can be analyzed consistently, but the ergonomics must be further improved.

In the future, we will also develop simulation techniques for improving the ergonomics, for example, for making key clicks more comfortable. To establish product quality in the upper stages of development, we will advance the high-level use of simulation technology, development of new simulation technology, and accumulation of technical knowledge and will also pursue excellent quality by considering the customers' view.

Fujitsu received the "Best Partner Prize" from NTT DoCoMo, Inc. in 2006 as our activities for the RakuRaku Phone[note)] market enlargement and the continuous quality improvement by considering customers' view were approved.

note) Name of a mobile phone series targeted for first-time mobile phone users and the middle-aged and elderly ones. Its universal design, features, and functions are characterized based on ergonomics.

Masayuki Satou, *Fujitsu Ltd.*
Mr. Satou joined Fujitsu Ltd., Kawasaki, Japan in 1983, where he has been engaged in research and development of digital quality assurance systems and their streamlining processes by utilizing structural simulation methods in design validation.

Taketsugu Kawamichi, *Fujitsu Ltd.*
Mr. Kawamichi graduated in Department of Commerce and Economics from Hosei University Junior College in 1980. He joined Fujitsu Ltd., Kawasaki, Japan in 1974, where he has been engaged in improving workability by visualization and strengthening validation processes at an early planning stage using virtual technologies.

Yutaka Nozaki, *Fujitsu Ltd.*
Mr. Nozaki joined Fujitsu Ltd., Kawasaki, Japan in 1983, where he has been engaged in research and development of mold construction technology and surfacing methods.

Sigeo Ishikawa, *Fujitsu Ltd.*
Mr. Ishikawa received the B.E. degree in Engineering from Miyazaki University in 1991. He joined Fujitsu Ltd., Kawasaki, Japan in 1991, where he has been engaged in research and development of physical simulation technology, which supports product development and promotion of product optimization.