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DEVELOPMENT OF DESIGN EVALUATION TOOL THROUGH AXIOMATIC

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ABSTRACT

There are two axioms in the axiomatic approach. The first axiom is the independence axiom which helps to prevent problems from occurring the initial stages of design resulting in the increase of overall system efficiency. The second axiom is the information axiom which helps to determine the most optimized design among the numerous proposed design. Information Axiom states that the information content was defined in terms of the probability of being able to satisfy a given FR. The proposed method for measuring information content can overcome the problems of the conventional method. By considering the weight for each design parameter when measuring information, an optimum design may be determined even when the total information content is the same. Furthermore, merits and demerits of each design may be understood by observing the information content of each design parameter. As a result places where special care is needed can be numerically seen. With similar method the information content of the functional requirement may be measured.

Keywords: information axiom, design appraisement, software, house of quality

1 INTRODUCTION

In design, information can be defined as amount of information required satisfying the functional requirement at a given level. The selection of design parameters for satisfying the functional requirement depends on the probability that the design parameter satisfies the functional requirement. If the functional requirement is always satisfied without any preliminary or supplementary information, then the functional requirement is always satisfied regardless of the design parameter selection. In actual design and manufacturing, design parameter that has the highest probability that it will satisfy the functional requirement is selected. The probability that the functional requirement is satisfied depends on the complexity of the information. Therefore, optimal design depends on the information that goes with the design.

One of the characteristics of design is that it accompanies a series of decision making process. As the life cycle of products got shorter, the importance of decision making became essential. This does not just go for product design, and it is applicable to all engineering design processes.

Design process is generally composed of three aspects. The first aspect is product design standards such as performance, quality, reliability, safety, and product life that are all reflects on the consumers. The second aspect is producing a design concept that considers the physical method that satisfies the design standards. Finally, the third aspect is specific design or the decision making process for selecting dimension, array of components, geometry of each parts, material, and so on that best satisfies the design requirement standards.

According to research by Lotter, the design stage can determine up to 75% of the total production cost. Furthermore, specific design cannot be made without a solid design concept. Therefore, much research is being done on the development of effective design tool and decision making tools. However, most of the research is being concentrated on just few of the design stages such as dimensions and array of parts.

In this paper, methods of evaluation of design concept for optimal design will be shown, and a design evaluation tool that helps the decision making by measuring the information of design will be proposed. A case study will be shown for the new design tool.

2 INFORMATION AXIOM

As explained in the previous section, optimal design is a design that satisfies the functional requirement intended by the designer. In axiomatic design, information axiom is used obtain the optimal design by choosing the design with the least information. However, a method for measuring information has not yet been established. The main difficulty in measuring information is quantifying it. Since an optimal design is chosen from among proposed design that satisfies the independence axiom, the relative amount of information of the design can be used to objectively quantify the information.

The information measuring method proposed in this paper can objectively measure information and intensity is used in the measurement to reflect the designer's intentions on the level of importance.

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2.1 MEASURING INFORMATION IN A SYSTEMATIC ENVIRONMENT

In most of the design and manufacturing process, the designer must set specific functional requirements. If a design satisfies the manufacturing system 100% then there is no information. On the other hand, if the design does not satisfy the manufacturing system then infinite amount of information cannot produce a satisfactory product. Therefore, the required information is closely related to the design and the performance of the manufacturing system.

In a design process, information is the probability that the functional requirement is satisfied. The probability for a given design is measured by considering the complexity of the functional requirement. The total information is obtained by measuring the information for each FR or DP. The probability of each functional requirement is closely related to whether the functional requirement is satisfied or not.

The relationship between functional requirement and manufacturing system performance is shown in Figure 1. In Figure 1, two ranges are shown and they are design range showing related tolerance and system ranges, which shows the capability of the manufacturing system. The common range determines the result where the two ranges overlap. Now the information can be written as follows.

$$I = \log\left(\frac{\text{system range}}{\text{common range}}\right)$$

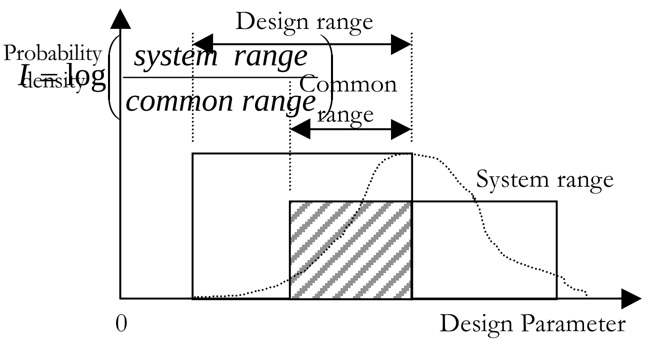

Figure 1. Probability distribution of a system parameter

3 DEVELOPMENT OF INFORMATION MEASURING METHOD

Information is measured objectively using the following steps.

Step 1: define what needs to be measured

Among many design variables, those closely related and has significant effect on the functional requirement are chosen.

Step 2: When the important variables are chosen, the relative information amount is measured.

The relative information is measured to eventually measure the total information.

Step 3: The relative order between the functional requirement and the information measurement is defined.

The order is defined to give intensity to the relative information amount.

Step 4: After the order mentioned in step 3 and the order of functional importance is decided, the ••• for each variable is calculated.

The intensity is multiplied by the relative information, and is used for measuring the total measurement.

Step 5: The information is calculated for each functional requirement, and the total information is measured.

A simple example on milling machine will be shown to explain the newly proposed method of measuring relative information. In choosing an optimal model of milling machine for a given set requirements, the independence axiom will be applied, and then the relative information for each machine will be measured to see which model is the most appropriate for the given set requirements.

The knowledge on the design and evaluation of milling machine is abundant and their interrelationship is very complicated. Therefore, such knowledge must be systematically categorized and arranged through research and investigation on the field and in literature. The example in this paper uses data of existing milling machine from literature to evaluate 4 types of milling machine. The milling machine is structurally divided into 3 modules, and the 3 modules are further divided into more specific aspect. These data are inputted into a database for use in the evaluation of the milling machines. Figure 2 shows structure of milling machine in 3 section

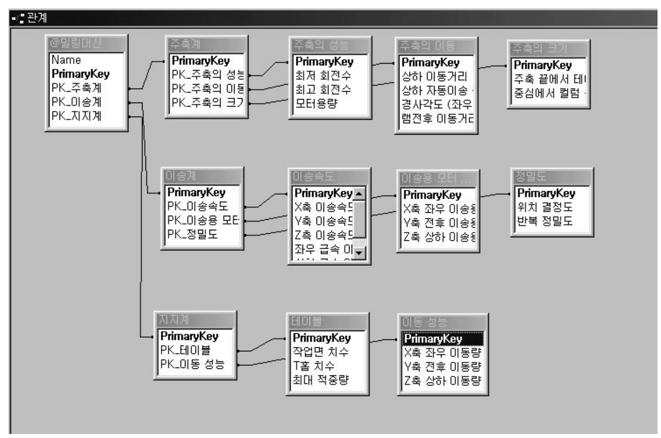

Figure 2. Structure of milling machine

4 DESIGN EVALUATION TOOL USING AXIOMATIC APPROACH

The evaluation method proposed in this paper was used to develop a software tool that helps choose an optimal design that satisfies the functional requirements. The software is called Design Evaluation Machine (DEM).

This software is a design evaluation tool that can in the future establish a basis for the development of Thinking Design Machine (TDM) by applying database structure and other evaluation methods. Figure 3 shows a key module for inputting the design information into a database to help the user search keywords for the functional requirements and define the relationship between data. The module is composed of a menu bar for modifying design information and menus for searching.

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This module can effectively setup a database and define searching methods as shown in the following figures.

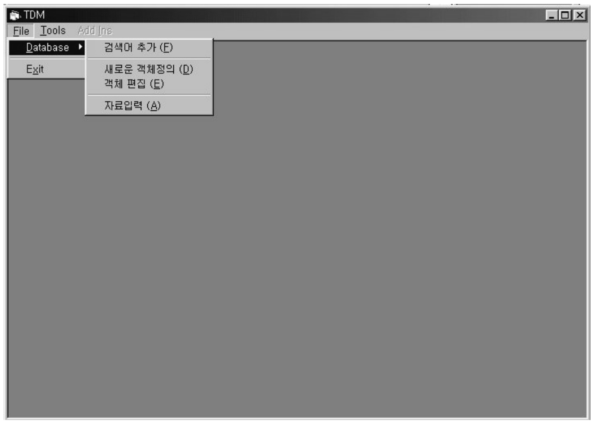
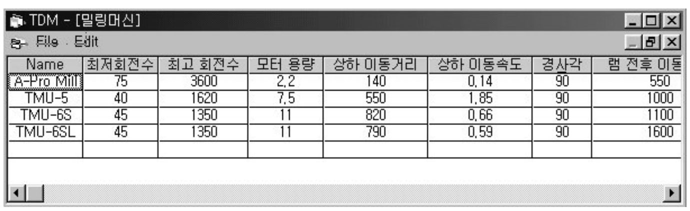


Figure 3. Input module window of DEM database

Figure 4 shows the database for 4 types of milling machines where data is inputted for each functional module. The database of milling machines shown in Figure A2 inputs data of higher level module to make searching for functional requirement simple. This structure has the development of TDM in mind and is explained below in more detail.



Name	최저회전수	최고 회전수	모터 용량	상하 이동거리	상하 이동속도	경사각	램 전후 이동
A-Pro Mill	75	3600	2,2	140	0,14	90	550
TMU-5	40	1620	7,5	550	1,85	90	1000
TMU-6S	45	1350	11	820	0,66	90	1100
TMU-6SL	45	1350	11	790	0,59	90	1600

Figure 4. Database structure of DEM

When the user inputs the functional requirement for searching, the used selects among the related keywords in the database as shown in Figure 5. The search is done based on the keyword using the searching algorithm defined when the database was established. The resulting data of the search shows the higher module as design parameters.

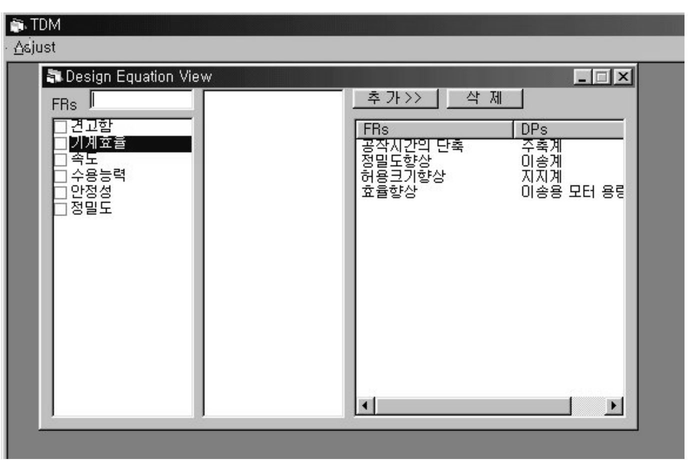


Figure 5. Input module window of DEM main frame

Since the computers today cannot fully recognize and process the numerous functional requirements of the designer, the keyword were added to the functional requirements for a general process through the use of the keywords.

The functional requirements and the design parameters must be inputted into the search algorithm and then be checked whether they violate the independence axiom or not. Design matrix is used to check for any violations of the independence axiom. This program uses the design matrix and the results are shown as coupled, decoupled, and uncoupled design. If the independence axiom is violated, the program shows what design parameter causes the coupled design and gives advice on how this can be solved. The result in Figure 6 shows that the given design does not violate the independence axiom and is a legitimate design.

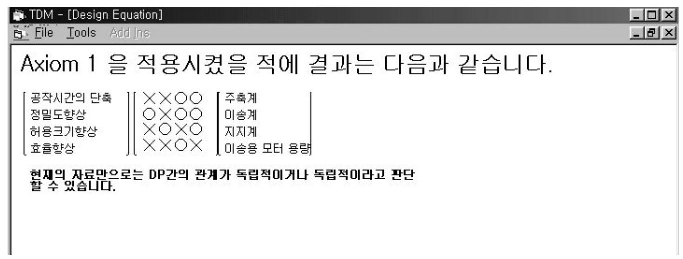
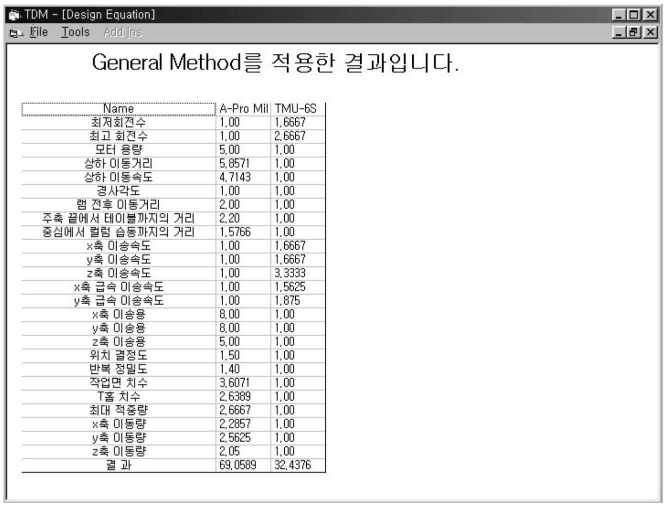


Figure 6. Independence axiom test result of DEM

In order to apply the information axiom, Figure 7 shows a module giving a list of data on designs and products to choose from.

Figure 7. Information contents measurement module window of DEM

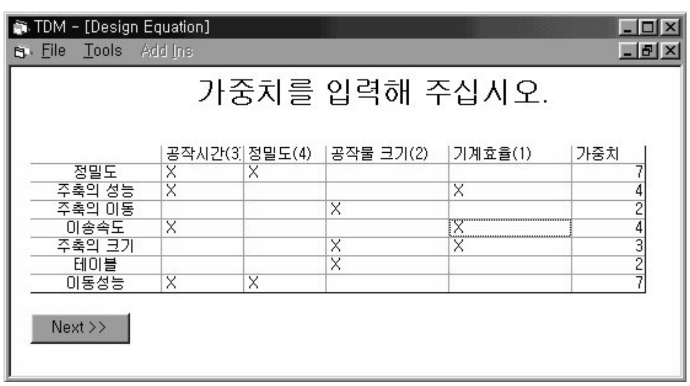
When the choices are made, information is measured and the results are shown in Figure 8. The result in Figure 8 is the measurement of relative information, and intensity is not considered in this result. The result can be used to examine the information of each elements of the proposed design, and the merit/demerit of each product can also be examined.



Name	A-Pro Mil	TMU-6S
최저회전수	1,00	1,6667
최고 회전수	1,00	2,6667
모터 용량	5,00	1,00
상하 이동거리	5,8571	1,00
상하 이동속도	4,7143	1,00
경사각도	1,00	1,00
램 전후 이동거리	2,00	1,00
주축 끝에서 테이블까지의 거리	2,20	1,00
중심에서 컬럼 습동까지의 거리	1,5766	1,00
x축 이송속도	1,00	1,6667
y축 이송속도	1,00	1,6667
z축 이송속도	1,00	3,3333
x축 급속 이송속도	1,00	1,5625
y축 급속 이송속도	1,00	1,875
x축 이송용	8,00	1,00
y축 이송용	8,00	1,00
z축 이송용	5,00	1,00
위치 결정도	1,50	1,00
반복 정밀도	1,40	1,00
작업면 치수	3,6071	1,00
T홈 치수	2,6389	1,00
최대 적중량	2,6667	1,00
x축 이동량	2,2857	1,00
y축 이동량	2,5625	1,00
z축 이동량	2,05	1,00
결 과	69,0589	32,4376

Figure 8. General information contents measurement result of DEM

Figure 9 shows a module for adding the intensity to the evaluation process. House of quality in QFD is used to objectively give intensity to the higher level module of the design parameters. The designer inputs the functional requirement and the intensity is given by the relevancy of the design parameter to the functional requirements.

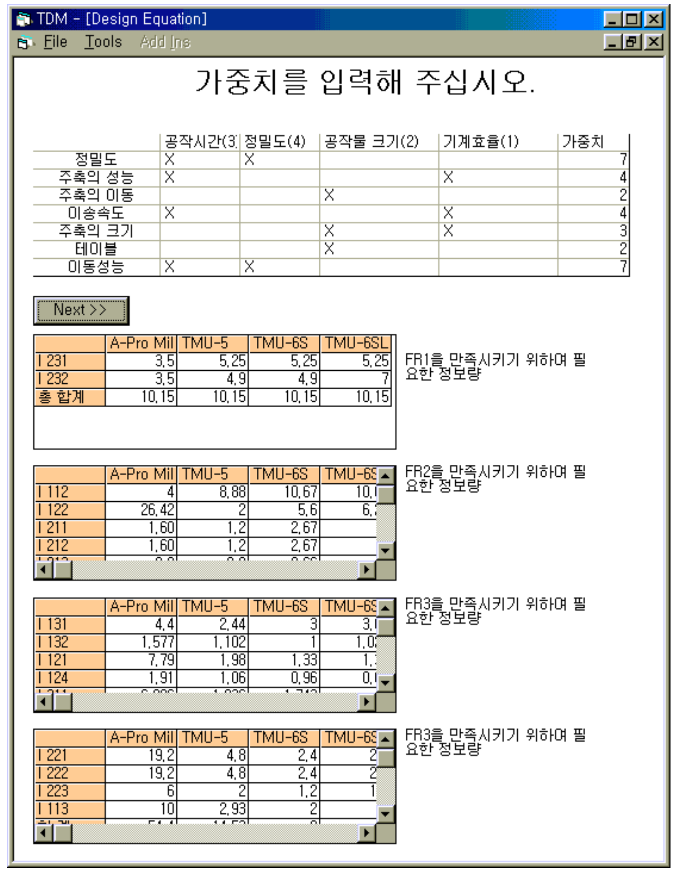


	공작시간(3)	정밀도(4)	공작물 크기(2)	기계효율(1)	가중치
정밀도	X	X			7
주축의 성능	X			X	4
주축의 이동			X		2
이송속도	X			X	4
주축의 크기			X	X	3
테이블			X		2
이동성능	X	X			7

Figure 9. Intensity weight input module window of DEM

By applying the intensity weight obtained by the module in Figure 10, the information of the proposed design can be measured. Figure 10 shows the result of the calculation of the information required to satisfy each element. In this figure, the intensity weight is considered in the result.

Figure 10. Result of applying intensity weight module of DEM



	공작시간(3)	정밀도(4)	공작물 크기(2)	기계효율(1)	가중치
정밀도	X	X			7
주축의 성능	X			X	4
주축의 이동			X		2
이송속도	X			X	4
주축의 크기			X	X	3
테이블			X		2
이동성능	X	X			7

	A-Pro Mil	TMU-5	TMU-6S	TMU-6SL
I 231	3,5	5,25	5,25	5,25
I 232	3,5	4,9	4,9	7
총 합계	10,15	10,15	10,15	10,15

5 CONCLUSION

A method of measuring information to choose an optimal design was proposed in this paper. This method selects the design with the least information among the proposed design. One of the difficulties in this method is quantifying the information, but measuring the relative information of the design and objectively quantifying it can solve this.

In order to evaluate the information, a new method of measuring information was proposed. This new method can solve the problem occurring when the total information is the same by adding intensity weight to the measuring process. Furthermore, the information of each element for satisfying the functional requirement can be examined allowing the merit/demerit of each design to be easily seen. This can help point out what parts of the design needs modification or support.

Using the new method of adding intensity weight in the information measuring process has the following advantages. First, just using the elements of the lower level even for designs with complex hierarchical structure can show the total information. Furthermore, the numerous elements of the lower level can be measured concurrently allowing concurrent execution for saving time needed for evaluation.

Second, this method can objectively quantify the elements for measuring information where the objectivity has been always

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a problem. House of quality is used to give intensity weight to the basic information to give relativity of importance between information.

Finally, module concept is used to simplify the algorithm of the evaluation tool. This makes the development of information evaluation program possible, and ultimately bringing us one step closer to the development of a total decision making tool. The new algorithm allows the examination of the total design when the information is altered in the lower level.

These advantages can help reduce the human factor in the process of design, and the new method shows a general and objective way of evaluating design.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Suh N.P., *The Principles of Design*, New York: Oxford University Press, 1990. ISBN 0-19-504345-6

[2] Yong Rak Moon, Sung Woon Cha, "Axiomatic Approach for Design Appraisement and Development DVD (I)," *Journal of the Korean Society of Precision Engineering*, Vol. 16, No. 5, pp. 124-131, 1999.

[3] Yong Rak Moon, Sung Woon Cha, "Axiomatic Approach for Design Appraisement and Development DVD (II)," *Journal of the Korean Society of Precision Engineering*, Vol. 16, No. 9, pp. 82-88, 1999.

[4] Taguchi, G., and Phadke, M.S., "Quality Engineering Through Design Optimization," I.E.E.E. Global Telecommunications Conference, GLOBCOM '84, Atlanta, GA, November 26-29, 1984.

[5] Moon Y.R., Cha S.W., Lee J. W., " Using Axiomatic Approach for Development of New Concept Product," Spring Conference on Mechanical Engineering*, KSME '99,* Daejeon, May 22-24, 1999.

[6] Yong Rak Moon, Sung Woon Cha, "Weight Reduction in Car Design Through Axiomatic Approach : Developing Integrated air fuel module," *Transaction of Korea Society of Automotive Engineers*, Vol. 7, No. 6, pp. 106-114, 1999.

[7] S. W. Cha, Y. R. Moon, "Using Axiomatic Approach for Developing DVD," International Conference on International Strategy Manufacturing System, *ISMS '98*, Tokyo, November 11-13, 1998

[8] Sung Woon Cha, Kyu Kab Cho, "Development of DVD for the Next Generation by Axiomatic Approach," *CIRP Annals,* Vol. 48, No. 1, pp. 85-88, 1999.

[9] Y. R. Moon, S. W. Cha, "Using Axiomatic Approach for Choice of Optimization Design," Conference on Precision Mechanical Engineering*, KSPE '98,* Seoul, November 15-164, 1998.

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