Development of the Miniaturized Indash CD Changer Deck (CH-05)

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Abstract

In 1997, FUJITSU TEN took the lead worldwide in releasing products installed with the 6-slot-in type in-dash changer deck (DA-26). In response to user demands for further miniaturization, high performance and price reduction, we have developed the 4th generation of the in-dash changer deck. This paper introduces its characteristics, etc.

1 Foreword

Our company has taken a world-wide lead in developing a 6-CDs 1DIN in-dash CD changer deck (model: DA-26), and ever since there has been particularly good progress in the genuine car audio market in the shift from single CD players to in-dash CD changers, with growth continuing today. As a result, Fujitsu TEN has started to supply its CD changer deck to external audio manufacturers since 2nd generation DA-32 as an OEM product, and thus we have continued to make smooth increases in production.

With OEM supply, each customer has a diversity of specification needs, thus rendering flexible response to those needs with previous models is quite difficult in a structural sense.

Furthermore, with AVN type products, another development by Fujitsu TEN which helped us take the lead over other companies, installable deck size has continued to be the CD (DVD) deck single type, and installation of changer functions has been in demand by users.

Therefore, it became necessary to reduce deck depth dimensions to realize a size enabling installment in AVN, as well as to develop a CD changer deck which can deal flexibly with various customer needs. Based on this background, we developed the 4th generation CH-05.

In this paper, we describe the CH-05 outline and characteristics from aspects of function and performance.

2 Basic concept of development

In developing the CH-05, we have set the following development target:

1) Miniaturization: reduction of deck depth dimension
2) Performance improvement: improvement of anti-vibration (anti-jumping) performance
3) Ensuring of flexibility: apply to required specifications through minor changes
4) Mass-production quality improvement: management within the process for product trend changes

Table 1 shows the methods and measures employed to achieve these target, and Table 2 shows the main development specifications.

Table 1 Ideas of target achievement

Item	Method, measure
1) Miniaturization	・Change in layout for the pickup drive ・Development of miniaturized split structure ・Change in insertion detection method
2) Performance Improvement	・Optimization of damper layout
3) Ensuring of flexibility	・Changeover of firmware specifications
4) Quality Improvement	・Measurement, within the process, of unit dimensions and loads ・Refinement of error code information

Table 2 Target development specifications

Item		Developed model CH-05	Previous model DA-32
Mechanism outline	Width	160 mm	154 mm
	Height	47 mm	47 mm
	Depth	145 mm	157 mm
Disc change time		10 s	14 s
Anti-vibration Performance		2 G	1.5 G
No. of stored discs		4/6	6

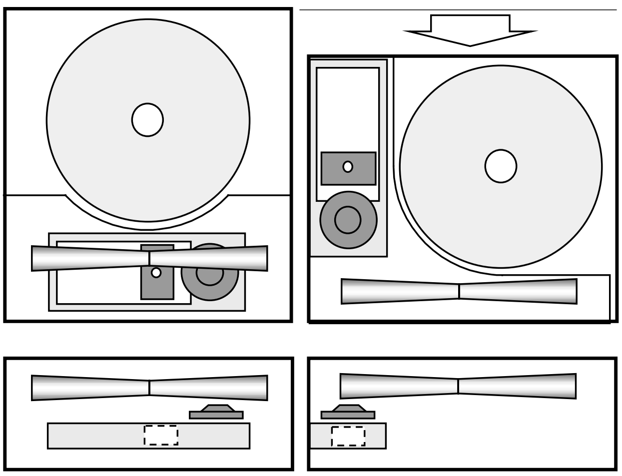
3 Miniaturizing technology

3.1 Layout changes in pick-up drive

Here we describe about reduction of depth dimension, which is one of the aims of the recently developed changer deck.

With the previous model, the disc storage portion (hereinafter referred to as stocker) was located to the back side when looking from the front area of the deck, and the disk replay portion (hereinafter referred to as drive unit) and the disk insert/eject mechanism were positioned so as to vertically overlap just in front of the disk storage portion. In other words, disk depth was basically set as the disk diameter and the dimensions of the pick-up composing the drive-unit. Now, however, the drive unit is located to the side of the stocker, and by making further maximum reduction of the dimensions of depth direction of the disk insert and eject mechanism, the depth of the overall deck was reduced. (refer to Figure 1)

With this revision of the mechanism layout, we also miniaturized the stocker portion, in order to minimize increases in width due to changes in drive unit positioning.



Previous model: DA-32　　Developed model: CH-05

Fig.1 Reduction of depth dimension

3.2 Development of a miniaturized split mechanism

In order to shorten deck depth, it is necessary not only to make layout changes but also to reduce the dimensions occupied by each internal mechanism. In particular, while the stocker's split mechanism, which is the main part of in-dash changer deck operation, had used up quite a bit of deck rear space in the previous model, now we have developed a new mechanism focusing on miniaturization.

Except for in play mode, all stockers are connected together. Stocker split refers to the operation of creating space in order to allow entry of the drive unit main frame and the clamper (for attaching a disk to the turntable in the drive unit), which is for the purpose of putting the selected disk into play mode. In other words, stocker split is the operation of splitting stocker groups 3 times. (refer to Figure 2)

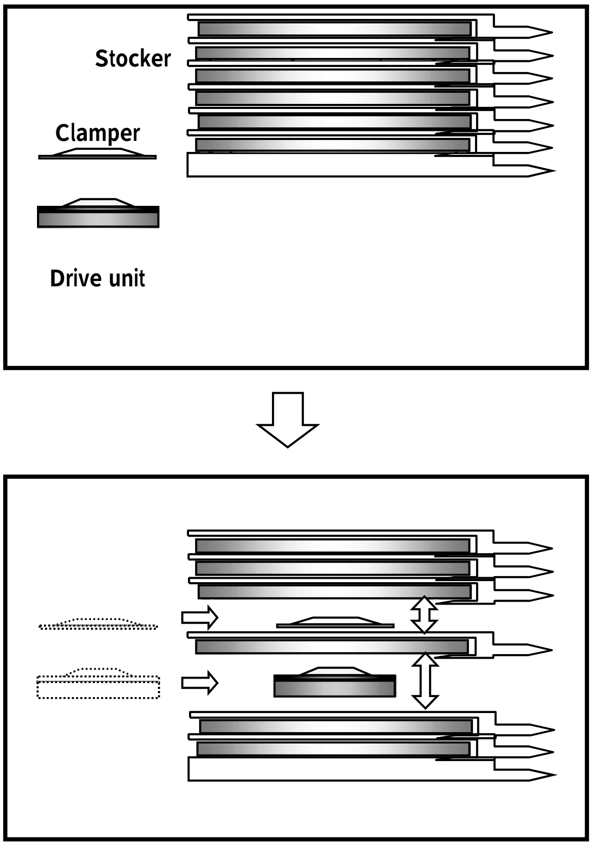


Fig.2 Stocker split

In order to establish a new mechanism in the previously stated deck outer shape, it is necessary to fit the split mechanism into the hatching section shown in Fig. 3 which consists of the 2mm width space of the deck's rear surface and right side the slit space created between the 120mm diameter disk and the corners of the square box-shaped deck.

First, lever assembly is located at 3 corners of the deck. This assembly consists of 3 levers (hereinafter referred to as split levers) of the wedge connecting the stocker above the clamp, the stocker between the clamper and the drive unit mainframe, and the stocker under the drive unit. The lever assembly engages with the stockers through rotating operation. By this engagement, for example, when playing the 3rd disk from the bottom, division is made of stockers into bundles for the 3 top disks, the disk for play in the middle, and the 2 disks at the bottom (in the case of specifications for 6 disks).

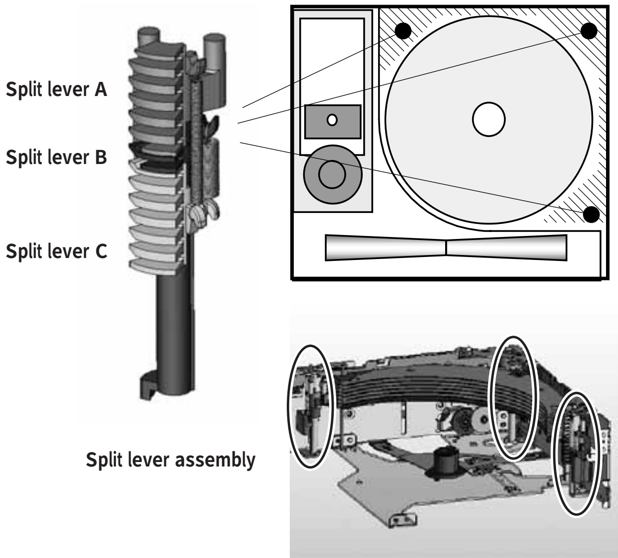


Fig.3 Location of split lever

The following shows how operation is conducted for creating space between the stockers divided by levers.

The lever engaged with the top stocker (hereinafter referred to as split lever A) is fixed in a vertical direction. Below that, the lever engaged with the stocker used for the played disk (hereinafter referred to as split lever B) and the lever engaged with the stocker below the drive unit (hereinafter referred to as split lever C) are capable of vertical movement. When not connected to the stockers, split levers A and C make contact through force of the connecting spring, and split levers B and C are also attracted to each other by the same spring force.

Due to this condition, when the lowest split lever, C, is lowered, space is created between the vertically fixed split levers A and B, and 2 splits are done for the stocker.

As split lever C is lowered, split lever B catches on to the stopper set up around the chassis and is held firm in that position, therefore creating space between split levers B and C as well. As a result, 2 spaces are created between the stocker groups, and the clamper and drive unit can move in between discs.

Lowering of split levers is conducted in the following fashion.

Stockers are stacked in layers above their foundation, the chassis (hereinafter referred to as stocker base), and when split is not taking place, both stockers and the chassis are raised and lowered together. The stocker base's raising and lowering operations are handled by levers positioned at the rear and side of the deck (hereinafter referred to as raising/lowering levers). The raising/lowering levers slide along the chassis surface of the rear and side, each having 2 declined linear cam grooves. Because the 4 shafts on the side of the stocker base are engaged with those cam grooves, operation changes from that of raising/lowering lever sliding to that of stocker base vertical movement, and the stocker base can make this vertical movement while keeping a horizontal position.

As with other stockers, the stocker base connects with split levers, thus the engaged split levers can be raised and lowered with the stocker base. In other words, if split lever C and the stocker base are engaged when raising and lowering, this helps realize the previously-mentioned stocker split operation.

Additionally, because the cam grooves are linear, the stocker base's halting position can be set optionally. Halting of position is performed through linear detection by sensors using variable resistors.

Using this stocker base movement, selection of disks for play is also performed. In other words, if the stocker storing the disk for play is stopped at a position matching that of split lever B to perform split operation, it is possible to select and play optional disks, and thus to carry out disk change functions. (refer to Figure 4)

This is how we developed a new mechanism realizing stocker split and selection functions, only using the space shown in Figure 3.

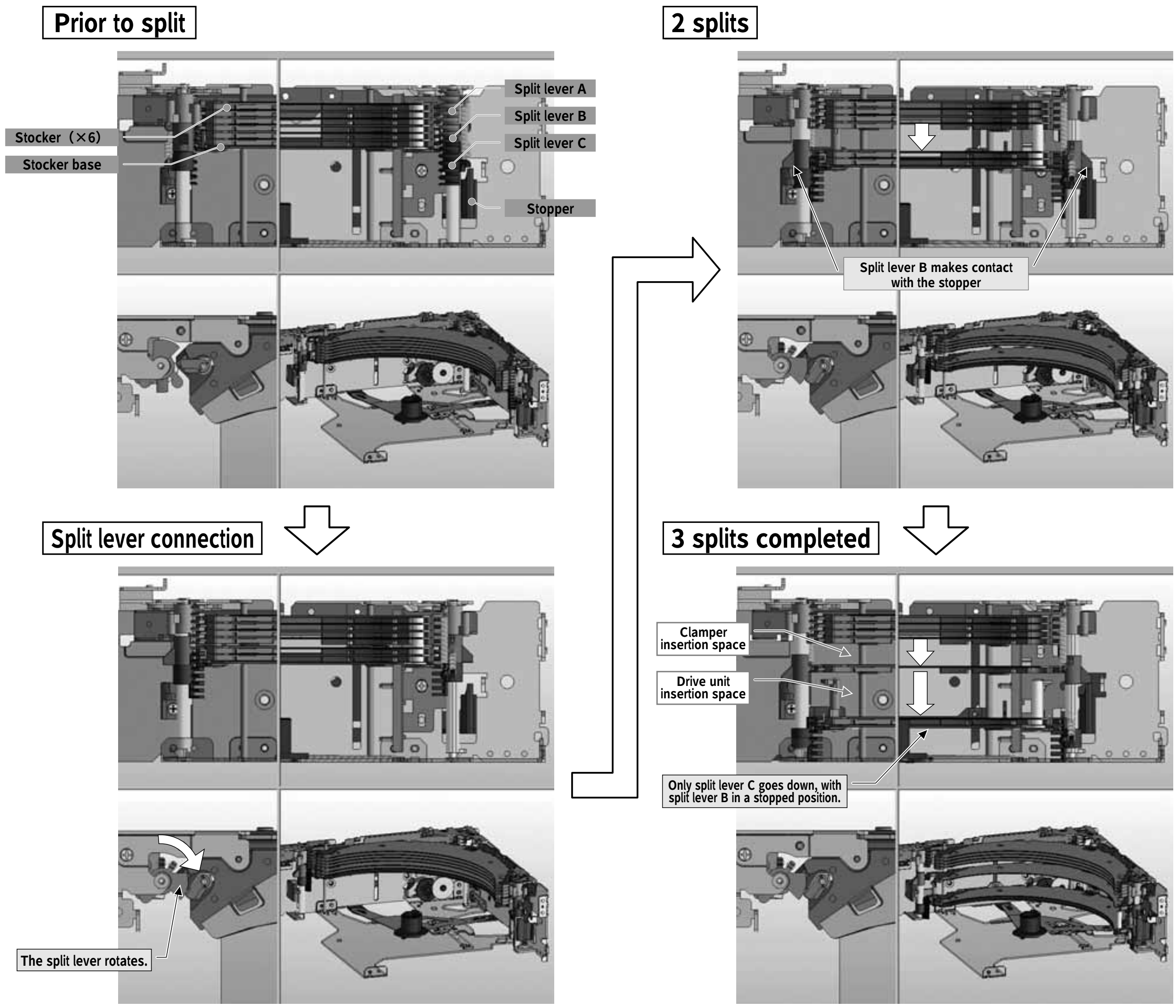


Fig.4 Stocker split operation

4 Improvement of anti-vibration performance

With car CD players, it is important that there is no sound skip even when there is vibration during driving. In-dash CD changers prevent such skip in various ways. One way is mechanical vibration absorption through floating in the replay area, which has used oil dampers conventionally. Another way is through a circuit-based anti-vibration method called "shock-proof memory." With this method, replay signals are gradually saved in memory IC, so that even if signal reading is disabled due to vibrations, playing is continued until data in the memory runs out.

From the beginning, CH-05 was developed on the assumption that DVD changer will be installed as a specification variation. However, a considerably greater amount of data is required for DVDs compared to CDs in replay per unit time, and so with memory capacity equivalent to that in a CD, there is less time for saving music performance.

In order to avoid cost increases due to memory increase, it was necessary to further enhance mechanical vibration absorption performance of the oil damper.

Because of that necessity, we included the following measures in development:

①Optimization of oil damper layout
②Use of the disk sandwich clamp method
③Implementation of vibration analysis through CAE

The following elaborates on each measure.

4.1 Optimization of oil damper layout

DA-32 had not been set up in an optimal arrangement as, due to mechanism layout, the gravity center of the floating portion was not in the center of the oil damper figure.

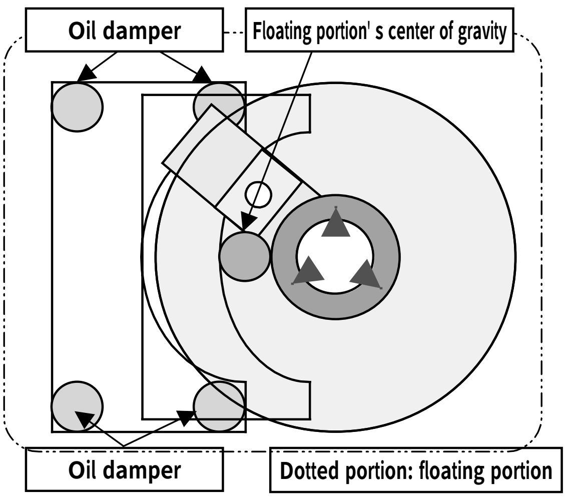


Fig.5 Oil damper layout of the previous model

In CH-05, arrangement for the drive unit was changed so that there was alignment between the floating portion's center of gravity and the center of the oil damper figure. By doing so, movement of the floating portion is rendered parallel with incoming vibrations, thus making it possible to easily bring out oil damper attenuation performance.

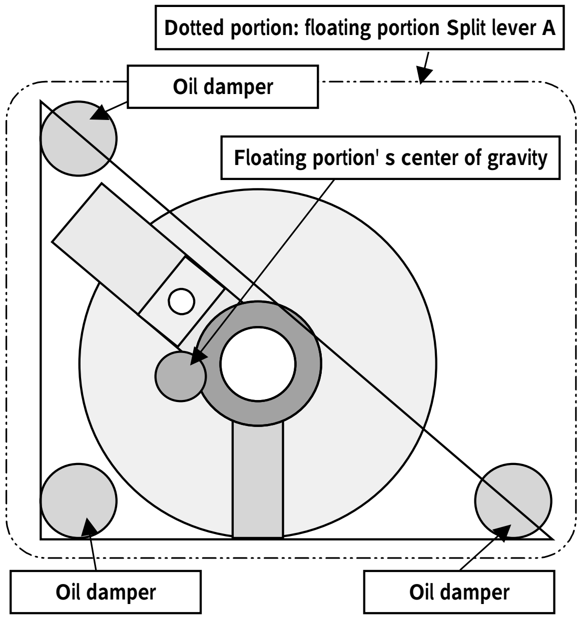


Fig.6 CH-05 oil damper layout

4.2 Use of the disk sandwich clamp method

With a CD player, it is necessary to keep (clamp) disks in the turntable and to have signals read while disks are spinning.

With previous model DA-32, a claw-shaped part for use as a disk clamping method, called a chuck, had been built into the turntable to maintain the position of the disk's center hole.

While this method has merits in being able to simply and miniaturize mechanisms, there was little area for keeping disks, and so it was necessary to make composition changes in order to increase storability and further enhance anti-vibration performance.

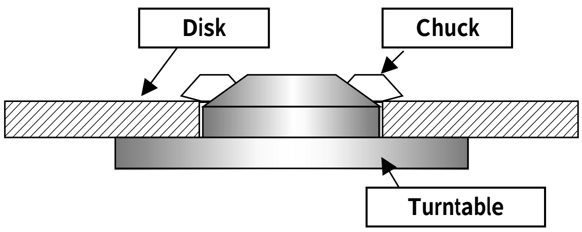


Fig.7 Clamp method of the previous model (chuck type)

With CH-05, a method was employed for clamping (the sandwich clamp method) in which a clamper, a disk-shaped part with the same diameter of the turntable, was used as a clamp method to grasp disks from an area opposite to the turntable. Originally, this method has been used in single CD decks, and with the turntable disks can be kept on wide surfaces. Thus, this method has more possibility than the chuck method for keeping disks stable on the turntable during vibrations, and is more advantageous in terms of anti-vibration performance.

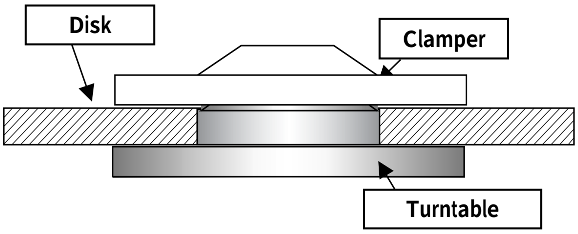


Fig.8 CH-05 clamp method (sandwich type)

4.3 Vibration analysis through CAE

Since DA-32, Fujitsu TEN's CD changer decks have been designed using 3-D CAD. For development of CH-05, we fully adopted computer simulations using 3-D CAD models right from the development stages, and made quality Improvements in the drafting evaluation stages. In regards to anti-vibration performance, by using CAE-based vibration analysis, we were able to confirm product resonance properties of the floating portion in the drafting stages. Based on the results of this confirmation, we performed material selection and figuration optimizing for the pickup drive chassis.

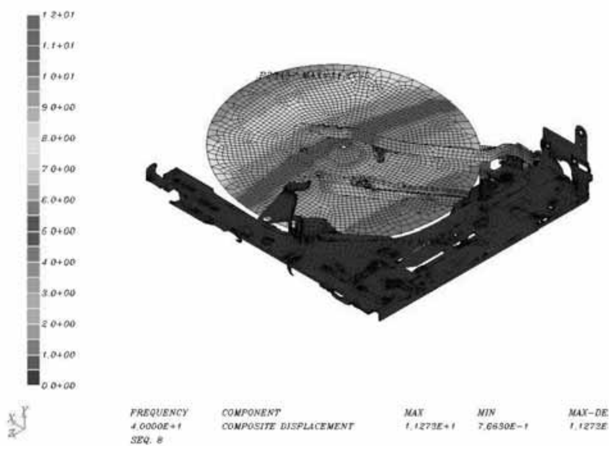


Fig.9 Simulation analysis of vibration

Through the previously mentioned measures, we have enhanced CH-05 anti-vibration performance by 30%, clearing the target of 2 G (19.61 m/s^2).

5 Ensuring specification flexibility

Since the making of DA-32, Fujitsu TEN has also been making OEM supply to other audio manufacturers with in-dash changer decks. As a result, we need many derivative models in order to respond to the various demands of users within and without the company.

From the beginning, with CH-05 we provided for the number of loaded disks (4 and 6), product outer shape varied depending on print board mounting location, and play-related variations (CD/DVD types). Furthermore, we dealt with specifications for a wide range of customers in regards to compression audio products.

However, we needed to develop these various specifications with a limited amount of manpower. We dealt with this situation by standardizing design as much as possible, thus solving this problem.

5.1 Firmware standardization

With previous models, software specifications differ between customers. Due to this, new software is developed in response to each increase in customers, and this creates problems with man-hours in terms of development and software management.

Therefore, we took a measure which involved changing the CH-05 microcomputer terminal through external resistance, and which involved using terminal conditions to change the same software into a program compatible with customers.

Software was unified by doing this, and as a result, when specification changes occur with common portions of multiple software products, we are able to reduce management hours, as it is no longer necessary to have design and evaluation man-hours in order to port distinctions between those products for customers. In addition, mask ROM for the microcomputer can also be performed all in one time, which also contributes to reduced costs.

5.2 Creating a library for changer mechanism control software

For the previous model, we had been making external sales only for deck mechanisms. When doing so, it was necessary for the customer to make designs for control boards and software, and so there had been a strong demand from customers for supply of a library of control programs requiring mechanism-specific know-how. However, in the past all control software, including mechanism controls, were written in assembly language unique to microcomputers. This reduced versatility, and complicated porting to microcomputers of other companies.

Therefore, for development of CH-05, we developed firmware with C language right from the start, making a library system for mechanism control.

Through this library system, we used microcomputer hardware different from CH-05 for DVD changer (DH-01) development, and for mechanism controls we were able to realize controls common with CH-05.

Naturally, it is possible to supply a library solely for mechanism control in terms of external sales for future deck mechanisms as well.

(Front: DVD type, back left: 6 CDs and top print board type, back right: 6 CDs and side print board type)

Fig.10 CH-05 family products

6 Activity for quality improvement

Our company needs not only to respond to recent strict demands for quality, but also to continue to provide products with stable quality, even if mechanisms become complicated due to miniaturization. As a new undertaking for development of the current CH-05, we made quality enhancements through improved levels of product function development, introduction of unit warranty, and enhancement of unit traceability.

6.1 Improved levels of product function analysis

Function analysis involves block division of functions (the following 5 functions) necessary for realizing CD changer deck mechanisms, and consideration of goals and restricting conditions regarding each of those function blocks. Having done so, functions are developed to a basic function with division made into first and secondary functions..., and derivation is made from the main points of functions realized through design.

Functions blocks for CD changer deck mechanism:

1) Playback function

2) Disk insert/eject function

3) Disk change function

4) Disk storage function

5) Communication function

In the past, basic functions were realized with development and design of products satisfying the specifications of completed products, paying heed to past problems and market demands derived from the benchmarks of other companies.

For development of CH-05, basic functions taken from function analysis were taken a step further into design specification items, and having clarified concrete design specification values and their grounds, we moved forward with more detailed design.

6.2 Introduction of unit assurance

In order to realize a CD changer deck mechanism, it is necessary to have more than 300 mechanism parts .

Team design is essential to carry on with such product designs of this scale, and so each function block is broken down into design units, and parallel designing is performed.

For CH-05, product development was done with division into 4 units.

When looking at changer deck mechanisms through the concept of units, it is necessary to satisfy unit design specifications for the quality of finished products, as well as to satisfy design specifications for lower sub-units and mechanism part units.

By looking in contrast, when sub-unit design specifications are satisfied, this also means satisfaction of design specification for higher units, which guarantees the quality of final finished products.

However, because units are composed of built-up multiple parts, variations exist between the interface areas and basic functions, and there is the inherent possibility of interference with quality stability of completed products.

In regards to precision of the location of stationary parts, because they are simply composed parts with layered dimensions, high unit design specifications for them can be achieved with part specifications. However, for halting position precision, operational loads and driving force, there is not only the possibility of variations between the dimensions of component parts, but also that of several variations occurring in the assembly process.

For deck mechanism assembly of previous models, there no process has been established for performing checks and inspections on such assembly process variations, with the only guarantee being that of variation verification results from paper calculations and simulations. And, for moveable parts, it is difficult even with simulations to perform design verification that encompasses variations throughout the entire range of operations. Thus, it is believed that verification cannot be done to completely cover variations, and that this is one factor in the occurrence of potential problems.

With the design quality enhancement measures, we have been presently working on, we will detect such potential instability factors before deck mechanisms become finished products, completely eradicating problems occurring in them.

For detailed efforts, as stated above, design specification values defined in units will be checked in the assembly process, and trends in this process will be controlled. By doing so, occurring changes will be detected in advance in the assembly process, and by making the proper response to the situation finished product quality will be guaranteed.

However, while determination of OK/NG for specification values is possible with only in-process checks, trends cannot be grasped for variations occurring within standard values. Therefore, we have made efforts to discover changes happening in the process through gathering measured data for each unit gathered in the process, and through implementing Xbar-R management for each data item.

We asked parts manufacturers as well to conduct Xbar-R management, as they had done in the assembly process, for part dimensions in areas related to design specification values defined in units. Through collection and analysis of information including the results of that management, changes which harbor predicted occurrence of potential problems were detected prior to unit assembly, which promoted preventative measures.

6.3 Improvement of unit traceability

In the above-mentioned Xbar-R management of unit and part dimensions, while trend management is implemented in manufacturing lot bases in which data acquisition is performed, it is not possible to grasp the features behind each unit assembled.

Due to this, as further efforts for quality enhancement, we also developed a quality tracing system in which data management can be performed on a unit scale.

It was decided that each unit be given manufacturing numbers which in the past had only been given to finished deck mechanism products, and that those numbers be automatically gathered in relation with values of unit specification items measured in-process. By gathering this obtained data in correlation with the manufacturing numbers of finished products, it is possible to confirm conditions during assembly of each unit when problems arise in finished products, as well as to use this information as fundamental data in cause analysis.

6.4 Enhancing of error codes for problem

The error codes mentioned here are those written into EEPROM when problems occur in CD changer decks in the assembly process and in the market, and are used as fundamental data in cause analysis of those abnormalities.

With CH-05, the amount of information included in one code is increased from that of 2 bytes of previous decks to 4 bytes. Information conceivably necessary for analysis is also increased, through acquisition of information on deck internal areas for added areas, including individual SW conditions and pick-up laser current values. Codes that were only written in when error halts occurred for the previous model have been set to be preserved during occurrence of abnormal phenomena even if not reaching the point of abnormal halting. In addition, when specific error codes were written in, the previous 20 profiles were copied to regions prohibiting overwriting. This helped avoid repetition of user operations after occurrence of problems, and prevented old codes from being overwritten when the number of code records exceeded memory capacity.

Through these approaches in CH-05, we reduced NTF and enhanced speed of analysis for determination of the causes of abnormalities after their occurrence.

7 Afterword

This concludes the outline and configuration of the currently developed in-dash CD changer CH-05.

We were able to achieve development goals such as miniaturization and enhancement of functions and performance, and to put our in-dash CD changers into the market as the 4th generation of their kind. We will continue to promote improvement, and we will enhance function and performance as well as bring down costs.

In closing, we would like to give a heartfelt thanks to all of you who gave us your cooperation and advice in the development of this product.

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