Axiomatic Design

Axiomatic design is a tool for designing products and processes exceeding customer expectations. The axiomatic design process is axiom driven assuring technology neutral and innovative solutions for increased competitive power. The customer requirements are decomposed in trees of independent and robust product functions successively translated to product specifications. Axiomatic design is widely applicable including design of simple products, design of integrated hardware- , sofware -, man /machine processes and design of organisations.

Design of products and processes are usually performed as an iterative organic growing process based on knowledge en experience within and outside the design project organisation. Design goals are usually set based on previous designs and customer requirements as defined by the designer.

Axiomatic design (AxD) is a widely applicable method used to achieve a well structured and efficient design process. AxD is knowledge based and focused on a systematical identification and breakdown of customer needs to product specifications resulting in products with to the customer robust attributes.

Mathmatics

AxD is based on mathematics. Mathematical definitions and concepts are combined and adapted to en efficient product developement management tool. The most important mathematical building blocks are *domians*, *functions, mapping*, *matrices* and statistical *density functions.*

The design process

An ongoing design process can be described as a mapping of **what** we want to achive (design goal) on an domain that describes **how** this will be achived (design result).

This model is to crude to be used as a design management tool. Axiomatic design use standardized domains to create structure and facilitate systematic decomposition of customer requirements. Axiomatic design is partitioning the design process as follows:

- Design goal;(Satisfy customer needs)
- Customer domain; {Customer requirements}
- Functional domain; {Functional requirements}
- Physical domain; {Design parameters}; (E.g. product design)
- Process domain; {Process variables} ; (E.g. production process);
- Design result; (Products that satisfies customer requirement in a robust way)

Rows in black are axiomatic design standard domains. Text in { } are domain elements. Each domain pair represent a mapping i.e. the upper represent a design goal (**what**) and the lower a design result (**how**).

Mapping and zigzagging in hierarchies

Designs with just one customer requirement are mapped with simple mathematical functions. However, most products have more than one customer requirement leading to mappings in martrix equation forms. These mapping equations are called design equations.

Complex products and processes are usually of a hierachichal design e.g. sturctured in a system, machine, component hierarchy. You usually zigzag between domain pairs when you work your way down through this type of hierarchy. This facilitates a creative design process without design solution preferences. Example: Mapping the functional domain onto the physical domain we chose an overall physical solution to satisfy an overall function and subsequently decompose the physical solution to functions at next hierarchical level and then mapping these onto the physical domain to create a more detailed solution. This is repeated until we have an implementable design.

The above described structure can be considered the design process fundamental structure. It provides good traceability and, if the independence axiom (se below) is satisfied, good scalability characteristics.

Axiom

Based on the domain structure above the design axioms are implemented to create robust high quality products with customer appeal.

In axiomatic design two design axioms are postulated – the *independence axiom* and the *information axiom*. Based on these theorems and corollaries can be derived. This presentation will only adress the axioms.

If we mapp the functional domain onto the physical domain the independence axiom can be defined as follows:

The Independence Axiom: Maintain the independence of the functional requirements

The design equation can be written in matrix form as **FR = A* DP** where **FR** is a vector with functional requirements, **A** is the design matrix with design coefficients and **DP** is a vector with design parameters. The coefficient matrix also called design matrix, should be either diagonal or triangular to satisfy the independence axiom. For all other desing matrixes, the design is dependent wich, given there is a solution, require an iterative method to find a useful design solution. This is also true for other domain pair combinations.

The product should satisfy the independence axiom in all parts including the chain from customer requirements via product design to process design and down through the hierarchical trees between the domain pairs. This usually tests the designer's creative skills. The result is often unique and patentable solutions.

Designs that satisfy the independence axiom are more robust, simplyfies the design work, result in a less komplex design organisation, simplyfies operation and maintenance and are easier to use as platforms when developing new products on previous design generations.

The Information Axiom: Minimize the information content of the design

The information content for a functional requirement is calculated with the functional requirement tolerance limits and the corresponding system performance density function as inputs. When the whole denisity function is within the tolerance limits the information function has its minimum value 0. For designs with more than one functional requirement, designs with independent functional requirements have the lowest information content.

The information content is used as a design quality measurement. It is used to compare different design concepts and solutions to select the design that satisfy the customer requirements in the best and most robust way.

Axiomatic design and quality of design

Standardized Design For Six Sigma (DFSS) processes have been designed with axiomatic design as one of the key components. Axiomtic design contributes to the design quality through the design axioms but also through the clear and customer focused structure facilitating coordination of other quality enhancing tools. Among these tools are TRIZ, innovation and patent databases, design for x, statistically designed experiments and associated robust design tools, cost / benefit analysis, risk management, FMEA, traceability systems and cost analysis.

Industrial applications

Well defined and executed axiomatic design projects usually yield good results. Some examples: MuCell – a new plastic material with lower weight while improving toughness and dimensional stability – resulting in an entirely new industry; Patented connectors – high reliability and low weight – Tribotek inc started based on the patent; Asian vehicle manufacturer used axiomatic design for "Lean" and "Value add" in the production process resulting in drastic reductions in "work in progress", cycle times and volume of transport.

XR TECH services

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