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Abstract. Firstly, clarify the background of the reconfigurable manufacturing system and the axiomatic design theory, axiomatic design has two axioms including independent axiom and information axiom. This paper is based on Axiomatic Design, Using the independent axiom to the function design of the reconfigurable manufacturing system, the overall goal of three-level decomposition, each level of decomposition will list the corresponding design matrix to verify whether it meets the independence, and then summarizes the integrity of the decomposition of the design, finally, the feasibility of the design scheme is verified by an example.

Introduction

In the era of increasingly changing demands of people and the pursuit of individualized, personalized customization becomes the focus in most enterprise production design. Reconfigurable manufacturing systems are presented in this context in order to be able to respond to market changes using innovative manufacturing methods in good cost-effectiveness [1]. In the aspects of hardware and software designing level of the reconfigurable manufacturing system, the literature [2] said it can use the top-down design method, design hardware and software function module function to achieve flexible reconfigurable Numerical control system design pattern. The literature [3] from the aspects of hardware structure analysis system needs and the use of field programmable gate array internal resource allocation and design to analyze the system reconfigurable features. The literature [4] in the view of axiomatic design method, using the "Z" type mapping method of axiomatic design, domain definition and transformation angle planning to realize the mapping process of reconfigurable product system. The literature [5, 6] from the system level, using axiomatic design decomposition of reconfigurable system to achieve the system's flexible features.

This paper is based on the establishment of decomposition control mechanism to optimize the mapping decomposition process of axiomatic design. The functional requirements and design parameters are classified and summarized, the properties of the parameters are analyzed, and the complete characteristics of the decomposition categories are summarized. To analyze the completeness of the design hierarchy as the principle of whether the decomposition of the control system is continuous or not.

Axiomatic Design

Overview of Axiomatic Design

Axiomatic design theory is proposed by the Professor Suh and his colleagues in the department of Mechanical Services of Massachusetts Institute of Technology in the United States in 1990, and in the next period time, its theory continues to develop and finally turns into the mature axiomatic design system, and consequently is applied to the design field [7]. The axiom design focuses on the analysis of customer needs (CAs) and accurately describes the customer needs with functional
requirements (FRs). The design work is done by mapping the functional requirements, design parameters (DPs), and process variables (PVs). The design framework is shown in Figure 1.

In the axiomatic design, the mapping refers to the "Z" type design between the two domains, according to the functional requirements to determine the design parameters, and then according to the characteristics of the design parameters, once again on the functional requirements of the secondary design. Decomposition refers to the design within the domain, the domain for each additional level, then more than one decomposition. Design level and decomposition, mapping is closely linked, the structure is shown in Figure 2.

**Decomposition Control**

The adequacy and completeness of the intra-domain decomposition of functional requirements is usually determined by the designer. The "Black" means that the information is not entirely clear, or that some of the information is not clear. While the "gray" is the transition area of the two, indicating that the information is not entirely clear, or that part of the information is not clear. In the design results often appear "left and right", "other metal parts" and other words, such as language functions required by the design parameters, process variables, mostly belong to the information gray field, the expression is not accurate [8]. In this way, the design of the resulting incomplete information to the actual production increased the cost and difficulty.

In the axiomatic design, the final level reflects the design information accuracy. According to the classification of the parameters, taking the type of parameters and the decomposition of the complete characteristics as an important basis for the decomposition of the design control level, that can be infinitely increased, or too simple to avoid redundant design and unsound design. The decomposition is classified as shown in Table 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Characteristics of the complete decomposition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical</td>
<td>The value of the design parameter can be quantifiable and within the controllable range</td>
<td>Product diameter design: 10 ± 0.05mm</td>
</tr>
<tr>
<td>Description</td>
<td>Object-oriented parameter has the implementation and can meet customer needs</td>
<td>Fridge insulation design: the insulation of the refrigerator door material</td>
</tr>
</tbody>
</table>

The decomposition control mechanism provides objective evaluation criteria for the decomposition of the axiom design process, reduces the overall design cost and saves the human resources, so that the design results are more in line with the customer's needs.

**Axiomatic Design Decomposition of Reconfigurable Manufacturing System**

Reconfigurable Manufacturing System (RMS) is a combination of Dedicated Manufacturing Lines (DML) and Flexible Manufacturing Systems (FMS), and is an innovative manufacturing approach. In order to enable enterprises to apply the system can achieve low cost, rapid response to customer needs and reliability and high utilization of purpose, according to customer needs, the use of axiomatic
design of the decomposition control mechanism for reconfigurable manufacturing system for
axiomatic design research.

**Customer Requirements Decomposition**

Manufacturing companies use a reconfigurable manufacturing system, the actual "customer" of the
system is a manufacturing company. Enterprise for the system of the two basic needs, one is to
respond quickly to the needs of market changes, with a reconfigurable nature. Followed by changes in
the dynamic market, making the interests of enterprises to optimize and low cost. According to the
description of customer needs, the first layer of decomposition design corresponds to the
corresponding functional requirements, FR1: enterprise restructuring function, FR2: good economy.

**The First Layer Decomposition**

In the development of good functional requirements, the corresponding design parameters DP1:
reconfigurable strategy, DP2: high efficiency. And FR1, FR2 are completed by DP1, DP2
independently. The design matrix is:

\[
\begin{bmatrix}
FR_1 \\
FR_2
\end{bmatrix} = \begin{bmatrix}
\times & 0 \\
0 & \times
\end{bmatrix}
\begin{bmatrix}
DP_1 \\
DP_2
\end{bmatrix}
\]

where: "\times" indicates that the functional requirement (FRs) is related to the design parameter
(DPs)"0" indicates that it is not relevant.

**The Second Layer Decomposition**

According to the decomposition control mechanism and the decomposition of the complete
characteristics, DP1: reconfigurable strategy and DP2: high efficiency, neither to meet the digital
quantification level, and not meet the feasibility, so continue to the second layer of dismantling. FR1
is further broken down into FR11: Enterprise Organization Reconfiguration, FR12: Manufacturing
System Reconfiguration. FR2 is further broken down into FR21: product development cycle is short,
FR22: low manufacturing cost. Correspondingly, the organizational restructuring function is
considered as DP11: enterprise structure reconstruction strategy. DP12: Manufacturing System
Reconstruction Strategy [9]. The relationship matrix is as follows:

\[
\begin{bmatrix}
FR_{11} \\
FR_{12}
\end{bmatrix} = \begin{bmatrix}
\times & 0 \\
0 & \times
\end{bmatrix}
\begin{bmatrix}
DP_{11} \\
DP_{12}
\end{bmatrix}
\]

The corresponding design parameters for the DP21: shorten the product development cycle, DP22:
control costs. Among them, the manufacturing cost is not only related to cost control, the cycle length
also affects the manufacturing cost, therefore, the relationship matrix is as follows, the triangular
matrix:

\[
\begin{bmatrix}
FR_{21} \\
FR_{22}
\end{bmatrix} = \begin{bmatrix}
\times & 0 \\
\times & \times
\end{bmatrix}
\begin{bmatrix}
DP_{21} \\
DP_{22}
\end{bmatrix}
\]

**The Third Layer Decomposition**

In the second layer decomposition, the matrix satisfies the diagonal matrix or the triangular matrix,
satisfying the independent axiom, without adjusting the parameters and the matrix. The
decomposition integrity of the decomposition control mechanism is then considered.

DP11 and DP12 are subjective ideas, is a man-made approach, there are still lack of implementation,
not in the decomposition of the complete type, it is necessary to continue to break down. FR11
decomposition into FR111: staff skills quality, FR112: information management level, corresponding to
the design parameters DP111: human resources development and management, DP112: modern
communication technology [10]. A matrix that satisfies the requirements of independent axioms.
FR_{12} is decomposed into FR_{121}: reconfigurable processing system, FR_{122}: reconfigurable logistics system, FR_{123}: reconfigurable shop floor layout. Design DP_{121}: Reconfigurable production line, DP_{122}: Reconfigurable transport system, DP_{123}: Standardized facility workshop. The matrix assumes a diagonal form.

\[
\begin{bmatrix}
FR_{111} \\
FR_{112}
\end{bmatrix}
\times
\begin{bmatrix}
0 \\
DP_{111}
\end{bmatrix} =
\begin{bmatrix}
DP_{111}
\end{bmatrix}
\]

DP_{21} is aimed to shorten the design and manufacturing cycle, which includes the design, manufacturing cycle of the short dual function requirements, which is redundant implementation, it needs the third layer of decomposition. FR_{21} is decomposed into: FR_{211}: product design cycle is short, FR_{212}: product manufacturing cycle is short. And these reflect design parameters: DP_{211}: axiomatic design optimization program, DP_{212}: shorten the unit manufacturing time. The design matrix satisfies the independent axiom.

\[
\begin{bmatrix}
FR_{211} \\
FR_{212}
\end{bmatrix}
\times
\begin{bmatrix}
0 \\
0
\end{bmatrix} =
\begin{bmatrix}
DP_{211}
\end{bmatrix}
\]

DP_{22} is a parameter that is involved in many designs. In this system, cost control is roughly divided into research, development, manufacturing, sales cost control. In the manufacturing costs of equipment, personnel, raw materials and other major costs. And each can be figured to a lot of details. Continuing to decompose and refine the cost control, not only becomes an excess part of the system design, but can not be used as a general method to adapt to each system. In the design of a reconfigurable manufacturing system, the DP_{22} control cost is a design parameter that does not have to be decomposed quantitatively and is not further decomposed. FR_{22} decomposition is complete.

**Decomposition Integrity Analysis**

After the decomposition of the third layer, DPs were analyzed. DP_{111}, DP_{112} have been able to meet the feasibility, respectively, can choose PV_{111}: human resources system improvements and PV_{112} communication technology applications as its process variables, the next step in the design mapping. FR_{11} decomposition is complete.

For the reconstruction of the manufacturing system, the designed DP_{121}, DP_{122}, DP_{123} provide a complete design for the subsequent process variables. Manufacturing departments to carry out the production line, transport system and the standardization of the layout of the facilities to re-configuration, transformation and optimization, to achieve the reconstruction of the manufacturing system. FR_{12} decomposition is complete. DP_{221} and DP_{222} have provided two design options for "axiomatic design optimization" and "computer aided manufacturing", and the further selection of PVs can be optimized for design and manufacturing cycles in accordance with the design parameters. FR_{22} decomposition is completed.

**Design Example and Analysis**

According to the mapping decomposition of the previous section, the design matrix is a diagonal matrix or a triangular matrix, so it conforms to the independent axiom. And the decomposition integrity of the mechanism of the analytical decomposition mechanism is obtained, and the system level integrity is proved one by one. The design has the controllable enforceability and becomes one of the optimal design. The design level is shown in Figure 3.
The design consists of three levels, and finally decomposed into eight functional requirements, mapped to eight design parameters. Each parameter is consistent with the numerical and descriptive parameters of the type, and guarantee meeting the integrity of the decomposition. From the enterprise perspective, the principle of decomposition control can meet the strategic point of viewability. From the point of view of the design engineer, the decomposition principle can meet the enforceability of the manufacturing.

Summary
In this paper, the further analysis of the imperfect decomposition level design is carried out from the point of view of axiomatic design, and thus obtaining the decomposition control mechanism under the background of rapid market change. The use of decomposition control design level, not only to meet the user's design needs, but also reduces the complexity of the design level, as well as enhancing the design results of the operability. The decomposition control mechanism is applied to the axiomatic design of the enterprise reconfigurable manufacturing system. The control of the decomposition level is realized, which avoids the imperfection and repetition of the design. It is a general and practical comprehensive scheme. And this provides a common set of solutions for businesses to adjusting the rapidly changing market demand.

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Reference


