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THE ANALYSIS, COMPARISON, AND REDESIGN OF CD-CASE USING THE PRINCIPLES OF AXIOMATIC DESIGN

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ABSTRACT

CD-cases with various capacity and functions such as portability and individual access to a specific CD have been designed and manufactured. In this paper, a cake-type CD-case is redesigned using the axiomatic design theory to have the advantageous functions of other CD-cases. First, a cake-type, a wallet-type, and a cabinet-type CD-case are analyzed by axiomatic design approach and design matrices are made to check whether the independence axiom is satisfied or not. Second, functional requirements (FRs) are derived from the FRs of the existing cake-type CD-case and the advantageous FRs of the other CD-cases. Constraints (Cs) are defined considering the volume and weight of the improved CD-case. Design parameters (DPs) are conceived in physical domain to satisfy these specified FRs and Cs, and two alternative DPs for one FR are proposed. One of these alternatives having the least information content is selected by defining FRs as the minimization of the production cost and time. Also marketability is estimated by comparing the information content of the redesigned CD-case with that of other CD-cases in consideration of capacity, volume, and price.

Keywords: CD-case, axiomatic design, independence axiom, information axiom.

1 INTRODUCTION

In order to develop competitive products, the same kind of product having the same functional requirements (FRs) at the highest level have different FRs at the next or lower level, and the products integrating these FRs are developed. In developing these products, the axiomatic design methodology is useful for the analysis, comparison and redesign of them. Especially using the information axiom the best design among alternatives can be selected and also marketability can be estimated.

In this paper, using the axiomatic design approach the functional requirements and the design parameters of the commercial CD-cases are analyzed, and a cake-type CD-case is redesigned to integrate the advantageous functions of other CD-cases. Firstly the commercial CD-cases are classified in three types, and the DPs are analyzed, then the main FRs of the each DPs are defined. Moreover the design equations are made to identify whether the designs satisfy the independence axiom. After this process, basically the FRs of a cake-type CD-case and the advantageous FRs of the others are adopted as the FRs of a redesigned cake-type CD-case, and DPs are selected or created to satisfy these FRs. Especially two alternative DPs satisfying one FR that is holding a CD are suggested, and using the information axiom the best DP is selected in the producer's point of view, also the redesigned CD-case is compared to the other CD-cases in the consumer's point of view to estimate the marketability.

2 THE ANALYSIS OF THE COMMERCIAL CD-CASES USING AXIOMATIC DESIGN

Many kinds of CD-cases are designed and developed according to the capacity and uses. Generally there are three kinds of CD-cases such as a cake type, a wallet (bag) type, and a cabinet type CD-case. The cake type CD-case is used as the packing box of large amount of CDs from the factory. It is useful for the carriage and storage of CDs because it has a large capacity in a small volume. But it is difficult to find a specific CD and to take it out or put it in individually. The Wallet type CD-case has also a large capacity in small volume, and it is easy to find a specific CD and to access it individually. A handle or a shoulder string makes it easy to carry the case. But it is not suitable to store large amount of CDs because it is made of leather or cloth. The cabinet type CD-case is useful for the classification of CDs and the individual access to each CD, and it has a large capacity. But it is not portable because of its volume and weight.

Using axiomatic design these three kinds of CD-cases are analyzed. First, the DPs are analyzed, and the main FRs of each DP is examined. Also the design equations are made to check whether the design is coupled or not.

2.1 THE CAKE TYPE CD-CASE

The DPs of a cake type CD-case are analyzed in consideration of functions, and it consists of a base for supporting CDs, a column for arraying CDs, a cover for protecting CDs against the damage or contamination from outside, and a lock mechanism for fastening the cover to the base. It is identified that the design of the cake type CD-case is decoupled by the design equation (1). In the function of supporting CDs the column is related with the base. A lock mechanism is physically integrated to the base and the cover.

● design analysis
DP1 : a base.
DP2 : a column.
DP3 : a cover.
DP4 : a lock mechanism.

FR1 : supporting CDs.
FR2 : arraying CDs.
FR3 : protecting CDs from damage or contamination.
FR4 : fastening the base and the cover.

● design equation

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \end{Bmatrix} = \begin{bmatrix} \times & \times & O & O \\ O & \times & O & O \\ O & O & \times & O \\ O & O & O & \times \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \end{Bmatrix} \quad (1)$$

Figure 1.A Cake type CD-case.

2.2 A WALLET (BAG) TYPE CD-CASE

The DPs of a wallet (bag) type CD-case are analyzed in consideration of functions, and it consists of sleeves for containing CDs, a cover for protecting CDs against the damage or contamination from outside, a handle or a shoulder string for carrying CD-case easily, and a zipper for fastening the each side cover. It is identified that the design is decoupled design by the design equation (2). In the function of protecting CDs the sleeves are related with the cover.

● design analysis
DP1 : sleeves.
DP2 : a cover.
DP3 : a handle or a shoulder string.
DP4 : a zipper.

FR1 : containing CDs individually.
FR2 : protecting CDs from damage or contamination.
FR3 : carrying the case easily.
FR4 : fastening each side cover.

● design equation

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \end{Bmatrix} = \begin{bmatrix} \times & O & O & O \\ \times & \times & O & O \\ O & O & \times & O \\ O & O & O & \times \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \end{Bmatrix} \quad (2)$$

Figure 2.A Wallet (Bag) type CD-case.

2.3 A CABINET TYPE CD-CASE

The DPs of a cabinet type CD-case are analyzed in consideration of functions, and it consists of a base for containing CDs, guides for arraying CDs, a cover for protecting CDs against the damage or contamination from outside, and locks for fastening the cover to the base. It is identified that the design is decoupled design by the design equation (3). In the function of protecting CDs the sleeves and the cover are related. The lock mechanism is partially integrated to the base and the cover.

● design analysis
DP1 : a base
DP2 : guides
DP3 : a cover
DP4 : a lock mechanism

FR1 : containing CDs.
FR2 : arraying or supporting CDs individually.
FR3 : protecting CDs from damage or contamination.
FR4 : fastening the base and the cover

● design equation

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \end{Bmatrix} = \begin{bmatrix} \times & O & O & O \\ O & \times & O & O \\ \times & O & \times & O \\ O & O & O & \times \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \end{Bmatrix} \quad (3)$$

Figure 3.A Cabinet type CD-case.

3 FUNCTIONAL REQUIREMENTS AND CONSTRAINTS

As a result of the analysis, CD-cases have the common FRs such as containing CDs, protecting CDs from damage or contamination, and fastening the base and the cover, and also they have the characteristic FRs such as arraying CDs, carrying a case easily, and containing CDs individually. The cake type CD-case is chosen to be redesigned because it has a large capacity in a small volume. The FRs of a redesigned cake type CD-case are defined as follows considering the common and characteristic FRs.

FR1 : supporting CDs.
FR2 : arraying CDs.
FR3 : protecting CDs from damage or contamination.
FR4 : fastening the base and the cover.
FR5 : enabling individual access to each CD.

As constraints, the volume of the case is limited to three times of the contained CD volume, and the weight is limited to one time of the contained CD weight.

4 DESIGN PARAMETERS

DPs are selected from the DPs of the existing CD-cases or created to satisfy the defined FRs. Especially two alternative DPs are suggested to satisfy the FR5 that is enabling individual access to each CD. Hence two kinds of CD-cases are proposed. One is the cake type CD-case with round CD holders, and the other is the cake type CD-case with crescent CD holders.

4.1 THE CAKE TYPE CD-CASE WITH ROUND CD HOLDERS

The round CD holder rotating around a column makes it possible to individually identify each CD and to take in or out CDs perpendicularly. The holder has a thin rim and a round arm to support a CD.

- **FRs & DPs**

FR1 : supporting CDs.
FR2 : arraying CDs.
FR3 : protecting CDs from damage or contamination.
FR4 : fastening the base and the cover.
FR5 : enabling individual access to each CD.
  FR51 : holding CDs individually.
  FR52 : enabling rotation of a each holder.

DP1 : a base.
DP2 : a column.
DP3 : a cover.
DP4 : a latch.
DP5 : a round CD holder.
  DP51 : a round holder arm.
  DP52 : a holder hole.

- **design equation**

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \\ FR5 \end{Bmatrix} = \begin{bmatrix} \times & \times & \times & O & \times \\ O & \times & \times & O & \times \\ O & O & \times & O & O \\ O & O & O & \times & O \\ O & O & O & O & \times \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \\ DP5 \end{Bmatrix} \quad (4)$$

$$\begin{Bmatrix} FR51 \\ FR52 \end{Bmatrix} = \begin{bmatrix} \times & O \\ O & \times \end{bmatrix} \begin{Bmatrix} DP51 \\ DP52 \end{Bmatrix}$$

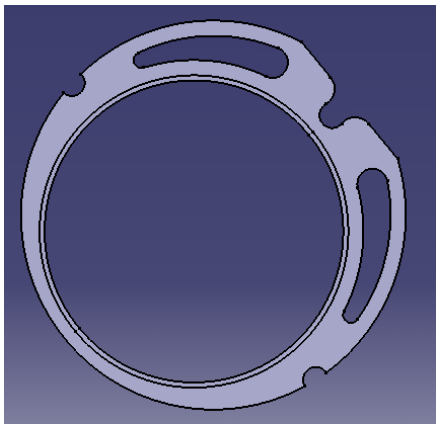

Figure 4.A Round CD holder.

4.2 THE CAKE TYPE CD-CASE WITH CRESCENT CD HOLDERS.

The crescent CD holder rotating around a column makes it possible to individually identify each CD and to take in or out CDs horizontally. The holder has a thin slot and a crescent arm to support a CD.

- **FRs & DPs**

FR1 : supporting CDs.
FR2 : arraying CDs.
FR3 : protecting CDs from damage or contamination.
FR4 : fastening the base and the cover.
FR5 : enabling individual access to each CD.
  FR51 : holding CDs individually.
  FR52 : enabling rotation of a each holder.

DP1 : a base.
DP2 : a column.
DP3 : a cover.
DP4 : a latch.
DP5 : a crescent CD holder.
  DP51 : a crescent holder arm.
  DP52 : a holder hole.

- **design equation**

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \\ FR5 \end{Bmatrix} = \begin{bmatrix} \times & \times & \times & O & \times \\ O & \times & \times & O & \times \\ O & O & \times & O & O \\ O & O & O & \times & O \\ O & O & O & O & \times \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \\ DP5 \end{Bmatrix} \quad (5)$$

$$\begin{Bmatrix} FR51 \\ FR52 \end{Bmatrix} = \begin{bmatrix} \times & O \\ O & \times \end{bmatrix} \begin{Bmatrix} DP51 \\ DP52 \end{Bmatrix}$$

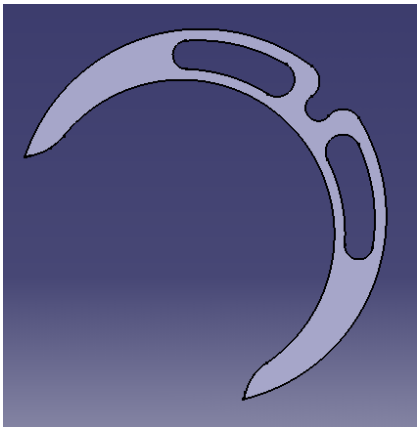

Figure 5.A Crescent CD holder

5 THE SELECTION OF BEST DESIGN USING THE INFORMATION AXIOM

The best design can be selected using the information axiom as the one that has the least information contents. Two design alternatives are different just in the CD holder shape. By the way, in producer's point of view the best design between the alternative DPs having the same function is the one that minimizes the production cost and time. Therefore the information contents of the cost and time to produce the holders are calculated.

The production cost is dependent on the price of the production machine and the cost of the material, which are selected according to the shape or size of the holders. The production time is determined by the performance of a machine and the material property. Therefore, after selecting the machine and material, the information contents of cost and time can be calculated.

5.1 THE PRODUCTION COST AND TIME

Generally, a cake type CD-case is produced by an injection molding machine with resin. The round CD holder has a simple shape, and does not need fine dimensions. Thus polypropylene (PP) resin that has a relative cheap price, an electrical insulation characteristic, a small shrinkage rate, and a good formability is selected. Also 350 ton series injection molding machine is chosen considering the pressure in the mold and the injection area. However, the crescent holder needs a high precision at the slot in which the edge of a CD is fixed. Thus polystyrene (PS) resin that has a little shrinkage rate, a great formability, and a good electrical insulation characteristic is selected. Also 450 ton series are chosen for fine precision.

From a market survey, the price of PP resin is about 864,000~876,000 won per ton, and 966,000~984,000 won for PS resin. The 350 ton series of injection molding machine are sold at the price of 82 ~ 100 million won, and 110~132 million won for 450 ton series. Therefore the material cost per holder is about 7.776~7.884 won for the round holder, and 5.796~5.904 won for the crescent holder.

The production time is dependent on the injection rate. The property of resin and the shape of product should be taken into consideration to determine the injection rate. Because the resins selected for each design have a good formability and the shapes are similar, the rate is dependent on the performance of the injection molding machine. The injection rate of 350 ton series is about 311~435 ㎤/sec, and 419~548 ㎤/sec for 450 ton series. The volume of the detail designed crescent CD holder is 6.297 ㎤, thus the time to produce one crescent holder is about 0.011~0.015 sec. In the case of the round CD holder, the volume is 9.162 ㎤, thus the production time is about 0.021~0.029 sec.

The cost of material, equipment, and the time to produce the each one holder is presented in Table 1.

Table 1. The production cost and time

	The material cost per holder (won)	The equipment cost (million won)	The production time per holder (sec)
A Round holder	7.78~7.89	82-100	0.021~0.029
A Crescent holder	5.80~5.90	110-132	0.011~0.015

5.2 INFORMATION CONTENTS

The design ranges for the production cost and time are determined according to the capital of a producer, the break-even point, the product amount and price, etc. As an example to show that the best design can be determined by the information axiom in producer's point of view, the design ranges are assumed as follows.

FR1 : The material cost per holder should be under 7.8 won.

FR2 : The production time per holder should be under 0.025 sec.

FR3 : The equipment cost should be between 90 ~ 120 million won.

The system ranges are defined as table 1, and the design ranges are determined as above the FRs. In the case of an uniform probability density function, the information contents for the each design are presented in table 2. The CD-case with a crescent type CD holder has the least information contents, thus it is the best design. However the system and design ranges can be changed, accordingly the best one can be change. Also if the information contents have an infinite value, the CD-case should be redesigned.

Table 2. The information contents for production

	A round holder	A crescent holder
Material	2.170	0
Equipment	0.848	1.138
Production time	1	0
Total	4.018	1.138

6 THE COMPARISON OF MARKETABILITY USING THE INFORMATION AXIOM

The redesigned cake type CD-case is compared to other type CD-cases using the information axiom in the consumer's point of view. To estimate the marketability, the design ranges can be determined on the basis of the market survey which is about the analysis of the system ranges of best sellers. Thus the rower the information contents value is, the more competitive the product is.

Excluding personal preference the items that can be considered in purchasing CD-cases are a price, a capacity, and functions. If the CD-cases have a similar capacity and function, the price and volume of the CD-case may be the main items. First, the price of the redesigned cake type CD-case is determined about 8,000 ~ 10,000 won for the capacity of 100 ~ 150 units, that is based on a market survey and the production cost. This price can be changed by a market strategy and a demand. Because the price and the volume of the existing CD-cases vary with the capacity, the rates of them per one CD are compared. The rates of the redesigned cake type CD-case and the existing CD-cases are presented in table 3.

Table 3. The system ranges of the CD-cases

	Wallet type	Cabinet type	Redesigned Cake type
Price / Capacity (won/unit)	70 ~ 158	106 ~ 167	66 ~ 80
Volume / Capacity (㎤/unit)	26.40 ~ 42.00	49.87 ~ 89.43	44.59 ~ 47.78

The information contents may be different according to the design ranges determined by each consumer. However in order to estimate marketability, the design ranges can be determined as the system ranges of the best sellers from the market survey. As an example the design ranges are assumed as follows.

FR1 : the rate of a volume per CD should be between 40 and 50 ㎤/unit.

FR2 : the rate of a price per CD should be between 70 and 150 won/unit.

The system ranges are defined from table 3, and the design ranges are determined as the FRs. In the case of uniform probability density function, the information contents for each CD-case are calculated and presented in table 4. The redesigned CD-case with crescent type CD holders has the least information contents, thus it is the most competitive product among them. However the design range can be changed, accordingly the best one can be changed. Also if the information contents have infinite value, it may be better to redesign the CD-case.

Table 4. The information contents for marketability

	Wallet type	Cabinet type	Redesigned Cake type
Price	0.138	0.471	0.485
Volume	2.963	8.249	0
Total	3.101	8.720	0.485

7 CONCLUSION.

The cake type CD-case was redesigned to integrate the advantageous functions of other CD-cases using the axiomatic design approach. Two alternative designs were proposed for one FR, and the best design was chosen using the information axiom in consideration of the cost and time for production. Also the marketability was estimated as the system ranges of the best sellers were taken as the design ranges of the consumers.

Consequently, the axiomatic design methodology was useful to develop the product which integrates the different characteristic functions of same kind of product. Also the information axiom makes it possible to determine a best design among alternatives and to estimate the marketability.

8 REFERENCE

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