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A Literature Review on Axiomatic Design in Dynamic Cellular Manufacturing System

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Abstract:

Although there are number of theoretical and application studies where Axiomatic design principles have been used in the last few decades. This principles used for those who are ready to change their conventional system into cellular manufacturing system. Though the systematic approach and consideration of independence axioms and Information axiom, used for highly complex projects to reduce the complexity in designing the layout of cellular manufacturing system. In this literature, first step is to study the principles of Axiomatic in manufacturing system and the second step is to observe the working personnel's in improving the overall production.
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Keywords :

Axiomatic Design Principles, personnel selection, Manufacturing Organization, Design Theory,

1. Introduction

With the increasing popularity of customer need, cellular manufacturing has become a significant point in manufacturing era. In concert with this development, there have been numerous publications on design and improvement of cellular manufacturing system. Among these ,we can list of part family and machine group determination (Nancy & Wemmerlov,2002), evaluation of grouping efficiency measures (Sarher & Mondal, 1999), group scheduling (Wemmerlov, 1992) machine layout in cells (Aneke & Carrie, 1986), Capacity planning in cellular manufacturing (Sule,1991), Design of software systems in Axiomatic principles (Kim, 1991), Designing of Quality system in Axiomatic Design(Suh,1995) and Design methodology in cellular manufacturing system(Kulak, 2005).Numerous modeling techniques have been used to group parts into part families and machines into machine cells. In the basis of AD methodology, the design process is considered as a series of domain mappings, such as mappings between functional requirements (FR) in the functional domain and design parameters (DPs) in the physical domain. After the mappings process, if the independence axiom is not satisfied, the design is not acceptable. In other words, one FR must be satisfied by only one DP. Otherwise, the design is bad or does not work well (Suh, 1990). However, some designs are acceptable although they does not satisfy independence axiom. Bae, Lee, and ve Chu (2002) present the sequential kinematic design of a suspension system based on axiomatic design principles. Axiomatic Design has established itself as a method for the system design and is mainly used in the design of complex systems. Axiomatic design is also used more and more for design of manufacturing systems due to its systematic way and the top-down approach. Axiomatic Design enhances creativity by eliminating bad ideas early and thus, helping to channel the effort of designers. Through the application of the axioms (Independence and Information Axiom) solutions of design parameters can be defined independent each other determining also the best solution for alternative for a system. Axioms are truths that cannot be derived but for which there are no counter-examples or exceptions. Many fields of science and technology owe their advances to the development and existence of axioms.1) Euclid's geometry, (2) the first and second laws of thermodynamics are axioms (3) Newtonian mechanics. The number of studies using AD principles is gradually increasing as AD's Superiorities create important advantages for decision makers in solving more problems. The literature review gives more number of answers for different questions. Personnel selection for the present day manufacturing organizations is the specified activity for appointing an employee with right set of skills and attitude according to the job's requirement.

2. Principles of Axiomatic Design

This section gives the brief introduction about Axiomatic Design

2.1 Introduction to Axiomatic Design

- Axiomatic Design enhances creativity by eliminating bad ideas early and thus, helping to channel the effort of designers.

2.2 Historical Perspective on Axiomatic Design

- Axioms are truths that cannot be derived but for which there are no counter-examples or exceptions.
- Many fields of science and technology owe their advances to the development and existence of axioms.

2.3 Axiomatic Design framework

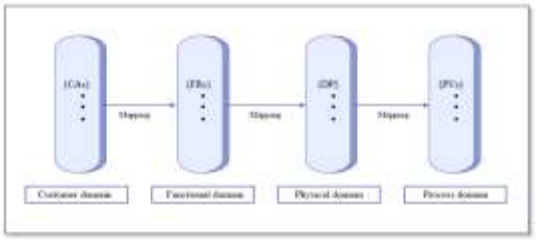

Fig1 : Axiomatic Design in four areas

Table 1: Axiomatic Principles in different domains

Domains Character Vectors	Customer Domain	Functional Domain	Physical Domain	Process Domain
Manufacturing	Attributes which consumers desire	Functional requirements specified for the product	Physical Variables which can satisfy the functional requirements	Process Variables that can control design parameters
Materials	Desired performance	Required Properties	Micro-structure	Processes
Software	Attributes desired in the software	Output specification of the program codes	Input variables or Algorithms Modules Program codes	Sub-routine machine codes compilers modules
Organization	Customer Satisfaction	Functions of the organization	Programs of Offices or Activities	People and other resources that can support the program

- **2.3.1 Axiom:**

An axiom is a self-evident truth or fundamental truth for which there is no counter examples or exceptions. It cannot be derived from other laws of nature or principles.

- **2.3.2 Functional Requirement:**

Functional requirements (FRs) are a minimum set of independent requirements that completely characterize the functional needs of the product (or software, organizations, systems, etc.) in the functional domain. By definition, each FR is independent of every other FR at the time the FRs is established.

- **2.3.3 Design parameter**:

Design parameters (DPs) are the key physical (or other equivalent terms in the case of software design, etc.) variables in the physical domain that characterize the design that satisfies the specified FRs.

- **2.3.4 Process variable**:

Process variables (PVs) are the key variables (or other equivalent term in the case of software design, etc.) in the process domain that characterizes the process that can generate the specified DPs.

- **2.3.5 The Design Axioms**

Axiom 1: The Independence Axiom Maintain the independence of the functional requirements (FRs).

Axiom 2: The Information Axiom Minimize the information content of the design

- **2.3.5.1 Design Matrix**

The relationship between {FRs} and {DPs} can be written as

{FRs}=[A] {DPs}

When the above equation is written in a differential form as

{dFRs}=[A] {dDPs}

[A] is defined as the Design Matrix given by elements :

Aij= ∂FRi/∂Dpi

3. Literature Review:

Erwin Rauch et al. [1] has identified in his literature about the application of Axiomatic Design for new challenges in manufacturing like sustainability and Independence Axiom is mainly applied and highly discussed by decomposition of FRs and DPs. The CAs and PVs play sub-ordinate role .Due to the fact, that CAs is highly important to define the right first level FRs and DPs are to be considered more in future. Kulak O et al.[9] identified in his literature review about the application of Axiomatic Design the application areas ranked by number of papers:

- Product Design
- Decision Making
- Software Design
- System Design
- Manufacturing System Design
- Others.

A manufacturing system can be defined as a large and complex system because it is subject to temporal variation and must be reconfigurable and adaptable. In such cases Axiomatic Design shows a suitable and helpful method to reduce complexity in the manufacturing system design

In the literature, AD methodology has been applied to various application areas that differ from product design to decision making since it was proposed by Suh in 1990. Some successful applications of AD methodology are as follows: (1) Software Design (Chen, 1998a; Kim, Suh, & Kim, 1991), (2) System Design (Suh, 1995, 1998), (3) Manufacturing System Design; (Babic, 1999; Cochran, Arinez, Duda, & Linck, 2001; Durmusoglu, Kulak, & Tufekci, 2002; Giachetti, 1999; Kulak et al., 2005a), (4) Process and Product Design (Chen, 2001; El-Haik & Yang, 1999; Huang & Jiang, 2002; Kar, 2000; Wu, Chen, & Tang, 1998), (5) Supply Chain Management (Ng & Jiao, 2004), (6) Civil Engineering Problems (Albano & Suh, 1992), (7) Environment Problems (Wallace & Suh, 1993), (8) Marine Design Problems (Jang, Yang, Song, Yeun, & ve Do, 2002), (9) Transportation (Goczyla & Cielatkowski, 1995). The solutions of problems defined in these studies are based on AD principles. Besides of these studies, there are some Decision Making studies including AD methodology in the literature (Celik, Cebi, Kahraman, & Er, 2009a, 2009b; Celik, Kahraman, Cebi, & Er, 2009c; Kahraman & Cebi, 2009; Kulak & Kahraman, 2005a, 2005b; Kulak, Durmusoglu, & Kahraman, 2005b; Kulak, 2005). And also there are a few theoretical studies in the literature. Tang, Zhang, and Dai (2009) analyzed the disadvantages of both axiomatic design and design structure matrix. According to the study, while AD helps the designer finding suitable design parameters meeting the functional requirements, AD cannot support the designer to know the interactions among the design parameters, including geometry, spatial layout, and interfaces. A design structure matrix has the advantages in recording and analyzing the interaction relationship between existing product elements. However, at the conceptual design stage or for a new

product that has never been designed before, it is difficult to make it by design structure matrix. Suh (2005a) used axiomatic design to reduce or eliminate the complexity via satisfying the FRs of products, processes, operations, and systems within the given constraints. Pappalardo and Naddeo (2005) applied the value of information, as a measure of equality of data among a set of values, in AD framework for the cases in which the number of functional requirements was greater than the design parameters. Melvin and Suh (2002) described a method to simulate designs which were created by using AD so that the final system performance was predicted. Deo and Suh (2004) presented the use of information transforms at the operational stage implemented by superimposing the system with a control system to convert coupled or decoupled system to uncoupled system and to eliminate imaginary complexity. Ng and Jiao (2004) used AD theory to develop a domain-based reference model. A domain-based approach was proposed to represent the intimate dependencies among customers, product families, production volumes, final-production, and sub-assembly supplies. Suh (2007) presented the usability of AD and complexity theory in Ergonomics.Su et al. (2003) developed some methods for measuring functional dependency and sequencing of coupled tasks in engineering design in order to improve the design process by reducing unnecessary iterations. The objectives of their study were to develop a method that measured the strength of the coupled design tasks and to develop an algorithm that found the best processing sequence for the coupled design tasks. The developed methodology transformed the binary structure of the design matrix into a matrix with quantitative coupling measures. Bulent Durmusoglu M et al.[3] in his review identified a systematic road map for designing cells using Axiomatic Design Principles. An application of the independence axiom was proposed throughout the design process to form cells. Suri R [7] & Hyer N et al.[8] has identified in his paper that the office layout should be cellular layout so that Communication and Controlling would be improved

Anant Khandekar et al.[2] has identified in his review that personnel selection is the most important tool as it works exactly and works exactly with the underlying principle of matching the functionality expectations in terms of DR with the qualifications traits of the personnel , to improve the productivity using axiomatic principles. Dursun et al. [10] has identified the multi criteria decision making techniques have been normally adopted for dealing with the personnel selection problems. Kulak O et al.[4] has identified in his review a complete and concise methodology for transforming a process oriented manufacturing facility into a CMS is based on Axiomatic Design principles and a feedback mechanism for continuous improvement of the cellular system under the guidelines of the AD principles

4. Conclusion

The literature review shows that AD becomes more and more important for manufacturing system design and it is utmost necessary to have the right and appropriate person at every job position. In most of the research works the independence axioms is mainly applied and highly discussed by decomposition of FRs and DPs. The results of the literature review a conclusion that there were so much work related to axioms in manufacturing system design and personnel selection is the most appropriate tool as it works exactly with the underlying principle of matching the functionality

expectations in terms of DR with the qualification traits of the personnel.

So, AD is becoming the most important instrument and design methodology in the manufacturing system. In the next step the literature should extend more through the analysis of research works in the area of dynamic cellular manufacturing system.

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