Structural Requirements and Evaluation Technology for Notebook PCs

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(Manuscript received July 10, 2007)

Newly developed technologies, improved social infrastructures, and an enhanced AV environment have contributed to much smaller, lighter, and more powerful notebook PCs, which are now gaining wider market acceptance. In fact, these PCs have become an indispensable tool in business and are also being widely used for personal purposes. Greater portability allows notebook PCs to be carried comfortably in a bag, but at the same time has resulted in many calls for improved durability, such as a stronger body, scratchproof exteriors, and more durable external connectors. Preparing for the expanded scenarios of using these PCs necessitates the ability to quickly identify customer requests for feedback to the product development and evaluation stages, so as to offer new models that customers can use conveniently and reliably. This paper introduces Fujitsu's design approach and evaluation technology for the structure of notebook PCs that it has developed in recent years.

1. Introduction

Newly developed technologies, improved social infrastructures, and an enhanced AV environment have contributed to much smaller, lighter, and more powerful notebook PCs. Greater portability allows these PCs to be comfortably used in various environments. Conversely, this development has resulted in many calls for improved durability, such as a stronger body, scratchproof exteriors, and more durable external connectors. In preparing for the expanded scenarios of use and environments for these PCs, we must offer new models that customers can use conveniently and reliably.

Fujitsu has established a notebook PC development and manufacturing system in Japan so that customers can use these products reliably. The high quality and usability of these PCs are assured because the products are "made in Japan". We quickly collect customer requests for feedback to the product development and evaluation stages, so as to improve the usability and reliability of these products.

This paper introduces Fujitsu's design approach and evaluation technology for the structure of notebook PCs that it has developed in recent years.

2. Changes in trend and use environments of notebook PCs

Recent CPU and memory modules offer remarkable increases in density, processing speed, and capacity, along with improved device functions and new types of usable media being added. These developments have improved notebook PC performance to provide various functions requested by customers for various use scenarios. Moreover, the high-density mounting of parts on printed circuit boards (PCBs) has been realized, with LCDs, HDDs, and optical disk drives (ODDs) becoming much smaller and lighter. This in turn has made notebook PCs much smaller and lighter. Thanks to reduced power

consumption and increased battery capacity for long-time operation, customers can use notebook PCs outdoors without considering battery depletion.

The expanded use of the Internet in business scenes and the provision of wireless communication networks have afforded more occasions for using notebook PCs in ubiquitous environments. In consumer markets, the TV function has been supported, and infrastructures for music and video broadcasting have been established, resulting in a significant increase in the number of notebook PC users and a tendency toward longer periods of PC use.

Notebook PC downsizing and weight reduction, extended battery operation time, the popularization of wireless communication, and an expanded TV reception environment have consequently afforded more occasions for carrying notebook PCs and greater use outside the home or office.

Improved levels of performance, increased load on the operating system and applications, body downsizing, and weight reduction have, however, posed various problems such as the overheating of components and a weak physical structure. These problems require certain countermeasures. In addition, new personal users are requesting more sophisticated exterior designs and colors, decorative body shapes, and superior surface finishing.

In view of the trend toward improved performance and expanded scenes of use described above, customers are reporting the following problems regarding body strength, overheating, dust, rough handling, and sensory trouble. These problems must also be continuously improved in the future.

1) Problems of strength
- LCD damage (by pressing the cover), cover damage, or cover scratching
- Operation error due to internal parts damage
- Damage to external connectors like power-input terminals (DC-IN) and USB connectors

2) Problems of overheating and dust
- Degradation of performance due to blocking by excessive dust
- Heating in the palm rest, lower cover, and around cooling fan vents

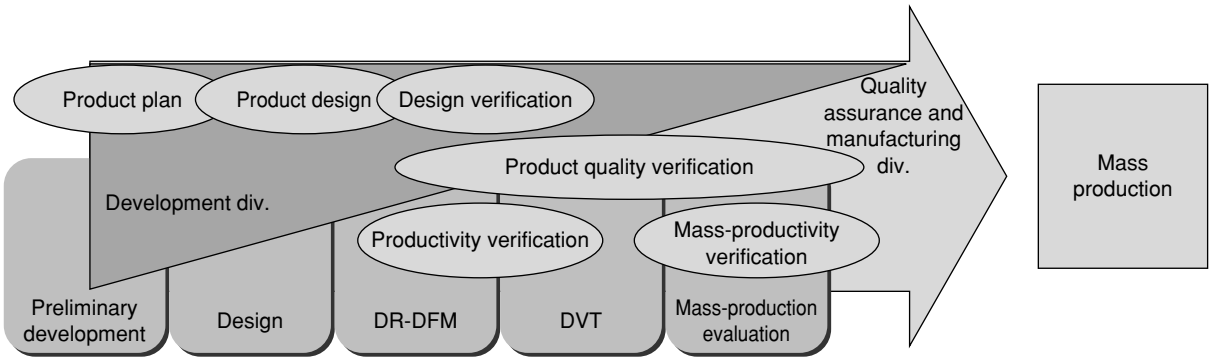
3) Problems due to rough handling
- Connector damage due to drops and other impacts
- Parts falling off when forcibly closing the back cover
- Startup disabled due to beverage spilled on the keyboard
- HDD damage due to impact

4) Sensory trouble
- Poor key action on the keyboard
- Poor operability of buttons or switches
- Exterior paintwork vulnerable to damage

3. Quality considerations in design phase

In order to maintain high product quality, Fujitsu believes that it is important to consider quality in the series of processes from prototype design and preproduction to mass-production design, evaluation, and manufacturing. Considering quality in earlier stages is particularly important.

For this purpose, the development division, manufacturing division, and quality assurance division must jointly and thoroughly confirm the conditions necessary in each phase relative to the following: design requested by the customer, measures to prevent trouble, productivity, and verification conditions. **Figure 1** shows the flow of development for considering quality in the design phase. This flow begins from the leftmost stage. Should review in any stage not be passed, processing must not go to the next stage. Quality considerations in the design stage are especially important when the period from development to manufacturing is relatively short (at about six months). As shown in the middle part of this



DR-DFM: Design review and Design For Manufacturing

Figure 1
Design phase with consideration of quality.

figure, both the quality assurance division and manufacturing division participate in the development and design stages. After trial production, it is difficult to change any structure-related conditions. Therefore, the results of field quality analysis and failure analysis, as well as customer requests, must be reported to the development and design stages as soon as possible.

The following describes an example of improving structural quality in recent years through joint efforts of the development division and quality assurance division.

1) High rigidity

The LCD, ODD, keyboard, and other unit components of notebook PCs are becoming smaller, thinner, and lighter every year. Therefore, all these components must be made more rigid by improving the cover shape, mounting structure, and other aspects of design. To protect the LCD panel of a very thin notebook PC in particular, the cover is made of a highly rigid magnesium alloy or equipped with a shock absorber to distribute and absorb external pressure.

To make notebook PCs even thinner and lighter, we are attempting to develop new composite mold materials that include plastic, carbon, or glass resin.

2) Cooling and silent design technology

Along with recent advances made in simulation technology, thermal conditions are being simulated based on parts heating data obtained from earlier steps of the design stage, with an appropriate component layout being selected by considering cooling efficiency. This consequently shortens the body case development period, with the case being designed by considering the heating of next-generation parts. We are now reviewing and changing the allowable temperature limit of each component to afford more comfortable use of the products by customers.

We also adopt a small cooling fan unit together with a heat pipe, and have adjusted fan positioning to reduce fan noise. Moreover, the frequency of fan rotation is controlled according to CPU temperature in order to provide more silent operation.

3) Increased strength of external connectors

The external connectors of notebook PCs are being used more frequently given the greater occasions for outdoor use, the use of external media, and the storing of PCs in an office cabinet for daily security. In particular, the frequency of using the DC-IN connector has gradually increased. We have enhanced the evaluation conditions and designed stronger connectors by retracting the connector edge from the body surface to prevent connector damage (by pinching).

4) Surface treatment evaluation

The paint and surface treatment of a notebook PC directly affect appearance, and are very important from the standpoints of carrying the PC by hand, outdoor use, and reliability. To prevent scratching, we test scratchproof performance by evaluating hardness and resistance to wear in the pre-development stage of new paint. The components of human sweat largely influence on paints. By assuming such components, we evaluate paint adhesion by using several types of synthetic-sweat developed for this evaluation.

5) Keyboard

The keyboard of a PC is frequently used, and must be easy to operate and durable. Fujitsu's keyboards offer a sufficient keystroke and key pitch, and employ a large, easy-to-read character font printed on each key top. A laser printing method is used to print key-identifying characters for minimizing wear even under the most demanding use conditions. The keyboards also feature a simple waterproof structure to minimize internal circuit damage in case the customer accidentally spills a beverage on the keyboard.

6) HDD protection

The HDD built into a notebook PC has a head load/unload function to unload the head while a read/write operation is not available. This largely reduces the risk of disk surface damage by the head in case of impact applied to the notebook PC. Needless to say, the disks must also be protected against vibration and impact during read/write operation. Enhancing the cushioning material generally improves resistance to impact, but reduces resistance to vibration. We utilized our unique technical knowledge to solve this problem by placing two types of cushions made of different materials at appropriate positions. The HDD must also be protected against magnetic fields generated by magnetic bracelets or magnets. A metal material for shielding against magnetic fields is inserted between the HDD and palm rest to prevent HDD errors, even if a magnet is placed on the palm rest.

7) Dust prevention

Given the growing use of PCs in dusty environments, a high-performance notebook PC requires a cooling fan of high-speed rotation due to frequent use in relatively dusty environments outdoors and in the home. We adopted a filter structure for the parts likely to be influenced by dust. Some PC models feature a structure allowing accumulated dust to be cleaned off.

4. Structural evaluation by considering use environment

In the development stage, we evaluate 1) hardware mainly by conducting electrical tests, 2) the system by conducting tests for the BIOS, operating systems, applications, and networks, 3) the reliability of newly adopted parts, and 4) the structure (**Figure 2**). The structural evaluation consists of five major vibration tests and 34 detailed tests. The vibration and drop tests (**Figure 3**) are conducted based on our independent evaluation standards determined by considering the use environments of notebook PCs. The following introduces the evaluation items designated only for notebook PCs.

1) Evaluation of LCD strength

The strength of the glass plate built into the LCD panel is very important. We make various materials and structural devices for increasing glass strength as previously described. We evaluate LCD strength by considering various use conditions.

- Strength of the back of the LCD panel

By assuming cases where the back of the LCD panel of a notebook PC contained in a bag is pressed on a crowded train or pressed by other objects contained in the same bag, we reviewed the evaluation standard for the LCD all-surface load test and added the LCD one-point load test to assure the necessary strength.

- Strength of the LCD monitor screen

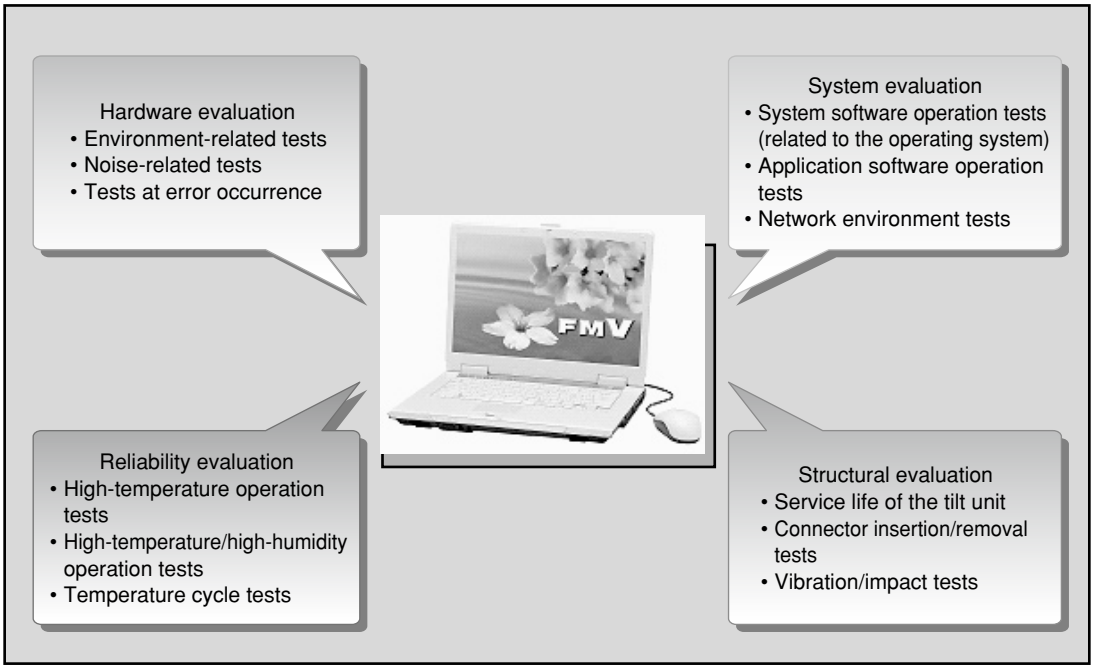
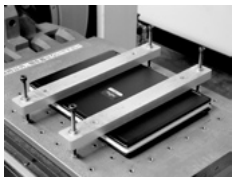


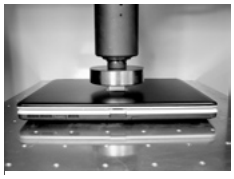
Figure 2
Evaluation by considering use environment in development phase.



■ **Continuous vibration test**
A PC is vibrated vertically and horizontally, and then checked to determine whether it operates normally.

■ **Drop test**
A PC is dropped and then checked to determine whether it operates normally.

■ **Opening/closing test**
The LCD panel is opened and closed repeatedly to check its durability.



■ **LCD one-point load test**
A load is applied to one point of the back of the LCD panel to check panel strength. All necessary points are checked.

■ **Electrostatic discharge test**
Electrostatic charge is discharged to an operating PC, which is then checked to determine whether any malfunction occurs.

■ **Electromagnetic radiation field immunity test**
The affects of an electromagnetic field from or to a PC are measured and checked.

Figure 3
Main structural evaluation tests for notebook PCs.

We have cautioned customers against pressing the LCD monitor screen, but some customers may lift a notebook PC by grasping the LCD monitor screen without much attention or catch an object between the LCD monitor screen and keyboard when closing the LCD panel. Therefore, we set a press strength standard for the LCD monitor screen, and confirm that the necessary strength is provided. Setting this standard reduced the frequency of LCD damage.

- Strength around the LCD panel

The speed of opening and closing the LCD panel varies depending on the customer. Rapid, abrupt closing of the panel may result in a poor connection of connectors and cause faults in the LCD and PCB parts. We employ an automatic testing machine to test the opening and closing of the LCD panel, and have added a new test function for changing the speed and force of opening/closing operation. Thus, we can now verify impact strength around the LCD panel as well as the tilt mechanism.

2) Strength evaluation of the operator panel

A load is assumed applied to the keyboard side and rear of the PC body in conducting the operator-panel load test. The stress applied to parts mounted on the PCB is actually measured to verify strength.

3) Strength evaluation of connectors

The durability of connectors for the AC adapter, USB, PS/2, PC card, and other external interfaces is checked by conducting repetitive connector insertion/removal tests and large-force pulling tests. In view of the recent trend toward carrying notebook PCs and storing PCs in office cabinets more frequently for security reasons, large repeated load is being applied to the connectors. In particular, there is a tendency of greater DC-IN connector damage. We randomly select the persons used in the testing, measure the load during operation, and set evaluation conditions by considering safety factors. Structural improvements and reviewing evaluation conditions have largely reduced the frequency of DC-IN connector damage.

4) Dust-proof evaluation

JIS and other standards specify dust tests. However, these standards mainly specify outdoor test conditions and do not specify test conditions using synthetic dust similar to actual dust found in the home and office environments. We repeated dust regeneration tests, developed synthetic dust, and evaluated the dust-proof conditions by using the dust in environments similar to actual use environments.

5) Evaluation of keyboard operability

When selecting a notebook PC, the keyboard operability is as important as the display quality of the LCD. Fujitsu keyboards have been highly evaluated by customers. As notebook PC bodies have become lighter and thinner, maintaining keyboard rigidity has become increasingly difficult, since keyboard operability depends on keystrokes and flexure of the keyboard itself. We use monitors to evaluate keyboard displacement during operation, established a flexure evaluation standard, and developed a dedicated automatic measuring instrument that uses laser beams. We then precisely measure KB displacement in fine detail to develop products offering excellent keyboard operability and small variations in flexure.

5. Evaluation in mass-production stage

Fujitsu's basic policy is to accept the challenge of being a world-leading manufacturer. We always strive to reduce the number of manufacturing defects to zero because we believe that every PC is very important to each customer. **Figure 4** shows part of our activities related to manufacturing and the test processes for quality assurance.

An image recognition system is introduced in the PCB manufacturing stage, where operators work cooperatively with manufacturing equipment. A screw-tightening omission prevention unit is introduced in the unit assembly stage

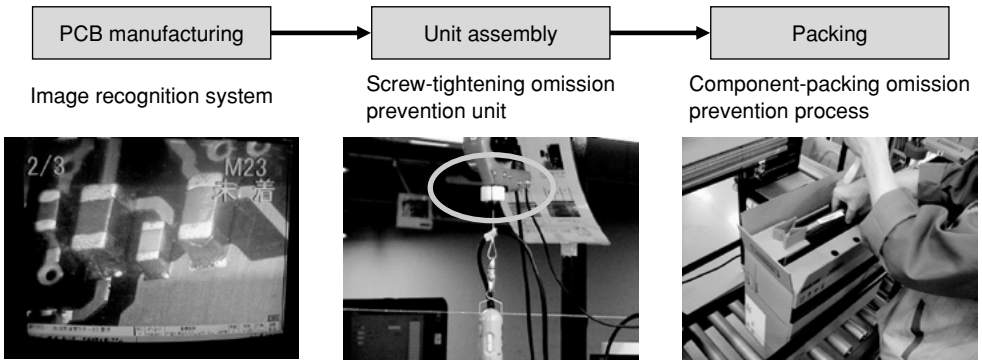


Figure 4
Verification processes in mass-production phase.

to effectively reduce human error and ensure continuous innovation.

6. Variations in inter-lot and intra-lot parts, and parts aging

In addition to inspecting each product in the processes of a mass-production plant, Fujitsu monitors the quality of mass-produced products. Specifically, a system or unit is randomly extracted for sampling from mass-produced products, followed by accelerated testing conducted with various types of stress applied to the sample. In this way, the aging faults of parts and systems can be detected early, and with effective measures taken to stabilize quality.

For example, ORT tests (accelerated testing under high temperature and high humidity) are conducted in mass-production plants. A two-week ORT test is equivalent to aging of about 1 to 1.5 years. The ORT-tested samples are then subject to system operation tests, operating part durability tests, and unit operation tests for achieving high effects. In the future, we will also review the test conditions and improve quality for even more stable operation at customer sites.

7. Conclusion

This paper described the improvements made to the structural design and evaluation technology of notebook PCs.

Customer use environments and the manner in which notebook PCs are used always vary according to social infrastructures and new trends. We must analyze such information on an ongoing basis. Customer requests and field repair information are important in understanding customer use environments and methods of PC use. Fujitsu developed a quality change monitoring system to monitor the status of daily field operation and repair information in order to detect problems early. We also periodically collect customer requests from the sales division and customer contact division, and visit the repair division to monitor whether there are any repeated or increasing faults. In this way, we continuously extract problems, determine the causes, and review the evaluation conditions.

In the future, we will also optimize the evaluation conditions from the development to the manufacturing stages, relative to the standpoint of customers, in order to supply products suited to customer use environments. We intend to provide functions necessary for proposing new methods of use, and supply products of the highest quality to ensure reliable use.

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